

WORLD FISH FARMING:
CULTIVATION AND ECONOMICS
SECOND EDITION



WORLD FISH FARMING: CULTIVATION AND ECONOMICS

SECOND EDITION

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avi

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This book is dedicated to a man who made it
possible and who collaborated on the Japan chapter:

Mr. S. Nishimura

A man who can move mountains

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Preface to the Second Edition

Until the *First Edition of World Fish Farming: Cultivation and Economics* was published several years ago, there was little or no economic and technical information on commercial aquaculture either by countries or by species. I tried at that time to partially fill the gap in the literature. In this *Second Edition*, I have updated data originally presented and increased the scope by adding new countries. New trout data have been added for 10 western European countries; sections on cost of production of food-sized catfish and fingerlings in the USA; new and improved chapters for Japan, Hungary, Indonesia, the Philippines, and the United Kingdom; and completely new chapters pertaining to Poland, Thailand, and Czechoslovakia have all been added to this edition. The book now includes 31 countries, including all major producing ones. Between 5.5 and 6.0 million metric tons of finfish, shrimp, and crayfish cultured production are represented, which accounts for about 90% of the world's total.

The People's Republic of China and the USSR, as well as countries on the continents of Europe, Asia, North America, and Oceania, are represented. Because of only minimal reported cultured fish production in Africa and South America, these continents have been omitted. Also, according to information received from New Zealand, there is no culturing of fish in that country other than for restocking of public waters.

More than 100 species of cultured fish, seven species of shrimp and prawns, and six species of crayfish are discussed. The manuscript includes more than 100 tables for the sedulous reader to peruse and about 150 illustrations and explanatory photographs. Data are presented in both the metric and U.S. customary systems.

Cultural data include feeding practices, foods, and types of production facilities for freshwater, brackish, and marine production. Pond, raceway, fiord, cage, net, and other culturing methods are presented. New techniques, such as the submergible net cage of Japan, are also presented and fully illustrated. Tilapia culture has virtually exploded in Japan, largely because of a simple, inexpensive way of controlled reproduction. Here for the first time is the story of this development. Freshwater prawn production

has increased dramatically in Hawaii in the past three years. This *Second Edition* covers this development and indicates where additional information can be obtained. For some countries, the intensity and density of production are included. A number of farm examples are presented when and where possible.

Economic data, which are difficult to obtain, are presented when possible for production systems by species. Producer prices, marketing margins, and consumer prices appear; and data on imports and exports are presented when possible. An attempt has been made to present the most recent and pertinent information available.

For some countries, information is presented by species for restocking of natural waters. For all countries, a list of fish and other aquatic species mentioned in that chapter appears at the beginning of the chapter.

Because of considerable interest in and good profit potentials for operators of recreation or fee fishing facilities, this area is included.

When possible, the outlook for the cultured fish industry of the individual countries is also presented.

I have tried to cover a wide range of subjects for private and public aquaculturalists, as well as for all those who have an interest in fish culture, whether as a large-scale enterprise or as a hobby, for importers or exporters, fisheries economists, students, and for those individuals who wish to learn more about an increasingly important worldwide food source.

I am pleased to acknowledge the assistance given me in this undertaking by the contributing chapter authors named in the list of contributors. Acknowledgment is also made of the contributions of the following individuals associated with the Department of Fisheries, Food and Agriculture Organization, Rome, Italy: Mr. W.P. Appleyard, Fisheries Industries Development Service; Mr. Jean-Louis Gaudet, secretary to EIFAC; Mr. Michael N. Mistakidis, Senior Fisheries Resources Office; and Dr. Ziad H. Shehadeh, Fisheries Resources and Environment Division. I would also like to recognize the special assistance of Mr. Wayne Goble for preparation of illustrations and of Mrs. Marybeth Brown for diligence and assistance in typing the manuscript.

E. EVAN BROWN

Preface to the First Edition

Previously there was little or no economic and technical information by countries or by species on commercial aquaculture. This book was written to fill this gap existing in the literature. I have tried to present in an easy-to-read style detailed information about 28 countries, including all major producing countries. Between 5.5 and 6.0 million metric tons of such production of finfish, shrimp and crayfish are covered, which accounts for about 90% of the world's total.

The People's Republic of China and the USSR, as well as the continents of Europe, Asia, North America and Oceania are represented. Because of only minimal reported cultured fish production in Africa and South America, these continents were omitted. Also, according to information received from New Zealand, there is no culturing of fish in that country.

Ninety-three species of cultured fish, 7 species of shrimp and prawns, and 6 species of crayfish are discussed. The manuscript includes 100 tables for the serious reader to peruse, 41 illustrations and 91 explanatory photographs. Data are presented in both the metric and American systems.

Cultural data include feeding practices, foods, and types of production facilities for freshwater, brackish and marine production. Pond, raceway, fiord, cage, net and other culturing methods are presented. New techniques, such as the submergible net cage of Japan, are also presented and fully illustrated. For some countries, the intensity and density of production are included. A number of farm examples are presented when and where possible.

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January 1977

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Introduction

FISH SPECIES

Carp

Eel

Salmon

Anadromous fish

Catadromous fish

Forage fish

Marine fish

Predator fish

Eggs

Fingerlings

Fry

Trash fish

Introduction

HISTORY OF FISH FARMING

Fish farming is very old. The Romans were able to maintain and raise fish in brackish water along the Italian coast. They probably learned methods of primitive fish farming from the Etruscans, who in turn learned them from the Phoenicians. Any exact date of development would be pure conjecture. However, in the Mediterranean area, fish farming dates back several thousand years. Egyptian bas-reliefs have scenes depicting fish raised in ponds.

In China and the Indo-Pacific regions fish culture is very old. The origin of aquaculture or fish farming in China is commonly attributed to Wen Fang, the founder of the Chou Dynasty. The last ruler of the Shang Dynasty had Wen Fang confined to an estate in Honan Province (1135–1122 B.C.). There, Wen Fang built one or more ponds, filled them with fish, and made the first recorded references to their behavior and growth. Much of the early skill in the rearing of fish is said to have originated with him and those working with him. For the next several centuries a number of early Chinese writings appeared that were related to fish rearing. In 460 B.C., Fan Li wrote his *Fish Culture Classic*, which described in detail the results of numerous experiments made by Fan Li and others. It was in this era that the keeping of carp for pleasure, as described by Wen Fang, changed to the rearing of carp for food. The size of ponds expanded and the ventures were exceptionally profitable.

TODAY'S TECHNOLOGY

From the early beginnings fish farming has expanded in area, methods, and technology. The modern-day industry can only be described as highly variable.

Species cultured today are raised in fresh (both warm and cold), brackish, and marine waters. Species include catadromous fish, such as the eel, which live their lives in fresh or brackish waters and go to the sea for spawning. Anadromous fish, such as salmon, live their lives in marine waters and

ascend rivers to go to spawning areas. Other species include marine fish which spend their entire life cycles in salt water, but may be raised in brackish waters. Freshwater fish can sometimes be raised in brackish waters nearly as well as in freshwaters.

Culturing systems have expanded from the earlier ponds to include flowing water systems (called raceways) and enclosure systems ranging from rafts and cages, both floating and submerged, to closed off and farmed fiords. Even the traditional pond system has been modified by varying the amount of water added, which ranges from simple replacement to water currents so rapid that they verge on being considered flowing water systems. The various systems may contain forage as well as predator fish.

The systems may be both extensive and intensive. These two terms are not well defined and may mean different things to different people. For example, a managed pond may yield only a few kilograms of fish per hectare. By adjusting the pH, adding natural or artificial fertilizers, and relying only on the resulting natural foods, yields may increase to 7 metric tons (MT) per hectare (ha) [3.1 short tons (ST) per acre] as can be found in Israel. This may still be considered extensive fish farming by some individuals, who differentiate on the basis that intensive production requires the feeding of trash fish or artificial foods such as pellets, or who are accustomed to very large yields per unit of area which may be found only in flowing water systems.

Considerable variation may also be found in the sources of and supplies of either eggs, fry, or fingerlings. With some species, the eggs, fry, and fingerlings for stocking can only be obtained from wild stocks. In other cases, fish for stocking can be obtained through raising and spawning adult fish. In the latter example, the modern practice of injecting hormones is often used to obtain spawning as well as to adjust photoperiods.

The development of artificial foods such as sinking or floating pellets within the past two or three decades has stimulated the production of some species. However the cost of such feeds, coupled with feed conversion, mortality, and other costs, has sometimes placed these fish in the "luxury" class. Further advances in production of these fish may well be limited by the ability to secure necessary feed ingredients, such as fish meal, and by the price of such ingredients.

Sea ranching, which may be called a variety of names in different parts of the world, is creating considerable interest. This method involves releasing hatchery-reared animals of various sizes into marine waters for rearing and the subsequent recapture of the adult fish upon their return to the point of release. This method involves political and public decisions which may restrict further development in some countries and areas.

GOALS AND ORGANIZATION

The goals of the author have been to present in easy-to-read fashion, on a country-by-country basis, the present state of the aquacultural arts, and to

answer some of the questions which hopefully have been raised by the preceding section. An attempt has also been made to present today's technology, using different culturing techniques. Coupled with these goals is one of presenting economic data (extremely difficult to obtain and constantly changing) to the reader so that differences that exist among culturing systems, species, and countries may be more thoroughly understood. The most recent cost-relationships, marketing margins, and other economic data have been included when possible and where available. Sometimes these data become useless after only a brief time as the result of one or more changing relationships. However, the data presented do serve as a benchmark for future comparisons.

To allow for maximum understanding by as many people as possible from various countries, both the metric and British (called U.S. customary units in this book, since the British have converted to metric) systems of measurement are used and presented. Hopefully, this helps rather than confuses the reader.

This book is organized by continents and by countries. It begins with North America, including the USA and Canada. It then proceeds to Europe where countries are presented from northern Europe through southern Europe, followed by eastern Europe. Asia is then presented, again proceeding from northern Asia (Asian USSR) to southern Asia. Then comes Oceania. The book concludes with a brief outlook by the author and an appendix.

Africa and Central and South America are not presented. Essentially, these continents were omitted because of limited aquaculture production. For example, Africa in 1975 was estimated to produce only 2.7% and Central and South America only 0.7% of the world's cultured fish (Pillay 1976).

The major producing country in Africa is supposedly Nigeria, while the main country in South America where culturing is supposed to have some importance is Brazil. The author has spent considerable time in Brazil and was unable to find any appreciable amount of culturing (a few hundred tons), nor were other USA fish culturists who had spent years in Nigeria and Brazil able to confirm any evidence of appreciable culturing in either country.

REFERENCE

PILLAY, T.V.R. 1976. The state of aquaculture. Paper presented at the FAO Tech. Conf. on Aquaculture, Kyoto, Japan, May 26-June 2, 1976.

United States of America

FISH AND OTHER AQUATIC SPECIES

American eel (<i>Anguilla rostrata</i>)	Herring
<i>Artemia</i> nauplii	Kuruma shrimp
Bait fish	Minnows
Bass (<i>Micropterus</i>)	Northern pike (<i>Esox lucius</i>)
Bottom fish	Pacific salmon
Brook trout (<i>Salvelinus fontinalis</i>)	Pelagic red crab
Brown shrimp (<i>Penaeus aztecus</i>)	Pink or lost salmon (<i>Oncorhynchus gorbuscha</i>)
Brown trout (<i>Salmo trutta</i>)	Pink shrimp (<i>Penaeus duorarum</i>)
Buffalo fish (<i>Ictiobus</i>)	Prawns (freshwater) (<i>Macrobrachium rosenbergii</i>)
Bullheads	Rainbow trout (<i>Salmo gairdneri</i>)
Carp	Red swamp crayfish (<i>Procambarus clarki</i>)
Catfish	Sockeye or kokanee or red salmon (<i>Oncorhynchus nerka</i>)
Channel catfish (<i>Ictalurus punctatus</i>)	Steelhead
Chinook or king salmon (<i>Oncorhynchus tshawytscha</i>)	Trash fish
Chum or dog salmon (<i>Oncorhynchus keta</i>)	Trout
Coho or silver salmon (<i>Oncorhynchus kisutch</i>)	Tuna
Crabs	Turbot
Crappies (<i>Pomoxis</i>)	Walleye (<i>Stizostedion vitreum vitreum</i>)
Crayfish (<i>Pacifastacus klamathensis</i>)	White river crayfish (<i>Procambarus blandingi</i>)
Cutthroat trout (<i>Salmo clarki</i>)	White shrimp (<i>Penaeus setiferus</i>)
Dogfish	[Anadromous and nonanadromous salmonoids]
Fishheads	[Cold freshwater fish]
Flathead catfish	[Warmwater fish]
Goldfish	
Hake	

United States of America

COLD FRESHWATER CULTURED FISH

Rainbow Trout (*Salmo gairdneri*)

Rainbow trout is the only species of cold freshwater fish cultured commercially in the United States. It is cultured in 45 of the 48 contiguous states (Fig. 1.1). Only Texas, Louisiana, and Mississippi do not culture trout. In the past 5 years, new techniques of growing out trout in the colder winter months in what is normally warm water are changing this situation. Since 1975, some trout have been grown out in catfish ponds in Mississippi but only on a pilot basis. Hence, depending on profitability, trout may soon be raised in all 50 states.

The number of trout producers by types is unknown. In 1979 there were



Fig. 1.1. Geographic distribution of rainbow trout farms in the United States.

an estimated 653 growers of all types (Anon. 1979A). The leading states in numbers of commercial growers are: Idaho, Wisconsin, Colorado, Michigan, and Pennsylvania. To this number must be added 1086 operators of trout fee fish-out ponds. In 1979 there were 200 of these in Colorado and 197 in Pennsylvania, alone.

The trout industry in the United States has specialists dealing with one phase of production. These can be classified as:

- (1) *Egg producers* who raise fish to sexual maturity—usually 2–3 years—and spawn them for 3 or 4 years before they are sold for either processing or fee-fishing stock. Fertilized eggs may be sold as eyed-eggs or incubated and hatched. Fry and fingerlings are sometimes sold.
- (2) *Fingerling producers* who either raise their own fry or purchase them in sizes varying from 2.5 to 12.5 cm (1 to 2 in.) and sell them at sizes ranging from 10 to 20 cm (4 to 8 in.). These fish are sold alive to individuals who raise them to marketable sizes for human consumption or to individuals who operate fee fish-out facilities.
- (3) *Market fish producers* who usually buy eyed-eggs to be incubated and hatched. Fry are then raised to market sizes of 25 to 35 cm (10 to 14 in.). At that time they are transferred alive to processing plants, which may or may not be on the premises. Some of these producers



Fig. 1.2. Rainbow trout fee fishing, Georgia.

may buy fingerlings for growing-out. Depending on water temperatures, a marketable rainbow trout may take from 10 to 18 months from hatching.

- (4) *Grow-out producers* who may raise fish for another producer. The grow-out operator raises 10 to 15 cm (4 to 6 in.) fingerlings to market size without ever taking title to the fish. He is paid on the basis of weight gained. Time required to do this is usually 4 to 6 months. This depends on water temperatures, size of fingerlings stocked, size of marketable fish desired, and management.
- (5) *Fee fish-out operators* who usually buy catchable sized fish which can be caught within a short period of time by fishermen. Sometimes these operators buy fingerlings and raise them for 4 to 6 months and then transfer them to the fish-out facility.
- (6) *Live haulers* who haul live fish from one farm to another, or to a processing plant or fee-fishing facility. Some of these haulers may transport live fish 750 to 3000 km (500 to 2000 mi.).
- (7) *Processor* who may or may not have a fish production facility. He receives live fish for processing into fresh and frozen items (Table 1.1).

Feeds. In general, trout rations contain:

Protein	32–55%
Carbohydrate	9–12%
Fat	5–14%
Fiber	15–17%
Essential trace minerals and vitamins	

The wide range in ingredients is due to different types of diets for particular sizes of fish. For example, fry have higher protein requirements than fingerlings. Prepared feeds are sold either in bulk or in 22.7 kg (50 lb) bags. Rations are in the form of dry crumbles or pellets. There are more than 15 trout feed manufacturing companies. Each has its own formulations.

History. The business of raising trout for market began in the 1870s in the northeastern United States. The main produce of these early commercial trout farms was adult brook trout (*Salvelinus fontinalis*), which were sold in the fresh fish markets of large eastern cities. The eggs stripped from the ripe females were a secondary consideration as a

TABLE 1.1. DRESS-OUT FIGURES FOR A 28 CM (11.3 IN.) RAINBOW TROUT

Item	Market Weights		Dressing Loss % of Round Weight
	oz	g	
Round weight	9.25	263	0
Dressed weight	7.4	210	20
Boned weight	6.45	183	31.3
Fillet weight	5.0	142	46

saleable item. In the early 1900s brook trout farming became important. Fish farms were increased in number and size by constructing raceways. Food for the fish was obtained from packinghouse products such as spleen, liver, heart, and lungs, which were ground together with frozen bottom fish and fed as a thick paste.

Rainbow trout were officially introduced into the eastern United States in the 1880s. Their introduction into commercial fish farming did not occur until after 1900. At that time they were raised primarily as a hobby-type operation by private fishing clubs. Limited production of brown trout (*Salmo trutta*) and cutthroat trout (*Salmo clarki*) has occurred at various times. Essentially, recent production has centered on rainbow trout.

From the early 1920s until after World War II, private trout hatchery production developed very slowly because of the availability of sport-caught fish and low market demand. From the late 1940s until the present, the trout industry has grown rapidly. The most rapid change has been in processed fish, destined for food use.

Production data for cultured fish, both live and processed, sold annually in the United States are very difficult to obtain. Data quoted in trade and scientific journals are often misleading and conflicting. There are no official state or federal production statistics.

Present Status. Even with the lack of corroborative production data, it is safe to say that the trout industry is growing. Evidence of this comes from feed manufacturers who state that they are selling more trout feed than ever before. Similar statements come from egg producers. This increased production is occurring from enlargement of older farms, new farms, and fee fish-out ponds. Production of processed trout has also been expanding.

Klontz and King (1973) state that the main trout production states are Idaho, California, Wisconsin, Michigan, Colorado, and Pennsylvania. The author adds North Carolina to this listing.



Fig. 1.3. Large rainbow trout farm with feed being dispensed by feeding cart suspended from overhead rails, Idaho.

Data obtained by Klontz and King in 1973 indicate a total production of 12,272 MT (27 million lb) by private growers. Of this volume, about 9100 MT (20 million lb) was marketed through fee fish-out ponds.

More recent data (Anon. 1980) for 9 selected states (Idaho, California, Georgia, Missouri, Pennsylvania, Washington, Wisconsin, Alabama, and Arkansas) indicated 42,576,000 trout, weighing 12,800,000 kg (28,159,000 lb) of trout sold for food between January and July 31, 1980. Idaho accounted for 88% of the total sales with over 99% of the Idaho sales going to processors. Idaho also accounted for 99.7% of all processed trout in these 9 selected states. Of the total of 12,800,000 kg (28,159,000 lb) sold during 7 months, processing accounted for 88%; fee and recreation fishing for 5%; direct sales to consumers for 2%; and live haul, other producers, and government agencies for 3%. It must be remembered that data were gathered for only 9 states for only 7 months. Other important producing states such as Michigan, Colorado, and North Carolina were not included. Hence, it is reasonable to assume that possibly 13,608,000 kg (30,000,000 lb) were produced in the 7 month period from all states. If sales for the last 5 months of 1980 continued at the same rate as for the first 7 months, total sales may have approached 23,409,000 kg (51,500,000 lb), worth estimated as \$44 million.

Of the processed volume, about 88% was contributed by one state, Idaho. The remaining volume was contributed by all other states combined which market their trout largely through fee fish-out facilities or limited sales of fresh fish to local restaurants. For example, Colorado is considered a major trout producing state, yet a reliable estimate by Dr. H.K. Hagan (1972) of Colorado State University indicates that production is probably less than 114 MT (250,000 lb).

The primary reason for overwhelming importance of Idaho as the major trout producing state is adequate water of proper temperatures. This happy event is due to a geological accident referred to as the Southern Idaho Aquifer. The water originates in the mountains and enters the vast lava plain in southern Idaho.

This lava plain extends about 240 km (150 mi.) from east to west and about 80–120 km (50–75 mi.) from north to south. This rock is extremely porous and the mountain runoff is absorbed. Water emerges from this aquifer from the side of a deep fissure cut by the Snake River. In essence, underground rivers emerge to the surface at the canyon wall. The water is 14.4°C (58°F) and temperatures fluctuate by only about 0.5°C (1°F). Water flow through a single hatchery may be as much as 920 liters per sec (14,583 gal. per min).

In Colorado, there are no private producers with more than 56 liters per sec (897 gal. per min), and average flow is probably less than one-third of this figure. In other major trout producing states the same situation exists. Surface water is often not reliable, may be too warm in summer or have reduced flows in winter because of freezing. Springs are usually small and too far apart for an individual to have a large volume of production. Most of

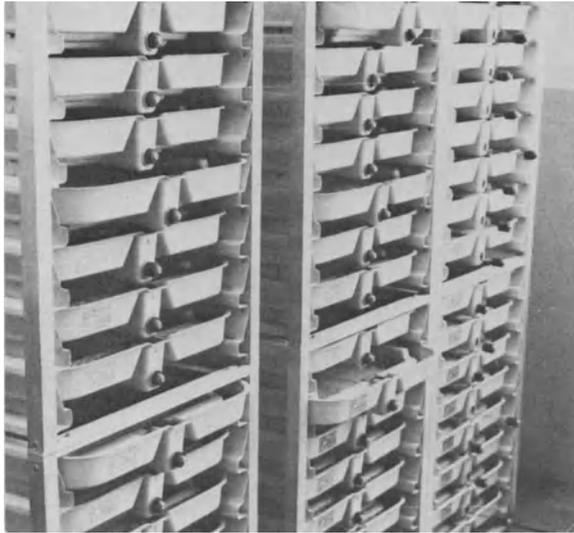


Fig. 1.4. Rainbow trout hatching trays in use.

these individuals are only part-time fish farmers. Even with small volumes, which in many cases do not exceed 5 MT (11,020 lb), some of these producers fare well. This is done by selling fresh dressed fish to local restaurants at prices above the frozen price or by sales through fee fish-out ponds.

The Idaho Fish and Game Department issued 72 permits to raise fish commercially in 1974. The majority of these permit holders were located along the Snake River.

The commercial food fish industry in Idaho is complex. No two individual facilities are alike from the viewpoint of raceway design, water utilization, feeding practices, fish density per unit of water volume or flow, and fish husbandry methods. In general, a raceway segment is 10 times longer than it is wide and is 1 m (36 in.) deep.

The industry in Idaho consists of: (1) egg producers who sell eggs both within and outside the state; (2) growers; (3) contract grow-out operators who furnish management, labor, and facilities; with contract grow-out operators the owner retains title and provides feed and technical assistance; (4) processors, who are integrated with a fish-raising facility; (5) fee fish-out operators; (6) live haulers; and (7) feed manufacturers.

Management. (a) Egg Incubation. After spawning, eggs are acclimated to water temperature at the hatchery. This is usually 13° to 14°C (56° to 58° F). After acclimation the eggs are placed in shallow trays in a single layer in baskets many layers deep. Trays of eggs are either stacked into deep troughs with baffles to provide upwelling currents of water through each stock, or in Heath incubators where water flows through each tray in an upwelling direction beginning with the top tray and progressing to the

bottom tray. The baskets are either placed into deep troughs, or into incubation boxes in which the water flow is upwelling at a rate that gently rolls the eggs. The time required for hatching is 21–23 days in 13°–14°C (56°–58°F) water. Hatching takes place 10 months out of the year. Only in July and August are eggs unavailable. In 1973, the Idaho trout industry eyed an estimated 165,320,000 salmonoid eggs of which 50,470,000 were incubated for hatching. Hatchability was 81.6%.

(b) Fry. The emergent yolk-sac fry are removed from incubator trays or baskets and put into troughs. When nearly all the yolk has been absorbed, they are started on feed dispensed by hand or automatic feeders. Several times a day they are fed an amount based upon the feed formulation of 7–9% of body weight, dependent upon water temperature. This management phase lasts for 3–5 weeks, depending upon facilities. Of the 41,180,000 fry hatched in 1973, 6,590,000 million died from various causes. The survivors were from 2.5 to 7.5 cm long (1 to 3 in.).

(c) Fingerlings. In this phase, fish are in outside ponds or raceways and are growing rapidly, sometimes over 2.5 cm (1 in.) per month. They are fed 4–5% of their body weight. During this phase, as the density of fish dictates by weight per cubic unit of water, they are distributed to other ponds or raceways. On some farms they are separated by size groups as they are distributed to new ponds. In 1973, 41,180,000 fry developed into 34,590,000 fingerlings. These fingerlings were from 7.5 to 15 cm (3 to 6 in.).

(d) Stockers. During this management phase, the fish are transported to either farm pond (grow-out) operations or fee-fishing establishments, or

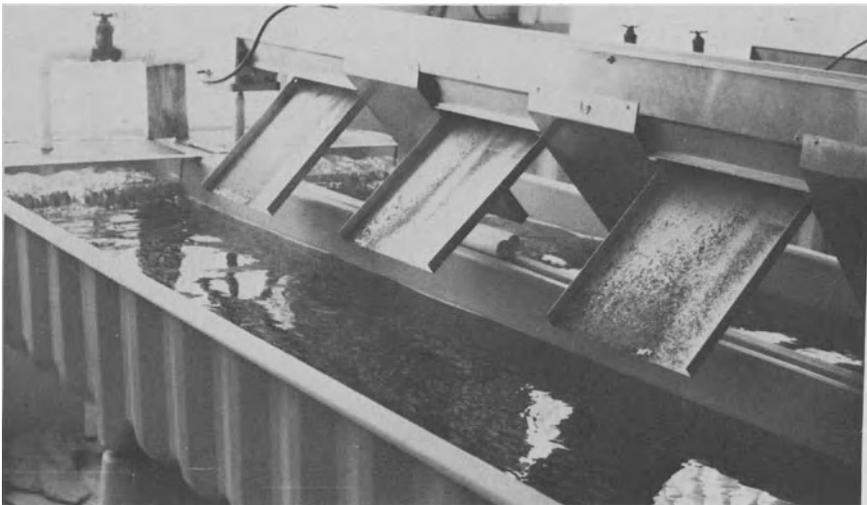


Fig. 1.5. Fry rearing troughs with automatic feeders for rainbow trout.

remain on the farm until they are of processable size. Inventorying and grading by size is done at monthly intervals. Since the growth rate has slowed, the level of feeding drops to 1–3% of body weight per day, depending on water temperature. In 1973, 34,590,000 fingerlings developed into 30,300,000 stockers.

(e) Marketables. These are fish that are 30 cm (12 in.) long or more. They are shipped from rearing ponds to processing plants. During 1973, 26,910,000 fish were sold live or processed. Hence, the survivability after hatching was over 65%.

Production and Marketing. There are no recent data available concerning production costs. Farmers in Idaho interviewed by the author in 1976 indicated that farm prices were near production costs. Farm prices for 280–390 g (10–14 oz) processable fish in May 1976 ranged between \$1.43 and \$1.54 per kg (\$0.65 and \$0.70 per lb). After processing, dressed fish, having undergone an approximate 20% weight loss, sold for \$3.30 per kg (\$1.50 per lb). Boned fish sold for \$3.74 per kg (\$1.70 per lb). Both dressed and boned fish prices were for frozen, packaged fish, FOB processing plant. Processed fish are usually sold by the processing plants to fish wholesalers whose marketing margin is about 20%. Hence, wholesale price was \$3.96 per kg (\$1.80 per lb) for frozen, packaged, dressed fish for sale to restaurants and retail stores, and about \$4.48 per kg (\$2.04 per lb) for boned fish. Retail store markup varies between 10 and 25% of wholesale price. Thus, retail store prices for dressed fish would vary from \$4.36 to \$4.95 per kg (\$1.98 to \$2.25 per lb). Prices of boned trout would vary from \$4.92 to \$5.60 per kg (\$2.25 to \$2.55 per lb).

Market sizes for the restaurant trade range between 225 and 336 g (8 and 12 oz) per dressed fish. Supermarkets prefer two 200–250 g fish in each package. This keeps the unit price down per 454 g or 1 lb package and is thought to increase retail sales. About 85% of Idaho's processed volume is sold frozen and 15% is sold as fresh, iced trout.

Fee Fishing. No one has any accurate idea of the number of trout fee fish-out operations in the United States. The author hazards a guess that there are between 1000 and 2000. In North Carolina alone there are over 100. These operators may buy fish already of catchable size (250 g or ½ lb) up to fish that have been used for spawning, or they may buy fingerlings and raise them up to catchable size.

These operators generally buy locally-produced live trout from nearby small-scale producers. The producers are insulated from competition of large-scale commercial producers in Idaho by several factors. To have live fish delivered from Idaho, hundreds or perhaps thousands of kilometers, is expensive. To lower costs, Idaho haulers may not deliver less than 1400 to 1800 kg (3000 to 4000 lb) in one load. Small scale fish-out operators may be willing and able to purchase only a few hundred kilograms or pounds at one

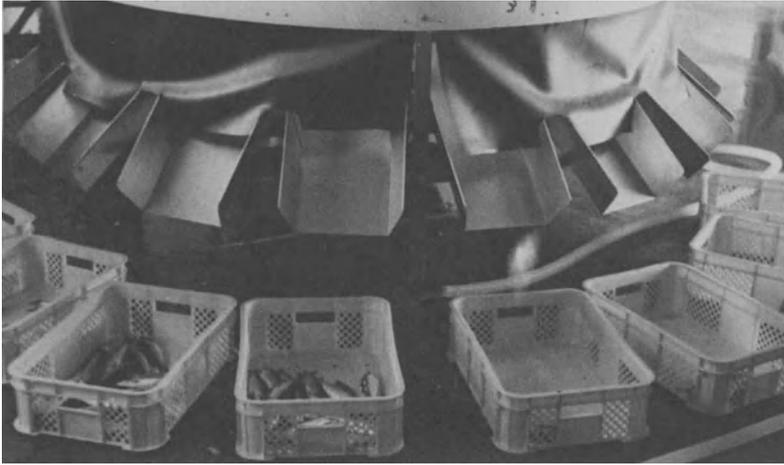


Fig. 1.6. Sizing dressed rainbow trout with automatic machine, Idaho.

time because of water restrictions. Hence, a long-distance hauler may have to coordinate sales to 6–10 outlets to dispose of one load. This is not profitable or feasible for haulers. The local producer can and does make deliveries of small lots at irregular intervals. The fee fish-out operator may secure from \$3.30 to \$4.40 per kg (\$1.50 to \$2.00 per lb) for fish caught at his pond. Thus, he is willing and able to pay more for his fish than the \$1.43 to \$1.54 per kg (\$0.65 to \$0.70 per lb) that Idaho producers secure from processing plants.

Fee fish-out facilities vary widely in size and volume sold annually. Some may sell only a few hundred kilograms (500 lb), while others may sell many tons. Usually, the catch-out price is a fixed amount per kilogram or pound of fish caught. The operator supplies fishing tackle and bait, dresses the fish, and packs them in ice for a small additional charge. These facilities are usually open to the public on weekends and in the main tourist season which varies by location. Either earthen ponds or concrete impoundments are used. The earthen ponds bear closest resemblance to a natural setting and are more popular with fishermen.

An example of popularity of such operations is the use of one fish-out facility in Georgia by over 3000 fishermen one year from which the operator sold more than 7300 kg of fish (16,000 lb) and grossed over \$25,000. There are undoubtedly many other larger operations in the United States.

Total Supply. Estimated cultured production volume of approximately 23,409 MT (51.5 million lb) of domestic production must be adjusted by deducting exports and adding imports to arrive at total supply. There are practically no exports of U.S. trout other than 50–60 MT annually to Canada. The major, if not only, country from which imports are made is

Japan. Imports of dressed frozen trout from Japan between 1967 and 1974 averaged 1136 MT (1252 ST) annually.¹ This would be equivalent to 1363 MT (1502 ST) of trout on a liveweight basis. Thus, total supply is about 24,722 MT (54,388,000 lb). About 95% of total supply is produced domestically and 5% imported.

Outlook. When the future of trout farming is discussed in the United States, it must be discussed from two viewpoints. These are: (1) the large-scale commercial processing segment, which is essentially in Idaho, and (2) the small-scale part-time enterprise which sells fish to one or two specialized trout restaurants and/or sells its output through fee fish-out facilities.

The outlook for the large-scale commercial processing segment varies from one of extreme optimism to one of cautious conservatism. At present, many producers feel that they are producing near cost and, unless production becomes more profitable, there will be little or no expansion. The majority of knowledgeable individuals believe that there are sufficient unused water sources in Idaho which can increase production by 20% within the next 10 years if producer prices increased faster than costs. Some producers express the view that average production costs can be slightly reduced under present conditions by better disease control. In the event production increases or remains stationary, the number of managements will decline, while average production per management increases.

The outlook for the small-scale, part-time trout farmer is good. Interest in and public demand for trout fishing is projected to increase rapidly. This means that market prices for fish producers will remain good or increase. Existing producers are unlikely to discontinue production while there are still sufficient water resources in the states of Wisconsin, Michigan, Missouri, Arkansas, Minnesota, Pennsylvania, and North Carolina for some expansion by new producers.

WARMWATER CULTURED FISH

Channel Catfish (*Ictalurus punctatus*)

Private warmwater fish culture in the United States probably began in the late 1920s and early 1930s. During this period a few individuals began raising minnows to supply the growing demand for fish bait for sports fishing.

Shortly after World War II, with the boom in farm pond and reservoir construction, the demand for minnows increased. By the late 1940s a dozen or more private operators were successfully producing bait fish. By 1953, the number had increased enormously, and farmers had begun raising buffalo fish (*Ictiobus*), bass (*Micropterus*), and crappies (*Pomoxis*). Many of these early attempts failed because of inexperience, improper construction

¹Export data obtained from customs data, Tokyo, Japan.

of ponds, or because low-value species were stocked.

The Southeastern Fish Cultural Laboratory was established at Marion, Alabama, in 1959; the Fish Farming Experiment Station at Stuttgart, Arkansas, in 1960; and the Fish Farming Development Center, Rowher, Arkansas, in 1963. These stations began research mainly in catfish (*Ictalurus*) and bait fish.

By 1961, the fish farming industry was again expanding. This time it was based on more experience and early results of research—especially catfish, which have proved to be the most desirable and profitable warmwater species.

In 1963, about 6830 ha (16,870 acres) were devoted to warmwater fish culture, 960 ha (2370 acres) of which were used in raising catfish. By 1969, the estimated totals were 27,530 ha and 16,194 ha (68,000 and 40,000 acres), respectively.

Data published by the U.S. Dept. of Agriculture for 1980 (Anon. 1980) indicated 22,741 ha (56,170 acres) used for catfish production in 19 selected states. For the entire USA, water area may approach 24,291 ha (60,000 acres). The 1980 crop of food catfish was about \$58 million at the farm and possibly \$140 million retail.

If the survey had been for 12 months instead of 7 months and if all states had been surveyed, food-size fish would have been about 32,727 MT (72,000,000 lb). Of this volume, 78% went to processors, 5% direct to consumers, 4% to fee and recreational fishing, 9% to live haulers and the remaining 4% to all other outlets. These comparisons dramatically attest to the explosive growth of the industry, particularly catfish production.

During these earlier days, fish farming was a welcome addition in the Delta areas of Arkansas and Mississippi. The field crops were rice and soybeans grown in rotation. Because of crop controls, some farmers had idle land that could not be planted to cotton, rice or soybeans. The fish returned a higher margin of profit than did some of the less productive crop hectareage. In addition, fish in the rotation added nitrogen for field crops and aided in weed control, which resulted in higher crop yields following the fish crop.

The farm-raised or cultured catfish industry, until about 1968, was based almost entirely on the market for live fish for stocking farm ponds, other fish farming operations, pay lakes, and reservoirs. Although these markets are still relatively important and still account for the majority of total sales, there has been a big shift toward production of catfish for the food market. With this shift has come the realization that marketing is at least as important as production efficiency and that independent restaurants, grocery chains, and fast food restaurants each have their own needs for portion control, custom preparation and packaging, and continuity of supply.

The channel catfish (*Ictalurus punctatus*) is the species most often raised on commercial warmwater fish farms. It adapts readily to pond conditions as well as raceways, cages, and tanks; accepts artificial feeds; and tolerates crowded conditions associated with intensive culture. Techniques for propagation have been developed so that large and adequate numbers of fingerlings can be produced.

Channel catfish are esteemed for the high quality of their meat, especially in southern states where the fish is a traditional delicacy. Dressed catfish retains a high quality when packed in ice and sold through traditional fish marketing channels. Frozen fish can be stored for extended periods without undue loss of quality if adequately packaged and refrigerated.

These attributes form the background for the expanding catfish industry. This expansion is described in the following sections.

Cultural Methods. Brood Stock. Large catfish usually spawn earlier than smaller ones and produce more eggs. Culturists prefer 1 to 5 kg (2 to 11 lb) brood fish, although stunted catfish can become sexually mature when they weigh only 340 g ($\frac{3}{4}$ lb). Fish larger than 5 kg (11 lb) are hard to handle. Channel catfish brood stock can be raised and reliably spawned in 3 years.

Brook stock should be selected prior to feeding. The female ready to spawn should have a well rounded abdomen with the fullness extending past the pelvis to the genital orifice. The ovaries should be palpable and soft, and the genitals swollen and reddish. Less care needs to be used in selecting males. Males with prominent secondary sexual characteristics such as a heavily muscled head wider than the body, dark pigmentation under the jaw, and large protruding genital papilla, usually have well-developed testes. Such males may be used successfully for as many as three times, whereas males with poor secondary sexual characteristics may be capable of fertilizing only one spawn.

Pairing. Successful pairing of fish, which is an essential part of pen and aquarium spawning, depends on the skill of the culturists in sexing and selecting the fish. Sex determination is slightly less important in pond spawning.

Channel catfish fish fight during the spawning season. Their bites are often deep enough to break the skin, and the resulting wounds may become infected. Fish sometimes die from severe bites, and for this reason, special care must be taken to pair fish properly in pens and aquaria. If the female, in particular, is not ready to spawn, the male will fight with her, and in the confinement of an aquarium may inflict enough injuries in 15 or 20 min to kill her. In spawning pens, the condition of the female is not quite as important, since the pen is usually large enough for her to escape from the attacking male. Even so, it is not uncommon to see bite marks on the female in a pen. When fish reproduce in ponds, they pair when they are ready to spawn, and fighting is not a serious problem.

Although most culturists prefer or require that the male be slightly larger than the female, biologists who have observed hundreds of pairs spawned in aquaria under different experimental conditions have concluded that males and females of similar size should be used. If the male is considerably larger than the female, spawning is usually successful; if the female is much the larger, however, she usually attacks the male and may not mate with him.

Care and Handling. Immediately after the spawning season, brood stock may be placed in a pond at the rate of 375 per ha (150 per acre). Although the fish are easily frightened, 90 to 95% of the fish held in small ponds will learn to come for feed within 1 week. If this same number of fish is held in a 0.40 ha (1 acre) or larger pond, 25 or 30% may never come for feed, and consequently will be in poor condition and undesirable for brood stock during the next spawning season.

One recommended practice is that of dividing the fish among several ponds to prevent destruction of the entire brood stock by a possible epizootic. Some hatcheries distribute the adult catfish throughout all available ponds during the summer. The scattered fish then need not be fed because sufficient natural food is available. When the ponds are drained in fall and winter, the catfish from several ponds are returned to a single pond and fed until time for spawning. The feeding of brood stock is important because diet quality and quantity largely govern the number and size of eggs, spawning time, and general health.

Brood fish that weigh 1 to 1.5 kg (2 to 3 lb) should be stocked at the rate of 750 to 1000 kg per ha (300 to 400 lb per acre) when additional growth is desired. Larger fish should be stocked at the rate of 2000 kg per ha (800 lb per acre) if further growth is not wanted. The feeding rate and diet depend partly upon water temperature. Brood fish should be fed 2 to 3% of their body weight on each of 3 or 4 days a week when water temperature is above 13°C (55°F). Since brood stock channel catfish feed sparingly even when the water temperature is as low as 7°C (45°F), they should be fed only on the warmest days of cold weather periods. When it is very cold, catfish feed on meat or diets high in animal protein better than they do on cereal feeds.



Fig. 1.7. Catfish spawn. Courtesy of Fish Farming Experimental Station, Stuttgart, Arkansas.

Meat diets can be readily utilized by the fish, and it is generally accepted that fresh or frozen meat or fish should be included in the brood stock diet.

Number of Eggs Laid. Females weighing 0.5 to 1.8 kg (1 to 4 lb) and in good condition produce about 8889 eggs per kg (4000 eggs per lb) of body weight; larger fish usually yield about 6667 per kg (3000 per lb). Fish in poor condition produce fewer eggs.

Egg Development and Incubation. The number of days required for eggs to reach various developmental stages varies according to temperature. Channel catfish spawn at 21° to 29°C (70 to 85°F); the optimum temperature is about 27°C (80°F). The incubation period ranges from 10 days at 21°C (70°F) to 5 days at 29°C (85°F). At incubation temperatures above 29°C (85°F), many deformed fry are produced.

The male channel catfish assumes a position over the eggs after spawning is finished and cares for the eggs during the incubation period. Although the female aerates the eggs during spawning, she is driven away along with other intruders after the male takes possession. The male generally faces in the same direction with his pelvic fins working alternately in a continuous beat. Occasionally he circles away from the eggs and returns. The most striking activity of the male is the vigorous shaking of his body as he presses and packs the eggs with the sides of his pelvic fins in a manner that moves the entire egg mass. Apparently this act helps aerate the developing eggs, especially those deep within the mass, but it may also serve to move the embryos within the eggs.

Many fish farmers who produce fingerlings for sale prefer to collect spawns and hatch them in artificial hatching systems. Good incubation and hatching are obtained at some hatcheries by the paddle wheel method (described later), which simulates the male's agitation of the eggs.

After the eggs hatch, the fry accumulate on the bottom and remain there for about 2 days before coming to the surface. At this time, the yolk is greatly reduced and the skin pigment is visible. By the third day, the fry start to feed and swim actively.

Pond Method of Spawning. In early attempts to induce spawning, tiles, beer kegs, nail kegs, or boxes were partly embedded in the bank of a pond, about 0.6 to 1 m (2 or 3 ft) below the water surface. After the brood fish placed in the pond had spawned, the newly hatched fish were removed from the containers and transferred to a clean pond. In later years, the egg masses were removed from the pond for incubation; continuous-motion paddles were used to agitate the water and the eggs. This system for hatching catfish eggs is still in use.

The pond method remains essentially unchanged. Brooders are placed in small, usually shallow ponds, ranging up to about 2 m (6–7 ft) deep. Equal numbers of males and females are placed in the pond at a stocking rate of 60 to 375 fish per ha (24 to 150 per acre).

Forty liter (10 gal.) milk cans and small drums are popular spawning containers. Ordinarily it is not necessary to provide a spawning receptacle

for each pair of fish, since not all fish spawn at the same time. Most culturists allow 2 or 3 receptacles for each 4 pairs of fish. The cans or drums are usually placed with the open end toward the center of the pond. Fish have spawned in containers in water as shallow as 15 cm (6 in.) and as deep as 1.5 m (5 ft). The receptacles can be most easily checked in water no deeper than arm's length.

Frequency of examination of spawning containers depends on the number of brood fish in the pond and the rate at which spawning is progressing. Caution should be used because an attacking male can bite severely. In checking a container, the culturist gently raises it to the surface. If this is done quietly and carefully, the male is not disturbed. If the water is not clear, the container may be slowly tilted and partly emptied until the bottom can be checked for eggs or fry.

Spawns may be handled in different ways by the fish farmer. In the pond method, he may either remove eggs or fry or leave them in the spawning receptacle. Removal of the eggs has several advantages: It minimizes the spread of diseases and parasites from adults to young; provides protection from predation; and may increase the percentage hatched. The main reason for removing fry is to improve control of stocking rates, although it also protects them from predation. Fry or eggs are often removed when spawns are produced for stocking other ponds. Large-scale producers commonly use special brood ponds.

If eggs and fry are left in the pond, the brood stock should be removed with a large-mesh seine. Periodic seining with a small-mesh seine provides information about numbers and growth of fingerlings.

Advantages of the Pond Method. The pond method is inexpensive because it requires minimal facilities of a pond and spawning containers and does not place demands on the farmer for critically selecting, sexing, and pairing his brood stock. The fish in the pond continue to feed and develop until they pair and spawn. If the brood fish are of marginal quality, the pond method is more likely to produce spawns than are the other methods.

Pen Method of Spawning. Pens about 3 m long and 1.5 m wide (10 ft long and 5 ft wide) are commonly used by federal and state hatcheries and by a few private hatcheries. The pens are constructed of wood, wire fencing, or concrete blocks. They may be enclosed on 4 sides, or the bank of the pond may be used as one side. The sides should be embedded in the pond bottom and should extend at least 30 cm (12 in.) above the water surface to prevent the escape of the fish. Water in the pen should be 0.6 to 1 m deep (2 to 3 ft).

Location of the spawning receptacle in the pen is not critical, but the opening generally faces the center of the pond and the receptacle should be staked down. Forty liter (10 gal.) milk cans, 45 kg (100 lb) grease drums, and earthenware crocks are popular spawning containers. After spawning, eggs or fry and parent fish may be removed and a new pair placed in the pen. Alternatively, the female may be removed as soon as an egg mass is found, and the male then allowed to hatch the eggs.

Advantages of the Pen Method. The pen method has several advantages: (1) it provides close control over the time of spawning since it may be delayed by separating females from males; (2) it offers the advantage of pairing selected individuals; (3) it facilitates removal of spent fish to a separate pond where they can be given special care; (4) it protects the spawning pair from intruding fish; and (5) it allows the use of hormones.

To succeed with the pen method, the culturist must know his or her fish well enough to be able to pair the right fish at the right time.

Aquarium Method of Spawning. The aquarium method provides still greater control than the pen. A pair of fish is placed in an aquarium with running water and induced to spawn by the injection of hormones (described later). The method capitalizes on limited facilities, use of hormones, and expert brood fish selection. It is an intensive type of culture in which many pairs can be successfully spawned in a single aquarium during the breeding season, since eggs are immediately removed to a mechanical hatching trough. The technique is used in federal, state, and a few private hatcheries.

In this method only well-developed females nearly ready to spawn should be used. Males need not be injected with hormones, but should be about the same size as the females with which they are paired. If the male attacks the female, he should be removed until after the female has been given one to three hormone injections. He may then be placed with the female again. Males may be left to attend the eggs in the aquarium; or, preferably, the eggs are removed to a mechanical hatching trough.

Spawning may be induced in catfish by injecting the female intraperitoneally with pituitary material from carp, buffalo fish, flathead catfish, or channel catfish. Potency of the pituitaries differs little among these species and is not affected by the date of collection. The total amount of acetone-dried pituitary material required varies widely. However, most females require about 6 mg per 454 g (1 lb)—that is, three injections of 2 mg per 454 g (1 lb) of body weight at 24–48 hr intervals. Most fish begin spawning within 16 to 24 hr after the injection.

Human chorionic gonadotropin at a dosage of about 800 international units (IU) per 454 g (1 lb) has been used successfully. A single injection is usually sufficient.

Fish spawned by the hormone method are not particularly disturbed by people moving around the area.

Advantages of the Aquarium Method. The aquarium method has several advantages: (1) Spawn can be obtained at a convenient time. The hormone injections eliminate such environmental variables as spawning areas, light, and temperature, and other climatic conditions. (2) The spawning period can be altered within reasonable limits, and total spawn-taking time reduced. (3) Fish that will not spawn naturally sometimes can be induced to spawn. (4) Culture ponds can be stocked with fry of uniform age and size. (5) Disease transmission from brood stock to offspring, as well as predation by adults, is minimized.

Controlling Spawning Time. The date and length of the spawning season for channel catfish vary from year to year and among localities. In various natural waters, the season may begin as early as April and end as late as August.

Encouraging Spawning. In June and early July, fish in pens occasionally spawn for a few days and then completely stop. Raising the water level rapidly 5–8 cm (several inches) will sometimes cause spawning to resume.

Some farmers inject brood females with human chorionic gonadotropin before transferring them to the spawning pond. Others have advanced the spawning time about 2 weeks by taking advantage of the warmer water of small, shallow brood ponds.

Spawning can be delayed 20 to 30 days by keeping the sexes separated. It may also be delayed by holding the fish at water temperatures of 17° to 18°C (65° to 66°F) during May, June, and July.

Hatching Eggs. For egg incubation, temperatures below 18°C and above 29°C (65° and 85°F) should be avoided. Temperatures between 26° and 28°C (78° and 82°F) are considered optimal. In this range, the eggs will hatch in about 6 days.

Color is an important index of the condition and stage of catfish eggs. Under proper conditions, the yellow eggs turn pink as the embryo develops and establishes its blood supply. Unfertilized or dead eggs turn white and enlarge.

All hatching devices must provide sufficient agitation to supply the entire egg mass with oxygenated water of a suitable temperature. When eggs are hatched in troughs, they are agitated with paddles driven by an electric motor or a water wheel. The agitation should be sufficient to move the whole spawn, but not enough to throw eggs out of the holding baskets. If well water is used, it must be aerated and of suitable temperature and quality. For example, water with a high iron content is not considered desirable. Gravity-flow water should be used if available because this system is not likely to fail.

Trough hatching systems may be constructed from a variety of materials. Aluminum is commonly used, but wood or steel serves equally well. The shaft is fitted with a pulley at one end and is belt-driven by an electric motor (frequently ½ hp) at a preferred speed of 30 rpm. Combinations of pulley sizes or a variable-speed gear box may be used to deliver the desired speed of rotation.

Spawn baskets are constructed of 1.6 cm² (¼ in.²) hardware cloth. Each basket is divided into 4 equal sections, and fitted with wire hooks so that it can be hung on the sides of the trough with the top edge 2.5 cm (1 in.) above the water. A flow of about 10 liters (2.5 gal.) per min of well-aerated water should be provided.

It is important that spawns in each section of trough be of the same age, because the mixing of spawns of different ages may prevent the use of prophylactic treatment.

A flush treatment of malachite green at about 2 parts per million (ppm) may be introduced at the head of the trough once or twice per day if needed to control fungus. Fungi grow on dead eggs and spread to living ones, eventually destroying the whole spawn. This chemical is not to be applied within 24 hr of hatching. If fry are present, it will kill them.

Rearing Fry. To remove fry from the hatching trough, the culturist simply siphons them from the trough with a hose into a washtub or pail. To remove fry from a pond spawning receptacle, he first removes the male, usually by frightening him away, then lifts the spawning container to the surface and carefully pours out part of the water. The remaining water with the fry can then be emptied into a floating tub that contains 2.5 to 5 cm (an inch or two) of water. Fry should be counted and then moved to either a rearing trough or a pond.

Trough Method. Rearing troughs may be made of wood, metal, fiberglass, or plastic. Typical troughs are 2.5–3.0 m long, 30 cm deep, and 20 to 50 cm wide (8 to 10 ft long, 1 ft deep, and 8 to 20 in. wide). Each trough must be supplied with running water and equipped with a drain and a standpipe. The fry from one or two spawns are put into each trough. A flow of about 20 liters (5 gal.) of fresh oxygenated water per minute is sufficient. Standpipes are screened so the fry are not washed over the standpipe and down the drain.

Fry begin to feed shortly after the yolk sac is absorbed and the fish begin to develop a grayish color. This usually occurs at 3 days of age. It is mandatory that suitable feed be available at this time. Channel catfish fry eat a variety of feeds. Feeding frequencies and particle size are important considerations. Young fry should be fed every 2 to 4 hr around the clock for the first week. Thereafter the fry should be fed about 4 times a day. Diets for channel catfish are now available commercially in the USA. Fry may be raised to the fingerling stage in troughs, or may be moved to a rearing pond at any time.

Pond Method. Although the area of rearing ponds for channel catfish varies from 1000 m² to 2 ha (1/10 to 5 acres) and larger, they are usually about 0.4 ha (1 acre).

Predatory insects are often a problem in the pond culture of fry. If a pond is not filled until immediately before it is stocked with fry, establishment of the insects is prevented. If water has been standing in the pond for several days, or if surface water is used, it should be treated with a nonresidual insecticide 2 or 3 days before the pond is stocked. The operator should use extreme care, however, because insecticides are dangerous to man.

Fry can either be released directly into the open pond or be held for the first few days in floating cages made of screen or a wooden frame with a screen bottom. They are then protected and can be fed during this vulnerable period. If a pond has a basin, fry may be placed in it and the rest of the pond kept dry. As the fry get larger, the pond is gradually filled.

Fry are stocked at the rate of 125,000 to 625,000 per ha (50,000 to 250,000 per acre), depending on the size of fingerlings sought at the end of the growing season. Young fish are fed daily along most of the shoreline at a rate of about 4 to 5% of their body weight at each feeding.

Rearing Fingerlings. Channel catfish fingerlings are reared in either ponds or troughs. In ponds, low-cost pelleted fish feed may be used, but in troughs a more expensive, balanced feed is required. In the two environments, different methods and techniques are used to stock, feed, and harvest the fish. Some farmers prefer to start the fry in rearing troughs and transfer the fingerlings to ponds after they are actively feeding. The choice of method depends on facilities and labor available, and on the number and size of fingerlings to be produced.

Regardless of the rearing method selected, attention should be given to the water supply. In the trough rearing method, the incoming water should range between 24° and 29°C (75° and 85°F) and contain not less than 6 ppm of dissolved oxygen. Factors such as pH, hardness, and dissolved iron content influence production of fish in troughs that are supplied with well water. When water from ponds is used for trough culture, these conditions may be disregarded. Then, however, a Saran screen or sand filter between pond and trough is desirable. In pond rearing, a major problem is fry-eating insects and fish. Predatory fish can be controlled by filling the pond with fish-free well water or by using a fine-mesh screen to filter water from other sources; fish-eating insects can be controlled by treating weekly with oil or kerosene, until the fish are about 3.8 cm (1½ in.) long.

Trough culture of fingerling catfish begins with yolk-sac fry from the hatching trough or from spawning containers in the ponds. It is a good practice if time and facilities permit because it give the culturist complete control of the small fish. When fry about 2 cm (¾ in.) long are stocked in rearing ponds, 60 to 90% can be harvested the following fall.

Techniques for feeding catfish fry are extremely important, particularly when the fry are learning to feed. For about the first 3 or 4 days after hatching, fry subsist on yolk and remain on the bottom of the pond or trough. After they have absorbed the yolk sac they become known as "swim-up" fry. When they are seen swimming along the sides and surface of the trough in search of food they must be fed at once. Fry that do not learn to feed during the first few days after absorption of the yolk sac will die.

In pond culture, either sac fry, swim-up fry, or feeding fingerlings may be stocked. Stocking rates vary, depending on the fingerling size desired. If the fish are to be harvested at 5–10 cm (2–4 in.) lengths after about 120 days, they are stocked at the rate of 250,000 to 375,000 per ha (100,000 to 150,000 per acre). If 20 cm (8 in.) fish are desired, the stocking rate should be reduced to 35,000 to 50,000 per ha (14,000 to 20,000 per acre). A combination of these methods may be used: The fish can be stocked at the maximum rate initially, and then partially harvested for sale or transfer to other ponds when they reach the 5–10 cm (2–4 in.) size.

When all the fingerling catfish in a pond are to be harvested, as many as 75% of the fish may be removed by seining the feeding areas before the pond is drained. In summer it is best to harvest the fish early in the morning while water and air are cool. Care should be taken to avoid excessive muddying of the water. If possible, sites with a firm obstacle-free bottom should be selected as feeding and seining areas. After the seining is completed, the pond is drained to recover the rest of the fish.

Rearing Fingerlings to Market Size. A large healthy fingerling, a good environment, and a conscientious feeding program are necessary for a profitable food-fish production program. If market sized fish are to be produced in one growing season, fingerlings 15–20 cm (6–8 in.) long or longer must be stocked. Such fingerlings will weigh at least 454 g (1 lb) after about 210 days, if properly cared for.

Time of stocking is not as critical as some believe. A pond should be stocked whenever it is ready to receive fish. A 5 cm (2 in.) fish stocked in July will be only 24–25 cm (9–10 in.) long by November and must be reared to market size the next summer.

The poorest stocking months are December and January because of the low water temperature. Fish feed least at this time of the year and sometimes do not resume feeding readily after they are moved. The fish that die after stocking at this time of year may never be seen. (Under warmwater conditions, fish that die bloat and eventually float. In winter, in cold water, dead fish may be eaten before decomposition creates enough gas to cause them to float.)

Fish should be fed during winter, but the feeding rate should be reduced as the water cools. Self-feeders are useful under such conditions. At low water temperatures, fish move slowly and do not seek out feed as they do when the water is warm; they also consume less food at each feeding and digest it much more slowly.

It is very important that fingerlings start feeding immediately after they are stocked in a pond. Well-fed healthy fish are more resistant than others to parasites, disease, and predators, and reach marketable size sooner. Fish soon learn to feed as food is provided along the entire edge of the pond on the day after they are stocked.

Once the fish start eating, a good feeding program should be initiated and followed. Food allowances are 3 to 6% per day of the estimated weight of fish in the pond; rates are lower (1½ to 2%) during unusually hot or cold periods. Feed is offered in the early morning and late afternoon in summer but only in late afternoon during the cooler seasons. If sinking pellets are used, it is desirable to scatter them along the shallow pond margin where feeding activity can be observed. Floating feeds may be scattered over the entire surface of the pond. Feeding activity is a good index of the well-being of the fish; rapid and vigorous consumption of the food suggests good environmental conditions and good health.

Catfish are being raised successfully in water from many sources. Well

water is best, but other uncontaminated supplies such as clean streams or springs are acceptable if they are free of fish and disease organisms.

Oxygen depletion is the greatest fish farming problem. Most oxygen depletion kills are preceded by a phytoplankton die-off and decay. This situation is aggravated by the decomposition of uneaten fish feeds and fecal waste. When excessively thick blooms of phytoplankton (algae) occur, it is desirable to add fresh water to the pond. Feed should be reduced in amount or withheld entirely until the condition has improved.

Catfish culture is also influenced by aquatic vegetation. Although rooted aquatic plants and filamentous algae are not as troublesome in pond rearing of catfish as they are in some other forms of fish culture, they should be removed if they appear. Manual removal and some chemical controls are feasible.

When treating a pond with chemicals, the culturist should be aware that the chemical may be toxic to the fish, and that killing too much vegetation at one time can result in an oxygen-depletion mortality. Ponds should be carefully checked for low oxygen each day for 7 to 10 days after applications of herbicides.

Production. Channel catfish are the principal warm freshwater food fish cultured in the United States. The principal states of production are the Mississippi Delta states, some of the southeastern states, and a few others. Major states, not in order of importance, are Arkansas, Mississippi, Louisiana, Texas, Oklahoma, Kansas, Missouri, Illinois, Indiana, Tennessee,



Fig. 1.8. Primary catfish-producing states.

Alabama, Georgia, South Carolina, Florida, California, and Idaho. Catfish may be cultured to some extent in 6–8 other states.

A survey made in 1970 (Anon. 1979A) indicated that there were 3802 enterprises engaged in the commercial production of catfish. To these must be added 2233 enterprises engaged in fish-out operations and 1,724,491 rural operators who have some recreational fishing in private ponds.

A typical food-size fish producer buys his fingerlings from a specialized producer. The specialized fingerling producer keeps brood fish and spawns and raises the fry to fingerling sizes. The size of fingerling stocked by food-size fish producers (grow-out operations) ranges from 6 to 22 cm (2 to 9 in.) depending on when he stocks the fish and when he hopes to harvest at 454 g (1 lb) size. In pond culture, most fingerlings stocked are between 13 and 20 cm (5 and 8 in.). They are usually stocked in March, April or May. These sizes reach market weights in the fall. The raceway and cage producers buy slightly larger fingerlings. Producers who plan to harvest in late spring or early summer of the following year buy smaller fingerlings.

The primary producing states in 1976 were essentially in the southeastern United States, an area blessed with ample water and a long grow-out season with warm conditions. Exceptions to this were California and Idaho. California produces fish in certain areas because the market price structure is conducive to higher cost grow-out operations. In Idaho, warm water springs and wells are used for year-round growth. The fish are marketed on the west coast.

Double Cropping. One rather interesting development taking place is the raising of channel catfish and rainbow trout in the same facility at different times of the year. Trout fingerlings are stocked in the fall of the year when water temperatures drop below 21°C (70°F). They are then fed out until the spring of the year when water temperatures increase to above 21° or 22°C (70° or 72°F). By stocking the proper sized fingerlings, the fish can reach market sizes in 120 days or less. After the trout are harvested, channel catfish fingerlings are stocked in the warm water. They are then fed out to the fall of the year when it is time to restock rainbow trout again. By stocking the proper sizes of catfish fingerlings, the fish reach market sizes of 454 g (1 lb) during an 8-month season. This work, which was begun in Georgia by the author and two co-workers in raceways, is slowly being developed commercially.

The major advantage to double cropping is the sharing of fixed expenses by two crops of fish. This lowers the production costs of both species. Net returns can be increased by 100% or more, using this technique.

Feeds and Feeding. The objective of any animal husbandry is to convert relatively low-cost feedstuffs into high value, high-quality protein. Fish farming is no exception.

Catfish are desirable for recreation and food. They may be raised in still water, flowing water raceways, tanks, troughs, pens, or cages. They may be fed wet or dry feeds prepared as meals, sinking pellets, floating pellets,

blocks, or crumbles. When stocked at high population densities in a restricted area, catfish soon exceed the production limit of natural foods and must depend on artificial feeds for growth.

There are no standard cages used for catfish. Usually, cages are homemade and between 1 and 2 m square, this size being suitable for treatments for diseases and parasites. Figure 1.9 shows a large-scale cage which is not suitable for catfish because of its large size but does serve to show what a cage looks like.

In pond tests, channel catfish fingerlings stocked at 3705 per ha (1500 per acre) showed an average net gain of more than 454 g (1 lb) in 6 months, with a feed conversion of 1.3 or 1 unit of gain per 1.3 units of feed.

A general formulation guide is as follows:

Crude protein	>30%
Digestible protein	>25
Fish meal protein	>35
Crude fat	>6
Crude fiber	>8 and <20

An economical minimum level of fish meal in the diet for ponds is 5 to 6%.

Feeds for raceways and cage culture, as well as other intensive production techniques, should contain more high-quality protein and more vitamins and minerals than those used in pond culture. This, of necessity, requires a more expensive feed.

The ingredients and amounts to make a ton of feed are given in Table 1.2. This feed formula has given excellent results at the Fish Farming Experimental Station, Stuttgart, Arkansas.

The Bureau of Commercial Fisheries recommends that feed be provided at the rate of 3% of body weight per day, 6 or 7 days a week. The feed should be distributed around the pond edge in water 0.6 to 1.3 m deep (2 to 4 ft). Feeding should be checked periodically to see that the food is being consumed. Checking can be done by using submerged feeding tables that can be raised and lowered. If after several hours feed remains on the table, the amount fed should be reduced.



Fig. 1.9. Catfish cage culture, Arkansas.

TABLE 1.2. INGREDIENTS AND AMOUNTS TO MAKE A TON OF FEED FOR CHANNEL CATFISH

Item	lb	kg	%
Fish meal	300	150	15.0
Bloodmeal	100	50	5.0
Feather meal	100	50	5.0
Rice bran	700	350	35.0
Distillers' solubles	100	50	5.0
Rice milldust	200	100	10.0
Soybean meal	400	200	20.0
Dehydrated alfalfa	70	35	3.5
Mineralized salt	20	10	1.0
Vitamin premix	10	5	0.5

Source: Anon. (no date).

According to the Fish Farming Experimental Station, Stuttgart, Arkansas, the following feeding rates have proved to be satisfactory: Feeding at the rate of 3% of body weight per day when the water temperature is 21° to 29°C (70° to 85°F); when water temperature is 27°C (85°F) or above, only that feed that is consumed in a 10 min period should be fed. When the water temperature is 15.5° to 21°C (60° to 70°F), feeding should be at the rate of 2% of body weight; when temperatures are 7° to 15.5°C (45° to 60°F), feed at 1% of body weight; and when temperatures are below 7°C (45°F), no feed should be given.

Channel catfish are excellent converters of feed. Research reports from



Fig. 1.10. Bailing catfish from live car, Arkansas. Courtesy of U.S. Bureau of Commercial Fisheries, Kelso, Arkansas.



Fig. 1.11. Mechanical loading of hauling truck from catfish live cars, Arkansas. Courtesy of U.S. Bureau of Commercial Fisheries, Kelso, Arkansas.

several experiment stations show conversion rates of 2:1 under actual field conditions. Under controlled experimental conditions conversions as low as $1\frac{1}{4}$ units of feed to 1 unit of gain have been achieved. It is not at all unrealistic to expect conversion rates of 2:1 for most fish farming operations.

Off-flavor. One problem which is sometimes encountered with catfish is off-flavor. This unfortunate occurrence, if it shows up, is noticeable as an off-fragrance during cooking and as an off-flavor during eating.

Test work by Armstrong and Boyd (1981) suggests that off-flavor may be distinctly noticeable in some 15 to 20% of ponds harvested. Off-flavor fish were found in ponds with low as well as high feeding rates. However, off-flavor was encountered more frequently and to a greater degree in ponds with the highest feeding rates of 66–112 kg/ha (50–100 lb/acre) per day. Variation in off-flavor is great. On the same farm, some ponds contain off-flavor fish and other ponds do not. In the same pond, fish are “off-flavor” one month and “on-flavor” the next month. No correlation was found between fish length, 20–45 cm (8–18 in.), and off-flavor.

Lovell (1981) reports that off-flavor is a complex and frustrating problem. A taste panel at Auburn University described the various off-flavors as: muddy or musty, stale, rancid, metallic, moldy or cobweb, petroleum, weedy, or a combination of off-flavors, and in some cases could not agree on a descriptive term to describe the offensive flavor.

The causes of most off-flavors are unknown. Some conditions that are believed to be associated with off-flavors are: excessive algae blooms; over-feeding; organic decay; muddy water; the use of certain chemicals; and diet. It is believed that the metabolites of some algae and products of natural

bacterial decomposition may be involved in many off-flavor problems. It is felt that off-flavors are an environmentally related problem, although the environmental conditions favoring a specific off-flavor problem are unknown.

Fish farmers have used several techniques to treat off-flavor problems. Hydrated lime, low concentrations of copper sulfate, potassium permanganate, and flushing of ponds have been used. Results have varied. The results of these treatment methods will continue to be questionable until scientists can identify the various causes of off-flavors because the treatment must be matched to the cause.

Farmers should check their fish for off-flavors just prior to harvest. Several fish from each pond to be harvested should be cooked and tasted to determine if there are any off-flavor problems. If an off-flavor problem is discovered, harvesting the pond should be delayed.

Smaller catfish farmers may sell all their product in one or more local markets, and selling off-flavor fish could result in losing these outlets. Large processors usually spot-check a load of fish before harvesting or before processing by cooking and tasting. This keeps the off-flavor product out of the marketing channels.

Harvesting. Harvesting catfish raised in tanks or cages is relatively easy; they are lifted out with a dip net, loaded into transfer containers, weighed, and placed in the live haul truck for transportation.

Raceways can be harvested using a seine. Since the raceway segments are usually not over 6 m wide (20 ft), a seine about twice this length is used. The seine is dragged the length of the raceway segment, crowding the fish against the concrete headwall where they are dipped out. A second alternative is to drain the segment. With this system a fish trap is placed below the headwall, and the fish are trapped as they leave the raceway segment.

Pond harvesting is much more complex. The USA has some of the largest, if not the largest, fish culturing ponds in the world. A few ponds are as large as 65 ha (160 acres). Ponds of 16 ha (40 acres) are commonplace.

In current practice, extensive preparations are usually required to ready ponds for harvesting the fish. Draining a pond and preparing for final harvesting operations by means of pumps or ditches require several days. During draining, some of the fish may die from being concentrated in a small volume of water with inadequate oxygen. Also, valuable amounts of water are wasted. Coordinating production with market demands is difficult. For example, to harvest and transport to market over 20 MT per day from one pond may not be possible. Hence, for ponds larger than 8 ha (20 acres) the volume of fish in the ponds exceeds the capacity of the market. Since each truckload is about 5 MT (5½ ST), an 8 ha (20 acre) pond requires the movement of 4 truckloads daily. This is not always possible. Harvesting the fish often must be limited to periods of the year when it does not conflict with other activities on the farm.

The smaller ponds below 16 ha (40 acres) are usually harvested using a haul seine. Ponds of about 16 ha (40 acres) and larger have necessitated

innovative harvesting techniques. A mechanical haul seine is commonly used.

Because larger ponds require such a long and heavy seine, a boat or barge is used to set the net around the pond. The seine is retrieved by using a mechanized wire-cable puller or a rope-line puller. The mechanized puller winds the cable or rope on to a double drum winch. As the fish are crowded into a harvesting area, they are dipped out by dip nets or crowded into a fish loading conveyer. When more than 8 ha (20 acres) are to be harvested, even these mechanized aids are not the sole answer due to the inability to sell over 20 MT (22 ST) per day. Thus, the fisheries experiment stations at Stuttgart and Kelso, Arkansas, have developed a new technique.

This new technique consists of having a "fish holding bag" or live car in the middle of the chute formed by the seine net. As the fish are crowded they swim into the live car. Each live car holds about 5 MT (5½ ST) of fish. When a live car is filled, it is detached and an empty live car attached (Fig. 1.13). The filled live car is then floated to deeper water to give the fish more water room and to get them out of the muddy harvesting water. The colder the water, the longer the fish can be held in the live car. If the fish become distressed, aeration can be started, or the fish can be released back into the pond in case of an emergency.

When the pond is harvested and the fish are in the live cars, each live car can be positioned near the bank and a mechanized brailer used to dip the fish out onto a sorting table positioned in the water. The small fish of less



Fig. 1.12. Three live cars filled with catfish during seining of large pond. Courtesy of Fish Farming Experimental Station, Kelso, Arkansas.

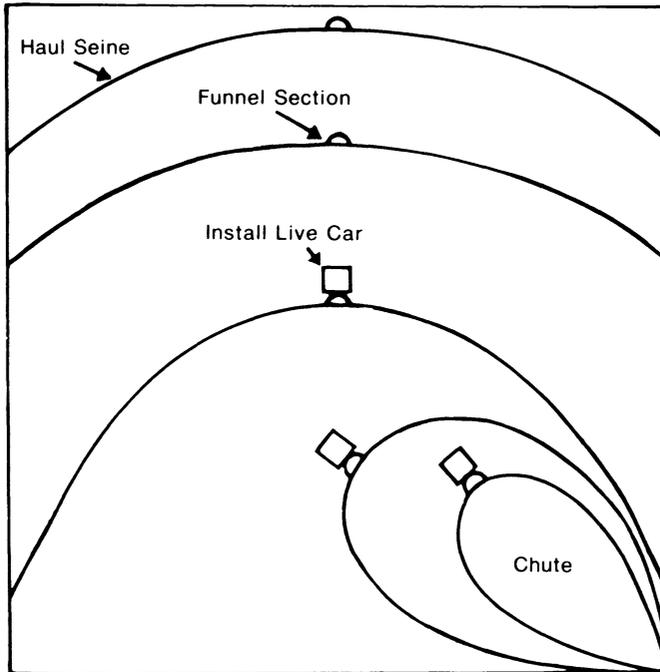


Fig. 1.13. Schematic drawing of haul seining procedure used with live car for harvesting catfish.

than 340 g ($\frac{3}{4}$ lb) can be released back into the pond or transported to another finishing pond. The fish between 340 and 1135 ($\frac{3}{4}$ to $2\frac{1}{2}$ lb) are loaded into the awaiting trucks for transport to the processing plant or other market. The larger fish over 1135 g ($2\frac{1}{2}$ lb) are sorted out for use as brood fish or are sold separately for fish fillets.

As many as 90% of the fish in a pond can be captured in a single haul. The remaining fish are permitted to stay in the pond, which is then restocked with fingerlings.

Some farmers with large ponds may not use haul seines at all. These farmers use trapping devices which may harvest several tons per day. Over a period of several weeks, as many as 80–90% of the fish may be harvested, and trapping ceases for that year. Use of this system permits a large pond to be harvested slowly so that the market is not depressed by too large a quantity of fish being harvested at one time. Several commercial trapping devices have been invented which, when baited with food, serve as efficient harvesters.

Utilization. There is detailed information on how cultured fish were utilized in 1980 (Anon. 1980). The U.S. Dept. of Agriculture made a rather complete survey in 10 selected states which probably included 95% of production of the fry and fingerlings sold; 63% went to other producers,

probably for growing out food fish; 20% went to live haulers who then sold fish to other producers for food production, to fee fish-out operators or for stocking farm ponds; 4% went to fish-out recreation ponds; and 13% to other sources, probably farm stock ponds.

Of the food-sized fish sold, 78% went directly to processors; and 9% went to live haulers, who in turn sold to consumers, fish-out operators, and farmer stock ponds. Five percent were sold directly to consumers, 2% went to other producers, and 2% to all other places.

In the heavy production areas of Mississippi and Arkansas, larger amounts went for processing, while in some states with limited production, such as California, perhaps two-thirds ended up in fee fish-out lakes. This hypothesis was also borne out by prices received by the producers in 1978. The lowest prices of about \$1.50 per kg (\$0.68 per lb) were in Mississippi, a state of heavy production. At the other extreme was California with an average producer price of \$2.97 per kg (\$1.35 per lb).

Live Haulers. Live haulers buy a significant part of total cultured production. They, in turn, sell the live unprocessed fish to farmers for stocking farm ponds, pay lakes, and other outlets. An unknown quantity of live domestic wild catfish also are purchased by live haulers. Hence, the activity of live haulers is of considerable importance although little is known about them. In fact, accurate estimates of the number of live haulers is not available. Information gathered for 9 out of 19 catfish-producing states indicates that there were more than 100 licensed live haulers in the 9 states. The other states failed to reply or did not license live haulers.

Fee Fishing. Live haulers and some catfish producers have good market outlets for catchable-sized fish for stocking fee fish-out ponds. In the main production areas and in other southeastern states as well as the midwest, there are thousands of fee fish-out ponds operated by individuals. Perhaps one-third of all cultured catfish are sold for fee fishing.

The ponds are smaller than those used for grow-out operations. Normally, they are not more than twice the distance that a fisherman can throw a line with a fishing rod. This enables the fishermen to fish the entire pond without the use of a boat. All tree stumps and debris are removed during construction. Ponds are earthen and are usually supplied with fresh water by a spring or by surface runoff. If a small stream is used as a water source the water goes through a screen to remove unwanted species. Channel catfish are the main species stocked.

Fish of different sizes are stocked. The minimum size is about 454 g (1 lb). Fish as large as 16 kg (35 lb) have been caught out of some ponds. The operator usually furnishes the bait, which may range from goldfish, earthworms, crayfish, chicken livers, blood bait, dough bait, cotton soap balls, and fatback to grapes.

Most catfish fee fish-out operators charge a fee for each kilogram or pound of fish caught. If no fish are caught, there is little or no fee charged.

The amount paid for fish caught varies widely. It may range from \$2.20 to \$4.40 per kg (\$1 to \$2 per lb).

Some fee fish-out operations have two ponds. One pond raises fingerlings and one is for the catching area. Other operators may have several ponds and buy only catchable-sized fish. The fish are stocked in fertilized ponds. Ponds are fertilized at the rate of about 111 kg of 8-8-2 fertilizer per ha (100 lb per acre). This is applied twice a year. It increases the natural carrying capacity of the pond and permits a lower feeding rate of commercial catfish feeds.

Net returns vary widely, ranging from a few dollars to \$10,000 per year. The profit depends on number of customers, competition, availability of wild fishing waters, and survival of fish stocked, and prices charged per kilogram or pound of fish caught.

Production Costs. Production cost data for aquaculture are difficult to find in most countries. This situation is also found in the USA. The most recent data for pond-raised channel catfish are found in Burke and Waldrop (1978) for Mississippi. The authors worked up production cost data for three different farm situations—one having 65 ha (160 acres), one having 130 ha (320 acres), and one having 260 ha (640 acres). In this book, data are given for the smaller size farm of 65 ha (160 acres). Readers who want more information should secure a copy of "An Economic Analysis of Producing Pond-raised Catfish for Food in Mississippi" (Burke and Waldrop 1978).

According to the authors, estimated total production from a land area of 65 ha (160 acres) would be 298,084 kg (655,785 lb), or 5262.5 kg per ha (4631 lb per acre), of water area. Estimated total investment for land, pond construction, water supply, feeders, and equipment would be \$291,334 in 1977. This investment averaged \$4414 per ha of land or \$1787 per acre. Annual fixed costs referred to as ownership costs amounted to \$36,771. Annual variable or operating costs amounted to \$249,421. Total costs were \$286,192 annually for 298,084 kg (655,785 lb) or \$0.959 per kg (\$0.436 per lb).

The weighted average price paid by processors in 1977 was \$1.28 per kg (\$0.58 per lb) for catfish FOB pond bank. With this return and with a cost of \$0.959 per kg (\$0.436 per lb), the net revenue for management and repayment of debt was \$130,934. The authors calculated that a price of \$1.10 per kg (\$0.502 per lb) was necessary for revenue to equal cost and anything over this amount was return to management.

Many catfish aquaculturists in the USA do not produce food-size catfish but raise fingerlings (these may be known as yearlings in some countries) for resale to growers who do produce food-size fish. We are fortunate that a production cost study of raising fingerlings was recently completed by Allain and Morrison of the University of Arkansas in 1978.

The authors (Allain and Morrison) estimated costs for two different sizes of fingerling farms. One size farm contained 26.68 ha (65.93 acres) while the larger farm contained 54.28 ha (134.13 acres) of surface water.

Investment costs of the smaller farm were \$244,265 while those of the larger farm were \$423,443. Fixed or ownership costs were \$53,577 for the small farm and \$81,507 for the large farm. Variable costs amounted to

\$71,222 and \$127,139, respectively. Total costs, including repayment of borrowed monies, totaled \$124,802 for the small farm and \$208,643 for the larger farm.

It was calculated that 125,000 fingerlings were sold each month from the smaller farm and 252,000 monthly from the larger farm. The average monthly price for 15–20 cm (6–8 in.) fingerlings in Arkansas during 1977, the year of the study, was 12¢. At this price and with the preceding above costs and number of fingerlings produced, the small farm returned \$55,198 annually to management while the larger farm returned \$154,237.

Processing. Processed production of catfish for the 12-year period 1969 through 1980 is shown in Table 1.3. It shows the increased volume of fish being processed for food use. Processed production in round weight (live weight) was only 1,455,000 kg (3,201,000 lb) in 1969. It increased dramatically through 1973 when 8,969,000 kg (10,731,000 lb) were processed. Then as a result of high fish food prices in 1973 and 1974 caused by the worldwide shortage of fish meal because of the poor Peruvian catch and of relaxed restrictions on rice productions in the United States, fish hectareage was cut back. Since the processed market was the residual market after live fish were sold for recreational fishing and stocking farm ponds, the volume going to processing plants in 1974 and 1975 declined. Starting in 1978 processing increased dramatically through 1980 when 21,120,000 kg (46,464,000 lb) were processed. During the 12-year period, processing volume increased 1352%, or 113% annually.

In 1980 a total of 21,120,000 kg (46,464,000 lb) of live weight fish were processed for the food market (Table 1.4). Volume of fish processed monthly varied considerably. The peak months for processing were February–May and August–October.

During the early 1970s when harvesting and processing were above the yearly norm, producer prices for fish were at the yearly low. When harvest-



Fig. 1.14. Catfish hauling truck with load going to market, Arkansas. Courtesy of Fish Farming Experimental Station, Stuttgart, Arkansas.

TABLE 1.3. PROCESSED PRODUCTION OF FARM-RAISED CATFISH, USA, 1969-1980
Round weight in thousands.

Month	1969		1970		1971		1972		1973		1974	
	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg
January	169	77	689	313	926	421	1,203	547	2,128	967	1,267	576
February	439	200	1092	496	1,154	525	1,520	691	2,257	1026	1,418	644
March	434	197	520	236	1,386	630	2,134	970	2,244	1020	1,734	788
April	194	88	177	81	897	408	1,487	676	1,388	631	1,355	616
May	23	11	97	44	487	221	1,531	696	1,259	572	1,395	634
June	52	23	149	68	556	253	1,365	620	1,324	602	1,436	653
July	104	47	221	101	716	325	1,180	536	1,646	748	1,303	592
August	193	88	241	110	918	417	1,638	745	1,773	806	1,541	701
September	273	124	348	158	1,008	458	1,483	674	1,642	746	1,277	581
October	349	158	723	329	1,673	760	1,673	760	1,249	768	1,530	695
November	421	191	715	325	1,097	499	1,781	810	1,690	568	1,324	602
December	550	250	769	350	1,006	457	1,221	555	1,129	513	1,364	620
Total	3201	1455	5741	2610	11,257	5117	18,331	8332	19,731	8969	16,944	7702

Month	1975		1976		1977		1978		1979		1980	
	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg
January	1,644	747	1,785	811	1,344	611	1,598	726	3,032	1,378	3,530	1,605
February	1,729	786	1,711	788	2,278	1,035	2,361	1,073	3,929	1,786	4,892	2,224
March	1,504	684	2,094	952	1,901	864	2,951	1,341	4,010	1,823	4,060	1,845
April	1,011	459	1,397	635	1,749	795	2,510	1,141	3,025	1,375	3,829	1,740
May	790	359	1,037	471	1,810	823	2,729	1,240	3,716	1,689	4,045	1,839
June	1,481	673	1,471	669	1,901	864	2,189	995	3,081	1,400	3,596	1,635
July	1,426	648	1,458	663	1,965	893	2,310	1,050	3,138	1,426	3,092	1,405
August	1,369	622	1,763	801	2,192	996	3,186	1,448	3,978	1,808	4,116	1,871
September	1,339	608	1,904	865	1,986	903	2,607	1,185	3,417	1,553	3,817	1,735
October	1,402	637	1,545	702	1,766	803	2,647	1,203	3,531	1,605	4,310	1,959
November	1,100	500	1,500	682	1,661	755	2,935	1,334	3,000	1,364	3,631	1,650
December	1,325	602	1,312	596	1,573	715	2,154	979	2,779	1,263	3,546	1,612
Total	16,140	7336	18,978	8626	22,125	10,057	30,177	13,717	40,636	18,471	46,464	21,120

TABLE 1.4. VOLUME OF CATFISH PROCESSED, PRODUCER PRICES, FOB PLANT PRICES FOR ICED AND FROZEN CATFISH, USA, 1980

Month	Liveweight of Fish Processed		Prices Paid at Plant		Average Price Paid to Producer		FOB Plant Ice Pack		FOB Plant Frozen	
	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
January	1,605,000	3,530,000	1.32-1.72	0.60-0.78	1.52	0.69	3.37	1.53	3.54	1.61
February	2,224,000	4,892,000	1.32-1.76	0.60-0.80	1.54	0.70	3.43	1.56	3.72	1.69
March	1,845,000	4,060,000	1.43-1.76	0.65-0.80	1.72	0.78	3.54	1.61	3.81	1.73
April	1,740,000	3,829,000	1.43-2.02	0.65-0.92	1.74	0.79	3.54	1.61	3.83	1.74
May	1,839,000	4,045,000	1.43-2.02	0.65-0.92	1.74	0.79	3.59	1.63	3.87	1.76
June	1,635,000	3,596,000	1.43-2.02	0.65-0.92	1.74	0.79	3.56	1.62	3.85	1.75
July	1,405,000	3,092,000	1.43-2.02	0.65-0.92	1.74	0.79	3.59	1.63	3.87	1.76
August	1,871,000	4,116,000	1.43-2.02	0.65-0.92	1.74	0.79	3.56	1.62	3.85	1.75
September	1,735,000	3,817,000	1.43-2.02	0.65-0.92	1.74	0.79	3.48	1.58	3.76	1.71
October	1,959,000	4,310,000	1.43-2.02	0.65-0.92	1.74	0.79	3.56	1.62	3.78	1.72
November	1,650,000	3,631,000	1.32-2.02	0.60-0.92	1.67	0.76	3.56	1.62	3.85	1.75
December	1,612,000	3,546,000	1.32-2.02	0.60-0.92	1.67	0.76	3.28	1.49	3.85	1.75
Totals and averages	21,120,000	46,464,000	0.95-1.21	0.43-0.55	1.08	0.77	3.50	1.59	3.81	1.73

Source: Anon. (1976-1980).

ing and processing declined in May, June, and July, producer fish prices rose and continued relatively high until the fall of the year, when both processing and producer prices declined as processors adjusted frozen inventories prior to the big buying splurge of fish in January, February, and March again. As the industry matured in late 1970, monthly processing volume stabilized as did producer prices (Table 1.5).

Rather interesting from the viewpoint of Asians and Europeans is the difference of dressed, iced fish prices compared to frozen. In the USA, frozen fish command a premium over fresh iced fish while in Europe and Asia frozen fish prices are generally lower.

Marketing. There are about 9 specialized sized processors of catfish in the United States. In addition, a considerable number of producers process all or part of their own fish for sale to fish dealers, restaurants, and individuals.

In 1980, fish processed by the specialized processors was highest in February–May period, reached a low in July, and rose again in August–October. Sales by the processors follow roughly the same ebb and flow of volumes. Inventory usually consists of about two weeks of sales. Table 1.4 shows the average prices for dressed fish either in ice packs or frozen FOB plant. The frozen product sells for slightly more than the ice-packed fish. The table also shows the ranges and averages of prices paid producers for fish delivered to the plant. Prices paid to producers in 1980 ranged from \$1.52 per kg (\$0.69 per lb) to \$1.74 per kg (\$0.79 per lb).

It should be realized that processing volumes and producer and processor prices shown in Table 1.4 do not include sales by farm processors who maintain their own small processing facilities, or sales by seafood dealers or restaurants who may buy live catfish and do their own processing.

Between 90 and 95% of sales are pan-ready, dressed fish. Fish steaks and fillets account for the remainder. This emphasis on pan-ready, dressed fish may indicate the strong desires of producers to sell a 454 g (1 lb) fish rather than to raise larger, older fish for the steak and fillet market when feeding efficiency declines.

Imports and Exports. There are virtually no exports of either live or dressed catfish from the United States. However, there are considerable imports.

In 1969, the first year for which records were maintained separately for catfish imports, there were 1,710,000 kg (3,762,000 lb) of dressed catfish imported. Since the dressout percentage is approximately 60%, this volume represented 2,856,000 kg (6,283,000 lb) of live or round weight (Table 1.5). Since imports were not recorded in January, 1969, the total imports may have been 6–10% higher than this volume. Since that time, catfish imports have increased considerably. After a slight drop in 1971, imports continued to increase. In 1979, imports were 352% higher than in 1969 and dressed imports totaled 4,958,000 kg (10,907,000 lb). On a live weight basis, this represented 12,296,000 kg (28,372,000 lb), for an average yearly increase of

TABLE 1.5. PROCESSED CATFISH IMPORTS ENTERING USA, 1969-1980
(1000 lb)

Month	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
January	No Record	420	378	231	543	947	1,496	661	797	1,846	995	1,308
February	285	341	85	743	307	290	641	398	2,626	752	1,683	1,513
March	367	413	190	290	632	454	663	1,313	1,319	1,936	639	1,170
April	200	277	58	394	737	670	1,421	778	1,751	2,188	2,522	1,045
May	344	584	184	216	434	561	749	1,169	1,715	2,534	2,014	1,108
June	364	208	123	277	523	1,671	782	595	1,380	1,046	945	2,225
July	255	475	209	358	335	486	997	271	1,206	863	2,273	1,105
August	344	423	338	678	473	795	1,090	1,137	1,471	968	760	2,430
September	518	358	321	361	593	187	332	936	1,254	1,525	889	1,425
October	274	437	121	503	1,068	937	979	812	1,594	814	1,298	284
November	531	644	264	450	396	789	606	1,092	1,194	2,728	1,361	863
December	280	221	932	370	572	657	1,151	1,099	1,676	1,173	1,610	444
Total lb dressed	3762	4801	3203	4871	6,613	8,444	10,907	10,261	17,983	18,373	16,989	14,922
Total lb round WT	6283	8018	5349	8135	11,044	14,101	18,215	17,135	30,032	30,683	28,372	24,920
Total KG dressed	1710	2182	1456	2214	3,006	3,838	4,958	4,664	8,174	8,351	7,722	6,783
Total KG round WT	2856	3645	2431	3698	5,020	6,410	8,279	7,789	13,651	13,946	12,896	11,328

35%. Between 80 and 90% of the imports are from Brazil, with lesser amounts from other Central and South American countries.

The major attraction of imported catfish is the relatively low price. Wild imported catfish commonly retail at prices as much as 30% below the domestic cultured product. For example, it is commonplace for the imported catfish to be priced at \$1.39 to \$1.65 per 454 g (1 lb) in a supermarket, while domestically cultured fish in adjacent stores are priced at \$1.79 to \$1.99. Estimated retail value of imported catfish sold in 1979 was about \$27 million.

Wild Catch of Catfish and Bullheads. Catfish and bullheads are native to nearly all freshwaters east of the Rocky Mountains. The largest catch occurs in the southeastern United States, particularly in the Mississippi River and its tributaries. Whether this is because of larger native populations, more intensive fishing pressures, or both is not known. States having the largest landings are: (1) Florida, (2) Louisiana, (3) Arkansas, (4) North Carolina, (5) Minnesota, (6) Tennessee, (7) Kentucky, (8) Mississippi, and (9) Virginia.

From 1969 through 1976 the catch was relatively stable, varying from a low of 15,088,000 kg (33,193,000 lb) in 1969 to a high of 17,892,000 kg (39,363,000 lb) in 1971 (Table 1.6). The value per kilogram or pound caught was stable from 1969 through 1972 at \$0.51–\$0.53 per kg (\$0.23–\$0.24 per lb), but in 1973 and 1974 the value per unit increased rapidly. From 1974 to 1976 unit value varied between \$0.74 and \$0.77 per kg (\$0.335 and \$0.348 per lb). Values per unit have increased slightly since then, while landings have remained about the same.

Because of the increased values per unit of catch, the total value of all landings increased from \$7,635,000 in 1969 to \$11,779,000 in 1974 with a slight decline since then.

It should be emphasized that this catch was obtained only by commercial fishermen and does not include the catch of sports fishermen. Hence, the total landings of wild catfish and bullheads is much larger than these impressive data indicate.

TABLE 1.6. WILD CATCH OF CATFISH AND BULLHEADS BY WEIGHT AND VALUE, USA, 1969–1976¹

Year	Catch or Landings		Value	Average Value per Unit	
	(1000 lb)	(1000 kg)	(\$ 1000)	(\$ per lb)	(\$ per kg)
1969	33,193	15,088	7,635	0.23	0.506
1970	35,217	16,008	8,241	0.234	0.515
1971	39,363	17,892	9,138	0.232	0.51
1972	36,568	16,622	8,788	0.24	0.528
1973	36,576	16,625	10,512	0.287	0.631
1974	35,056	15,935	11,779	0.336	0.739
1975	34,848	15,840	11,654	0.335	0.737
1976	31,538	14,335	10,960	0.348	0.766

Source: Natl. Mar. Fish. Serv. (1980).

¹From 1976 to 1980 landings averaged about 13,500 to 15,300 MT (15,000 to 17,000 ST) with values increasing slightly.

Outlook. The outlook for catfish in the United States is for increased supplies. The wild catch is likely to keep declining slowly as the number of commercial fishermen decline. Culturing is predicted to increase, but at a slower rate than in the past explosive 15 years. The market for food fish is by no means saturated, but as the market has widened, imports of foreign wild catfish have increased since 1969 at an annual rate of 35%. Unless this torrent of imports is checked or modified by quotas, tariffs, or purchases by some other country, the cheaper imports are likely to continue to have a restrictive influence on domestic production.

American Eel (*Anguilla rostrata*)

The United States is not an eel consuming country. Each year, between 2000 and 3000 MT (4,408,000 and 6,612,000 lb) of wild fish are caught. The major markets for these are countries in Western Europe, with a few tons sold to Japan. Domestic consumption is probably less than 100 MT (110 ST). The fisherman's price in 1980 was between \$2.20 and \$2.97 per kg (\$1.00 and \$1.35 per lb). The major catching areas for larger and adult eel are in Virginia, Maryland, Georgia, and Florida. Limited quantities of elvers are caught in South Carolina for export to Japan. During 1975 and 1976 limited commercial culturing started, destined for Japan, but nearly everyone had ceased operating by 1981.

Holding Eels Before Shipment. It takes eels 3–5 days to digest food, depending on water temperature. Thus, when eels are harvested for marketing they must be kept without food for this time before they can be sent live to market. If this process is not carried out, the eels defecate during transportation, containers become polluted, and eels arrive in poor condition.

Eels during the 3–5 day starvation cleanout period need a good oxygen supply. The eels can be placed in polyethylene perforated tubs under showers in a special shed. The baskets are stacked on top of each other and water trickles down from the top to the bottom. Another method is to place the eels in perforated polyethylene baskets with tops to keep the eels in. The baskets are placed in a concrete sluiceway of fast-moving freshwater.

During the cleanout phase the eels will lose about 5% or more of body weight. Starvation beyond this period will cause continued loss of weight, particularly if the temperature is warm and eels are active. Adult silver eels lose weight much more slowly than immature eels.

Prawns (Freshwater) (*Macrobrachium rosenbergii*)

Macrobrachium rosenbergii is a large freshwater decapod caridean crustacean distributed by nature through areas of Southeast Asia, India, Australia, and elsewhere around the South China Sea. Field researchers from Hawaii have measured a 654 g (1.4 lb) male in New Guinea. Reports indicate a 1000 g (over 2 lb) animal found in Taiwan.

Experimental research on adapting this crustacean to economical pro-

duction in the Continental United States, Hawaii, and Puerto Rico began about 10 years ago. At present, pilot production of some scale is underway in Texas, Louisiana, Florida, South Carolina, and Puerto Rico. Production, however, is small, probably less than 20 MT (22 ST) in total in the areas named above. Researchers, encouraged by recent developments in Hawaii, continue their efforts to achieve viable, economical production systems. Interest in freshwater prawn culture remains high and at least two large mainland based U.S. companies remain in freshwater prawn aquaculture. These are: the Weyerhaeuser Corporation, which maintains a hatchery and Research & Development facility at Homestead, Florida; and Red Lobster Inns, which has a freshwater produce farm in Central America.

The exciting chapter in production and one of the most promising developments in U.S. aquaculture in years has been developing in Hawaii in the past 10 years.

Prawn culture in Hawaii is economically viable (Shang and Fujimura 1977; Lee 1979). The present industry was built upon the development of mass rearing techniques (Fujimura and Okamoto 1970) and under the guidance of the Anuenue Fisheries Research Center which provides seedstock to aquafarmers and engages in a major extension program involving pond site selection, construction, management, and product handling. The extension services are available to all prawn operators and seedstock is provided free for a 3-year period under a contractual arrangement.

In 1972, Hawaii had only 0.6 ha (1.5 acres) of prawn ponds producing about 2 MT (2.2 ST) of prawns from one or two very small producers. By 1980, production had reached 136 MT (150 ST) from 20 producers, and in 1981 is projected to reach 182 MT (200 ST) from 24 producers, Table 1.7.

Interest in Hawaii has grown to the point that a Hawaii Prawn Producers Association was founded in December 1977. The state government developed an Aquaculture Development Program in the late 1970s to work with prawns and other potentially economically viable water animals.

Life Cycle. The genus, *Macrobrachium*, contains hundreds of species which have been monographed for Southeast Asia (Holthuis 1950) and the Americas (Holthuis 1952). *M. rosenbergii* apparently is a species that is evolving "out of the sea" in that its larvae require brackish water for their development. In fact, the "breakthrough" in closing the life cycle of *M. rosenbergii* came when Ling (1969A) raised the salinity in his larval culture aquaria to 16‰ (Goodwin 1977). Previous attempts to rear larvae to metamorphosis failed because only freshwater was used.

There are constraints in prawn aquaculture but these do not involve life cycle factors. The various stages in the prawn's life cycle including maturation, courtship, mating, brooding, spawning, larval development, and juvenile to adult growth may be accomplished in tanks, ponds, or aquaria. Breeding behavior has been described by Rao (1965) and Ling (1969B). Mating occurs between hard-shelled males and newly molted females. Adults form single pair bonds and undergo amplexus at which time a

TABLE 1.7. AREA, PRODUCTION, AND VALUE OF FRESHWATER PRAWNS IN HAWAII, 1972-1981

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981 Projected
Acreage	1.5	1.5	5	26	26	33	107	210	300	400
Hectarage	0.6	0.6	2	10.4	10.4	13.2	42.8	84	120	160
Production (lb)	4277	4378	10,960	40,259	43,300	54,937	110,159	210,000	300,000	400,000
Value (Dollars)	14,970	15,323	38,460	140,907	151,550	206,000	420,000	840,000	1,200,000	1,600,000
Wholesale price per lb (Dollars)	3.50	3.50	3.50	3.50	3.50	3.75	3.82	4.00	4.00	4.00
Price per kg (Dollars)	7.70	7.70	7.70	7.70	7.70	8.25	8.40	8.80	8.80	8.80

spermatophore (sperm packet) is deposited on the female's abdomen (Sandifer *et al.* 1980). Eggs, extruded through the female's gonopores, pass through this packet, are fertilized, and remain attached to the female's ventral abdomen ("tail") during incubation. This lasts for about 15 days after which free-swimming protozoa larvae are released ("hatched") into the water column. These undergo 11 larval molts followed by 1 molt into benthic crawling post larvae (PL). Since there is considerable variation in individual growth which leads to a size frequency distribution with a large variance, growth to sexual maturity is variable (6–9 months), and harvestable (> 35 g) prawns are available in 9–11 months.

Hatchery. The first step in the Hawaiian production cycle involves obtaining gravid females from commercial ponds. No separate brood stock ponds are maintained by hatcheries. A strain called the "Anuenue" strain is presently utilized in all hatchery and pond production although other strains are under evaluation (Malecha 1977). Prawns mate in commercial ponds and females brood their eggs. Embryological development in *Macrobrachium rosenbergii* takes about 15 days and experienced hatchery operators can tell by the egg color about when hatching will occur and thereby capture only females that will hatch in keeping with a predetermined starting time for the first hatching cycle.

At the Anuenue Fisheries Research Center (AFRC) hatchery, females are brooded in 1136 liter (300 gal.) tanks. Eggs hatched into free-swimming larvae are then transferred down into the larval rearing tanks. Initially about 1×10^6 (130 liters) larvae are kept in one tank. This is split into 300,000 larvae (43 liters) during the 3-week or so development cycle. On the average, 150,000 PL/tank (15–20 larvae/liter) are produced. Larvae are fed newly hatched *Artemia* nauplii and strained fish flesh. The latter is made up in three particle sizes by means of forcing fillets of tuna through screens with the pressure from a stream of water. Larvae are reared in water containing about 5×10^5 to 1×10^6 cells/ml of unicellular phytoplankton, usually *Chlorella*. This "greenwater" is cultured in large 18,950 liter (5000 gal.) circular tanks and pumped into the rectangular larvae rearing tanks. The latter are flushed every 2 days after the first 12 days. The phytoplankton-rich "greenwater" increases survivability by maintaining good water quality through waste removal. In essence, the "greenwater" is a biological filter. Larvae may passively ingest the phytoplankton cells but they do not assimilate them into their tissue as shown by Cohen *et al.* (1976). Other *Macrobrachium rosenbergii* hatcheries have raised larvae to PL with good success using other biological filtration than "greenwater" for water quality maintenance.

Ponds. The Anuenue Fisheries Research Center has developed a pond management strategy that consists of regular stockings of earthen ponds with hatchery-reared juveniles and regular, selective harvesting of marketable prawns. PLs are stocked as soon as possible following metamorphosis. At this time PLs are about 1 cm and are stocked at a rate of about 16.14 animals/m² (1.5 animals/ft²) of pond bottom.

Pond sizes vary from 0.10 to 1.64 ha (0.25 to 4.0 acres) and they are of all shapes from nearly square to those with length-to-width ratio exceeding 3 to 1. Embankment slopes vary from 1.5:1 to 2.5:1 depending on soil types. The total land area required for a 0.4 ha (1 acre) pond is 1.20 ha or 112.4% of the actual pond area in order to allow for 4.6 m (15 ft) wide berms and access roads surrounding the ponds.

Grass is planted on road banks for bank stabilization and to provide shelter for young and molting prawns and to foster natural productivity to supplement the prawn's diet.

Ponds are usually supplied with water from wells or stream diversions which flow continuously at rates varying from 142 to 236 liters/min per ha (15 to 25 gpm per acre). Discharge rates are usually 18.95–56.85 liters/min ha (5–15 gpm per acre) taking into account natural evaporation and seepage. The water delivery system consists of pipes running from the main line to the "head" of the pond. An outlet is located at the opposite end. Farmers *try* to maintain a rich bloom of green algae (500,000 to 2,000,000 cells/ml) in each pond. Feeding is usually done once in the evening by means of broadcasting from the pond banks. Prawn farmers are currently using a ration of broiler starter which costs about \$0.31 per kg (\$0.14 per lb). The current average conversion ratio is about 3.3:1 (exact information is not available).

Growth and production vary from pond to pond. Approximately 7 to 9 months after the initial stocking, selective harvesting begins. A seine net with a bag attached to the trailing end is used to cull large prawns. A team of three or more workers enters the pond at one point and pulls the leading edge of the seine net around the perimeter. After the pond or a portion of it has been completely encircled and the leading edge of the net returned to the point of entry, the net is then pulled in and the bag closed off. A 3-man crew can harvest approximately 3 0.20 ha (half-acre) ponds per day.

After the entire net is pulled in and only the bag remains in the water, the prawns are scooped out of the bag, sorted, and loaded by hand into transportation tanks. The harvesting efficiency, or percentage of desirable prawns caught, depends on the workers' skills and pond bottom and bank conditions. Generally the method captures only 50 to 75% of the marketable prawns in the pond, with only a few undersized ones.

Harvesting continues at a nearly constant rate with decreases in yield during various periods. The reason for the fluctuations in production is not known. All in all, stocking and harvesting management strategies do not appear to be optimum so there is ample room for experimentation and improvement.

Post-harvest Handling and Processing. Almost all prawns grown in Hawaii are marketed either alive or chilled on ice. Some farmers blanch whole prawns for 20 sec at 65.6°C (150°F) at the pond site and then pack the animals in ice for delivery. This procedure only safely extends shelf-life by about 4 days, even though local market outlets prefer a longer shelf-life rather than have high inventory turnover. Of course, exploiting export

markets will demand a long shelf-life.

Industry-wide standards for the grading and sorting of prawns have not yet been developed. Customers have exhibited a willingness to purchase all harvested prawns regardless of size. This has been especially evident in the purchase of live prawns on the retail market where prawns have been purchased by the kilogram or pound and not by size or type. Restaurants have indicated a preference for consistent product size (9 count or larger, i.e., 9 animals per lb; 20 per kg) and volume. However, up to mid-1979 most restaurants purchased whatever product was available. The largest producers were able to grade by sizes into medium-sized prawns, 9 count and smaller, and large prawns, 9 count and larger, but most producers under 8 ha (20 acres) in size were unable to sort and grade in consistent amounts to satisfy their accounts.

Producers indicated a harvest size range of 11 to 27 animals per kg (5 to 12 animals per lb) (count size) with an average of 8 count sizes. The Anuenue Fisheries Research Center has also indicated an industry average of 8 count animals from field samples.

Normally, freshly harvested prawns have a clean greenish hue with bright blue pincers. Their shells are resilient and the animals are lively and kicking. Producers also harvest prawns in other physical states: egg-bearing females, soft-shell prawns (from recent moltings), and terminal growth prawns (those that have stopped growing and are covered with algal moss), but soft-shelled and terminal growth prawns make up only a small percentage of the harvest. These animals are usually separated from those intended for sale. The possibility exists for developing specialized markets for the egg-bearing and soft-shelled forms of prawn.

Marketing. Markets for freshwater prawns seem to be little different from those of other crustaceans of similar size and price. Demand for crustaceans (and all aquatic foods) can be expected to rise in the coming years so that emphasis in the area of marketing should be to provide a consistent high-quality supply.

In Hawaii, prawns are marketed between 6 and 10 count (6 to 10 animals per lb, ~13 to 22 animals per kg) with the heaviest emphasis between 8 and 10 count. The harvest seining captures only these sizes. However, pending the demonstration of its economic feasibility, many more size classes can be marketed ranging from the "cocktail shrimp" or "bait" category to the lobster size (0.45 kg or 1 lb).

For the year 1978, the distribution of product forms in the marketplace was 61.9% sold live, 24.2% blanched/chilled, 12.6% chilled, and 1.3% frozen. As production continues to increase, it is expected that live sales will become less predominant while frozen sales increase. In 1980, it was reported that with farm prices of \$8.80 per kg (\$4 per lb), retail prices ranged from \$12.10 to \$17.50 per kg (\$5.50 to \$7.95 per lb). The lower prices were for fresh-chilled animals while higher retail prices were for live animals (Corbin 1981).

Crayfish

Crayfish are versatile animals and are found on nearly every continent except Africa and Antarctica. About 500 species are found throughout the world, and over 250 species and subspecies are found in North America.

Biology. Life for most crayfish begins in a hole in the ground known as a burrow. Some of these may be only a few centimeters (inches) deep, serving as a temporary home, while others may be more than 1 m (39 in.) deep. Most burrows have a mud chimney or are capped with a mud plug. The time of mating varies by species and region. A fairly typical mating may occur in May or June. At this time the female will dig a burrow. The male deposits sperm in an external receptacle on the female. The sperm are held until late summer or early fall until the female lays her eggs. As the eggs are laid, they are fertilized by the sperm. The fertilized eggs are held to the female's body by a sticky substance. The number of eggs laid varies greatly by species. Some may have as few as 10 and others up to 700.

The eggs appear as a bunch of "grapes" on the underside of the female's tail and she is said to be "in berry." The eggs hatch in 1 to 2 weeks. Once hatched, the young stay attached for a week or two while they undergo 2 molts. Later the young leave the female and the burrow and forage for themselves. Crayfish eat a variety of foods, usually plant material and small organisms.

Crayfishing. Crayfish can be caught in almost every body of water in North America. In California, the species *Pacifastacus klamathensis* is the principal crayfish caught. In Oregon, one of the leading states of production, fishing is carried out in the slower moving streams of the flat agricultural valleys. In the state of Washington some crayfishing occurs. Other than the

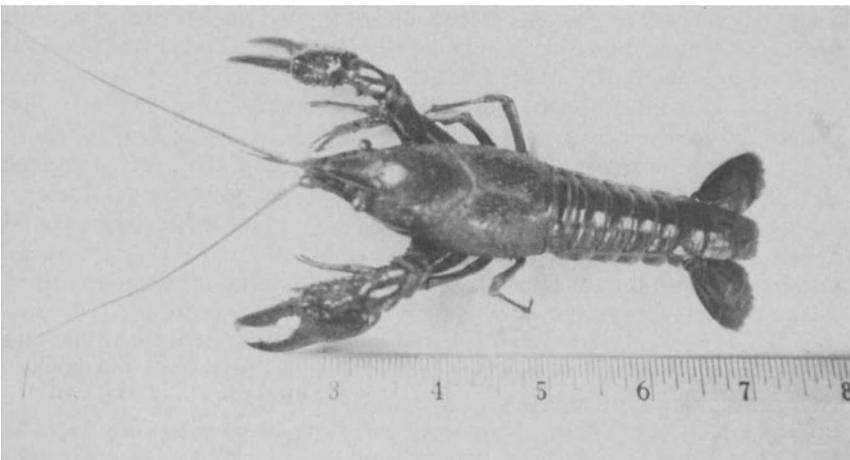


Fig. 1.15. Adult crayfish. 1 in. = 2.54 cm.

Pacific states, commercial catching in the East is largely in Louisiana and Mississippi. In these two states there are at least 29 species. The two dominant commercial ones are the red swamp crayfish, *Procambarus clarkii*, and the white river crayfish, *Procambarus blandingi*.

Crayfish Farming. Most of the crayfish farming area is found in Louisiana and until a few years ago was confined to the southern part of the state. In this area over 4,500,000 kg (10 million lb) valued at over \$5 million is harvested annually, and about 35 crayfish processing plants are licensed.

Crayfish farming, as such, began over 25 years ago, possibly by accident. It is thought that a rice farmer flooded his rice field one fall, following the harvest of rice, to provide duck hunting. The next spring the duck pond was teeming with crayfish. Duck hunters were transformed into crayfishermen and harvested the unexpected crop of crayfish. Today, crayfish farming has changed little from this accidental beginning.

Crayfish are currently being farmed in three types of ponds: rice-field ponds, wooded ponds, and open ponds. In rice-field ponds crayfish are rotated with the rice. The general procedure followed by the rice farmers is to remove water from the rice field about two weeks before harvesting. This permits drying of the field to facilitate harvest. When drying begins, crayfish burrow. The second growth of rice and grasses, along with rice straw, provides food for the crayfish.

Wooded areas are also used, but make poor crayfish ponds. Dense growths of trees and shrubs hinder harvest. Wooded ponds usually have poor wind circulation, resulting in oxygen depletion. Also, water in wooded ponds is often acid, resulting in a low pH and a low total hardness. Neither condition is conducive to good crayfish production. Despite these drawbacks, wooded areas are sometimes used for crayfish ponds because the land is idle and owners feel some production is better than none.

Open ponds are often constructed solely for crayfish farming. The procedure for farming these ponds is generally the same as for farming wooded and rice-field ponds. Crayfish are stocked in the ponds in late May or June. Brood stock, usually bought from a dealer, is stocked at rates of 23 to 56 kg per ha (25 to 50 lb per acre), depending on the amount of vegetation and the number of native crayfish present. Once stocked, the crayfish burrow. In July the ponds are drained, mainly as a means of predator control since racoons and wading birds may make serious inroads on the crayfish. When young crayfish are found in the burrows, generally in September or October, the ponds are flooded to release them. Once the ponds fill, the young crayfish forage on native plants. If the winter is mild, crayfish can be harvested the same year. Some crayfishermen may harvest the first crop as early as November 25, although typically, it is spring of the next year before the main crop is ready.

Crayfish cultured in ponds are harvested in the same manner as in the wild. Both lift nets and funnel traps of wire are used. Wire baskets or cages are baited with fish, or fishheads. A trapper usually handles 12 to 25 traps per ha (5 to 10 per acre), depending on accessibility. Lift nets are fished in a



Fig. 1.16. Crayfish burrows, Louisiana. Courtesy of James W. Avault, Jr.

similar manner. Most crayfish farmers employ professional crayfishermen who are paid one-half the going market price for live crayfish.

Ponds with good production might yield from 225 to 900 kg per ha (200 to 800 lb per acre) of crayfish. Some reports tell of up to 1136 kg per ha (1000 lb per acre). The early crop of farm-raised crayfish brings the best price, and crayfish may sell for over \$2.20 per kg (\$1 per lb). Later, when the "wild" crop comes in, the price drops. By May the season has peaked, and by June the harvest is nearly complete.

The future of the crayfish industry looks promising and ponds devoted to crayfish farming are increasing rapidly. In Louisiana, over 4850 ha (12,000 acres) were devoted to crayfish culture in 1969. By 1979 the area had increased to nearly 16,200 ha (nearly 40,000 acres) (Anon. 1979A).

Levees can be constructed with rice-field equipment or with conventional farm equipment. By setting up a pump for filling ponds from a nearby stream or sinking a well, the farmer has his water. No feed is used and harvesting presents no real problem since trapping rights are usually leased. Profits for the pond owner range from \$150 to \$300 per ha (\$50 to \$100 per acre).

Processing. Upon arrival at a typical processing plant, crayfish are stored in a cooler at 3°C (38°F). The next day the live crayfish are removed from the cooler and thoroughly washed. After washing, the clean crayfish are put into stainless steel tanks for blanching. The crayfish are blanched for 5 min and no spices or additives are used. The blanching does three things: (1) kills the crayfish; (2) destroys or inhibits the bacteria and

enzymes in crayfish; and (3) facilitates manual peeling.

The blanched crayfish are then transported into the processing room where the meat is separated from the shell manually. As many as 50 persons may be employed for this job.

There are various methods used for packaging. A common package is a 454 g (1 lb) bag. It is kept under refrigeration and has a shelf-life of about 5 days.

MARINE CULTURE

Salmon

Coho or silver salmon (*Oncorhynchus kisutch*)

Chinook or king salmon (*Oncorhynchus tshawytscha*)

Chum or dog salmon (*Oncorhynchus keta*)

Sockeye or kokanee or red salmon (*Oncorhynchus nerka*)

Pink or lost salmon (*Oncorhynchus gorbuscha*)

Culture. Salmon are cultured for food in three states in the USA. These are Washington and Oregon on the West Coast and Maine on the East Coast. In 1980 there were two farms in Washington and Oregon specializing in fingerling production only, three farms producing fingerlings and pan-sized cultured salmon, and three farms producing only pan-sized salmon. Two of these eight farms were also engaged in sea ranching.

Production of pan-sized salmon for 1980 for Washington and Oregon was estimated at 455 MT (500 ST).

Salmon culture in Washington and Oregon has had many obstacles to overcome. The initial culturing was begun by the Bureau of Commercial Fisheries in 1967 in floating net pens. The predecessor of the Bureau of Commercial Fisheries is the National Marine Fisheries Service. In 1970 early attempts at private commercial culturing were initiated. By 1973–1974 production was about 350 MT (385 ST). Two years later, in the 1975–1976 season, production was estimated at 681 MT (750 ST). By 1980, production had declined to 455 MT (500 ST) as some producers had ceased operating.

In Washington, private growers are not allowed to spawn fish. Eyed-eggs are purchased from public agencies. In Oregon, private spawning of chum salmon was first permitted in 1971. In 1973, coho and chinook salmon were also added to the list of species that could be privately spawned.

Culturing has evolved primarily into culturing only coho salmon in Washington, Oregon, and Maine. Only small numbers of chinook and chum are cultured. Interest has centered on coho because of its resistance to disease and willingness to accept pelleted dry feed. This is fortunate because coho is one of the most desired species and sells for a relatively high price.

Unlike trout, coho salmon eggs are obtained between October and De-

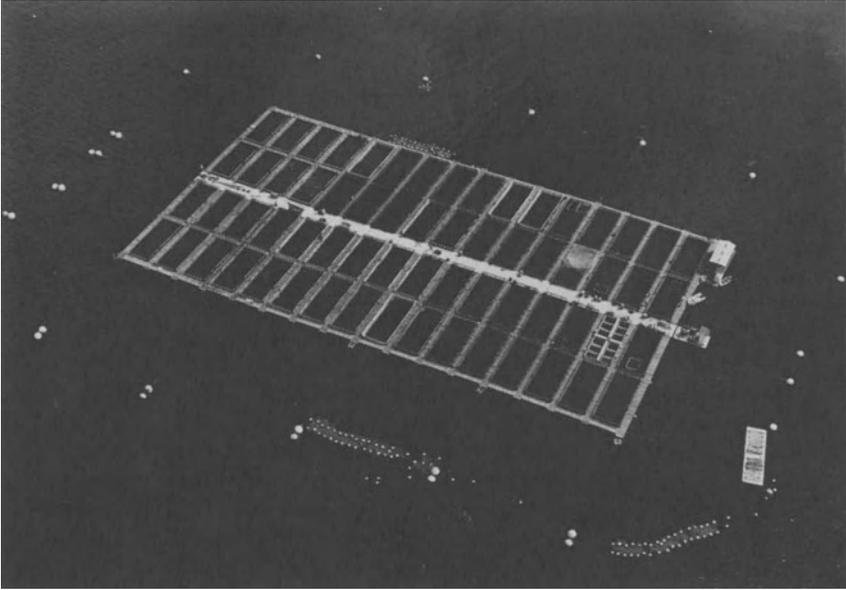


Fig. 1.17. Floating net cage culture of salmon, Washington. Courtesy of Mr. Jon M. Lindbergh, Dømsea Farms, Inc.

ember and hatch in January. Hatching takes about 60 days in 9° to 13°C (48° to 55°F) water. The fry are maintained in heated water between 10° and 15°C (50° and 60°F). The fry are raised in vertical silos or troughs in recirculated freshwater. Liquid oxygen is sometimes used for oxygenation. This permits 10 times the fry and fingerling density of non-oxygenated water.

After 4–5 months the fingerlings transform into smolts, which weigh between 15 and 25 g ($\frac{1}{2}$ and 1 oz). In June or July the smolts are acclimated to salt water and transferred to saltwater floating pens, or ponds on land, into which salt water is pumped.

There are no standard sized pens used. They vary from 3 m square (9 × 9 ft) to more than 7 m square (21 × 21 ft). Ponds are usually 6.1 m wide × 24.4 m long × 1.5 m deep (20 ft × 80 ft × 5 ft deep) with flowing water and mechanical aeration.

By December of the same year, the smolts reach pan sizes of 380 g (14 oz), and the larger ones are sold. About one-half are dressed and one-half are boned. The dressed weight is about 80% of live weight while the boned-fish weight is about 70% of live weight. Production cost is about \$3.30 per kg (\$1.50 per lb). About 50% of the marketed fish are sold directly to restaurants and hotels and about 50% to supermarkets. Some of the fish are marketed fresh on ice while others are frozen.

The cultured fish are fed the “Abernathy diet” during production. During the last 4 weeks pelagic red crab is fed to pink up the flesh.

TABLE 1.8. FORMULA FOR THE ABERNATHY DRY DIET

Ingredient	%	Type
Fish carcass meal ¹	44.5	Salmon, dogfish, hake, herring, or turbot
Dried whey product	17.0	Not less than 15% protein (Foremost or equal)
Wheat germ meal	16.5	Not less than 25% protein and 8% lipid
Cottonseed meal	15.0	Not less than 50% protein
Soybean oil	6.0	Fully refined soybean oil (Natl. Soybean Processors Assoc. Code) with 0.01% BHA and 0.01% BHT added
Vitamin supplement	1.0	See Table 1.9

¹To have protein content of more than 70%, lipid less than 12%, water less than 7%, and a TBA (2-thiobarbituric acid) value of less than 40.

Cultured production is less than 1% of the wild catch. However, there is no competition between wild and cultured fish. The cultured fish are individual portions or pan-sized and appeal to the gourmet market. Some 1 kg (2.2 lb) fish are cultured and marketed. These take up to 18 months in the 10° to 13°C (50° to 56°F) water. Most of the cultured fish are sold between December 1 and April 1 periods when the wild catching season is closed.

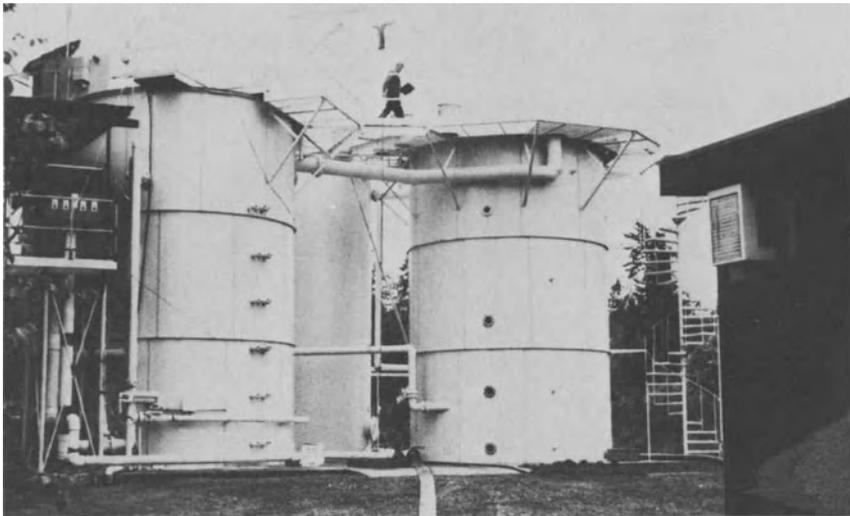


Fig. 1.18. Silos for rearing salmon fry to smolts, Washington.

However, some cultured fish are sold in every month of the year.

Feeds. The basic feed (Fowler and Burroughs 1971) fed to cultured salmon is based on the Abernathy dry diet (Table 1.8). It is formulated to contain approximately 45% protein with about 3200 calories per kg of diet. The protein calories range from 50 to 55% of the total. The vitamin mixture added is shown in Table 1.9. Although the formula is designed as a dry feed, it may be made into a moist diet by the addition of water. Water is added at the rate of 25% or less, which produces a dough-like mixture. A binder, carboxymethyl-cellulose, is also added at the rate of 2% to prevent the finished pellets from disintegrating too rapidly while being fed. After preparation the moist pellets must be quick frozen and kept in frozen storage. They are usually thawed before feeding.

Recommended particle sizes are shown in Table 1.10. Particle size plays a major role in the acceptance or rejection of the diet, and is more critical in the dry than in the moist diet. Too large a dry particle will be repeatedly

TABLE 1.9. ABERNATHY VITAMIN SUPPLEMENT

Ingredient	Amount (g)
Thiamin mononitrate	0.15
Riboflavin	0.69
Pyridoxine hydrochloride	0.30
Niacin	4.77
D-Pantothenic acid	0.68
Inositol	13.65
Biotin	0.03
Folic acid	0.10
DL-Alpha-tocopherol acetate (10,500 IU)	10.50
Ascorbic acid	25.50
Carrier ¹	397.23
Total	453.60

¹May be wheat middlings or cottonseed meal sized to pass through a U.S. Sieve No. 30.

TABLE 1.10. RECOMMENDED PARTICLE SIZES OF THE ABERNATHY DIET AS CORRELATED WITH FISH SIZE

Granule or Pellet Size	Fish Size [No. of Fish per 454 g (1 lb)]
Starter granule ¹	More than 800
0.8 mm (2/64 in.) granule ²	800 to 500
1.2 mm (3/64 in.) granule	500 to 200
1.6 mm (4/64 in.) granule	200 to 100
2.4 mm (6/64 in.) granule	100 to 80
2.4 mm (6/64 in.) pellet	80 to 50
3.2 mm (8/64 in.) pellet	Less than 50

¹Composed of 95% of the basic Abernathy formula as shown in Table 1.8 plus 5% additional soybean oil.

²Composed of 98% of the basic formula plus 2% additional soybean oil.

rejected by the fish, especially when they first start to feed or when they are being shifted to a larger pellet.

Feeding the small fish should be as frequent as possible. This leaves some waste but a conversion rate of 2:1 can still be expected. Later the feed conversion will range from 1.0 to 1.5.

Table 1.11 was developed for chinook salmon. For other species slightly more or less feed may be required. The feeding program can be used from first feeding to adult sizes. In practice, pelagic red crab is ground and fed to pink up the fish.

Sea Ranching. Sea ranching is another culturing technique. However, instead of feeding the fish throughout the production process, the smolts are released into the sea. The mature fish return after 2 to 5 years to the point of release. Returning fish may be as high as 6%. With this technique, production cost may be only one-third that of fish fed out in pens or ponds.

Sea ranching by individuals or corporations is an extension of public restocking efforts which have been in process for years. The only difference is that the individual harvests all of the returning fish that come back to the privately owned point of release and rearing. Sea ranching of salmon is legal only in Oregon, California, and Alaska. It is not authorized in Washington. Efforts are being made in the Washington State legislature to legalize this technique. There are two farms engaged in sea ranching in Washington; however, both of these are Indian enterprises which the state cannot regulate. In 1980 there was 1 sea ranching operation in California and 13 in Oregon. Five of these have been operating long enough to have recapture. In 1980, about 40,000 salmon, mostly chum, averaging 2.3 kg (5 lb) each, were harvested.

Shrimp

Brown shrimp (*Penaeus aztecus*)

White shrimp (*Penaeus setiferus*)

Pink shrimp (*Penaeus duorarum*)

Culture. There is only one commercial marine shrimp culturing farm in the United States (Bente 1975). This farm is known as Marifarms, Inc., Panama City, Florida, and experimental production was begun in 1968. Farming is extensive compared to the intensive techniques used in Japan. Drawing upon the hatching and rearing experience of Japanese scientists working with kuruma shrimp, the operation began. However, instead of the farm's containing only a few hectares or acres of water, it contains a 1012 ha embayment (2500 acres) with tidal exchange of water leased from the state of Florida, and two 121-ha (300 acre) marine lakes with pumped water exchange constructed on uplands leased from a private owner.

Both types of farms have bottoms which are typically soft and sandy and in which benthic organisms abound. It was intended that the shrimp feed

TABLE 1.11. FEEDING CHART FOR THE ABERNATHY DRY DIET
(Amount of food per day expressed as a percentage of body weight.)

Average Water Temperature °C	Number of Fish per lb (454 g)							
	2500-1000	1000-300	300-150	150-90	90-40	40-10	10-Under	
4.4	2.6	2.2	2.0	1.7	1.3	0.8	0.6	
5.0	2.7	2.3	2.0	1.8	1.4	0.9	0.6	
5.6	2.8	2.4	2.2	1.9	1.4	0.9	0.7	
6.1	3.0	2.5	2.2	2.0	1.5	1.0	0.7	
6.7	3.1	2.6	2.4	2.1	1.6	1.0	0.7	
7.2	3.2	2.8	2.5	2.2	1.7	1.0	0.8	
7.8	3.4	2.9	2.6	2.3	1.8	1.1	0.8	
8.3	3.6	3.1	2.7	2.4	1.8	1.2	0.9	
8.9	3.7	3.2	2.9	2.5	1.9	1.2	0.9	
9.4	3.8	3.4	3.0	2.6	2.0	1.3	1.0	
10.0	4.0	3.6	3.2	2.8	2.1	1.4	1.0	
10.6	4.2	3.7	3.3	2.9	2.2	1.4	1.0	
11.1	4.5	3.9	3.5	3.1	2.4	1.5	1.1	
11.7	4.7	4.1	3.6	3.2	2.4	1.6	1.2	
12.2	4.9	4.3	3.8	3.4	2.5	1.7	1.2	
12.8	5.1	4.5	4.0	3.6	2.7	1.7	1.2	
13.3	5.3	4.6	4.2	3.7	2.8	1.8	1.3	
13.9	5.6	4.8	4.4	3.9	2.9	1.9	1.4	
14.4	5.8	5.1	4.6	4.1	3.1	2.1	1.4	
15.0	6.0	5.3	4.8	4.3	3.2	2.1	1.5	
15.6	6.5	5.6	5.0	4.5	3.4	2.2	1.6	

partially on naturally occurring marine life, which would provide sufficient growth stimulants and nutrients so they could be fed a cheaper diet than is customary in Japan. Feeding has evolved from feeding a slurry of ground-up trash fish to feeding a dry pellet. In general, the pellets contain 30% fish meal, 24% shrimp meal or crab meal or combination, 20% soy meal, 20% meat scraps, 2% whey, 2% vitamin mix, and 2% binder. In 1974, 1000 MT (2.2 million lb) of these pellets were used to produce 65 million shrimp weighing 375,000 kg (825,000 lb).

In 1974, the two 121-ha (300 acre) marine ponds harvested were 136,000 and 91,000 kg (300,000 and 200,000 lb), respectively. The conversion ratio using the pellet feed was 1.8 and 1.9 units fed per unit of shrimp harvested. Indications are that conversion ratios may go as low as 1.4 in raising shrimp averaging 9 g (50 per lb) each, heads on basis.

Techniques of gathering gravid females, hatching, and rearing shrimp to the proper size for stocking the grow-out areas are similar to those used in Japan (see Chapter 23 on Japan, Shrimp Culturing).

In farming tidal waters, the baby shrimp were initially planted in circular pens enclosed by fine mesh nylon nets having openings about like that of window screening. A chain fastened to one edge of the net sealed off the bottom, while a line of cork floats at the other edge held the net to the surface. Since small shrimp move about much as do suspended particles in riled water, in rough weather the shrimp would sometimes be washed out with waves breaking over the top of the pens. Though still on the farm, these liberated shrimp were in an area where predators had not been removed and where feed was not added. Therefore, survival was low, and growth somewhat slower until the shrimp grew large enough to move about in search of food.

It has been found to be most productive to retain baby shrimp behind open nets or within the ponds until they are at least 0.3 g in size.

Shrimp behave very differently in large growing areas than in small experimental ponds. White shrimp migrate in schools, whereas brown and pink do not. Shrimp also move to find natural feeding grounds. As shrimp grow larger they seek deeper water, but frequently move back into warm, shallow waters to feed on natural foods that seem to abound where more sunlight reaches the bottom. They do not generally seek to escape until they are young adults, at which time they would normally move out to sea with the tides. This tendency occurs just prior to and during harvest periods. At such times, Marifarms attaches a specially designed supplementary collar of floats to the top of its nets in order to stop the shrimp from swimming over the top during rough weather. Marifarms uses some 24 km (15 mi) of nets.

Multiple Cropping. Marifarms has learned enough about the availability of mother shrimp and the hatching and growing patterns to make it practical to grow two consecutive crops of shrimp in the very same areas. The first crop is brown shrimp. These are hatched in February and March, planted in the starting areas in April and May, moved progressively through

the nursery and into the grow-out areas, and harvested in June to August. Some pink shrimp may be included in this crop.

The hatchery, meanwhile, shifts to white shrimp, which are hatched in the May and June period. These move progressively through the same areas, arriving in the grow-out areas after the summer harvest of brown shrimp has been completed. The white shrimp are then harvested in the October–December period.

While it is theoretically possible to run a third crop of pink shrimp through the system—hatching them in the July–August–September period, holding them in juvenile form through winter when it is too cold for growth to continue, and subsequently continuing growth in the spring and harvesting them together with the brown crop during the next summer—tests show that wintering-over operations should have fairly deep holding areas so that the water does not cool during cold snaps as much as it does in shallower areas.

Survival, in the shallow pond areas in particular, is too low to justify such efforts. When water temperature drops below 10°C (50°F), survival falls off markedly. At 4°C (40°F) the effect is lethal. Operations further south ought to make a third crop feasible.

Harvesting. In shrimping at sea, the catch is manipulated by hand. Sometimes as little as 10% of what is caught is shrimp. First of all, the trash fish and other marine life are sorted out by hand and thrown overboard. Then while trawling continues, the crew members squeeze the heads off the shrimp by hand, place the tails in wire baskets, and, after washing, finally store these with ice below deck. [Washing on the boats is necessary after deheading to prevent brown spotting by polyphenoloxidase (tyrosinase) enzymes.] When a load is accumulated, the trawler returns to port to unload and stock up on provisions, and then returns to fishing at sea. Ships stay out a week or more at a time.

By contrast, Marifarms uses similar trawlers, but since the farmed waters contain little but shrimp, there is no need to sort the catch by hand on deck. The catch is dropped on deck, spread out, and layered with shaved ice. During trawling, the catch is generally kept covered by a canvas. After a few hours of trawling, the boat has a load of several thousand pounds on its stern deck. Then the boat returns to a dock at shore on the farm where the catch is unloaded by a vacuum lift with the aid of a heavy stream of water.

In the procedure used in harvesting the farmed marine lakes, as the shrimp are caught, they are placed into a transfer net on the special skiff used for the trawling. Every hour or so the skiff stops at a docking point so that the transfer net can be lifted out and immediately emptied into a tank of ice water mounted on a trailer. Every few hours this is hauled to a vacuum lift for final unloading.

The shrimp are discharged from the lift into a large agitated tank of ice water from which they are removed by a metal chainlink type of conveyor belt. The shrimp on the conveyor pass across an inspection table where

debris and the relatively few fish, crabs, etc., are removed by hand. [The crabs are accumulated and sold as a by-product. Crab yield in 1974 was about 9090 kg (20,000 lb) live weight.] At the end of the conveyor the shrimp are weighed into standard fish boxes holding 45 kg (100 lb) each. They are kept chilled by placing a layer of ice on the bottom, in the middle and on the top of each box of shrimp. These boxes are loaded into a tractor trailer, and loads of 9090 to 13,636 kg (20,000 to 30,000 lb) are hauled off to nearby processing plants within a day of being caught.

The shrimp are delivered untouched by human hands. Consequently, the bacterial count is low. The shrimp do not give off a strong fishy smell when cooked. They have a sweet taste, devoid of the iodine-like flavor often encountered in other shrimp. Thus, the quality of the cultivated shrimp produced by Marifarms is reported to be superior to the standard product.

Outlook. It is extremely doubtful if there will be any future development of farms like Marifarms, Inc., in the United States. In general, sportsmen, fishermen, shrimpers, and public officials will be reluctant to lease large bay areas to a single individual or corporation. While it is possible to develop pond enclosures on land and pump marine waters, it takes tremendous capital to do so. Possible investors have developed a wait-and-see attitude and are awaiting word that Marifarms is highly successful commercially before making such investments. Hence, in the foreseeable future, cultured shrimp are likely to be produced only by Marifarms. From 375 MT in 1974 (825,000 lb), officials of the company expect to reach capacity of 2273 MT (5 million lb) based on two crops a year raised during an 8-month period.

RESTOCKING

All states except Delaware and Mississippi operated at least one state hatchery during 1973 (Anon. 1974A). The total number of state fish hatcheries was 425, of which 297 produced coldwater fish, 73 produced warmwater fish, 29 produced walleye (*Stizostedion vitreum vitreum*) and Northern pike (*Esox lucius*), and 26 produced various combinations.

The average number of installations per state was 8.5. Washington had the most with 66 individual hatcheries, of which 57 produced anadromous salmonoids. Oregon was next with 31, with a strong emphasis on Pacific salmon and steelhead. The nationwide system of state hatcheries is growing slowly with 37 additional units scheduled for operation by 1978. This represents an 8.8% increase in 4 years.

There were 91 national hatcheries in 39 states operated by the U.S. Fish and Wildlife Service in 1978 (Anon. 1979). Of these, some reared trout exclusively while others reared trout and other types of fish. Only a few national hatcheries raised warmwater fish exclusively, although about one-third produced them in combination with other species.

National hatcheries from October 1978 to September 1979 produced and distributed 49 million warmwater fish; 120 million coolwater fish; 67 mil-

lion nonanadromous salmonoid with nearly one-half of them being rainbow trout, and 114 million anadromous salmonoids consisting primarily of chinook and chum salmon. A total of over 350 million cultured fish were raised and distributed from national hatcheries. The state hatcheries produce and distribute about 80% of the total and the national hatcheries about 20%. Hence more than 1.5 billion fish were cultured for distribution.

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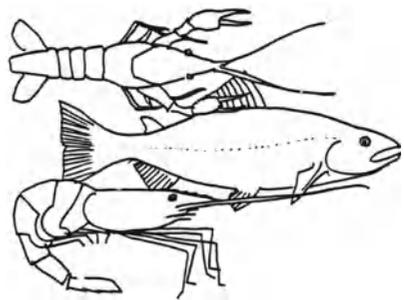
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Canada

FISH AND OTHER AQUATIC SPECIES

Arctic char	Pacific salmon
Atlantic salmon (<i>Salmo salar</i>)	Perch (Percidae)
Black bass (<i>Micropterus</i>) (Centrarchidae)	Pickereel (Percidae)
Brown trout (<i>Salmo trutta</i>)	Pike (Esocidae)
Carp	Rainbow trout (<i>Salmo gairdneri</i>)
Char	Salmon
Cisco (Coregonidae)	Speckled (brook) trout (<i>Salvelinus fontinalis</i>)
Cutthroat trout (<i>Salmo clarki</i>)	Splake (<i>Salvelinus fontinalis</i> × <i>namaycush</i>)
Eels	Trout
Lake trout (<i>Salvelinus</i> <i>namaycush</i>)	Whitefish
Lobsters	Centracid fish
Marine shrimp	Coregonid fish
Maskinonge (Esocidae)	Esocid fish
Milkfish	Percoid fish
Minnows	Salmonoid fish
Mussels	Canned and smoked fish
Oysters	Ornamental and tropical fish

Canada

Dr. Hugh R. MacCrimmon

Aquaculture in Canada began in the Province of Quebec where the Atlantic salmon (*Salmo salar*) and the speckled trout (*Salvelinus fontinalis*) were propagated commercially by 1857. With establishment of the Newcastle Hatchery in Ontario by the Canadian government in 1866, a system of salmonoid production was established which strongly influenced both private and government aquacultural developments in Canada, if not North America, over the century which followed. Similarly, the construction of a series of major jar hatcheries along the Great Lakes, beginning in 1875, heralded the advent of a culture method which was generally adopted in North America for the culture of coregonid, percoid, and, more recently, esocid and other fish. The pond culture of centrachid fish, begun by government agencies in 1900 for the production of black bass (*Micropterus*) for live release, is presently limited to modest government and private operations, largely in the Great Lakes region. While fisheries research and the management of fisheries resources has been a priority consideration in Canada for many years, a concerted effort toward the application of fisheries science to the commercial production of food fish and marine invertebrate organisms in confinement is of comparatively recent origin.

Under terms of the British North America Act of 1867, overall responsibility for the Canadian freshwater and marine fisheries lies with the federal government, but specific aspects of education, research, and management are matters of provincial concern. Consequently, aquaculture in Canada has evolved within both federal and provincial frameworks. In 1972 there were some 21 federal and 31 provincial government hatcheries, 163 commercial hatcheries, and an additional 113 licensed domestic operations using sloughs situated in the prairie provinces of western Canada. Not included in these figures is an unknown number of small private hatcheries, principally in eastern Canada, which are being operated more or less exclusively by fishing clubs for stocking their own waters.

Federal and provincial governments have continued to maintain a rather traditional approach to the artificial propagation of fish, both in terms of species cultured and the almost exclusive use of the product for live release within sport and commercial fisheries. Small numbers are used for aquacultural and other aspects of fisheries research in government and university research laboratories. Production from government hatcheries in 1972

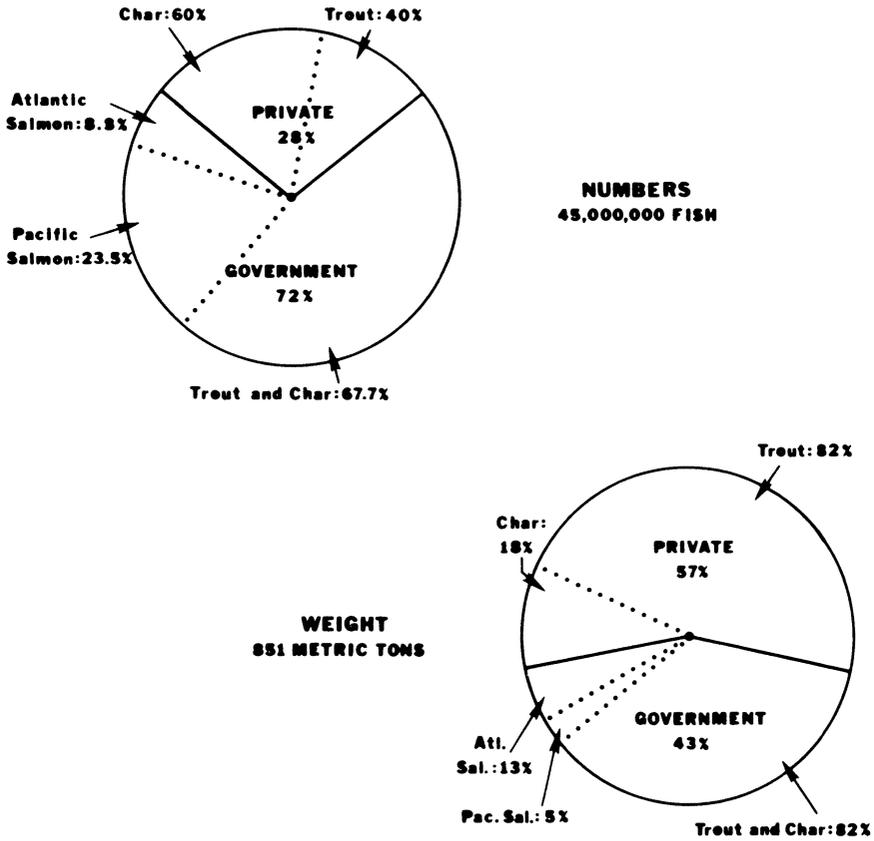


Fig. 2.1. Aquacultural production of salmonoids, 1972.

approached 369 million fish with an aggregate weight exceeding 500 MT (551 ST), of which salmonoid fish made up only 8.8% by number and 86.4% by weight. Some 94.3% of the production by number and 85.3% by weight came from provincial facilities spread across the continent. Of the total production of salmon, trout, and char in Canada by government and commercial hatcheries, private enterprises were responsible for about 28% by number and 57% by weight (Fig. 2.1). Other species reared in federal and provincial establishments for live release included 265 million whitefish and cisco (*Coregonidae*), 265 million pickerel and perch (*Percidae*), 29 million pike and maskinonge (*Esocidae*), and 180,000 black bass (*Centrar-chidae*).

Commercial fish farmers in the same year (1972), excluding experimen-

tal harvests of stocked rainbow trout from prairie pothole lakes marketed nearly 13 million fish weighing an estimated 485 MT (534 ST), largely rainbow and speckled (brook) trout (Fig. 2.2). Of the salmonoids produced, some 70% by number and 31% by weight were sold for live release, principally into private waters across Canada. Brook trout made up some 65% by number and 61% by weight. The balance was: rainbow trout (*Salmo gairdneri*), except for comparatively few lake trout (*Salvelinus namaycush*); brown trout (*Salmo trutta*); cutthroat trout (*Salmo clarki*); Atlantic salmon (*Salmo salar*); and splake (*Salvelinus fontinalis* × *namaycush*). Collectively these made up less than 1% of the total production of salmonoids marketed. The principal market for commercially produced live fish lies in the provinces of Ontario and Quebec where there is a strong demand for trout and char to stock private ponds and stream systems, and in the prairie provinces where considerable numbers of trout are released in privately owned pothole lakes for subsequent commercial recovery and domestic sale.

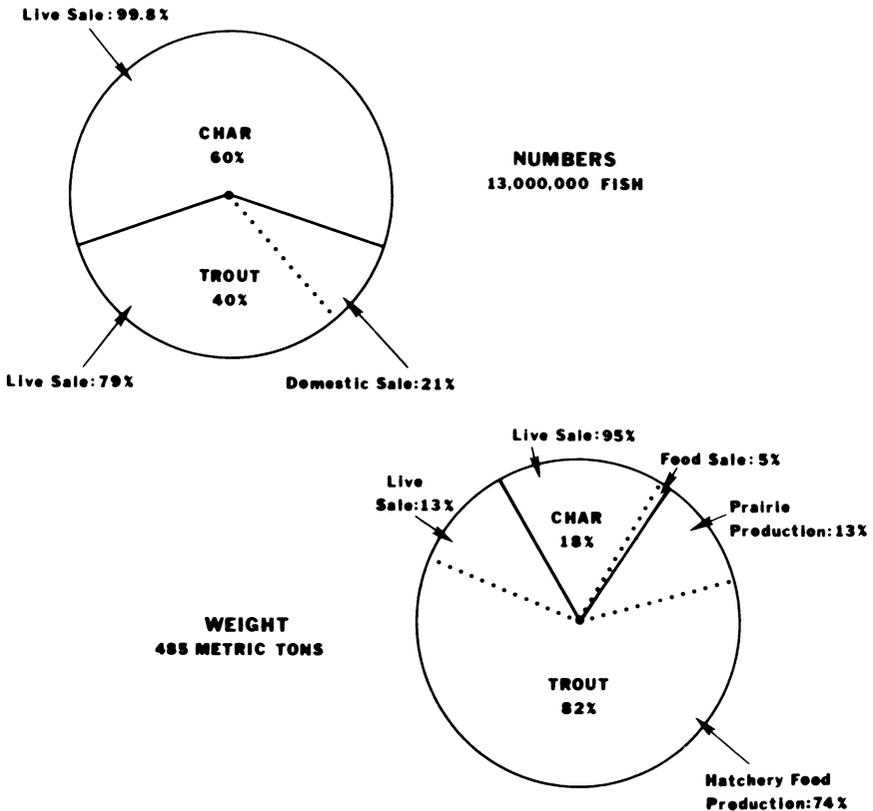


Fig. 2.2. Commercial production of salmonoids, 1972.

The commercial farming of freshwater salmonoids for human consumption in Canada is of comparatively recent origin because of a traditional local respect for the speckled (brook) trout as a sport fish, and because of a lack of evidence that the Atlantic and Pacific salmon could be profitably cultured to marketable size. Thus government agencies were hesitant to change long-standing legislation prohibiting sales of prized sport fish to accommodate a new aspect of private enterprise. As a result, the development of a viable Canadian aquacultural industry based on food fish sales lags appreciably behind that of most countries which have established fish farming industries. The transition of existing trout farming units, previously geared only to the production of trout for live sale, has been a rather slow process accomplished by slowly increasing the production to meet unknown but seemingly attractive market potentials. Despite expressed interest within the business community, aquacultural development in Canada has generally been left to the family unit level of operation. There are at present no large corporate aquacultural undertakings in Canada which have developed beyond the pilot experimental stage. The economic viability of large-scale production units remains to be proven. However, a number of previously established and new trout farms have become geared for the intensive culture of food fish. Their operators accumulated several years of invaluable experience in producing trout for human consumption.

In 1972 food sales of Canadian products totaled an estimated 1.1 million fish weighing 352,227 kg (775,000 lb), of which 99% was rainbow trout. The remainder was brook trout. Sales of speckled (brook) trout for human consumption are still prohibited by law in Quebec, although the species made up over 92% of the live sales in that province during the past year. Most fish marketed for human consumption in Canada were in the 170 to 280 g (6 to 10 oz) range, although one commercial unit in Quebec had begun to produce in volume rainbow trout of approximately 2.3 kg (5 lb)—principally for a specialized Montreal and New York market. The majority of rainbow trout produced for human consumption across Canada was sold by individual producers to local shops and restaurants, with some fish being distributed by chain store systems. Cooperative marketing of rainbow trout was limited to fish harvests from prairie potholes (sloughs) in western Canada, which were distributed on an experimental basis by the Freshwater Fish Marketing Board. At present the Ontario Fish Farmers' Association is advocating a cooperative approach toward the purchase of feed and other production items, and the collective marketing of their products.

Despite restrictive measures adopted by federal and provincial governments on the importation and transfer of eggs and fish, a reported 11 million rainbow trout and 2.5 million brook trout were imported into Canada from the United States in 1972. These eggs and fingerlings came from Washington, Idaho, Montana, and the New England states. Reported transfers of live fish across federal and provincial boundaries totaled approximately 14.6 million eggs and 4.8 million fry and fingerlings.

In Canada there are, as yet, no specialized brood hatcheries geared to

meet the egg requirements of the trout farming industry. However, most of the well-established trout farmers maintain their own brood stocks with a considerable "in-trade" market for eggs and young fish. Because of concern over the transmission of infectious fish diseases, there has been a general tightening of regulations by both federal and provincial governments pertaining to the importation and transfer of fish. Acting under authority of the Fisheries Act of Canada, the Fisheries and Marine Service of Environment Canada implemented new constraints on transfers of eggs and fish under the Fish Health Protection Regulations. The regulations apply to live fish, eggs of fish, and dead products of cultured fish destined to move into Canada or across provincial boundaries within Canada. Beginning January 1, 1977, it became illegal to make such transfers without a permit provided by a local Fish Health Officer, following periodic inspections of hatchery facilities and failure to detect any of the following pathogens: the kidney disease bacterium; the redmouth bacterium, *Aeromonas salmonicida*; the protozoans *Myxosoma cerebralis* and *Ceratomyxa shasta*; and the viruses causing viral hemorrhagic septicemia, infectious hematopoietic necrosis, and infectious pancreatic necrosis; myxobacteria; the motile aeromonads, and the vibrios. Further clarification of these regulations can be obtained from the National Registry of Fish Diseases, Environment Canada, Ottawa. Various provincial agencies have their own regulations as well, pertaining to fish propagation and transfers. At present the Great Lakes Fisheries Commission has proposed stringent regulations pertinent to that region of North America.

IMPORTS

Imports of cultured food fish into Canada during 1972 totaled 986 MT (2,169,406 lb) (Tables 2.1 and 2.2). Included were: 6234 kg (13,715 lb) of carp from Hong Kong, Taiwan and the USA; 909 kg (2000 lb) of milkfish from the Philippines; and 978,950 kg (2,153,691 lb) of trout from Denmark, Great Britain, the USA, Japan, and Portugal. Most of the trout were frozen, but shipments included about 3636 kg (8000 lb) of canned and smoked fish, principally from Denmark and Portugal. Imports of rainbow trout to Canada have more than doubled during the past five years despite the embargo imposed on Danish fish (Table 2.1).

MARKETING

Canadian aquaculturists have, with the exception of the prairie pothole farming operations, received no more than token government assistance in advertising or marketing the hatchery product, in contrast to the strong support given historically to agriculturalists and other aspects of the fisheries industry. Permission to sell "game" fish in Canada is, in itself, of comparatively recent origin. The developing fish farming industry has had to contend with various regulatory restrictions which, in combination with

TABLE 2.1. CANADIAN IMPORTS OF RAINBOW TROUT FOR HUMAN CONSUMPTION¹

Country of Origin	1967		1968		1969		1970		1971		1972		1981	
	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)	(kg)
Denmark	574,000	259,800	546,000	247,000	412,000	187,000	132,000	60,000	45,000	20,400	5,900	2,682	~8,008,200	—
Great Britain	371,000	168,000	550,000	249,000	399,000	181,000	27,000	12,200	1,500	673	14,900	6,773	~1,809,630	~ 975,294
Japan							275,000	125,000	1,616,000	734,000	2,003,200	910,545	~	—
Portugal											1,200	545	~	—
USA	55,000	25,000	95,000	43,000	114,000	52,000	207,000	94,000	124,000	56,409	128,500	58,409	~	—
eggs														
juvenile fish														
dead fish														
Other countries														
eggs														
juvenile fish														
dead fish														
Totals	1,000,000	454,000	1,191,000	543,000	924,000	418,000	641,000	292,000	1,786,500	803,954	2,153,691	978,954	~	~ 108,366
eggs														
juvenile fish														
dead fish														
														1,083,660

¹To determine kg imported during 1967 - 1971, multiply pounds by 2.20.

negligible government support until the present, have often been cited by fish farmers as being suppressive to growth and viability. Only in 1972 were prairie trout farmers permitted to sell directly to retailers, being previously restricted to direct sales to consumers or the Freshwater Fish Marketing Board. The Province of Quebec still prohibits the sale of native speckled (brook) trout for human food, whether of wild or hatchery origin, although there is extensive commercial propagation of the species for live release. Within the Canadian provinces there has been a gradual liberalization in attitude toward the domestic production and sale of salmonoid fish. Consequently, in most instances it is the ability of the fish farmer to profitably grow char, salmon, and trout to marketable size that governs the production of Canadian aquaculture. The production and marketing of salmonoid fish in Canada, therefore, continues to depend almost solely on the expertise and ingenuity of individual producers, although there has been very limited government support of private aquacultural systems by development grants and the like. Sales promotion among private fish farmers for the marketing of their products continues to be minimal, with a dependence on verbal communication with new and established clientele.

Sales of live trout for release into fishing waters are usually made on a local or regional basis, although not infrequently interprovincial and transcontinental transfers of eggs and fish (using oxygen-filled plastic bags) have been made by air freight. Sales of hatchery-produced salmonoids, principally rainbow trout, for human consumption are made in both fresh and frozen form. Until recent government authorization of the legal sale of these species on the food market, Canadian consumers were dependent on frozen packaged trout imported principally from Japan, Denmark, and Britain. Frozen trout of foreign origin, usually dressing out at 170 to 280 g (6 to 10 oz) per fish, are usually retailed at two to a package for the home consumer or bulk packaged for the restaurant trade. Thus, the Canadian production of domestic trout provided, for the first time, fresh and unfrozen trout for the local consumer. Trout farmers have found a ready

TABLE 2.2. IMPORTS OF DOMESTIC FRESHWATER FOOD FISH INTO CANADA DURING 1972

Fish	(kg)	(lb)	Country of Origin
Trout			
fresh	6,773	14,900	Great Britain
fresh and frozen	910,545	2,003,193	Japan
fresh and frozen	58,409	128,528	USA
canned and smoked	2,682	5,898	Denmark
canned	545	1,172	Portugal
Carp			
fresh and frozen	1,045	2,300	Taiwan
fresh and frozen	36	80	Hong Kong
fresh and frozen	4,948	10,885	USA
salted roe	205	450	USA
Milkfish			
fresh or frozen	909	2,000	Philippines

market for this product in direct sales to consumers and to the restaurant and retail food trade. Only surplus trout grown in Canadian hatcheries are usually frozen. Hence fresh locally-produced trout have a distinct market advantage over processed imports. Markets for Canadian domestic trout are best developed in Quebec, Ontario, and British Columbia, although prairie trout farmers have found suitable markets for their harvests of rainbow trout from pothole lakes, including a smoked product. Quebec producers are, at the moment, developing a unique market for large smoked rainbow trout in eastern American cities. At existing levels of trout production across Canada there is a healthy market for domestic trout despite negligible to modest market promotion and product development.

It is estimated that about 1.3 kg (2.9 million lb) of domestic salmonoids were marketed in Canada during 1972 for human consumption. Of this quantity 979,000 kg (2,150,000 lb) were imported, with 93% of this amount coming from Japan and 6% from the USA. Thus only 26.5% of the domestic trout marketed in Canada was produced by the Canadian fish farming industry. Sales of hatchery-grown freshwater fish in Canada in 1972 were solely rainbow trout, except for a few speckled (brook) trout (0.3%) produced and sold in the provinces of Nova Scotia and Ontario. While no precise figures are available on the present production and sales of hatchery-produced domestic salmonoids in Ontario, the trout farming industry has undergone substantial development since 1972. Efforts have been restricted largely to the increased production of rainbow trout for the food market. However, there is growing interest in the cage culture of Atlantic and Pacific salmon in coastal waters, and in the potentials of the Arctic char for rearing in cold waters typical of most Canadian hatcheries on a seasonal if not continual basis.

The sale of salmonoid eggs is essentially an in-trade operation by Canadian trout producers, although numerous stocks of ova and fry (mostly notably of rainbow trout and salmon) have been made available by governments to private operators from time to time for purposes of experimentation and commercial production. The trend of ova importations from the United States has been one of decline as the capability of Canadian trout farmers to meet their own production requirements has increased almost to

TABLE 2.3. PRICE STRUCTURE FOR LIVE SALE OF TROUT IN CANADA DURING 1972

(in.)	Size (cm)	Price per Thousand (\$)
Eggs		3.00-6.50
1-2	Less than 1	20.00-35.00
2-3	1	40.00-60.00
3-4	1.5	75.00-150.00
4-6	2	150.00-200.00
6-8	2.5-3	400.00-450.00
8-10	3-4	600.00-750.00
10-12	4-5	800.00-1000.00
Adults		3.00 each and up

the point of self-sufficiency. However, exchanges of eggs, fry, and fingerlings among Canadian hatcheries, both government and commercial, is a continuing activity and one which has come under much closer government scrutiny with the new Federal Fish and Health Regulations and various provincial enactments. The now considerable market for live trout for stocking private and commercial "pay-fishing" ponds is bound to expand as demands for recreational fishing near larger centers of population increase. A number of trout farmers also profitably operate "pay-fishing" ponds in conjunction with their production hatcheries.

Price Structure

Live Sales. Sales of fish eggs by private hatcheries in Canada are limited to those species produced, namely the rainbow trout and brook (speckled) trout. There is at present little price differential between the two species. Eggs sold in 1972 for between \$3.00 and \$6.50 per thousand depending on locality, quality, quantity purchased, and availability.

The price of fish, again restricted to brook and principally rainbow trout, is based on size, demand, numbers purchased, and availability (Table 2.3). Live trout purchased by the trout farming industry are typically fry or fingerlings averaging 10 cm (2 to 3 in.) in length.

The market for larger and older trout is restricted largely to sales of fish to owners of ponds or other fishing waters used for personal angling, or for the sale of recreation. The Ontario Fish Farmers' Association looks forward to the day when members may have the opportunity to bid on government contracts for fish to be released in public waters, thus welcoming the opportunity to compete with the government hatchery system in terms of cost and quality of product. In 1972 "keeper-size" trout sold across Canada for prices ranging from \$600 per thousand for 15 cm (6 in.) fish to \$1000 per thousand for 30 cm (12 in.) fish. Mature adults for brood stock sold at upwards of \$3.00 per individual fish. Brook (speckled) trout were priced slightly lower than rainbow trout despite a generally slower growth rate.

The sale of recreational angling for hatchery-reared trout held in confinement is increasing in popularity across Canada. The operation takes several forms. Traditional fishing clubs, particularly in Ontario and Quebec where some clubs have been in existence for a century or more, charge substantial membership fees and may place a daily or seasonal creel limit on its members. Newer clubs have tended to expand their facilities to include other forms of family outdoor recreation with annual fees on a single or family basis. As membership in private clubs utilizing private ponds, streams, or small lakes is too costly, or perhaps not appealing to many Canadians, the "pay-fish" or "U-Catch-em" operations are providing anglers with an alternative to private fishing clubs or public waters. The charge normally consists of a "gate" or "fishing pole" fee, plus a charge for all fish caught. The usual cost of the trout lies between \$0.25 and \$0.38 per cm (\$0.10 and \$0.15 per in.). Thus, the price of a "single portion" sized trout

averages between \$1.00 and \$1.50 each, or about \$4.00 to \$8.00 per kg (\$2.00 to \$3.00 per lb), plus admission or fishing fee. A comparison of sale prices for live hatchery-reared fish over the past decade has indicated surprisingly little change in value to compensate for increasing costs of production.

Food Sales for Human Consumption. Canadian aquaculturists must compete with imported trout in terms of price and quality. Bulk prices of frozen, dressed Japanese rainbow trout to west coast packers averaged \$1.25 per kg (\$0.57 per lb) in 1972. Wholesale prices for the frozen Japanese product averaged between \$1.80 and \$2.00 per kg (\$0.80 and \$0.90 per lb), while similar USA fish sold at \$2.75 to \$3.30 per kg (\$1.20 to \$1.50 per lb). Retail value of the Japanese product (2 fish per package) was \$2.10 to \$2.45 per kg (\$0.95 to \$1.10 per lb) whereas the U.S. product retailed at \$3.00 to \$4.20 per kg (\$1.35 to \$1.90 per lb) in west coast cities.

Prairie trout farmers received \$1.10 to \$1.35 per kg (\$0.50 to \$0.60 per lb) for dressed trout shipped to the Freshwater Fish Marketing Corporation. Wholesale prices for fresh fish processed by the corporation averaged \$1.90 per kg (\$0.85 per lb) with the fish advertised on the retail market at \$3.35 to \$4.00 per kg (\$1.50 to \$1.80 per lb). However, those prairie farmers selling a fresh product directly to local markets realized a substantial financial advantage, receiving better than \$2.00 per kg (\$0.90 per lb) for dressed fish.

Hatchery-produced rainbow trout sold directly to local stores, restaurants, and individual consumers in British Columbia, Ontario, and Quebec brought prices of up to \$4.25 per kg (\$1.90 per lb) for gutted iced fish. The production and sale of trout for human consumption would seem to be the most advanced in the Province of Quebec, especially in the production of large fresh and smoked rainbow trout, exported to New York at prices similar to those received for prime Atlantic salmon at \$6.50 to \$7.50 per kg (\$3.00 to \$4.50 per lb).

The value of freshwater aquacultural fish products marketed in Canada during 1972, exclusive of aquarium-reared ornamental and tropical fish, was estimated at \$3,141,000. Live sales of fry and fingerlings (72%) and yearlings and older salmonoids (28%) were valued at \$2,154,000, representing 69% of the total value of all fish produced. Sales for human consumption made up the remaining \$987,000. Salmonoids propagated in hatchery facilities including rearing ponds and cages made up 86%, and prairie pothole production comprised 14% of the value of these sales.

The marketability of trout produced in Canadian aquacultural systems, according to the 1972 survey, was excellent. Only among trout harvested experimentally from prairie pothole lakes was there any evidence of problems of product quality; these stemming from difficulties in autumn harvesting procedures and an unusual taste imparted to the flesh from some waters. Many prairie trout, however, were of top quality. Like trout produced elsewhere in Canada for human consumption, they found ready

markets in local and urban centers in competition with foreign imports.

NUTRITION

Rations purchased by government and licensed private hatcheries for feeding those fish produced in 1972 exceeded 1136 MT (2.5 million lb) with a cost of nearly \$460,000. With the exception of a few kilograms of minnows purchased to feed esocids, the feed was utilized solely for the production of salmonoids.

An overall (average) food conversion rate of 1.4 was realized for salmonoids produced in Canadian aquacultural systems based on reported food purchases yield data. This resulted in an average feeding cost of about \$0.53 per kg (\$0.23 per lb) of trout produced for food or live release. Despite limitations on the use of the data because of differences in hatchery objectives, and especially in the size and age of the final products, an analysis indicated that these feed conversions and costs per kilogram of fish were realized by the commercial fish farmers. Of the total weight of food fed to salmonoids, some 84% was formulated dry rations (avg \$0.35 per kg or \$0.159 per lb) 10% fresh or frozen liver and spleen (avg \$0.61 per kg or \$0.278 per lb), and 6% marine shrimp. Because of rapidly escalating food costs on Canadian and world markets, the cost of salmonoid production has undoubtedly increased substantially since 1973.

Dry rations were purchased for Canadian government and private hatcheries from 8 feed manufacturers in 1972, but considerably less than 10% of the marketed product was manufactured in Canada. The present situation is relatively unchanged with a dominance of foreign-manufactured salmon and trout feeds on the Canadian market, although, particularly in the Province of Ontario, there has been a rather modest increase in the local manufacture of formulated trout diets. Canadian feed manufacturers continue to be hampered in their operations by the need to import some of the ingredients necessary to meet prescribed ration formulae. Significant research on salmonoid nutrition and on the formation of diets utilizing principally locally-grown agricultural products is presently underway at several federal and university laboratories across Canada.

WATER SUPPLIES AND USE

Canada is blessed with an abundance of ground and surface waters, yet only insignificant quantities are presently being used for freshwater aquaculture. It is estimated that government and commercial fish hatcheries in Canada are currently using on a continuous basis about 13,000 liters per sec (205,000 gal. per min) of clean groundwaters provided by wells, springs, and headwater streams. During the era when government jar hatcheries in the Great Lakes were popular for coregonid and percoid culture, it is probable that pumped lake water increased the total continuous consumption of

water flowing through Canadian hatcheries to about 14,000 liters per sec (225,000 gal. per min).

In view of the emphasis presently placed on the production of salmonoid fish in Canadian aquaculture, present hatcheries and rearing stations are situated principally on coldwater sources. Headwaters (especially flowing springs, artesian wells, and feeder creeks) continue to be the favored water sources for intensive salmonoid propagation in eastern Canada and, to a lesser extent, in western Canada. Water supplies to Canadian hatcheries have a reported hardness ranging from 5 to 1570 ppm (expressed as CaCO_3), while pH values of 6.5 to 8.0 are typical. Two characteristic ecological features of Canadian freshwaters used commonly for salmonoid production are low temperature and low nutrient levels. Aquifer (and hence, well and spring water) temperatures across Canada are locally constant, ranging from as low as 4.4°C (40°F) in parts of Quebec to as high as 13.9°C (57°F) in parts of British Columbia. However, seasonal variability in surface waters and hatchery facilities typically ranges downward toward the freezing point. In some instances, these waters approach the lethal temperatures of salmon and trout during the summer months, causing significant seasonal difference in fish growth rates within and among government and commercial hatcheries.

Despite the abundance of freshwater in Canada, both government and private aquaculturists have experienced difficulty in locating new potential hatchery sites with adequate groundwater discharge to meet requirements for the volume production of salmonoid fishes. Further, fish production in a number of government and private establishments across Canada is limited by water shortages on a permanent or seasonal basis. Consequently, more novel aquacultural procedures utilizing prairie pothole lakes on a live trout release and annual recovery basis, and cage culture in freshwater lakes and coastal saline waters, offer seemingly attractive alternatives to the traditional dependence on surface and pumped waters. Although cage culture has been used for the commercial production of salmonoids and other food fish species in other countries for some time, this method is still at the experimental stage in Canada, with the exception of a proven operation in the Province of Quebec now serving a Montreal and New York market.

As the use of recirculated water would seem to solve simultaneously the problems of inadequate water supply and coldwater temperatures characteristic of north temperate climates, the partial recirculating of water is now a reality in several government and private hatcheries. About 7.5% of the production hatcheries in Canada re-use some warmed water, although usually only for the incubation of eggs and the early rearing of fry. Major recirculation systems using heated waters have been initiated in a few government hatcheries. However, at present the necessary testing has not been done which will indicate the economic justification for major investment by commercial operators. While there is considerable government and private interest in the use of heated wastewaters from power generating plants for fish production, feasibility studies undertaken to date are less

optimistic than might be expected, despite the attractiveness of such potential sources of low cost energy.

RESEARCH AND EDUCATION

Canada has an outstanding record in terms of marine and freshwater fisheries research dating back to the early formation of the Biological Board of Canada and, until recently, the Fisheries Research Board of Canada with its directors drawn from representatives of governments, universities, and the fishing industry. At present, fisheries research at the federal level is being undertaken by the various laboratories of the Fisheries and Marine Service of Environment Canada at St. John's, Newfoundland; Halifax, Nova Scotia; St. Andrew's, New Brunswick; the Canada Centre for Inland Waters, Burlington, Ontario; the Freshwater Institute at Winnipeg, Manitoba; and at Nanaimo and Vancouver in British Columbia. Most provincial governments also support fisheries research laboratories with studies related to the management of inland fisheries resources.

Graduate studies in one or more of the disciplines embraced by fisheries science are offered by most Canadian universities. However, integrated fisheries programs are given at comparatively few. The following seven institutions of higher learning in Canada are presently receiving major federal financial support for aquatic studies: Memorial University (Newfoundland), Dalhousie University (Nova Scotia), McGill University (Quebec), University of Toronto (Ontario), University of Guelph (Ontario), University of Victoria (British Columbia), and the University of British Columbia. Also, the Freshwater Institute of Environment Canada is located on the University of Manitoba campus. Considerable provincial support is given to a number of universities for fisheries research of particular benefit to the management of local inland waters. In addition, the Huntsman Marine Laboratory on the east coast (Bay of Fundy) and the Bamfield Marine Laboratory on the west coast (Vancouver Island) provide marine training and research facilities for Canadian universities on a consortium basis.

Despite the very significant Canadian investment in fisheries research at the federal, provincial, and university levels, studies directed toward the solving of biological problems inherent in the development of commercial aquaculture in Canada have, until comparatively recently, been a token consideration. Thus it seems fair to state that private aquaculture in Canada has evolved to its present status largely as a result of private enterprise working within regulatory constraints imposed by governments, particularly for purposes of enforcement, statistical record, and disease control. During the past decade there has been increasing federal and provincial support for environmental, fish disease, and nutrition studies. Progressively better provisions have been made for diagnostic services to assist both government and private aquaculturists. However, it is only very recently that the Fisheries and Marine Service of Environment Canada made the decision to redirect substantial resources to aquaculture, thereby

giving essential impetus to the solving of development, operational, and production problems in the growing fish farming industry.

Representative aquacultural research and development programs presently activated across Canada by federal and, to a lesser extent, by provincial funding include: studies on the nutrition, biochemistry, physiology, and behavior of oysters, lobsters, mussels, and salmonoids; harvesting and processing methods for aquatic vegetation, most notably marine kelp and Irish moss and freshwater macrophytes in eutrophic lakes; hatchery facility design and technology for salmonoid fish and marine invertebrates; recirculation hatchery systems; experimental cage culture of Atlantic salmon, rainbow trout, brook (speckled) trout, Arctic char, splake, and the Pacific salmon; prairie pothole trout farming; eel farming; modular aquacultural systems; genetics and fish breeding; fish processing and marketing; fish pathology; trout nutrition and diet synthesis with Canadian-grown ingredients; feasibility studies on use of thermal energy from power generating plants; and a wide variety of fundamental biological studies being undertaken within government and university laboratories. The North American Salmon Research Center (a combined project of the International Atlantic Salmon Foundation, the Huntsman Marine Laboratory, and the Fisheries and Marine Service of Environment Canada) is a new facility with its principal activity in the area of genetics and selective breeding of salmonoids, especially the Atlantic salmon. Among the several Canadian universities actively engaged in fisheries research, a comprehensive aquaculture program has been best developed at the University of Guelph where, as a component of undergraduate and graduate teaching programs in the aquatic sciences, there is long-standing research and practical experience in the environmental, physio-behavioral, nutritional, and pathological aspects of fish propagation.

SUMMARY

This chapter has attempted to present the reader with an overview of the growth and present status of government and private aquaculture in Canada; and, in particular, to indicate the exciting developments which are just beginning to take form with increased government commitment to scientific aquaculture. Despite over a century of successful and often innovative culture of aquatic life in Canada, aquaculture as a resource industry is just in its infancy. Endowed with an abundance of water and the dedicated support of the scientific community, government agencies, and practicing aquaculturalists, the principal limiting factor to the development of aquaculture as a significant protein-producing industry in Canada would seem to be its as yet unproven economic viability in other than small-scale operations. Finally, it should be noted that in addition to its support and participation in fisheries research and management programs in Canada, the Canadian government maintains a strong international commitment

toward aquacultural research and development in Third World countries.

REFERENCE

MACCRIMMON, H.R., STEWART, J.E. and BRETT, R., JR. 1975. Aquaculture in Canada. Research Board of Canada (1973 and 1975) Bull. 188.

Norway

FISH AND OTHER AQUATIC SPECIES

Atlantic salmon (*Salmo salar*)

Rainbow trout (*Salmo gairdneri*)

Red capelin (*Mallotus villosus*)

Sea trout

Shrimp

Trash fish

Norway

In 1975 Norway had about 300 fish farmers. About 250 were engaged in rainbow trout production, but 100 of these, particularly the older ones, were more or less out of production. The remaining 50 were culturing Atlantic salmon (see Fig. 3.1). These were the only two cultured fish species grown in Norway. Hence, this chapter is divided into two subparts: one for Atlantic salmon and one for rainbow trout. Most of the cultured fish industry is concentrated in the area north and south of Bergen (see Fig. 3.2). Restricted production in northern Norway is due to difficulties in raising fingerlings in the colder waters.

Types of Fish Culture

There are four types of fish-culturing establishments in Norway: (1) freshwater farms on land; (2) seawater farms on land; (3) enclosures in seawater; and (4) coves, sounds, or fiords closed over by enclosures of concrete, net, or wire.

Most of type (1) establishments, freshwater farms on land, are sited so that they are fed by gravity flow. In only a few cases is pumping of groundwater done. The ponds or raceways are of concrete, earthen, or lined with wooden materials.

Type (2), seawater farms on land, usually use brackish water. Seawater is pumped and mixed with freshwater to increase water availability and water temperatures. The ponds, or raceways, are constructed of concrete, are earthen, or are lined with wooden materials. Both freshwater farms and seawater farms on land produce eggs, fry, and fingerlings. From these two types of establishments the fingerlings are transferred to type (3) enclosures in seawater and type (4) coves, sounds, or fiords, for growing out as food fish. There are about 70 of the (1) freshwater farms on land, and (2) seawater-on-land types of farms; their production, however, is small.

Type (3), enclosures in seawater, is further divided into two subtypes. One is a floating enclosure of nylon netting in the sea. These may be circular, rectangular, or square, and of varying depths.

Floating enclosures are the most common type of fish farm, accounting for about 200 of the 300 different fish farms in Norway.

The second subtype is nets which go out from the shoreline into the sea or

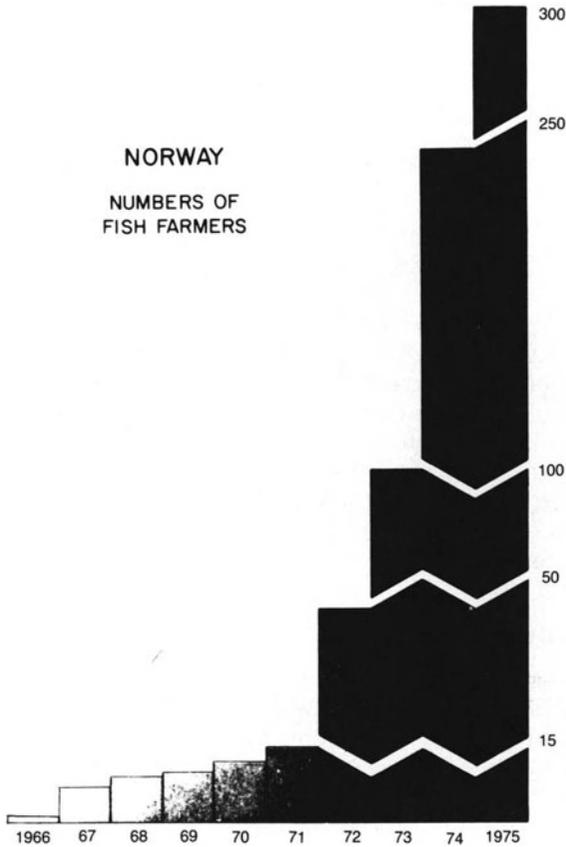


Fig. 3.1. Changes in the number of fish farmers, 1966–1975.

brackish water area. The shore constitutes one side and netting suspended from driven poles constitutes the other three sides.

Type (4), coves, sounds, or fiords, relies on tides and currents to exchange water. However, sometimes seawater is pumped through the enclosure if the natural flow of water is not sufficient to maintain a given density of fish. There are 10–15 of these types of farms.

ATLANTIC SALMON (*Salmo salar*)

Atlantic salmon resemble sea trout in color and can grow to more than 1 m (3 ft) in length. It is an anadromous fish, migrating from salt to freshwater to spawn and then migrating back to salt water until it reaches sexual maturity. The sea stage can last from 1 to 3 years, after which the salmon migrate to freshwater, swimming upstream to spawn in the waters

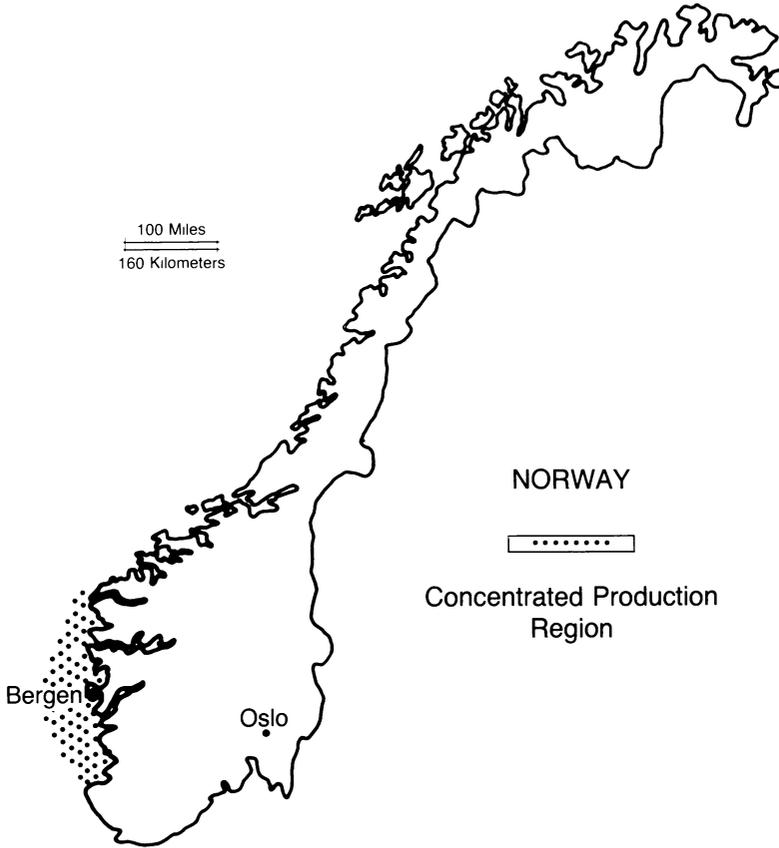


Fig. 3.2. Concentrated production area for cultured fish, 1975.

from which it originated. Young salmon may remain in the freshwater for one to two years before returning to the sea.

In Europe, Atlantic salmon are found in waters from the Arctic Ocean, the North Sea, and Baltic Sea, around Great Britain and Ireland, south to Portugal. Only in very recent years has it been cultured by man as a food fish.

In culturing, spawning usually occurs in November and December with eggs hatching the following April or May. During the first summer of growth, the fry should be fed every hour; continuous feeding is best. These fry eat very little when the water temperature is below 10°C (50°F) and growth ceases below the 5° to 7°C (41° to 45°F) range.

During the second summer of growth, the fry, which are now considered fingerlings, can be fed every other hour. The fingerlings are able to tolerate lower temperatures than the first summer fry. However, growth still ceases

at about 5°C (41°F). During the winter seasons when water temperatures are below 5°C (41°F), the fish are given only one small feeding every second day.

By about May 1, one or two years after hatching, the fingerlings turn into so-called smolts, averaging between 13 and 20 cm (5 and 8 in.). If heated water is used, smolts can be produced in one year. Using water with natural temperatures generally requires two years to develop smolts.

The smolts are stocked in the early spring into net enclosures, fiords closed off by nets, or concrete impoundments. After a minimum period of one year in the sea, some of the salmon have grown to a size suitable for sale in the spring. However, most of the food fish are sold after 18–24 months of feeding, i.e., for Christmas, or Easter in the spring. Average weight at this time is about 5 kg (11 lb). The record salmon produced in 4 years after hatching was 16 kg (35 lb).

Optimum water temperatures for feeding salmon are unknown, but good growth is reported up to about 15°C (69°F). Because of the colder freshwaters in northern Norway there are cultural problems with fry and fingerlings. Hence, salmon fish farmers in the north import their fingerlings by wellboat from the southern areas. This has not proven to be entirely satisfactory due to high mortality en route.

Salmon prices are highest during the Christmas and Easter seasons. Hence, production is keyed to marketing at these two peak seasons. In 1974 the lowest price received by salmon culturists was \$3–\$4 per kg (\$1.36–\$1.82 per lb). In August 1975, the price was \$4.50 per kg (\$2.05 per lb). In Norway, salmon prices for cultured fish are determined by world market prices for wild fish.

About 1972, in an effort to spread the benefits of fish farming to as many people as possible and to avoid concentration into the hands of a few individuals or firms, the authorities passed a law stating that the maximum size of any production facility could be only 8000 m³. Translated into practical terms this would mean about 60–80 MT of salmon production per management. At present, very few producers produce over 50 MT of salmon, while the average is less than 25 MT. Investigations are still underway to determine what a practical-sized economical production unit should be. However, the salmon farms that contained over 8000 m³ of water prior to passage of the law were permitted to keep operating. The largest farm is reported to produce more than 500 MT annually. While some farms are presently producing 50 MT per man-year of labor, some Norwegians think that the optimum size for economical production might be 250 MT, employing 3–4 persons.

A typical management may consist of a fiord enclosure, or floating pens, on the southwestern coastline. All production is in salt or brackish water. The first one or two years (depending on water temperature) will get the fish up to 1 to 2 kg (2.2 to 4.4 lb). During the final year of feeding, from about May 1, the fish will reach marketable size by September–November (3.5 to 5.0 kg or 7.7 to 11 lb). Harvesting and marketing start then and continue

until Easter (March or April) of the following year. Small frozen trash fish bought in blocks of several pounds (about 100 to 200 kg) each are thawed and fed to the fish. The frozen trash fish are brought by boat or truck to the production area from nearby fishing villages.

A fiord enclosure usually consists of blocking off a fiord, which may be 70–80 m wide (200–250 ft), by using nets on both the seaward and the land side. These two nets may be up to 300 m (more than 900 ft) apart. Pumps are sometimes used to keep water flowing through the enclosures instead of relying solely on the moderate tidal action.

Growth of the salmon culturing industry has been rapid. In 1973, there were an estimated 275 MT produced. By 1974, production had increased to 800 MT with a further increase to 950 MT in 1975. The production in 1976 was estimated to be more than 1500 MT and has not changed significantly since then (personal communication). This is a significant amount when compared to the 1600–1800 MT of wild salmon caught in Norwegian waters.

An estimated 80% of the cultured salmon is exported to other countries. The major importing countries are France, Federal Republic of Germany (West Germany), and Sweden. The salmon are sold fresh, iced, to Sweden and France, while about one-half of the German imports are frozen. Some of the fresh salmon sold to Germany are then smoked.

Typically, harvested salmon are killed and dressed at the point of production and then go by truck or boat to a central distributor. The distributor then sells domestic fish to fish-mongers or retail markets. The exported salmon go to importing firms in the recipient countries. There are large efforts by producers to organize a cooperative to serve the first distributor functions.



Fig. 3.3. Unloading frozen trash fish for salmon feeding.



Fig. 3.4. Salmon farming in Norwegian fiord, feeding ring shown in center.

RAINBOW TROUT (*Salmo gairdneri*)

Spawning time for rainbow trout in Norway is usually from February to April. Because of the cold water, hatching is usually in May. After hatching, the fry are raised in rearing tanks made of fiberglass using freshwater. If they are grown in warmer waters they may grow to about 70–100 g (up to 4 oz) by October and about 330 g by the next May. In colder waters they may only reach 10 g (0.4 oz) by October.

In October some fingerlings, about 10 cm in length (4 in.), are stocked in saltwater enclosures. The usual practice is to stock in salt water in May of the year following hatching. At this time the fingerlings are about 15 cm (6 in.) and weigh about 45 g (1.6 oz) each. The fish, whether stocked in October or May, are often harvested the following fall in October or November.

Harvest weights will average between 1.0 and 2.0 kg (2.2 and 4.4 lb) after only one grow-out season. Many fish farmers produce larger trout up to 3.5 kg (7.7 lb) after 18 months in the sea. If kept longer, most of the trout reach sexual maturity, which spoils both quality and growth for a considerable time.

Trout farms are generally located in salt or brackish waters along the coast. Very few of the 250 trout farms are located in freshwater, partly because of the stoppage of growth caused by lower water temperatures in winter and partly because of more fish diseases, compared with saltwater

farming. Salt and brackish waters are part of the public domain and there are no fees charged by the government for use of such waters as in some other countries. According to Norwegian authorities, about 30 hatcheries produce eyed-eggs or fingerlings for their own use or for sale to other fish farmers.

Of the remaining 220 fish farms, about 175 are small-scale production units producing less than 20 MT (22 ST) annually. Only about 30 farms produce over 50 MT of food fish annually.

Until the fingerlings are stocked into grow-out facilities the fish are fed pelleted food. When ready for stocking in October or May they are usually transferred to float net type enclosures, either round, square, or rectangular, up to 10 m (40 ft) round or per each side. They are then continued on 40% protein pellets for one month and shifted to eating wet food. The wet food is chopped or diced trash fish with pre-mixed vitamins added and made into a paste. Because of the adding of shrimp waste or other color components to the wet food (minced trash fish) the trouts' flesh color is red and texture is a little softer and more delicate than that of salmon. Red-colored flesh is preferred in Norway and white-fleshed trout produced in other countries on pelleted feed is not in demand.¹ The trout production in Denmark, however, is based solely on wet food, but without shrimp added, they produce only white-fleshed trout.

Ample natural food is available for further expansion of the cultured fish industry. At present the industry is using less than 25,000 MT of trash fish annually. It is estimated that there are between 250,000 and 300,000 MT of trash fish produced yearly. Hence, the cultured fish industry has enough cheap feed to expand to about 12 times its present size.

Floating net enclosures (pens) may be as small as 3 m² (3.6 yd²) and 3 m deep. Usually there is no pumping of water; tides bring fresh water into the pens. Production per m³ depends on water flow rates, the area of the country, and water temperature. Average production per m³ (35.3 ft³) is 20–30 kg or 1.3–1.9 lb per ft³.

Placement of floating net enclosures is important. If the pens are inside a fiord where water is only slightly brackish, the fiord may freeze over in winter, thus reducing the oxygen supply. These farms harvest their fish in October and November, resulting in temporary low prices and the need to freeze some fish to avoid breaking the market. About 1/3 to 1/2 of the

¹ Red colored flesh is obtained only by adding color components in sufficient quantities and time to the food (for instance, 1/7 shrimp waste, 6/7 trash fish). For wet food, Norwegians use shrimp waste, red capelin oil (of *Mallotus villosus*) containing 50 mg astaxanthin per kg. However, artificial red pigment powder, containing 10% canthaxanthin, may also be added to the wet food. For dry food, capelin oil and canthaxanthin are added and red colored flesh is thereby obtained. This color or shade is particularly suitable for smoking or marinating processes. However, if insufficient color components are added, the red color of the flesh can be weakened and turn pink when cooked. This occurs also when only canthaxanthin is added to the dry food. However, a right balance of capelin oil and canthaxanthin secures a better and more stable color of the flesh.

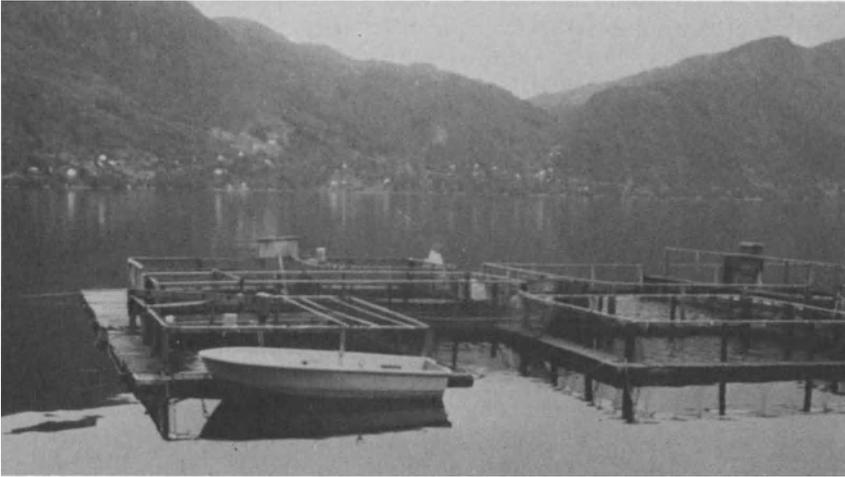


Fig. 3.5 Floating rainbow trout pens in Norwegian fiord.

cultured trout is frozen for later use. In addition, many trout become sexually mature at this time, with growth nearly stopping. Hence, these fish are also harvested.

In 1974 market prices to trout culturists were depressed, resulting from rapid industry expansion. Prices ranged from \$1.50 to \$2 per kg (\$0.68 to \$0.91 per lb). In 1975 trout fish prices delivered from the farm were averaging about \$2.20 per kg (\$1 per lb) in the round. Fresh fish, at retail, averaged about \$4.96 per kg (\$2.25 per lb) for gutted fish with heads on. Frozen trout, at retail, averaged \$4.04 per kg (\$1.84 per lb). A limited quantity of trout were smoked and prices averaged \$14 to \$15 per kg (\$6.59 per lb). However, about 50% of the weight is lost during the smoking process. Unlike salmon, which is duty free in the Common Market, trout prices are mainly determined by domestic supply and demand. The present duty on trout is 12% which helps restrict the sale of the large rainbow trout in export channels. In 1974 and 1975 the domestic market became oversupplied and prices became erratic. The situation was not aided by the existing marketing system wherein some producers market trout directly to consumers and retail outlets while some producers market through numerous fish buyers. However, in 1975/1976 there was a considerable increase in the price of salmon, which improved the sales and exports of large rainbow trout.

In 1962 production was an estimated 200 MT (220 ST). In 1972 and 1973 the number of fish farmers increased dramatically (see Fig. 3.1) and production soared to 1300 MT (1433 ST) by 1973 and increased to about 2200 MT in 1974 (2400 ST). Only about 300 MT were exported. In 1975 exports increased to 450 MT (496 ST). These were fresh or frozen and were sold to Sweden, West Germany, and France. A limited amount was also sold to the USA. In 1975 production declined and was estimated at about 1800 MT

total, largely because of lower stocking in October 1974 and May 1975 as a result of low producer prices encountered in 1974. By 1979, production had totaled 2690 MT (2960 ST) with about 200 MT (220 ST) exported.

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Sweden

FISH SPECIES

Arctic char (*Salvelinus alpinus*)

Atlantic salmon (*Salmo salar*)

Brook trout (*Salvelinus fontinalis*)

Brown trout (*Salmo trutta*)

Lake trout (*Salmo trutta lacustris*)

Rainbow trout (*Salmo gairdneri*)

Sea trout

Sweden

RAINBOW TROUT (*Salmo gairdneri*) AND ATLANTIC SALMON (*Salmo salar*)

In Sweden only salmonidae are cultured. These include rainbow trout (*Salmo gairdneri*), Atlantic salmon (*Salmo salar*), sea trout (not identified), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), lake trout (*Salmo trutta lacustris*), and Arctic char (*Salvelinus alpinus*). However, rainbow trout and Atlantic salmon are the only two species cultured for food consumption.

There are about 100 private fish farms raising fish for the domestic food market. These are generally small-scale enterprises varying from 0.5 to 50 MT annually and averaging about 4.0 MT of production (4.4 ST). There is a total domestic production of about 400 MT (440 ST) of cultured fish destined for immediate consumption. Of this amount, 300 MT or 75% of the total are rainbow trout and 100 MT are Atlantic salmon. Rainbow trout culture is essentially done in freshwater with some experimental work being conducted in brackish and salt water. Production is in earthen ponds, concrete raceways, tanks, nets, and cages. Salmon culture is done in salt water using net enclosures.

In addition to the 400 MT of domestically cultured fish, Sweden in 1974 imported about 550 MT (606 ST) of rainbow trout with nearly all of it coming from Denmark as live and frozen shipments. Less than 100 MT (110 ST) of rainbow trout were imported from Norway. In addition, between 100 and 150 MT (110 and 165 ST) of fresh iced salmon are imported from Norway. There are no exports of any consequence; hence, the total supply of cultured fish for consumption is slightly less than 1000 MT (1102 ST).

The domestically produced fish are generally sold locally by producers as live fish. Trout and salmon from Norway are iced. About one-half of the Danish rainbow trout are iced and the remainder frozen.

Rainbow trout spawn in April and May, and between 15 and 25 months are required to raise the fish to the 250 to 300 g (9 to 11 oz) fish sold by domestic producers. Rainbow trout imported from Denmark and Norway are about the same size as domestically produced trout. Imported salmon

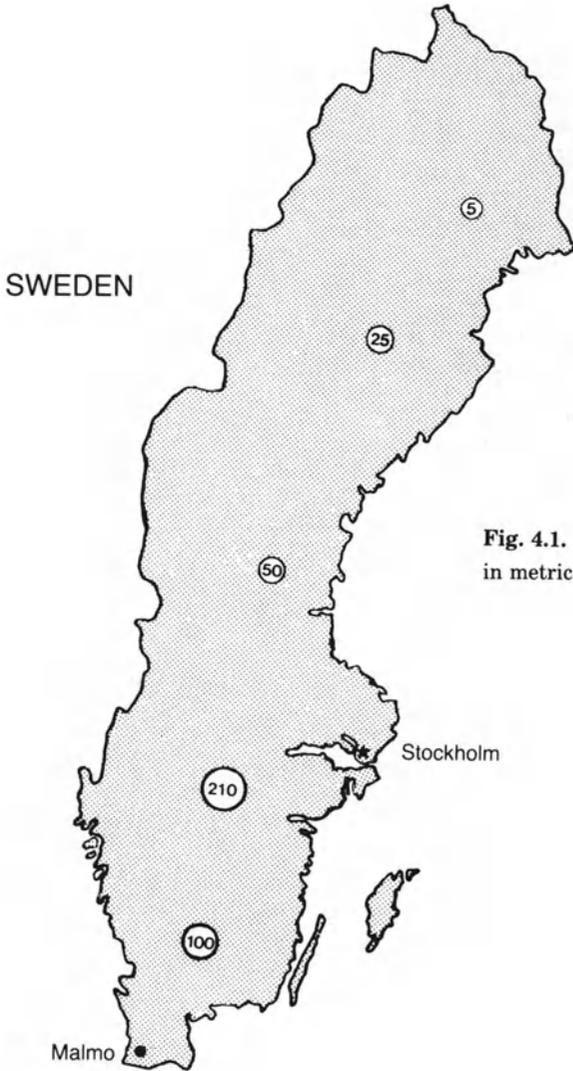


Fig. 4.1. Production of rainbow trout in metric tons by regions, 1972.

from Norway average about 5 kg (11 lb). Domestically produced Atlantic salmon take about 2 years of culturing to reach market sizes of 5 kg (see Chapter 3).

Nearly all cultured fish production comes from southern Sweden where the water is warmest and most conducive for farming activities (Fig. 4.1). Production of both trout and salmon is expected to increase as research findings on culturing these two species in brackish and salt water are adopted.

In addition to production of cultured fish for food consumption, there are intensive efforts by the government in restocking. Major emphasis is on producing Atlantic salmon and sea trout. About 1.8 million smolts are released annually in an effort to restock the Baltic Sea. Additionally, the government restocks brown trout, brook trout, lake trout, and Arctic char in fresh waters for public fishing.

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Denmark

FISH SPECIES

Brown trout (*Salmo trutta*)

European eels (*Anguilla
anguilla*)

Herring

Rainbow trout (*Salmo
gairdneri*)

Sand eels

Silver eel

Sperling

Trash fish

Whiting

Denmark

RAINBOW TROUT (*Salmo gairdneri*)

Only one species of fish is presently cultured in Denmark for production as a food fish, and this species is rainbow trout. Previously brown trout (*Salmo trutta*) was also cultured. The first Danish trout farms were established about 1890 in Jutland, the western portion of Denmark which is attached to the European continent (Bregnballe 1963). In the beginning brown trout was the dominant species cultured. Within a short period of time, however, rainbow trout were introduced and soon became predominant; and more recently, rainbow trout has become the exclusive food fish cultured.

The Danish trout industry was the first in Europe to become established and to grow to maturity. Other countries are still rapidly increasing the numbers of fish farms and volumes of production. However, by 1961 there were already 500–525 trout farms in operation in Denmark, only 6 of them outside Jutland. In 1975 there were an estimated 530 trout farms, indicating very little change in numbers over a 15-year period. The output of rainbow trout has increased, but at a much slower rate than for other European countries such as Norway, France, Italy, Spain, Switzerland, and West Germany. In 1962, export of rainbow trout from Denmark was 7781 MT (8575 ST). By 1972 it had reached 14,600 MT (16,100 ST) and then began to decline. In 1974 export was below 13,000 MT (14,265 ST). In 1975, 14,763 MT (16,269 ST) of exports was output. However, by 1979, total production was 17,950 MT (19,745 ST), with exports accounting for 15,341 MT (16,875 ST) or 85% of the total.

Production

Of the 1975 total of 530 rainbow trout producers, about 150 produced eggs, fry, and fingerlings only. In general, they are the first fish farms located nearer the headwaters of small streams and rivers west of the Jutland ridge area. Production is mainly concentrated in the western and central part of Jutland (see Fig. 5.1).

Of the 530 producers, all but three produce trout in freshwater. These three producers, with a total production of about 200 MT are located in

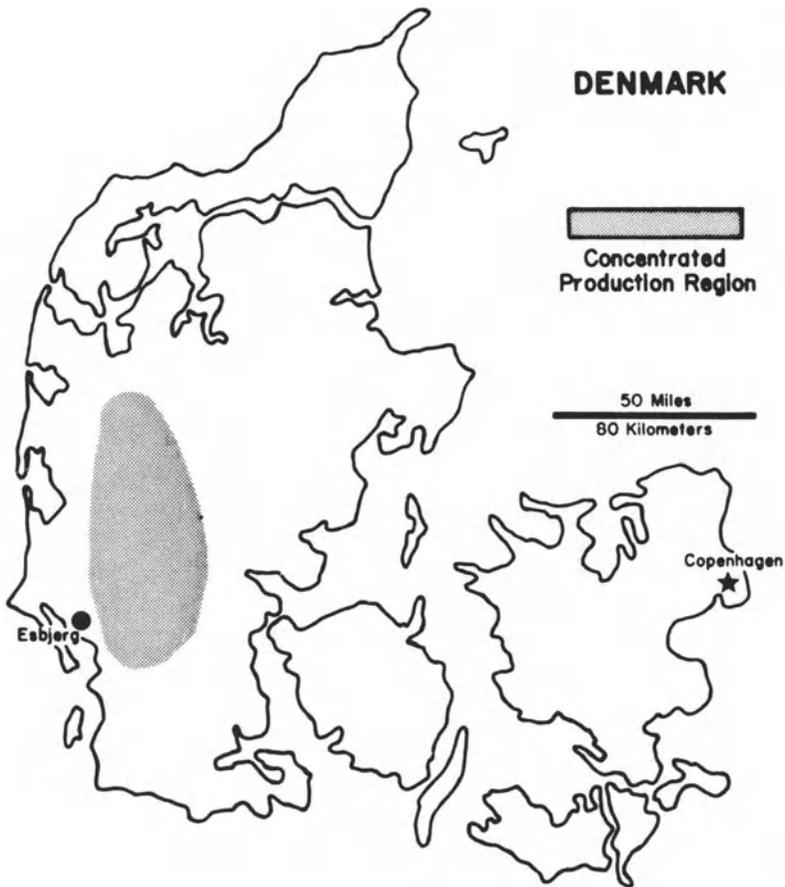


Fig. 5.1. Concentrated fish culturing area, 1975.

Ringkøbing Fiord north of Esbjerg. This production is in brackish water with a salt content of about 1 ppm.

A typical Danish trout farm is constructed in the following way: the water in a river or brook is dammed and led through two inlet channels to two rows of parallel rectangular ponds; from the ponds the water can be released into the outlet channel and flow back into the river. The outlet channel is provided with a fish screen and is also used for trout production. The water is used first in the ponds and then in the outlet channel. Though each pond receives only a relatively small water supply, the channel receives water from all ponds (Fig. 5.2). All ponds are earthen, and the channels are also excavated from earth. Inlet and outlet pipes are made of wood or polyvinylchloride (PVC). A middle-sized Danish trout farm will have 35 to 60 ponds.

There is no net or cage culture in Denmark. All culturing of grow-out fish

is in earthen ponds which are usually about 300 m^2 (2916 f^2). The typical pond measures 30 m (97 ft) long by 10 m (39 ft) wide and is from 0.5 to 1 m (18 to 39 in.) deep. The water exchange rate is three times daily. Each pond produces about $2\frac{1}{2} \text{ MT}$ of fish yearly (1.0 lb per f^3). This is far less than could be produced in a raceway system. However, water temperatures in the winter approach 0°C (32°F) and at times small streams are partially frozen and water flow may stop for several hours. With fewer fish per unit of water flow and water volume in ponds, there is still sufficient "oxygen reserve" to keep the fish alive until the water flow is reestablished. This would not be true if raceways and denser stocking were allowed.

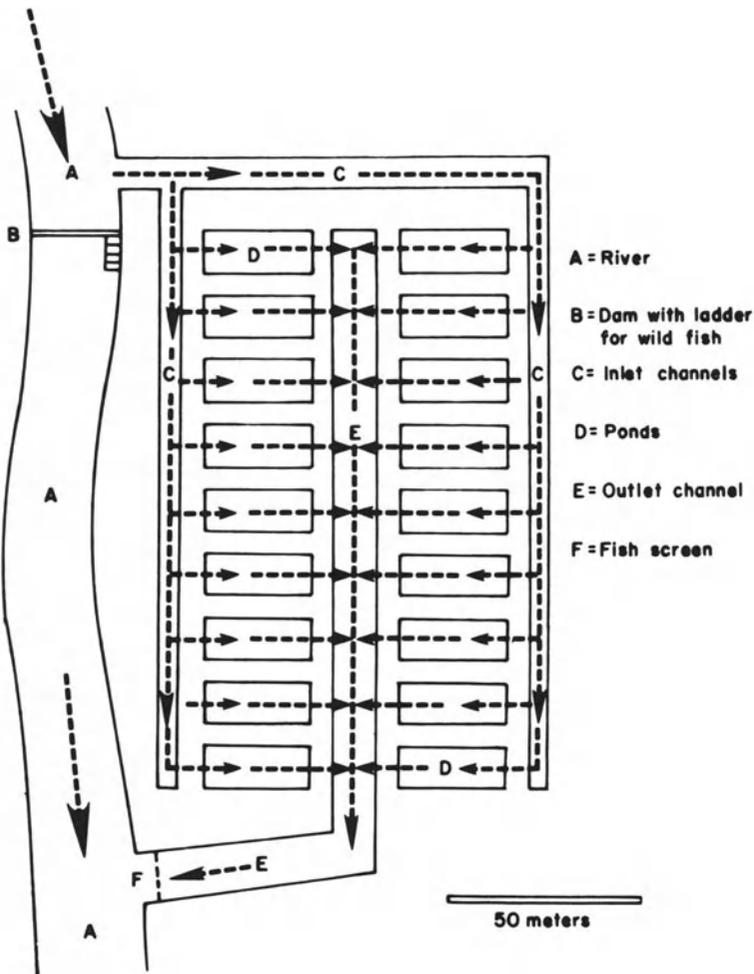


Fig. 5.2. Typical trout farm, 1975.



Fig. 5.3. Typical trout farm.



Fig. 5.4. Earthen trout ponds showing limited water use.



Fig. 5.5. Floating aerator in trout pond.



Fig. 5.6. Drying and cleaning earthen trout pond for disease control.

Even with this less intense stocking rate in earthen ponds, many fish farmers will mechanically aerate their ponds in the summer and recirculate part of the water back through the ponds.

Concrete tanks are used in Denmark, but only for special purposes. Whirling disease (caused by the sporozoan *Lentosporea cerebralis*) was a real problem during the 1950s. This problem was solved by keeping the fry in concrete tanks until they reached a length of 5 cm (2 in.). These fingerlings could then be kept in earthen ponds infected with *Lentosporea* without being damaged by the parasite.

Marketing

As stated earlier, the Danish rainbow trout industry has probably reached its peak in production (Table 5.1). Less than 15% is consumed domestically, and the remaining 85% of production is exported.

Though slightly less than 10% of domestic production was consumed internally during the 1971–1974 period, this was still a considerable increase over 1962 when less than 2% of production was consumed internally (Fig. 5.7). Denmark is essentially a nation of saltwater fish consumers. This custom is probably perpetuated by the fact that the price of cultured freshwater trout is higher than that of wild, saltwater fish.

The leading and increasingly important trout export market is Germany. In 1973 and 1975 it purchased between 56 and 65% of all exports (Table 5.1). Other important importing countries in order of importance are: (1) Belgium-Luxembourg, (2) Great Britain, (3) Switzerland, (4) Sweden,

TABLE 5.1. PRODUCTION AND EXPORTS OF RAINBOW TROUT, DENMARK, 1962 AND 1973–1979¹

Country	1962	1973	1974	1975	1976 ²	1977 ²	1978 ²	1979 ²
	Metric Tons							
West Germany	789	7,092	6,985	9,582	—	—	—	—
Belgium, Luxembourg	948	2,157	1,754	2,231	—	—	—	—
Great Britain	1,077	1,164	991	876	—	—	—	—
Switzerland	508	985	838	778	—	—	—	—
Sweden	846	573	426	424	—	—	—	—
France	127	250	279	448	—	—	—	—
Austria	42	121	129	128	—	—	—	—
Holland	86	136	148	164	—	—	—	—
Italy	1,804	43	60	58	—	—	—	—
Finland	68	60	17	1	—	—	—	—
Norway	78	0	30	14	—	—	—	—
Others	149	99	111	60	—	—	—	—
USA	967	—	—	—	—	—	—	—
Canada	168	—	—	—	—	—	—	—
Total exports	7,657	14,217	15,341	12,680	11,768	14,764	13,640	13,200
Total production	7,781	17,500	17,950	13,950	12,945	16,700	15,100	15,450

¹Data secured from Anon. (1971–1979). Data for 1973 and 1974 correspond to information from Anon. (1975). Data for 1962 secured from an article by Dr. F.B. Bregnballe (1963).

²Export volumes by countries could not be obtained.

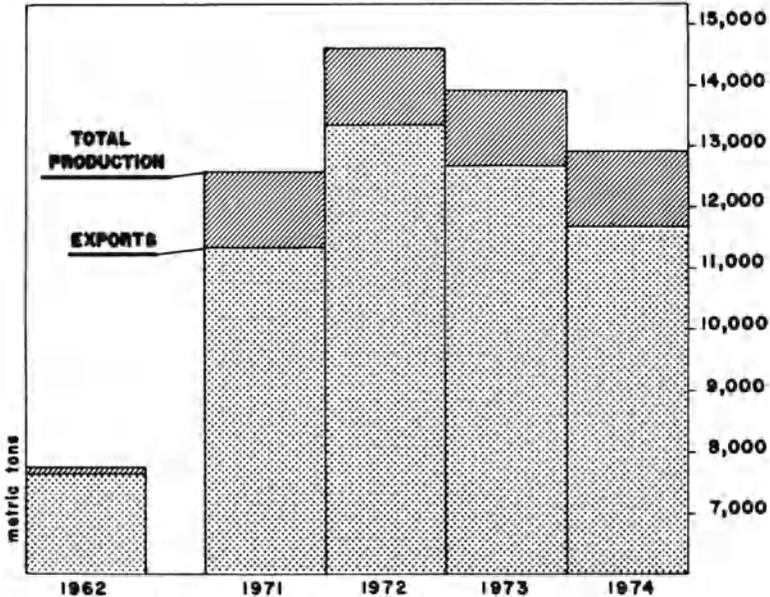


Fig. 5.7. Total production, exports, and domestic consumption of rainbow trout in Denmark, 1962, 1971–1974.

(5) France, (6) Austria, and (7) Holland. Minor volumes are also exported to Italy, Finland, Norway, and other countries (Fig. 5.8).

Comparison of 1962 data for exports and total production with 1975 data is very revealing: (1) there were considerable increases in exports to West Germany and Belgium-Luxembourg; (2) exports to Italy declined from over 1800 MT to almost nothing; and (3) exports to the USA and Canada completely vanished. These shifts are explained by (1) Italy's increasing rainbow trout production from that of a deficit nation to one of exportation and (2) restrictions on importation of trout into the USA and Canada to prevent the spread of European fish diseases to North America—especially whirling disease [*Myxosoma (Lentospora) cerebralis*]. Losing these markets, the Danes shifted to the nearer markets of West Germany and Belgium.

Since 1971, exports to Great Britain have been slowly declining as production has increased in that country. Switzerland has been shifting to imports from Italy, and Sweden to imports from Norway.

Of the maximum 15% of domestically-consumed trout about 30% is smoked. The remainder is sold to local restaurants where the fish are generally boiled or broiled, or to the final consumer for boiling, broiling, or frying in the home.

Market sizes of trout range from 180 to 350 g (6½ to 12 oz). The sizes from 180 to 250 are sold as portion fish; those from 250 to 350 are often smoked.



Fig. 5.8. Export sales of Danish rainbow trout to European countries, 1974.

In 1975, 43% of the export trout were sold live, 37% were frozen, and 21% were sold iced. A normal shipment of live trout is about 2400 kg (2.6 ST) per truck. When a trailer is attached, a load can contain as much as 4800 kg (5.3 ST) of live fish.

Culture

The usual spawning season is January–March, but there are certain strains that produce eggs in the November–December period. Hatching time varies depending on water temperatures. This is usually calculated as 300 to 320 day degrees. Each 1°C of temperature is calculated as 1 degree-day. Hence, if hatching water is a constant 10°C (50°F), each day counts as 10 degree-days and it would take 30 to 32 days for hatching. After hatching, it takes 1 to 1½ years to grow a 200 g trout, depending on water temperatures. Most fry are hatched in April and after consumption of the yolk sac are ready to feed in May. Fry are then reared in concrete tanks until June–July and then, at about 6 cm (2–2½ in.), are transferred to earthen ponds. They can be sold the following April–July period or later.



Fig. 5.9. Unloading sized fish into trout pond.



Fig. 5.10. Tank for feeding minced trash fish to rainbow trout.

Very few producers produce eggs only. The usual custom is to produce eggs and raise through fingerling or food sizes. However, there are a number of producers who purchase fingerlings for grow-out operations only. Egg and fingerling producers are usually the farms nearest the headwaters of

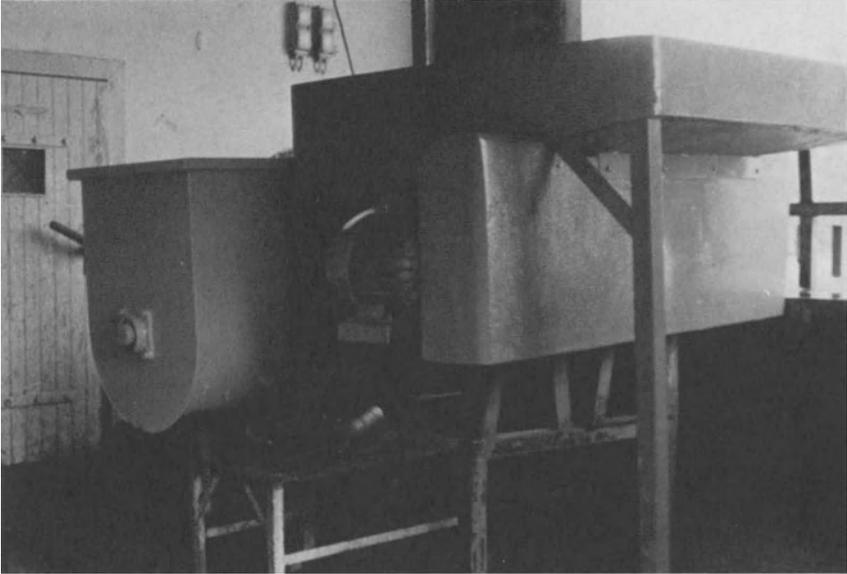


Fig. 5.11. Equipment for mincing trash fish for trout feeding.



Fig. 5.12. Mechanical feeder on tracks for feeding minced trash fish to trout.

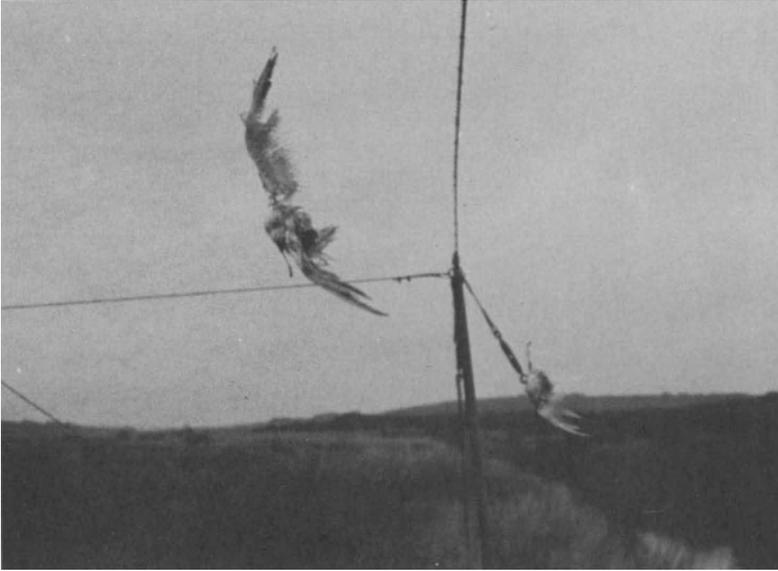


Fig. 5.13. Predator birds caught in protective netting over trout ponds.

streams or small rivers where water quality is best. They, in turn, sell fingerlings to grow-out operations located further downstream on the same river.

Nearly all fry, after hatching, are grown in concrete tanks. Dry pelletized food of 43% protein is fed until the fry reach 6 cm (2–2½ in.). They are then transferred to earthen ponds and gradually shifted to a wet diet which is composed of fresh minced trash fish obtained from the marine fishing fleet.

Most marine fishing is near the coast, and the fleet returns daily, 6 days per week. From the ports all trout ponds are within 2–4 hr driving time. The minced fresh fish, essentially herring, sand eels, whiting, and sperling, are made into a “slurry” with alginate added as a binder. Trash fish in 1975 averaged about \$0.075 per kg (\$0.035 per lb), not including transportation costs, binder, or mixing costs. With a feed conversion of 5:1, the cost of adding 1 kg of weight to cultured fish was about \$0.375 (\$0.175 per lb). In Denmark this is a cheaper method than feeding commercial fish pellets.¹

¹In efforts to minimize pollution of public waters, the government by 1980 had forced many producers to use sediment basins or convert to dry foods or both.

Denmark is the only country in Western Europe (possibly the only one in the world) where fresh wet food is fed. This is possible only because of the fishing fleet's returning to port daily and the short haul from the ports to cultured fish production areas. Norway feeds a wet food but because the fishing fleet ranges further offshore, there is not a daily supply. Hence, the trash fish are frozen into blocks for purchase by fish culturists (see Chapter 3 on Norway). As a result of the diet, Denmark's rainbow trout are considered as "fat" fish. This is believed to give them a superior flavor. The trout's flesh is white instead of pink or red.

Costs

Average price received at the farm by fish farmers in 1975 was \$1.64 per kg (\$0.75 per lb). Very efficient producers are reported to have a total production cost as low as \$1.05 per kg (\$0.48 per lb), while the average producer was reported to have production costs of \$1.35 per kg (\$0.61 per lb).

There are about a dozen fish buyers in the concentrated area of production. The largest of these, Dantrout, a farmer's cooperative, buys about one-third of total production. The remainder is purchased by other fish dealers, some of whom are large fish producers themselves. About one-half (5) of these other fish buyers also process and freeze trout. These 12 large buyers export about 95% of Danish trout. However, in 1974 there were 60 other buyers who exported the remaining 5%. Many of these were red meat sellers who included a small amount of fish in their total shipments.

One of the major costs of marketing Danish trout is transportation. With 42% of all trout sold being delivered live, delivery cost of live fish is very important. The average size truck hauls 2.4 MT of live fish. With a trailer attached, 4.8 MT can be hauled. For a 500 km (310 mi) one-way trip the cost



Fig. 5.14. Tank truck for hauling live trout to processing plant.

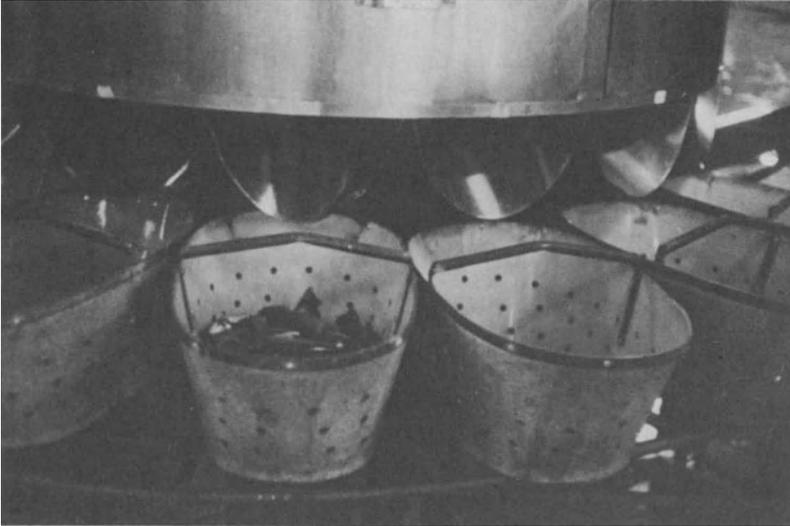


Fig. 5.15. Mechanical trout sizing in processing plant.

is \$725. This amounts to \$0.15 per kg (\$0.068 per lb). Fish shipped on ice is more economical. About 15 MT of fish can be transported per load and transportation cost drops to \$0.048 per kg (\$0.022 per lb). Frozen fish is still cheaper to transport since there is no ice or water to haul.

Reported prices for 1975 include eyed-eggs at \$3.03 per 1000. Fry sold for \$13.47 per 1000. These were 6 cm (2½ in.) in length. Fingerlings between 12 and 15 cm (5 and 6 in.) sold for \$0.051 each.

Distribution

There is no record of the number of rainbow trout eggs sold through export channels. The numbers are certainly in excess of 100,000,000 eggs, however. Nearly every country in Western Europe imports some eggs. In addition, limited quantities are sold to countries in Eastern Europe.

No rainbow trout are stocked in public waters since they are considered a foreign species. Some, however, are stocked in old sand and gravel pits for use as fee fish-out ponds. The number of these is small and they are operated almost solely for use by German tourists during the summer.

Outlook

Forecasts of future Danish rainbow trout production by various knowledgeable individuals range from no increase beyond the present 18,000 MT (19,800 ST) of production to a possible increase of 20%. The latter is optimistically forecast, assuming effective disease control measures will reduce

losses, and pollution control and water use standards do not become more restricting. Such restrictive measures would result in higher capital costs for clean-up techniques and equipment to treat efflux from present fish facilities and would reduce production by an amount equivalent to gains expected from disease control measures now being instituted. In the past few years many producers have switched from wet to dry feeds. The results have been less water pollution and intensification of fish stocking. This permitted production to increase by over 3000 MT (3300 ST) between 1974 and 1979.

BROWN TROUT (*Salmo trutta*)

Brown trout was the original species of trout living in Danish waters. It was also the first trout cultured in Denmark. In recent years, however, no brown trout have been raised as a food fish. Nevertheless, brown trout is still cultured for restocking domestic waters and for export. Most restocking of domestic waters is with 12–15 cm (5–6 in.) fingerlings. Restocking is carried out by fishery clubs and by those producers who are required to furnish fingerlings to the river as payment for use of river water.

About 15 million brown trout fry are sold to Germany for restocking. Estimates of total brown trout fingerlings produced for domestic use and export sale are 50 MT annually. This means that about 1.1 million brown trout fingerlings are produced annually. In addition, between 50 and 100 million eggs are exported to various European countries and probably 100 MT (110 ST) of trout between 100 and 200 g (4 and 8 oz).

EUROPEAN EELS (*Anguilla anguilla*)

No eels are cultured in Denmark. The water is too cold for rapid growth and the estimated cost of production is higher than anticipated returns. However, some elvers are captured for restocking of lakes to increase fishing catches. The elvers are normally caught in April and May on the North Sea coast of Jutland. In addition there is commercial fishing for wild silver eel. A comparison of the catch of silver eel over time is shown herein:

1948	4242 MT
1958	3287 MT
1969	3624 MT
1970	3309 MT

These figures suggest that the eel catch may be declining. This could be due to less fishing effort as well as to pollution effects and natural conditions.

The silver eels are normally caught in the August 1–November 1 period. They are captured as they pass through the narrow straits of the Baltic Sea going into the North Sea.

Nearly all of the silver eels are consumed domestically, smoked, or fried.

The limited volume exported is shipped live to Holland, Belgium, and Germany.

SPECIAL ACKNOWLEDGMENTS

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Netherlands (Holland)

FISH SPECIES

Carp (*Cyprinus carpio*)

Eel (*Anguilla anguilla*)

Pike (*Esox lucius*)

Pike-perch (*Lucioperca
lucioperca*)

Rainbow trout (*Salmo
gairdneri*)

Roach (*Rutilus rutilus*)

Netherlands (Holland)

In Holland several species of fish are cultured. These are: (1) roach (*Rutilus rutilus*), (2) pike-perch (*Lucioperca lucioperca*), (3) carp (*Cyprinus carpio*), (4) pike (*Esox lucius*), and (5) rainbow trout (*Salmo gairdneri*). All, with the exception of 50 to 60 MT of rainbow trout, are cultured for restocking or stocking of ponds, lakes, streams, and canals.

Four different cultural systems are used. These are: (1) pond culture, (2) raceways for trout, (3) controlled conditions in glass houses where water temperature and oxygen levels are maintained artificially, and (4) cage culture in the warmwater discharge of a power plant. In the cage culture

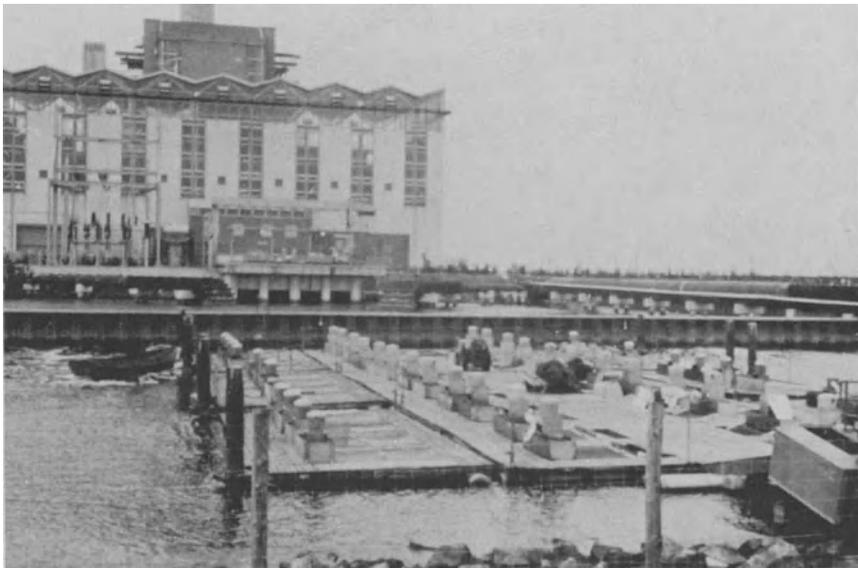


Fig. 6.1. Using warmwater discharge from an electrical power plant for rearing restocking fish.

system, cages are 6.5 m^3 (229 ft^3) in size, with each one producing 1625 kg of fish (3575 lb or 15.6 lb per ft^3). In this operation there are 48 cages.

The fish are released into public waters at various sizes: roach at a 15 cm minimum size (6 in.); pike-perch at 10 cm in length (4 in.); carp as either 2-year-old fish of 25 cm length (10 in.) or as 3-year-old fish of 40 to 45 cm (16 to 18 in.); pike as either 5 or 10 cm fish (2 to 4 in.); and rainbow trout at either 25 cm (10 in.), the legal size for anglers, or at 200 g (7 to 8 oz).

Between 20,000 and 50,000 roach are stocked annually. Stocking of pike-perch varies between 70,000 and 1.5 million; carp between 150,000 and 200,000; pike about 1.5 million and trout about 150,000 annually. Total production of these stocking fish approximates 200 MT annually for angling by about 1.25 million sports fishermen. All these fish are raised and released under government auspices. As mentioned earlier, between 50 and 60 MT (55 and 66 ST) of rainbow trout are raised as food fish by one commercial fish grower.

In addition, the commercial catch of eel (*Anguilla anguilla*) varies between 823 and 875 MT (1971–1973 data) (907 and 964 ST). In 1973 there were 3500 MT of eel imported. These came from Denmark, Turkey, the USA, and other countries. They were received alive, dressed, and smoked. About 800 MT (882 ST) of smoked eel were then exported to various western European countries.

Imports of trout and salmon were estimated at 1000 MT in 1973 (1102 ST), these were either fresh or smoked. About 40% of these fish were, in turn, exported to other European countries, generally as a smoked product.

Available data concerning rainbow trout imports and exports suggest that Holland is similar to Denmark in that consumption of rainbow trout is very low. In 1973 only 137 MT (151 ST) were imported—mainly from Denmark with a few tons coming from Germany. In 1974 only 148 MT (163 ST) were imported with all of it coming from Denmark. Negligible quantities of 5 to 10 MT (5.5 to 11 ST) annually are transhipped to Germany and France.

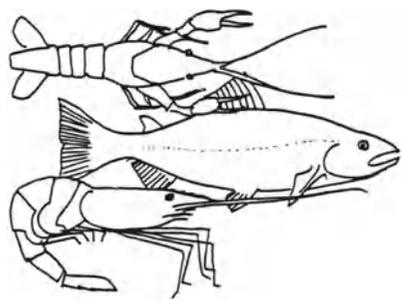
SPECIAL ACKNOWLEDGMENTS

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Belgium and Luxembourg

FISH SPECIES

Black eel

Brown trout (*Salmo trutta*)

Carp (*Cyprinus carpio*)

Common bream (*Abramis
brama*)

Eel

European eel (*Anguilla
anguilla*)

Pike (*Esox lucius*)

Pike-perch (*Lucioperca
lucioperca*)

Rainbow trout (*Salmo
gairdneri*)

Roach (*Rutilus rutilus*)

Tench (*Tinca tinca*)

Belgium and Luxembourg

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

In 1975 there were 18 rainbow and brown trout fish farms in Belgium and none in Luxembourg. Total production of food fish was estimated to be only 300 MT (331 ST) of rainbow trout annually as recently as 1979.

Rainbow and brown trout are produced in both pond and raceway production units. Most rainbow and brown trout eggs are imported from Italy, Denmark, and France. In addition, some fingerlings are also imported. All of the brown trout are destined for restocking for angling in private and public waters, as either fingerlings or small adult fish. Some catchable-sized rainbow trout are also stocked in public waters for angling. However, most of the rainbows are destined for the table as food fish.

Available data indicate that Belgium and Luxembourg are large and growing importers of rainbow trout. In 1968 an estimated 2350 MT (2590 ST) were imported. By 1974 imports had reached 3619 MT (3988 ST). The major sources of supply are Denmark, France, and Italy (Table 7.1 and Fig. 7.1). Minor amounts, less than 100 MT annually, are also imported from Germany, and amounts varying from 65 to 231 MT from Japan.

Belgium-Luxembourg is thought by many individuals concerned with European cultured fish to be a large transshipper of trout. In other words, food fish are thought to be imported into the two countries for exportation

TABLE 7.1. IMPORTS OF RAINBOW TROUT INTO BELGIUM-LUXEMBOURG, 1968-1974¹

Origin	1968	1969	1970	Years 1971	1972	1973	1974
Denmark	³	³	³	2087	2433	2141	1754
France	³	³	³	294	311	433	1161
Germany	³	³	³	53	75	56	³
Japan ²	186	231	112	65	143	222	153
Italy	³	³	³	7	213	252	704
Totals	2350	2350	2234	2502	3175	2882	3619

¹Data obtained from Anon. (1971-1979).

²Japanese data secured from Anon. (1968-1974).

³Unknown.

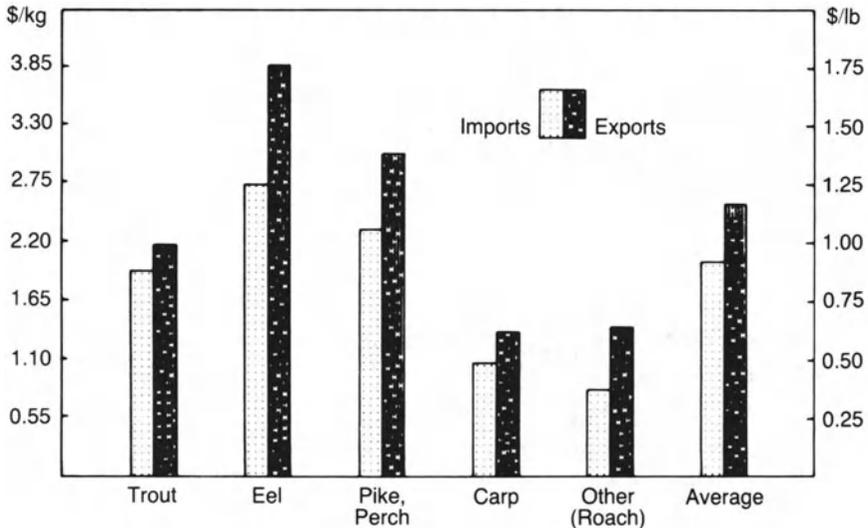


Fig. 7.1. Values of freshwater fish—imports and exports, 1974.

outside the area. However, available data for 1970, 1973, and 1974 indicate that less than 13% of imported and domestically raised trout is exported. In 1970 only 255 MT were exported. The volumes for 1973 and 1974 were 170 and 521 MT, respectively. Export sales were essentially to France and Germany with small amounts sold into Holland.

In 1972, of the total imports of 3175 MT (3499 ST), 1642 MT (51.3%) of living rainbow trout were transported in water, 930 MT or 29.0% were ice-packed fresh fish, and 628 MT or 19.7% were deep frozen fish for both Denmark and Japan. These data indicate the market demand for non-frozen fish (more than 80%). Data were not available to determine if make-up of the 1972 imports is the general rule or whether the data pertain only to 1972. Available data indicate that frozen trout importing prices and retail prices are between 7 and 8% higher than for live or ice-packed fish.

In 1974, a total of 6371 MT (7021 ST) of freshwater fish were imported into Belgium-Luxembourg. These fish had total value of over \$12½ million (Table 7.2). Main imports, in order of tonnage and value, were (1) trout, both brown and rainbow, (2) eel, and (3) other, mostly roach.

The 3686 MT of trout imported were divided into about 3619 MT (4062 ST) of rainbow trout and about 67 MT (74 ST) of brown trout. Imports of trout were valued at \$6.9 million and exports at \$1.1 million.

CARP (*Cyprinus carpio*)

In 1975 there were 19 culturalists of cyprinids such as carp, tench (*Tinca tinca*), and roach (*Rutilus rutilus*), with small quantities of pike (*Esox lucius*) produced by some.

All carp were produced in earthen ponds. Production was essentially for sport fishing in private angling club ponds or streams. However, a few tons were sold immediately for food.

The supply of domestically raised carp was estimated at less than 100 MT annually. In addition, 213 MT were imported. Most of these imports were from France. Thus, total supply of carp was about 313 MT (345 ST). Forty-seven percent of the total supply or 146.5 MT were exported (Table 7.2). These were nearly all destined for West Germany.

TENCH AND ROACH (*Tinca tinca* and *Rutilus rutilus*)

Tench and roach are cultured extensively in earthen ponds by some of the 19 culturalists of cyprinids. Little or no feeding of the fish is done, and often the ponds are not even fertilized. Production is between 200 and 300 kg per ha (180 and 270 lb per acre). Total supply of domestically raised tench and roach is probably less than 200 MT. To this supply must be added the 710 MT of imported fish, Table 7.2. Hence, the total supply is about 800–900 MT annually.

Only a few tons of this amount are destined for immediate food consumption. Essentially, these fish are destined for restocking. Since there is no state restocking, all restocking of angling water is under the auspices of angling and local fishing clubs. Fish are restocked at catchable sizes of 250–300 g (9–11 oz).

PIKE AND PIKE-PERCH (*Esox lucius* and *Lucioperca lucioperca*)

There is no separate culture of pike or pike-perch in Belgium-Luxembourg. However, most carp producers stock 10–20 fingerlings of each species per ha (4–8 per acre) in their carp ponds. At the end of the first or second summer of growth for the carp, pike and pike-perch are also harvested. Total annual production of pike and pike-perch is probably not over 20 MT. To this amount one can add the 50.5 MT imported, Table 7.2. Total supply is thus around 70 MT. About 10 MT are exported so total available supply is about 60 MT (66 ST).

These fish are stocked at sizes ranging from fingerlings to food sizes. Pike, in particular, are stocked in waters overpopulated or threatened to be overpopulated by native fish. The pike, a voracious fish, keeps these waters in balance by consuming most of the fry and fingerlings of these fish. Only small quantities, perhaps less than 2–3 MT are consumed as a food fish.

EUROPEAN EEL (*Anguilla anguilla*)

There is no eel culturing in Belgium-Luxembourg. However, between 300 and 400 kg (660 and 880 lb) of elvers and young black eel are captured in the

TABLE 7.2. IMPORTS, EXPORTS, AND VALUES OF FRESHWATER FISH FOR BELGIUM-LUXEMBOURG, 1974

Species	Imports		Exports		Value in U.S. Dollars for Imports		Value in U.S. Dollars for Exports	
	Metric Tons		Metric Tons		per kg	per lb	Total	per kg
Trout, brown and rainbow ¹	3685.8		520.5		1.87	0.85	1,121,481	2.15
Eel ²	1711.6		414.3		2.75	1.25	1,609,815	3.89
Pike and perch ³	50.5		10.6		2.31	1.05	32,057	3.02
Carp ³	212.8		146.5		1.05	0.48	189,424	1.29
Other ³ (mainly roach)	710.4		116.1		0.81	0.37	162,516	1.40
Totals	6371.1		1208.0		—	—	3,115,793	—

¹Living, frozen, smoked, etc.

²Living, smoked, etc.

³Living.

rivers for restocking in more fertile inland waters. An estimated 100,000 such fish are restocked annually.

About 50 MT of eels are captured annually in native waters. In 1974, an additional 1712 MT were imported. Most of these were live eel from France. Hence, total supply is about 1762 MT. Of this amount, 414 MT were re-exported as live or smoked eels to Holland and West Germany. Hence, the total domestic consumption is about 1348 MT (1485 ST).

The total value of eel imported in 1974 was \$4.7 million, while exports amounted to \$1.6 million. Value per kilogram of imported eel was \$2.75, while value of exports was \$3.89 per kg, Table 7.2. The difference in values is accounted for by the fact that a higher proportion of exported eel are smoked and have a higher value per unit of sale, Fig. 7.1.

RECREATION FISHING

As previously mentioned, there is no state restocking of public waters. Restocking fish come almost solely from fish raised by private fish farmers or imports. Sales are made to local angling clubs. The most important wild fish caught by anglers in public waters is roach, followed by brown trout, eel, carp, pike, tench, and pike-perch, Table 7.3. The total wild catch annually is about 450 MT (496 ST).

TOTAL SUPPLY

The total supply of freshwater fish annually in Belgium-Luxembourg is about 5307 MT (5848 ST). This is composed of 300 MT of rainbow trout produced domestically plus 3094 MT of net imports, a few metric tons of brown trout, perhaps 100 MT of carp, a few MT of tench and roach, a few MT of pike and pike-perch, and 1348 MT of eel. To this volume of 4857 MT must be added the wild freshwater catch of 450 MT.

TABLE 7.3. CATCHES OF WILD FISH BY ANGLERS IN PUBLIC WATERS, BELGIUM AND LUXEMBOURG, 1972-1974

Species	1972	Year	
		1973	1974
		Metric Tons	
Brown trout (<i>Salmo trutta</i>)	60.1	64.2	63.4
Roach (<i>Rutilus rutilus</i>)	135.6	152.6	142.3
Eel (<i>Anguilla anguilla</i>)	49.4	50.0	50.5
Carp (<i>Cyprinus carpio</i>)	28.8	29.0	27.9
Pike (<i>Esox lucius</i>)	22.3	21.7	21.9
Tench (<i>Tinca tinca</i>)	9.4	8.6	10.2
Pike-perch (<i>Lucioperca lucioperca</i>)	1.0	1.1	1.5
Others ¹	138.9	138.3	129.6
Totals	445.5	465.5	447.3

¹About one-third of all others was common bream (*Abramis brama*).

OUTLOOK

Future production can be expected to be relatively static since no large increases in production can be foreseen. This is largely due to inadequate volumes of suitable water for fish culture.

SPECIAL ACKNOWLEDGMENTS

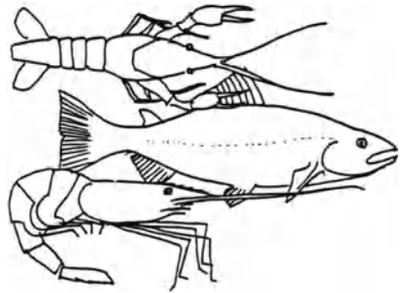
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Federal Republic of Germany (West Germany)

FISH SPECIES

Brook trout (*Salvelinus fontinalis*)

Brown trout (*Salmo trutta*)

Carp (*Cyprinus carpio*)

Common or northern pike (*Esox lucius*)

European eel (*Anguilla anguilla*)

Lake trout (*Salmo trutta lacustris*)

Perch

Pike-perch

Rainbow trout (*Salmo gairdneri*)

Silver eel

Tench (*Tinca tinca*)

Yellow eel

Coregonids

Cyprinids

Federal Republic of Germany (West Germany)

In Germany, six species of fish are cultured for food. These are: (1) rainbow trout (*Salmo gairdneri*), (2) brown trout (*Salmo trutta*), (3) carp (*Cyprinus carpio*), (4) European eel (*Anguilla anguilla*), (5) tench (*Tinca tinca*), and (6) common or northern pike (*Esox lucius*).

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

About 8000 MT (8800 ST) of trout were produced in West Germany in 1979 by 1400–1500 enterprises. The major trout areas are: (1) Baden-Württemberg, with 31% of total production, and (2) Bavaria, with 27% of total production (Fig. 8.1). Nearly all of these enterprises produce trout in earthen ponds with running water. Only a few producers use concrete raceways. In 1975 there were between 30 and 50 cage producers, who produced between 10 and 50 MT each. There were numerous other producers having only one or two cages, who produced 1 to 2 MT annually as a hobby. Cage culture is usually in old gravel pits containing 10–40 ha (25–100 acres) of surface water and being from 8 to 15 m deep (25 to 50 ft). Cages range from 50 to 70 m³ (170 to 238 ft³) and produce about 1 MT annually. The number of cage producers is increasing.

Cage culture is year round. In summer the water is cold enough for feeding and growth. Swimming activity of the fish keeps the water in and around the cages from freezing in winter when the pond or lake freezes over.

In earthen ponds, the usual calculation is 1 liter of water flow per second for 100 kg of annual production. This means that 14 lb of fish are produced per gal. of water flow per minute.

It is estimated that less than one-half of the rainbow trout eggs are produced domestically. Most remaining eggs are imported from Denmark. Domestic eggs are produced in the September–May period.

German trout are sold in portion sizes of 250–300 g (9–11 oz) for cooking. About 70% of all trout is sold for this purpose. About 30% of all trout by weight is sold as 300–500 g (11–18 oz) for smoking. Producers try to sell their production locally within a 50–80 km (30–50 mi) radius. Sales are

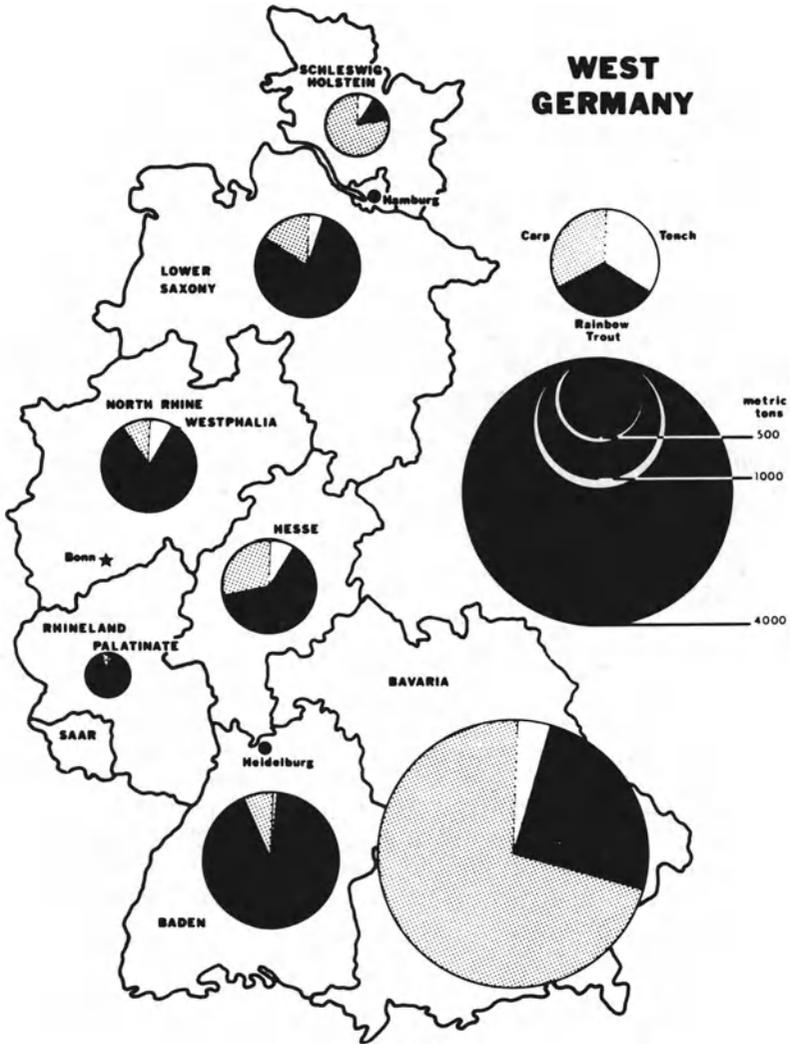


Fig. 8.1. Production of cultured fish, by species, by regions, 1975.

to restaurants or individual families. The 1975 price was about \$3 per kg (\$1.36 per lb). Domestic trout that cannot be sold through this channel must be sold at wholesale. The wholesale price is determined by live or frozen imports and the 1975 price was \$1.91 per kg (87¢ per lb), which was only about 64% of the live domestic price. Some of the live imports are fish that weigh less than the 250–300 g sizes in demand, which are stocked by producers and fed out until they reach market size and then resold.

Increasing amounts of the larger (300–500 g) fish are being produced for smoking. Retail prices of smoked fish averaged about \$7.80 per kg (\$3.54 per lb) in 1975.

One unique German cooking feature is that nearly all fresh or frozen fish are boiled or steamed. This is one of the few countries in Western Europe that does not fry or grill trout.

In 1972, a study was made of the trout industry for West Germany (Anon. 1972A). The study indicated a total of 1465 salmonoid producers (Table 8.1). These were classified by size of pond area. Pond area was construed to mean not only the water surface area but also the surrounding land which the farmer considered to be an integral part of the pond(s) area.

There was a wide array of salmonoid producers by size of enterprise as measured by "pond area." Over 62% of the enterprises had less than 1 ha (2.47 acres) of "pond area." This group averaged 4.2 ponds each, with an average size per pond of 0.03 ha (0.07 acre). The total water area for each of these farmers was 0.13 ha (0.29 acre). At the other extreme were 15 farmers with 18.4 pond each and with each pond containing 0.24 ha (0.59 acre). These larger producers had 4.42 ha (10.9 acres) of water area. The average salmonoid farmer had 7.1 ponds with each pond covering 0.07 ha (0.16 acre), for an average total water area of 0.50 ha (1.24 acres).

These 1465 enterprises contained 10,448 separate ponds, having a total water area of 731.4 ha (1807 acres). A complete estimate of total annual production of food-sized fish was not obtained for all 1456 enterprises. Production data were obtained for 1386 enterprises with total annual output of 3446 MT (3797 ST). If it can be assumed that the missing enterprises had the same average output as those reporting, then annual production would have been 3642 MT (4013 ST). In addition, several hundred metric tons are produced in concrete raceways, some 1200 MT in cages, and several hundred more MT by hobbyists. When added together, allowing for some growth in the industry between 1972 and 1975, we arrive at the 1975 level of 5300 MT (5841 ST).

TABLE 8.1. NUMBER OF SALMONOID ENTERPRISES, NUMBER OF PONDS, AND TOTAL WATER AREA BY SIZES OF ENTERPRISES, WEST GERMANY, JUNE, 1972

Pond Area ha	Enterprises		Ponds		Water Area		
	No.	%	No.	Average	Total ha	Average Each Pond ha	Acres
Under 1	911	62.2	3781	4.2	130	0.03	0.08
1–2	259	17.7	2439	9.4	139	0.06	0.14
2–5	189	12.9	2567	13.6	203	0.08	0.20
5–10	55	3.7	849	15.4	101	0.12	0.29
10–20	26	1.8	479	18.4	70	0.15	0.36
20–50	15	1.0	199	13.3	47	0.24	0.58
50 and over	10	0.7	134	13.4	24	0.18 ¹	0.44
Totals and averages	1465	100.0	10,448	7.1	713	0.07	0.17

¹ Pond size was smaller than for farmers having a pond area of 20–50 ha (49–124 acres). Evidently, these farmers had a larger land area and a smaller water area.

For 1386 salmonoid enterprises of a total 1465 there were 139,630,000 eggs produced; 92,382,000 fry; and 32,093,000 fingerlings (Table 8.2). There was a total of 12,406,000 two-summer fish with an average market weight of 275 g. Thus, there were 7.4 fry and 2.6 fingerlings for each fish marketed at the end of the second summer of growth (Anon. 1972A).

In 1465 salmonoid enterprises in West Germany in 1972, rainbow trout were dominant, with nearly 75% of the total fry, nearly 83% of the total one-summer fingerlings, and nearly 95% of the two-summer or food-size fish (Table 8.3). The remainder was brown trout.

Rainbow trout are raised almost exclusively for food fish or for stocking fee fish-out ponds. The fish used for stocking fee fish-out ponds are food-sized (two summers). Hence, the data shown in Table 8.4 are really an indication of survival. This table shows that out of every 100 fry there are only 43.1 fish at the end of the first year of growth, and only 19.3 fish each market size of approximately 275 g (10 oz). Brown trout and other salmonoids are used almost exclusively for restocking angling waters. Most brown trout are restocked at the end of the first summer of growth, as shown by the decline from 37.8 fingerling fish to 4.2 food-size fish. Some two-summer fish are also stocked. Other salmonoids such as brook or lake trout (*Salvelinus fontinalis* and *Salmo trutta lacustris*) are commonly stocked in angling waters as fry, or at the end of the first summer of growth (Table 8.4).

TABLE 8.2. NUMBER OF SALMONOID ENTERPRISES BY SIZES AND TYPE OF PRODUCTION, WEST GERMANY, JUNE, 1972

Pond Area (ha)	No. of Enterprises	Eggs	Fry	One-summer Fingerlings	Two-summer Food Fish (Metric Tons)
		1000 Animals			
Under 1	843	11,586	11,039	5,904	731
1-2	248	29,887	18,013	7,026	881
2-5	185	47,461	36,007	9,270	1013
5-10	57	15,501	6,704	3,841	433
10-20	25	15,850	11,050	3,666	277
20-50	17	7,055	961	1,330	67
50 and over	11	12,290	8,608	1,056	84
Totals	1386	139,630	92,382	32,093	3486

TABLE 8.3. NUMBER AND DISTRIBUTION OF SALMONOIDS BY STAGE OF GROWTH, WEST GERMANY, JUNE, 1972

Stage of Growth	Rainbow		Species of Trout				Totals	
	1000	%	Brown		Other ¹		1000	%
			1000	%	1000	%		
Fry	61,678	74.9	11,012	13.4	9692	11.7	82,382	100.0
One-summer (fingerlings)	26,564	82.8	4,166	13.0	1,362	4.2	32,092	100.0
Two-summer ² (food size)	11,889	94.8	465	3.7	184	1.5	12,538	100.0

¹ Brook, lake, etc.

² Assumed to be 275 g fish (10 oz).

TABLE 8.4. NUMBER OF ONE-SUMMER AND TWO-SUMMER SALMONIDS PER 100 FRY BY SPECIES OF SALMONOID, WEST GERMANY, JUNE, 1972

Stage of Growth	Species of Trout		
	Rainbow	Brown	Other ¹
Fry	100.0	100.0	100.0
One-summer (fingerlings)	43.1	37.8	14.1
Two-summer ² (food size)	19.3	4.2	1.9

¹ Brook, lake, etc.

² Assumed to be 275 g fish (10 oz).

The stocked waters are usually leased by angling clubs. About 80% of the 600,000 licensed anglers fish in leased waters or at daily fee fish-out ponds. About one-fourth of total fish caught on rod and reel equipment is at daily fee fish-out ponds. Hence, this outlet is an important market for fish culturalists.

Density of Production

Table 8.5 indicates the density of salmonoid production by stages of growth listed by size of enterprise. With the two-summer or food fish, there is a perfect correlation between output per hectare of water area and size. The larger the farm, the smaller the output of food fish per hectare of water. This was also true for one-summer fingerlings. These data suggest that larger enterprises are more likely to produce eggs and fry than the smaller producer, while the smaller producer is more likely to raise fingerlings up to market size fish.

Imports and Exports

Imports of rainbow trout into West Germany have been increasing rapidly. In 1970, total imports were 4374 MT (4820 ST); by 1975, imports had reached 10,996 MT (12,118 ST). This was an increase of 151% in 5 years, or an average annual increase of 30% (Table 8.6 and Fig. 8.2). Denmark is the most important country from which trout are imported. In 1975, Denmark accounted for 87%. Imports from Italy are increasing rapidly, but they are small compared to those from Denmark.

West Germany imports rainbow trout from about 10 countries. Information obtained by the author indicates about 59% of the fish arrive live by truck and the remaining 41% arrive as iced or frozen fish.

In 1975, the average import price was \$1.91 per kg (\$0.87 per lb). Prices paid by countries varied considerably. For example, trout from Yugoslavia were worth \$1.53 per kg (\$0.70 per lb) while those from Norway were \$3.10 per kg (\$1.41 per lb). This difference was probably due to some Norwegian trout's being larger and arriving as smoked fish, while fish from Yugoslavia were portion-sized and unprocessed.

TABLE 8.5. DENSITY OF SALMONOID PRODUCTION BY TYPE OF PRODUCTION AND SIZE OF ENTERPRISES, WEST GERMANY, JUNE, 1972

Pond Area (ha)	Enter- prises (No.)	Avg. No. Ponds	Avg. Water Area per Pond (ha)	Total Water Area per Enter- prise (ha)	Avg No. Eggs		Avg No. Fry		One-summer Fingerlings		Avg Kg Two-summer or Food Fish	
					Per Enter- prise	Perha of Water Area	Per Enter- prise	Perha of Water Area	Per Enter- prise	Perha of Water Area	Per Enter- prise	Perha of Water Area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Under 1	843	4.2	0.03	0.13	13,744	105,723	13,095	100,731	7,004	53,877	876	6669
1-2	248	9.4	0.06	0.56	120,512	215,200	72,633	129,702	28,331	50,591	3,391	6055
2-5	185	13.6	0.08	1.09	256,546	235,363	194,632	178,561	50,108	45,971	5,476	5024
5-10	57	15.4	0.12	1.85	271,947	146,998	117,614	63,675	67,386	36,425	7,596	4106
10-20	25	18.4	0.15	2.76	634,000	229,710	442,000	160,145	146,648	28,346	11,080	4014
20-50	17	13.3	0.24	3.19	415,000	130,094	56,529	17,721	78,235	24,525	3,941	1235
50 and over	11	13.4	0.18	2.41	1,117,276	463,598	782,545	324,707	96,000	39,834	7,636	3168
Totals and averages	1386	7.1	0.07	0.50	100,743	201,486	66,654	133,308	23,155	46,310	2,486	4972

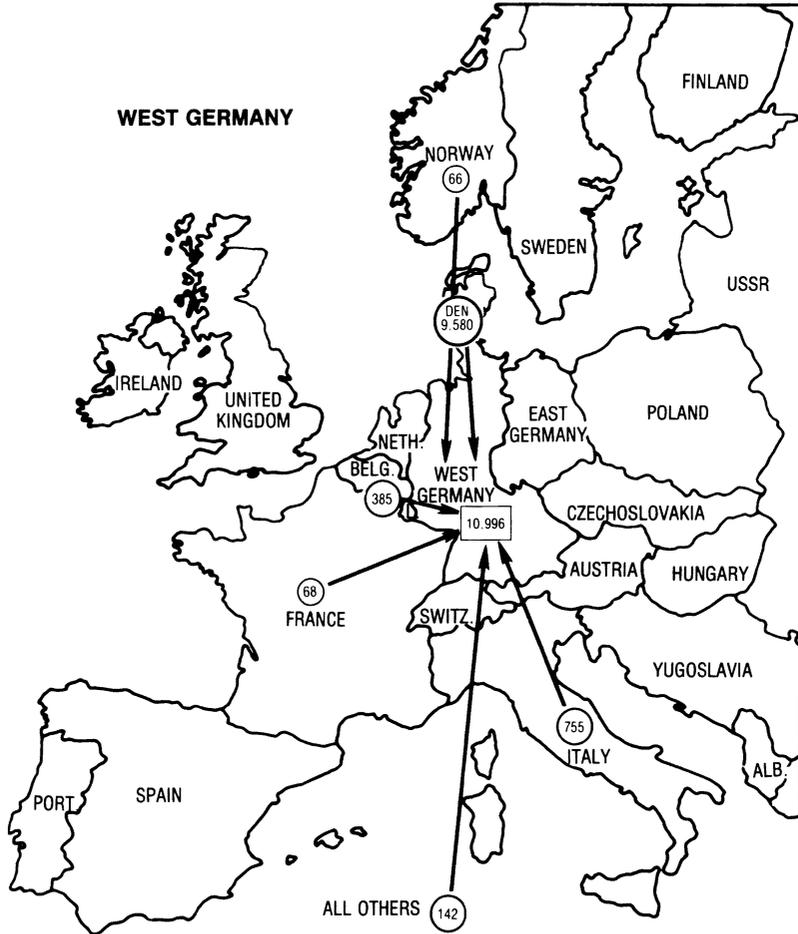


Fig. 8.2. Imports of rainbow trout into West Germany by countries, 1975.

TABLE 8.6. IMPORTS OF RAINBOW TROUT INTO WEST GERMANY, 1970-1975

Country	Year					
	1970	1971	1972	1973	1974	1975
	(Metric Tons)					
Denmark	3314	5021	6253	7188	7324	9580
Italy	195	338	410	549	1014	755
Belgium	85	129	103	162	387	385
Japan	773	80	143	160	22	109
France	5	21	3	10	46	68
Norway	1	2	4	68	15	66
Others ¹	1	11	7	21	8	33
Total (metric tons)	4374	5602	6323	8158	8816	10,996
Total (short tons)	4820	6173	6968	8990	9715	12,118

Source: Professor Pachmann (Anon. 1970-1975).

¹ During various years, included Holland, Poland, USSR, Yugoslavia, and Canada.

Only minor amounts of trout are exported from West Germany. In 1975, total exports were 85 MT (94 ST). Total value of these exports was \$251,751. Average price received per kilogram was \$2.96 (\$1.35 per lb).

Total Supply

Total supply of rainbow trout for West Germany in 1979 was about 20,000 MT (22,000 ST). Of this amount, 8000 MT were produced domestically, 12,000 MT were imported, and 85 MT were exported.

CARP (*Cyprinus carpio*)

In general, production of desired sizes of carp in West Germany takes three years compared to only two years in Central and Southern Europe where the waters are warmer.

In the first year, the eggs are hatched and fry are raised in spawning and first-rearing ponds. In the second year, carp of two summers are grown to larger sizes. In the third year or third summer, the carp reach market sizes. In general, carp ponds have a minimal flow of water coming into the pond. Usually only enough new water is added to replace evaporation losses.

Distribution of farmer's water area between different sizes of fish is dependent on that farmer's individual arrangement. Because of difficulty in raising the exact number of fry needed as two- or three-summer fish, some farmers raise only fry, and other farms buy one- or two-summer fish for rearing or growing-out. For a complete operation, roughly 12.5% of the water area will be devoted to first-summer fish, 25.0% to second-summer fish, and the remainder, or 62.5%, to third-summer fish.

Carp is a warmwater fish. Spawning is delayed until water temperature reaches 18° to 20°C (65° to 68°F). These first summer fish will weigh 35–50 g (1–2 oz) in the autumn, with a length of 9–12 cm (3½–5 in). At the end of the second summer of growth, they average 350 g (12 oz) and vary from 250 to 500 g (8 to 17 oz); and, after the third summer of growth, they weigh an average 1¼ kg (2¾ lb), varying between 900 and 1600 g (2 to more than 3 lb). Nearly all carp are harvested at a weight of 1 to 2 kg (2.2 to 4.4 lb). These are intended to be family-size fish as compared to individual portions for trout.

Most carp farms are very extensive. This means that there is little fertilization carried out and few or no artificial foods fed. A study conducted (Anon. 1972) indicated that only 13% of the enterprises were feeding any artificial foods. Amount fed based on total production was 1 kg (2.2 lb) for every 4 kg (8.8 lb) of fish produced. In actual practice, the amount fed per unit of production is lower than these figures indicate, since a considerable amount of feed goes to newly-hatched and first-summer fish.

In 1972 a study was made of the West German carp industry (Anon. 1972B). The basic month, or benchmark month, was June. This study indicated a total of 4295 separate carp enterprises as producers (Table 8.7).

TABLE 8.7. NUMBER OF CARP ENTERPRISES, NUMBER OF PONDS, AND TOTAL WATER AREA BY SIZES OF ENTERPRISES, WEST GERMANY, JUNE, 1972

Pond Area ha	Enterprises		Ponds		Water Area (ha)	
	No.	%	No.	Average	Total ha	Each Pond Average
Under 1	2065	48.1	3,585	1.7	625	0.17
1-2	870	20.2	2,477	2.8	861	0.35
2-5	786	18.3	3,549	4.5	1,749	0.49
5-10	281	6.5	2,003	7.1	1,450	0.72
10-20	140	3.3	1,406	10.0	1,475	1.05
20-50	90	2.1	1,415	15.7	2,272	1.61
50 and over	63	1.5	1,929	30.6	5,252	2.72
Totals and averages	4295	100.0	16,364	3.8	13,684	0.84

Eighty-one percent of total production was in Bavaria, Fig 8.1. These were classified by size of pond area, which was construed to mean not only water surface area, but also the surrounding land which the farmer considered an integral part of the pond(s) area.

There was a wide array of carp farmers by size of enterprise measured by "pond area." Over 48% of the enterprises had less than 1 ha of "pond area." This group averaged 1.7 ponds each with an average size per pond of 0.17 ha (0.4 acre) each, for a total water area of about 0.25 ha (less than three-fourths of an acre). At the other extreme were 63 farm enterprises with 30.6 ponds each and with each pond having 2.7 ha of water surface. These larger producers had an average of 83.2 ha of water area (206 acres). The average carp farmer had 3.8 ponds, each covering 0.84 ha (2.1 acres, for an average total water area of 3.2 ha (nearly 8 acres).

These 4295 enterprises contained 16,364 separate ponds, covering a total water area of 13,684 ha (33,800 acres). A complete estimate of total annual production of food-sized fish was not obtained for all 4295 enterprises. Production data were secured for 4015 enterprises, having a total annual output of 3368 MT (3705 ST of food fish production. If it can be assumed that the missing enterprises had the same average output as was found for those reporting, then annual production would have been 3602 MT (3962 ST).

With approximately 62.5% of all carp waters devoted to third-summer fish for food, then the 3602 MT were produced from 8553 ha (21,126 acres), for an annual average yield of 421 kg per ha (375 lb per acre).

For the 4015 separate enterprises out of the total of 4295, there were 19,461,000 one-summer fingerlings and 6,300,000 second-summer fish (Table 8.8). With an average harvest weight of 1 kg (2.2 lb) for the three-summer fish, there were a total of 3,368,000 of these fish. Thus, there were 5.8 first-summer fish and 1.9 second-summer fish for each third-summer fish harvested. These data indicate that large sales of first- and second-summer fish are made to angling clubs, restocking of public waters, and fee fish-out ponds. While mortality does account for part of the decline in numbers, it is also known that sale of first- and second-summer fish is high.

TABLE 8.8. NUMBER OF CARP ENTERPRISES FOR SIZES AND TYPE OF CARP PRODUCTION, WEST GERMANY, JUNE, 1972

Pond Area (ha)	No. of Enterprises	One-summer Fingerlings	Two-summer Fingerlings	Three-summer Food Fish
		1000 Animals		Metric Tons
Under 1	1893	291	179	245
1-2	812	592	387	274
2-5	750	1,284	614	542
5-10	266	1,374	565	425
10-20	137	2,555	757	311
20-50	89	4,770	1365	469
50 and over	68	8,598	2431	1102
Totals and averages	4015	19,461	6300	3368

Intensity of Production

Table 8.9 clearly shows the makeup of different sizes of fish produced, by year of production. For example, as size of enterprise increases (shown by total water area per enterprise), the percentage of total fish made up of one-summer fish increases from 40.7 to 72.2%. Also, as size of enterprise increases, the proportion of food-size fish (three summers) declines. These data indicate that larger enterprises concentrate more heavily on one-summer fish and smaller enterprises on producing food-size or three-summer fish. The average carp farmer with more than 10 ha of water surface in ponds may have 75% more concentration of one-summer fish than the small enterprise, while the small enterprise may be nearly five times as concentrated in food-size or three-summer fish (compare 7.1 to 34.1%).

Density of Production

Table 8.10 indicates density of carp production by years of growth, by size of enterprise. With food fish (three summers), there is a perfect correlation between size of enterprise and output per hectare of water surface. Production was 445 kg per ha (396 lb per acre) of water surface for the smallest enterprise and continually decreased to 195 kg per ha (174 lb per acre) for the largest enterprise. Also, there was almost a perfect correlation between size of enterprise and density of one-summer fish. Fish numbers increased from 531 fish per ha (215 fish per acre) of water for the smallest enterprise to 2120 (858 per acre) for the next largest enterprise. These data indicate that larger enterprises are more likely to produce one-summer and two-summer fish (fingerlings), while smaller enterprises are more likely to produce food or three-summer fish.

The fact that density of fish numbers for one- and two-summer fish, as well as kilograms of three-summer fish, declined for the enterprise group having largest water area (83.23 ha or 206 acres per enterprise) suggest one of several observations: (1) these producers are more extensive and do not feel the need to intensify production; (2) these farmers have a lesser degree

TABLE 8.9. INTENSITY (PERCENTAGE) OF CARP PRODUCTION BY YEARS OF GROWTH AND BY SIZES OF ENTERPRISES, WEST GERMANY, JUNE, 1972

Pond Area (ha)	Enterprises (No.)	Total Water Area per Enterprise (ha)			Avg No. per ha of Water			Total No. Fish	Proportion (%) Fish by Years			Total (%)
		Enterprises (No.)	One- summer Fingerlings (1)	Two- summer Fingerlings (2)	Three- summer Food Fish ¹ (3)	One- summer (5)	Two- summer (6)		Three- summer (7)			
										(4)	(8)	
Under 1	1893	0.29	531	328	445	1304	40.7	25.2	34.1	100.0		
1-2	812	0.98	744	487	344	1575	47.2	30.9	21.9	100.0		
2-5	750	2.21	775	371	327	1473	52.6	25.2	22.2	100.0		
5-10	266	5.11	1011	416	313	1740	58.1	23.9	18.0	100.0		
10-20	137	10.50	1776	526	216	2518	70.5	20.9	8.6	100.0		
20-50	89	25.28	2120	607	208	2935	72.2	20.7	7.1	100.0		
50 and over	68	83.23	1514	454	195	2163	70.0	21.0	9.0	100.0		
Totals and averages	4015	3.19	1519	492	263	2274	66.8	21.6	11.6	100.0		

¹ Assumes an average harvest weight of 1 kg per fish.

Note: Columns (1) through (3) come from Tables 8.7 and 8.8; Column (4) is summation of Columns (1), (2), and (3); Column (5) is proportion that Column (1) is of Column (4); Column (6) is the proportion that Column (2) is of Column (4); and Column (7) is the proportion that Column (3) is of Column (4).

TABLE 8.10. DENSITY OF CARP PRODUCTION BY YEARS OF GROWTH AND BY SIZES OF ENTERPRISES, WEST GERMANY, JUNE, 1972

Pond Area (ha)	Enterprises (No.)	Avg No. Ponds	Avg. Water Area per Pond (ha)	Total Water Area per Enterprise (ha)	Avg No.		Avg No.		Avg kg	
					One-summer Fingerlings Per Enterprise	Two-summer Fingerlings Per Enterprise	Three-summer Per Enterprise	Production of Per ha of Water Area		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Under 1	1893	1.7	0.17	0.29	154	531	95	328	129	445
1-2	812	2.8	0.35	0.98	729	744	477	487	337	344
2-5	750	4.5	0.49	2.21	1,712	775	819	371	723	327
5-10	266	7.1	0.72	5.11	5,165	1011	2,124	416	1,598	313
10-20	137	10.0	1.05	10.50	18,650	1,776	5,526	526	2,270	216
20-50	89	15.7	1.61	25.28	53,596	2120	15,377	607	5,270	208
50 and over	68	30.6	2.72	83.23	126,000	1514	35,750	454	16,206	195
Totals and averages	4015	3.8	0.84	3.19	4,847	1519	1,569	492	839	263

Note: Column (2) from Table 8.9; Columns (3) and (4) from Table 8.7; Column (5) determined by multiplying Column (3) by Column (4); Columns (6), (8), and (10) determined by dividing appropriate data in Table 8.8 by Column (2); Columns (7), (9), and (11) determined by dividing Columns (6), (8), and (10) by Column (5).

of pond and fish management skills; or (3) the waters in these enterprises are less productive.

Commercial Wild Catch

In 1971, the last year for which data are available, total commercial wild catch of carp and cyprinids was 715 MT (788 ST) (Table 8.11). This catch was 53% from rivers and 47% from lakes. Thirty-six percent of the wild catch came from the state of Bavaria, and 28% from Schleswig-Holstein and Hamburg (Table 8.12). The remaining 36% came from the other six German states including West Berlin.

Imports and Exports

In 1975, a total of 3763 MT (4147 ST) of carp were imported into West Germany. Imports have increased continually since 1970. Total increase in imports since 1970 is 50% (Table 8.13 and Fig. 8.3). Imports are essentially from eastern Europe where carp are cultured extensively. Major imports each year come from Yugoslavia, Hungary, Poland, and the USSR, while lesser amounts are imported from France, Belgium, Holland, and Switzerland.

Only minor amounts of carp are exported from West Germany. In 1975, total exports were 51 MT (56 ST). Total value of these exports was \$73,541. Average price received per kilogram was \$1.44 (\$0.65 per lb).

Total Supply and Prices

Total supply of carp in Germany in 1975 was 8029 MT (8848 ST). This was composed of an estimated 3602 MT of cultured fish, 715 MT of commercial wild catch, and 3763 MT of imports minus 51 MT of exports. Hence, total supply was 45% cultured fish, 9% wild catch, and 46% net imports.

Since imports play such a large role, domestic producers' prices are nearly the same as import prices. In 1975, farmer prices averaged \$1.04 per kg

TABLE 8.11. CATCH OF WILD FOOD FISH BY SPECIES, WEST GERMANY, 1971

Species	River Fisheries	Lake Fisheries	Total
	kg		
Eel	121,367	124,374	245,741
Pike	34,539	56,073	90,612
Perch	8,178	44,453	52,631
Pike-perch	19,744	27,266	47,010
Carp	18,672	43,280	61,952
Cyprinids	362,279	291,072	653,351
Coregonids	1,682	375,596	377,278
Others	266,011	21,247	287,258
Total food fish	832,472	983,361	1,815,833

TABLE 8.12. CATCH OF WILD FOOD FISH BY SPECIES BY STATES, WEST GERMANY, 1971

Species	River Fisheries by States (kg)								Total
	Schleswig-Holstein and Hamburg	Lower Saxony	North Rhineland-Westphalia	Hesse	Rhineland-Palatinate	Baden-Württemberg	Bavaria	West Berlin	
Eel	9,472	51,615	8,712	8,116	6,621	13,081	20,095	3,655	121,367
Pike	1,138	3,177	833	3,738	3,140	7,298	13,446	1,769	34,539
Perch	666	911	103	200	610	3,534	1,638	516	8,178
Pike-perch	2,702	1,048	126	495	2,348	1,449	5,543	6,033	19,744
Carp	420	1,146	489	965	2,241	1,442	11,856	113	18,672
Cyprinids	2,682	28,008	5,878	44,588	66,122	60,094	149,491	5,416	362,279
Coregonids	—	156	—	3	1,342	181	—	—	1,682
Others	228,713	5,484	1,310	1,442	2,496	11,649	14,161	756	266,011
Total food fish	245,793	91,545	17,451	59,547	84,920	98,728	216,230	18,258	832,472
Lake Fisheries by States (kg)									
Eel	90,774	16,790	1,052	4,214	—	937	10,607	—	124,374
Pike	36,868	3,918	750	55	—	2,039	12,443	—	56,073
Perch	38,848	1,692	1,855	46	—	433	1,579	—	44,453
Pike-perch	6,308	8,993	802	2,725	—	1,520	6,918	—	27,266
Carp	19,239	590	1,400	1,190	—	1,810	19,051	—	43,280
Cyprinids	176,253	18,572	3,260	3,331	—	12,155	77,501	—	291,072
Coregonids	44,296	—	22,000	—	—	—	309,300	—	375,596
Others	10,151	2,608	—	300	—	901	7,287	—	21,247
Total food fish	422,737	53,163	31,119	11,861	—	19,795	444,686	—	983,361
Total Lake and River Fisheries by States (kg)									
Eel	100,246	68,405	9,764	12,330	6,621	14,018	30,702	3,655	245,741
Pike	38,006	7,095	1,583	3,793	3,140	9,337	25,889	1,769	90,612
Perch	39,514	2,603	1,958	246	610	3,967	3,217	516	52,631
Pike-perch	9,010	10,041	928	3,220	2,348	2,969	12,461	6,033	47,010
Carp	19,659	1,736	1,889	2,155	2,241	3,252	30,907	113	61,952
Cyprinids	178,935	46,580	9,138	47,919	66,122	72,249	226,992	5,416	643,351
Coregonids	44,296	156	22,000	3	1,342	181	309,300	—	377,278
Others	238,864	8,092	1,310	1,742	2,496	12,550	21,448	756	287,258
Total food fish	668,530	144,708	48,570	71,408	84,920	118,523	660,916	18,258	1,815,833
Percentage of total	36.8	8.0	2.7	3.9	4.7	6.5	36.4	1.0	100.0

TABLE 8.13. IMPORTS OF CARP INTO WEST GERMANY, 1970-1975

Country	Year					
	1970	1971	1972 (Metric Tons)	1973	1974	1975
Yugoslavia	635	592	751	689	1190	1225
Hungary	459	566	790	723	1430	916
Poland	386	469	561	425	444	708
USSR	192	192	378	340	408	514
France	792	773	735	636	426	300
Belgium	34	92	115	195	175	99
Others ¹	3	4	2	8	5	1
Total (metric tons)	2501	2688	3332	3016	4078	3763
Total (short tons)	2756	2962	3672	3324	4494	4147

Source: Professor Pachmann (Anon. 1970-1975).
¹ Includes various years, Holland and Switzerland.



Fig. 8.3. Imports of carp into West Germany by countries, 1975.

(\$0.47 per lb). Wholesaler prices ranged between \$1.05 and \$1.36 per kg (\$0.48 and \$0.62 per lb). Retail prices were between \$1.95 and \$2.33 per kg (\$0.89 and \$1.06 per lb).

EUROPEAN EELS (*Anguilla anguilla*)

In general, water temperatures in West Germany are too cold for good growth of eels. Under natural conditions, it takes 7 to 15 years for eels to mature in natural waters. Since the Germans prefer the mature silver eel rather than the immature yellow eel, this means that culturing is at a distinct economic disadvantage. This disadvantage is due to high costs of producing a fish which has such a long growth period. Hence, the only German eel culture is found in the warm water discharge of electrical generating plants. Since availability of such water is limited, cultured eel production is also limited. In 1975, total cultured production was about 10 MT (11 ST).

Because of the German fondness for eel, particularly smoked, there is considerable commercial effort to catch wild eels in rivers and lakes. In 1971, the latest year for which the author could secure wild catch data, the wild catch totaled 246 MT (271 ST) (Table 8.11). About one-half the catch came from rivers and one-half from lake fishing. More than two-thirds came from the two states of (1) Schleswig-Holstein and Hamburg and (2) Lower Saxony (Table 8.12). However, eels are caught in every state, including West Berlin.



Fig. 8.4. Feeding eels in West Germany. Courtesy of Mr. Harold Koops.

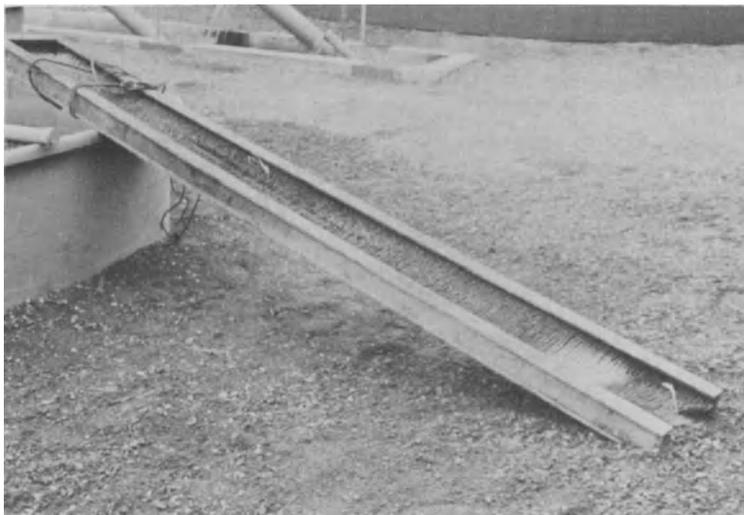


Fig. 8.5. Simple device for capturing elvers.

Imports of Eel

West Germany imports significant amounts of eels. Between 1970 and 1975, a total of 31,489 MT (34,701 ST) were imported. This averaged 5248 MT (5783 ST) annually, Table 8.14 and Fig. 8.6. Eels are imported from practically every country in the world where they are captured or cultured. Major imports are made annually from Denmark, which accounts for nearly 38% of Germany's total.

In 1975, eel imports accounted for \$21,494,000. Average price paid for imported eel was \$4.02 per kg (\$1.87 per lb). Price paid per unit of import varied from country to country, depending on the degree of processing undergone by the imported eels. For example, the lowest price was for eels imported from New Zealand. These eels—worth \$1.60 per kg (\$0.73 per lb)—are all unprocessed and are received frozen. At the other extreme were eels imported from Sweden, which were worth \$5.11 per kg (\$2.32 per lb). Many of these were imported as a smoked product. The remainder was imported as live fish. The fish from Denmark, which in 1975 accounted for 38% of all imports, amounted to \$4.86 per kg (\$2.21 per lb). This price difference was probably due to a smaller percentage of Danish eels being processed than for Swedish fish.

While West Germany imports significant volumes of eels, they also export smaller amounts. In 1975, exports were made to nine European countries. A total of only 208 MT (229 ST) were exported: chiefly to Holland and Sweden, with minor amounts to Finland, Denmark, France, Poland, Belgium, Switzerland, and Austria. Total eel exports amounted to \$591,000.

TABLE 8.14. IMPORTS OF EEL INTO WEST GERMANY, 1970-1975

Country	1970	1971	Year		1974	1975
			1972 (Metric Tons)	1973		
Denmark	2056	1949	2186	2224	2057	2023
New Zealand	406	588	682	441	388	576
Holland	715	646	507	396	569	547
Canada	171	455	593	419	475	421
Sweden	176	234	256	285	288	380
Poland	256	298	250	390	333	348
USA	319	442	323	310	282	286
Australia	44	77	92	133	191	212
Belgium	116	107	97	125	219	179
France	90	188	167	253	164	110
Italy	2	7	15	17	46	88
Turkey	68	142	73	67	32	32
Great Britain	23	11	101	72	96	21
Mainland China	45	47	36	—	30	27
Greece	22	—	—	43	—	26
Ireland	56	60	37	54	70	25
Others ¹	93	72	111	97	64	41
Total (metric tons)	4658	5323	5526	5326	5304	5352
Total (short tons)	5133	5866	6090	5869	5845	5898

Source: Professor Pachmann (Anon. 1970-1975).

¹ Includes Norway, Switzerland, USSR, Hungary, Austria, Spain, and Taiwan.

Average selling price per kilogram for exports was \$2.84 (\$1.29 per lb), indicating that most exports were unprocessed.

As a result of exports and imports, West Germany's net supply of eels increased by 5144 MT (5669 ST) in 1975. The net amount paid out was \$20,903,000.

Net Supply

Net eel supply in West Germany in 1975 was an estimated 5400 MT (5951 ST). This was derived from 10 MT of cultured fish, 246 MT of wild catch, and net imports of 5144 MT.

Prices

As indicated previously, prices for imported eels varied widely, depending on the proportion of fish received in some processed form. The New Zealand price of \$1.60 per kg (\$0.73 per lb) was for unprocessed frozen fish. The domestic price for wild and cultured eels would be somewhat higher because of the higher quality of live fish which are superior for smoking. Fishermen's prices would, of course, be lower than retail price. In 1975, retail prices for fresh live eels ranged between \$4.67 and \$5.45 per kg (\$2.12 and \$2.48 per lb). The smoked fish however, retailed for \$11.67 to \$13.62 per kg (\$5.30 to \$6.19 per lb).



Fig. 8.6. Imports of eel into West Germany by countries, 1975.

TENCH (*Tinca tinca*)

Tench is raised as a food fish in West Germany. It is nearly always grown in conjunction with carp production. However, the growth rate is slower than carp.

Very little information is available about West Germany's tench production, which is about 300 MT per year (330 ST). The major production area is Bavaria, with about 45% of total production (Fig. 8.1).

While carp are harvested for food fish at the end of the third summer of growth, averaging 1½–2 kg (3.3–4.4 lb), the slower growing tench may weigh only 250 g (9 oz), and are rarely grown past 700 g (1½ lb).

Tench prices are not affected by imports, so in essence there is no wholesale price level. Fish are sold directly to consumers or to retail outlets. Average prices for these sales varied between \$2.33 and \$2.72 per kg (\$1.06 and \$1.24 per lb) in 1975.

COMMON OR NORTHERN PIKE (*Esox lucius*)

There is no separate culture of pike in West Germany. However, many carp producers stock 10–20 pike fingerlings per ha (4–8 per acre) in their carp ponds. Pike normally attain 15–20 cm (6–8 in.) during the first summer they are stocked with carp. In the fall, carp ponds are drained or seined for harvest. At this time many of the pike fingerlings are sold to sportsmen's clubs for stocking angling waters, although some of the pike fingerlings are returned to the carp ponds for a second summer of growth. At the end of the second summer, these pike usually measure over 40 cm (16 in.) and average about 1 kg (2.2 lb) of weight. They are then harvested and sold either as fish for angling waters or for immediate consumption as food.

When pike are grown with carp, the usual production rate is between 5 and 15 kg per ha (4 and 13 lb per acre). If it can be assumed that an average of 10 kg per ha (9 lb per acre) is produced by one-fourth of the carp producers who have a total water area of 13,700 ha (33,800 acres), then total annual production would be about 350 MT (385 ST). Even by the most liberal interpretation, annual production must be considerably less than 1000 MT (1100 ST).

Prices of pike vary widely. In 1975, an average of \$2.33 per kg (\$1.06 per lb) was received by fish farmers, while pike sold in southern West Germany may have been worth 50% more than in the northern part of the country because of differences in local and regional demand. Only a few metric tons of pike are imported annually. These come in from Poland and Denmark.

RECREATION FISHING

Angling clubs lease fishing waters, and 80% of the fishing by some 600,000 anglers is in club waters.

About 25% of all fish caught on rod and reels are from daily fee fish-out ponds or enclosures. These types of fishing establishments are in great demand in West Germany, and in fact, this is one of the few countries in Western Europe that has a large pay-and-fish system. Unfortunately, the number of such establishments or total volume of the catch is not known.

OUTLOOK

Trout production is unlikely to increase significantly because of (1) limited water area and (2) the availability of relatively cheap imports from Denmark and Italy where production costs are less.

Production of carp is also unlikely to expand significantly for the same reasons as trout. At present, domestic producer prices are set by import prices. Since carp can be imported at relatively low prices from Yugoslavia, Hungary, Poland, and the USSR, there is little economic incentive to increase domestic production. However, domestic output is unlikely to decline since there is no other economical use for carp waters.

"Other" cultured fish production is related to carp production. Since the area devoted to carp production is unlikely to expand, these other species will always be found in limited supply.

Germany's waters are too cold for eel production. Hence, in spite of high prices, production will remain small.

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Switzerland

FISH SPECIES

Arctic char (*Salvelinus alpinus*)

Brook trout (*Salvelinus fontinalis*)

Brown trout (*Salmo trutta*)

Carp (*Carassius carassius*)

Carp (*Cyprinus carpio*)

Common bream (*Abramis brama*)

Danubian wels (*Silurus glanis*)

European eel (*Anguilla anguilla*)

Grayling (*Thymallus thymallus*)

Lake trout (*Salmo trutta lacustris*)

Lake whitefish (*Coregonus lavaretus*)

Northern pike (*Esox lucius*)

Perch (*Perca fluviatilis*)

Pike-perch (*Lucioperca lucioperca*)

Rainbow trout (*Salmo gairdneri*)

Steelhead trout (*Salmo irideus*)

Assorted rough fish

Switzerland

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

There are two species of salmonoids cultured for food fish production in Switzerland—rainbow trout and brown trout. Total production of both species in 1974 was about 300 MT (331 ST). Reliable estimates of proportions of each species produced are difficult to obtain. However, a generally accepted estimate is about 270 MT of rainbow and about 30 MT of brown trout. There are no exports. However, Switzerland does import rainbow trout from Denmark, Italy, and France. In 1974 a total of 1032 MT (1137 ST) was imported (Table 9.1). Denmark accounted for more than 80% of all imports, followed by Italy with 15%, and with minor quantities from France. Total supply, including domestic production and imports, was an estimated 1332 MT (1468 ST). Domestic production accounted for only 23% of total supply, with imports accounting for the bulk of total supply.

For domestically produced trout, rainbow trout spawning season is in February and March, while the brown trout spawning season is in November, December, and January. After spawning, fry are raised in concrete rearing tanks until they are about 6 cm (2.5 to 3 in.) and are then placed in grow-out facilities. Grow-out facilities are primarily earthen ponds with some concrete raceways used. Commercial pelletized trout food is fed throughout the production cycle.

It takes between 12 and 24 months to raise rainbow and brown trout to

TABLE 9.1. PRODUCTION AND IMPORTS OF RAINBOW TROUT FOR SWITZERLAND

	Metric Tons			
	1971	1972	1973	1974
Production ¹	200	240	275	300
Imports ²				
Denmark	1001	1160	985	838
Italy	NA	NA	NA	159
France	NA	NA	20	35
Total supply ²	1201	1400	1280	1332

¹Estimated.

²Source: Anon. (1971–1974).

NA—Not Available.

market sizes. Market demand is for fish between 180 and 200 g (6.5 and 7.5 oz).

An output of 300 MT of trout is achieved by 30 fish farmers. Hence, the average farm produces only 10 MT. This indicates that trout enterprises are essentially supplementary farm or nonfarm enterprises.

Nearly all sales are direct from farmer to homemaker, who then prepares the trout in a variety of ways. Cooking methods include frying, boiling, and grilling. All domestic production is sold live and about 80% of imported trout are also sold live. Only about 20% of imported trout are frozen. Imports are generally sold in fish markets and supermarkets.

CARP (*Cyprinus carpio*)

There is limited production of carp for food use in Switzerland. This is because of less than optimum water temperatures, which result in slow growth and limited demand. In 1975 there were 5 carp farmers averaging only 0.4 MT each, with a total output of 2 MT annually *in toto*.

The usual spawning period is in April and May. Fry are then placed in small earthen ponds, with few if any artificial foods fed. Total production time to market sizes of 1.5 kg (3.3 lb) varies between 3 and 4 years. All of the limited production is found in the French (western) part of Switzerland. The fish are sold live directly from farm to homemaker, who then either bakes or boils the fish for the family.

OTHER CULTURED FISH

In addition to commercial raising of rainbow trout and carp as food fish by private growers, the Swiss government has an intensive restocking program under way to build up or maintain fishing in public waters. During 1974, production of governmental fish hatcheries was 25,216,258 fish (Table 9.2). This included young fry, fingerlings, and year-old fish. The species of fish released in greatest numbers were: (1) northern pike (*Esox lucius*), accounting for 37.8% of all released fish; (2) brown trout (*Salmo trutta*), accounting for 28.6%; (3) lake whitefish (*Coregonus lavaretus*), accounting for 17.5%; (4) steelhead trout (*Salmo irideus*), accounting for 6.4%; (5) lake trout (*Salmo trutta lacustris*), accounting for 4.6%; and (6) grayling (*Thymallus thymallus*), accounting for 2.7%. Other fish released included arctic char (*Salvelinus alpinus*), brook trout (*Salvelinus fontinalis*), pike-perch (*Lucioperca lucioperca*), perch (*Perca fluviatilis*), Danubian wels (*Silurus glanis*), carp (*Carassius carassius*), and European eel (*Anguilla anguilla*).

Success of the restocking program has been significant. The catch in the 118,720 ha (293,238 acres) of public waters in 1967 was 1,898,876 kg (4,178,000 lb). By 1971 the catch had increased to 2,755,734 kg (6,063,000 lb) (Table 9.3). This table also shows the catch per hectare of water per year. It ranged from a low of 6 kg to a high of 35 kg per ha (from 5 to 31 lb per

TABLE 9.2. PRODUCTION OF THE SWISS FISH HATCHERIES DURING THE HATCHING PERIOD, 1974

Species	Number of Fish Placed in Open Water Under Official Control over a Multi-monthly Period		Yearlings		Total	
	Pre-summerlings Head	(%)	Head	(%)	Head	(%)
Lake trout (<i>Salmo trutta lacustris</i>)	815,905	4.8	335,652	4.6	6,314	0.8
Brown trout (<i>Salmo trutta</i>)	1,829,455	10.7	4,795,850	66.0	559,719	69.8
Steelhead trout (<i>Salmo irideus</i>)	280,100	1.6	1,184,966	16.3	156,801	19.5
Arctic char (<i>Salvelinus alpinus</i>)	252,900	1.5	169,500	2.3	10,162	1.3
Grayling (<i>Thymallus thymallus</i>)	531,912	3.1	135,387	1.9	22,279	2.9
Brook trout (<i>Salvelinus fontinalis</i>)	1,100	0	13,700	0.2	2,300	0.3
Lake whitefish (<i>Coregonus lavaretus</i>)	4,392,777	25.6	10,000	0.1	—	—
Northern pike (<i>Esox lucius</i>)	9,040,678	52.7	486,541	6.7	5,935	0.7
Pike-perch (<i>Lucioperca lucioperca</i>)	—	—	48,900	0.7	—	—
Perch (<i>Perca fluviatilis</i>)	—	—	—	—	700	0
Danubian wels (<i>Silurus glanis</i>)	—	—	—	—	4,400	0.5
Carp (<i>Carassius carassius</i>)	—	—	—	—	3,310	0.4
Eel (<i>Anguilla anguilla</i>)	—	—	15,000	0.2	—	—
Other	—	—	73,570	1.0	30,445	3.8
Total	17,144,827	100.0	7,269,066	100.0	802,365	100.0
% Production	68.0		28.8		3.2	

Source: Anon. (1974).

TABLE 9.3. CATCH OF WILD FISH BY LAKES AND TRIBUTARIES, SWITZERLAND

Lake Waters and Tributaries ¹	Area (ha)	Annual Production (kg)				Production by Hectare (kg per Year)
		1967	1968	1969	1970	
Genfersee	34,745	215,294	669,369	367,628	317,236	854,619
Neuenburgersee	21,581	318,018	197,157	319,812	502,852	213,228
Bodensee mit Untersee	17,144	527,951	442,950	521,093	700,232	716,575
Vierwaldstättersee	11,380	167,322	167,646	214,345	200,598	266,428
Zürichsee mit Obersee	8,852	143,872	155,265	196,506	183,241	171,730
Thunersee	4,780	56,852	48,996	91,155	121,221	172,565
Bielersee	3,920	125,745	81,693	105,302	114,320	134,183
Zugersee	3,824	209,481	195,970	97,678	79,934	91,676
Brienersee	2,918	23,961	13,168	16,421	23,500	18,101
Walensee	2,423	34,385	26,504	36,469	31,765	42,174
Murtensee	2,282	22,755	21,236	17,118	37,091	17,418
Hallwilersee	1,030	8,148	6,317	4,112	5,223	6,514
Lac de Joux	953	8,331	18,962	20,825	16,569	1,449
Greifensee	856	15,447	9,977	8,848	8,794	7,169
Sarnersee	773	14,875	12,778	18,270	11,596	13,683
Aegerisee	724	not given	9,067	12,199	9,906	11,520
Pfäffikersee	334	3,062	5,798	2,697	2,244	2,475
Lungernsee	201	3,377	3,899	4,286	3,931	4,227
Total	118,720	1,898,876	2,086,752	2,054,764	2,361,344	2,755,734

Source: Anon. (1967-1971).

¹ Excluding the portion from foreign countries.

TABLE 9.4. CATCH OF FISH IN SWITZERLAND,¹ BY SPECIES

Species	1967		1968		1969		1970		1971		Total kg 1967-1971	
	(kg)	(%)	(kg)	(%)								
Perch (<i>Perca fluviatilis</i>)	744,984	39.2	987,662	47.3	871,601	42.4	1,022,565	43.3	1,335,038	48.5	4,961,850	
Lake whitefish (<i>Coregonus lavaretus</i>)	584,058	30.8	521,794	25.0	682,795	33.2	672,969	28.5	757,072	27.5	3,218,688	
Assorted rough fish	426,085	22.4	406,752	19.5	343,847	16.7	500,843	21.2	501,196	18.2	2,178,723	
Common bream (<i>Abramis brama</i>)	27,739	1.5	50,731	2.4	46,350	2.3	63,611	2.7	47,727	1.7	236,158	
Northern pike (<i>Esox lucius</i>)	52,760	2.8	53,377	2.6	47,231	2.3	40,638	1.7	41,995	1.5	236,001	
Lake trout (<i>Salmo trutta lacustris</i>)	32,358	1.7	32,583	1.6	31,208	1.5	27,324	1.2	31,284	1.1	154,757	
Arctic char (<i>Salvelinus fontinalis</i>)	8,602	0.5	8,182	0.4	12,507	0.6	9,145	0.4	10,120	0.4	48,556	
Other	22,290	1.1	25,671	1.2	19,223	1.0	24,249	1.0	31,302	1.1	122,735	
Total	1,898,876	100.0	2,086,752	100.0	2,054,764	100.0	2,361,344	100.0	2,755,734	100.0	11,157,470	

Source: Anon. (1967-1971).

¹Water area involved, in hectares—118,720.

acre). This variation was caused by natural fertility of the water and restocking intensity.

The commonly caught wild fish, many stocked as fry or fingerlings, are shown in Table 9.4. The three most commonly caught fish were perch, lake whitefish, and assorted rough fish. The wild catch increased from 1899 MT in 1967 to 2756 MT in 1971. A breakdown of the wild fish catch by species is shown in Table 9.4.

OUTLOOK

The future appears bright for Switzerland's cultured fish industry. Production of rainbow trout is predicted to keep increasing at the rate of 10% annually. However, because of lack of suitable terrain for production sites, cost of land, high production costs, and cheaper imports, production may never exceed 800 to 1000 MT. This means that, even if demand does not increase, Switzerland will never become self-sufficient in trout production unless imports are restricted by tariffs or quotas.

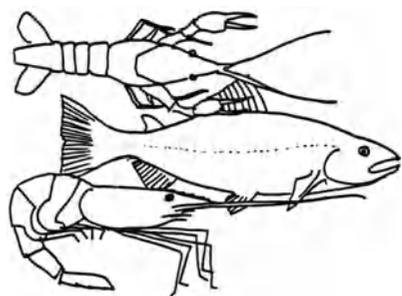
Production of carp is very limited and, because of lack of good growing conditions, will probably stay small.

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Austria

FISH SPECIES

Carp (*Cyprinus carpio*)

Grass carp (*Ctenopharyngodon idellus*)

Lake whitefish (*Coregonus albula*)

Rainbow trout (*Salmo gairdneri*)

Tench (*Tinca tinca*)

Austria

There are several species of fish cultured in Austria. Among these are: (1) rainbow trout (*Salmo gairdneri*), (2) carp (*Cyprinus carpio*), (3) tench (*Tinca tinca*), (4) grass carp (*Ctenopharyngodon idellus*), and (5) lake whitefish (*Coregonus albula*). Since Austria is a landlocked country, all fish raised are freshwater species.

RAINBOW TROUT (*Salmo gairdneri*)

The major fish cultured in Austria, by tonnage produced, is rainbow trout. In 1979, an estimated 1400 MT (1540 ST) were produced. Major trout producing areas are Upper Austria, Tirol, Vorarlberg, Styria, Carinthia, and Salzburg (see Fig. 10.1). Trout are produced in concrete and earthen raceways with flowing water and in ponds and reservoirs, such as old gravel pits, using both net enclosures and cages.



Fig. 10.1. Rainbow trout and carp production areas, 1980.

Since Austria is a major tourist country, it is deficient in domestic production of cultured fish. Less than 20 MT of trout are exported yearly while 230–250 MT are imported. Imports are essentially from Denmark and Italy. In 1974, 129 MT (142 ST) were imported from Denmark while 101 MT (111 ST) were imported from Italy. A few tons are also imported from West Germany.

Market size of trout is between 250 and 300 g (9 and 11 oz). The usual spawning months are February and March. After spawning, between 10 and 20 months are required to grow the fish up to market sizes. The exact time for growth depends upon water temperatures, which vary from very cold Alpine waters to warmer waters in eastern Austria. The most usual grow-out time varies between 16 and 18 months.

Only very small quantities of eyed-eggs are exported. They are sold to Switzerland, Turkey, and Persia. Sales to Turkey and Persia are in small quantities for breeding experiments.

Limited water resources do not permit high production by individual growers. A large trout farm produces only 20 to 50 MT (22 to 55 ST). In 1975 there were 72 members belonging to the Association of Austrian Trout Producers. These producers might be considered as commercial operators. In addition, there are an estimated 800–825 other producers, who culture trout for their household consumption or as a hobby.

Nearly all trout are sold live. Almost every large city has one or more fish buyers. There are an estimated 10–12 buyers in the country. The trend, however, is toward direct sales of live fish to hotels, restaurants, and homemakers, the major outlets being hotels and restaurants. A minor outlet for trout is as a smoked product. At present, only about 2% of the cultured trout is sold smoked. The market, however, is increasing rapidly.

Because of the unique geographic position of Austria and its German-related culture, some trout are boiled as in West Germany. However trout are also broiled, grilled, and pan-fried, as is customary in most other European countries.

CARP (*Cyprinus carpio*)

The second most important fish species cultured is carp. About 600 MT (660 ST) are raised annually. Major production areas are Northern Lower Austria (Waldviertel), Bergeinland, and southeastern Styria (see Fig. 10.1). All carp are produced in earthen ponds, usually adding water only to keep up with evaporation.

As is true for rainbow trout, Austria is a deficit carp-producing country. Only some 20 to 30 MT (22 to 33 ST) are exported yearly. More than offsetting these exports is the import of 200 MT (220 ST) of carp from East European countries and West Germany.

Market size of carp is from 1000 to 2000 g (2.2 to 4.4 lb). Usual spawning

months are May and June. After spawning, between 2 and 3 years are required for the fish to reach market size. For further information about production practices, the reader is requested to read the carp section of Chapter 8 on West Germany.

The third summer of production averages 300 kg of food fish per ha (267 lb per acre). After making allowances for maintenance of brood fish, fry, and fingerlings, about 2000 ha (4940 acres) are devoted to production of three-summer fish and 3200 ha (7900 acres) devoted to the entire production cycle.

There are two carp producing associations with total membership of about 40 producers. In addition, there are an estimated 160 small enterprises and hobbyists who are not commercial producers. The average commercial producer has about 80 ha of water area or less and producers about 15 MT annually (about 17 ST from 200 acres of water area).

Nearly all carp are sold live. Marketing channels differ considerably from those for trout in that most sales are made directly to fish buyers instead of hotels and restaurants.

As in West Germany and other carp-producing and consuming countries, most carp are cooked slowly by boiling or baking. This permits the flesh to peel away from the bones during eating.

OTHER CULTURED FISH

Other species cultured include: (1) tench (*Tinca tinca*), (2) grass carp (*Ctenopharyngodon idellus*), and (3) lake whitefish (*Coregonus albula*). About 30 MT (33 ST) of tench, 20 MT (22 ST) of grass carp, and 5 MT of lake whitefish are produced annually.

Most of these fish are produced in conjunction with carp, hence there are no meaningful figures available on production per hectare or per unit of water flow.

Spawning times for tench are May and June, for grass carp the month of June, and for whitefish April. After spawning, it takes between 2 and 3 years to raise the tench to market weights of 200 to 300 g (½ lb) and between 3 and 4 years to raise the grass carp to market weights of 3000 to 4000 (6.6 to 8.8 lb). Market weights and the production cycle of the lake whitefish could not be obtained by the author.

SPORTS FISHING

Because of intense interest in sports fishing and inability of the government to keep public waters well stocked, fishing clubs and fee fishing are important. Nearly all running water streams and lakes are in the public domain. The provinces issue yearly fishing licenses for public fishing. However, fishing clubs also lease fishing rights from private owners and

stock these areas. The individual club member's license may vary from one day to one year and is expensive. About 5% or 50 MT (55 ST) of cultured trout and about the same volume of cultured carp are stocked annually in private waters for special licensed fee fishing.

OUTLOOK

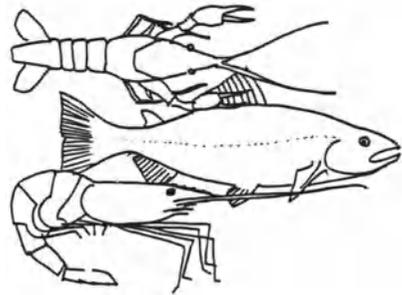
Because of the strong demand from Austrians, as well as from tourists, trout production is increasing. It is estimated that production will increase 10% during the next few years. The limiting factor is water supply, rather than a market with profitable producer prices.

Unlike trout, producer prices for carp are such that the profitability of carp farming is low. For this reason, production is stagnating and is unlikely to increase under present cost-benefit relationships. However, production is not likely to decrease because there is little alternative use for the carp ponds.

Production of tench, grass carp, and lake whitefish is usually in conjunction with carp. Unless the water area for carp expands, production of these other species is unlikely to increase significantly.

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Italy

FISH SPECIES

Black bullhead (*Ictalurus melas*)

Black eels

Brown bullhead (*Ictalurus nebulosus*)

Carp (*Cyprinus carpio*)

Catfish

European eels (*Anguilla anguilla*)

Gilthead (*Sparus auratus*)

Mulletts (*Mugil cephalus*, *M. auratus*, *M. chelo*, *M. saliens*)

Rainbow trout (*Salmo gairdneri*)

Sea bass (*Dicentrarchus labrax*)

Sea fish

Silver eel

Italy

RAINBOW TROUT (*Salmo gairdneri*)

Trout culture in Italy was originated in the mountains, in a region called Trentino, roughly at the beginning of the century. Development in this region was related to the common belief that since natural trout live in mountain brooks, trout farms should be built in the mountains. These early trout farmers erroneously believed that altitude was an important factor. They did not know that the limiting factor was high quantity of water with constant flow and constant temperature. Consequently, for many years trout farming was done in mountain areas where water was scarce, winters were long, and land was restricted. In this way trout farming was born, but its development in the mountains stopped soon after because of restricted areas and water supplied. Producing marketable trout in mountain trout farms took more than 24 months, and the amount produced was not enough to supply 10% of the national demand. Italy, until about 1965, was the best market for the production of other countries such as Denmark.

Beginning about 1960, several Italian innovators found that trout could be produced in the plains south of the Alps. In parts of this area were large marshes fed by springs. Water temperatures at the springs were about 12° to 13°C (54° to 55°F). Individual springs had flows of 2000–3000 liters per sec (31,680–47,520 gal. per min). The marshes were drained and the spring flows channelized. Within a few years, by 1964–1965, modern and scientific rainbow trout fish farming was in full swing and production increased by leaps and bounds. The major production areas are shown in Fig. 11.1.

By 1965 or 1966, Italy had changed from a trout-importing nation to a trout-exporting nation. During the 1970s, Italy became the largest producer of rainbow trout in Western Europe, surpassing France and Denmark. Production increased from 12,000 MT (13,224 ST) in 1968¹ to 16,430 MT (18,106 ST) in 1974, a dramatic increase of 37% in seven years (Table 11.1). By 1979, production had reached 19,900 MT (21,890 ST). Trout exports increased even more dramatically, increasing from 1000 MT (1102 ST) or 8.3% of production in 1968, to 3819 MT (4209 ST) or 23.3% of production in 1974. Total increase from 1000 MT to 3819 MT was 282%, which was an outstanding feat.

¹1968 was the first year for which the author was able to gain reliable data on production and exports.



Fig. 11.1. Major trout production areas, 1975.

Data from Table 11.1 indicate domestic consumption of trout in Italy stayed near 12,000 MT during the seven-year period, with production over this figure going into export channels. Export data for the years 1971 through 1974 indicate major markets for Italian trout exports were: France,

TABLE 11.1. PRODUCTION AND EXPORTS OF RAINBOW TROUT, ITALY, 1968-1978

Year	Production (Metric Tons)	Exports ¹ (Metric Tons)
1968	12,000	1000
1969	13,000	1500
1970	13,500	1500
1971	14,000	1800
1972	15,500	2200
1973	15,000	2043
1974	16,430	3819
1975	16,120	²
1976	17,000	²
1977	17,250	²
1978	19,900	²

¹Imports were only a few tons annually.

²Export data not available.

about 60%; Germany, about 25%; and other countries about 15% in 1971 and 1972. In 1973 Belgium became a significant importer. More recent data for 1974 indicate that exports from Italy were as follows:

	MT		MT
France	1744	Austria	101
Germany	1060	Denmark	42
Belgium	704	Others	109
Switzerland	159	Total	3818

Disposition of domestic trout (about 12,000 MT annually) was about evenly divided between sales to wholesalers (50%) and to other outlets. About 40% of "other" outlets' trade was to fee fish-out lakes where customers pay so much per kilogram for the amount caught. Remaining fish sales are divided nearly equally between direct sales to consumers, direct sales to retailers, and direct sales to restaurants. Before the oil crisis of late 1973 and early 1974 a larger proportion went to fee fish-out lakes. With higher gasoline prices, trips of fishermen to these outlets have declined.

Data for 1974 indicate average production cost of rainbow trout in Italy was \$1.21 per kg (\$0.55 per lb). Prices received by farmers, at the farm, were \$1.43-1.47 per kg (\$0.65-\$0.67 per lb) for live fish. Ice packed fish in the round sold for \$1.50 per kg (\$0.68 per lb), and deep frozen fish for \$2.31 per kg (\$1.05 per lb). A small specialty market for smoked trout existed. Average producer price was \$5.26 per kg (\$2.39 per lb).

Farm Examples

Case 1. One of the largest, if not the largest, fish farms in the world is Salvador farms near Treviso, Italy. This is a total of 8 different farms under

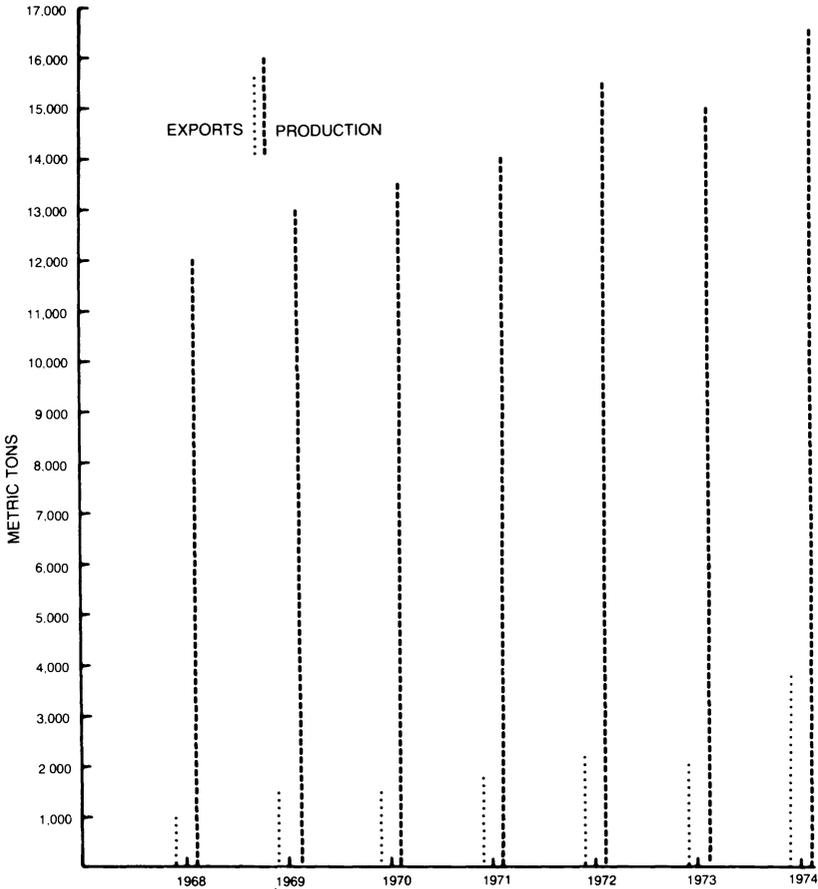


Fig. 11.2. Production and exports of rainbow trout from Italy, 1968–1974.

one private ownership, most of the farms' being specialized. Total production is several thousand metric tons of rainbow trout annually. Several farms raise only spawning fish and produce eyed-eggs. One raises fish up to about 50 g (2 oz) and three other farms then finish them from 50 g size up to market weights of 180–300 g (6–11 oz), depending on which country the fish are sold to.

Typically, each farm uses the stream flow from one or more large springs for raising fry, fingerlings, and food fish. Well water of 12.6°C (55°F) is used for hatching purposes. About 20,000,000 eggs are produced annually and eyed-eggs and fry are sold to other growers.

Water used for food fish production is from streams flowing from nearby springs. Because of the distance from the springs, water temperature may

drop to as low as 9°C (48°F) in winter and rise to as high as 16°C (61°F) in summer. Each concrete raceway system may be up to 500 m long (1640 ft). These systems are divided into several different segments with the water being aerated throughout the system. The raceways are 10 m (37 ft) wide and 1 to 2 m deep (3 to 6 ft).

At one of the Salvador farms, the operation is completely integrated: spawning fish are raised, eggs hatched, and fish grown out to market sizes in the same production facility.



Fig. 11.3. Large trout farm of 1000 MT.

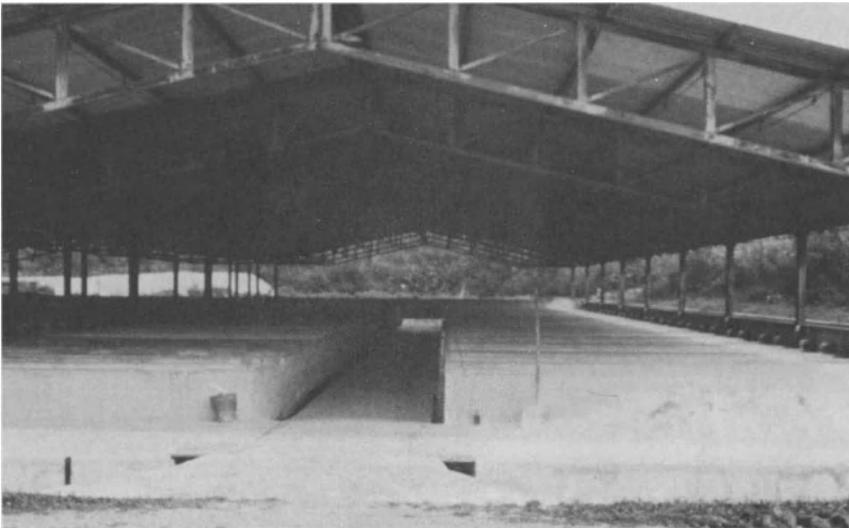


Fig. 11.4. Rainbow trout hatchery.

At this farm, one spring with a constant year-round temperature of 12°C (53°F) is used for hatching eggs. Spring flow is 500 liters per sec (7920 gal. per min). Over 9 million eggs are hatched annually. A second spring with an additional 500 liters per sec is used for growing the young fry.

At about 4–5 cm (2–2½ in.), the fry are transferred by machine to the growing-out segments of various raceways. Here, water is fed by a large stream of 4000 liters per sec (63,360 gal. per min), with temperatures varying from 10.5°C (51°F) in winter to 13°C (55°F) in summer. During the grow-out period of 4½–5 months, fish are graded and sorted by automatic equipment and transferred to different raceway segments by pumped water pipes.

Fish are always fed by tractor driven feeders. Resulting labor efficiency is 500 MT of fish annually or over 80 MT of fish for each of 6 workers.

Case 2. One large rainbow trout producer near Milan produces between 500 and 1000 MT of food fish annually. The farm is supplied by numerous springs, the largest of which has a flow of 4000 liters per sec (63,360 gal. per min). Total spring flow is 7000 liters per sec (110,880 gal. per min). The temperature of the water at the springs is 12° to 13°C (54° to 55°F); and the water effluent temperature (waste water) is between 17° and 18°C (63° and 64°F).

The farm has numerous earthen and concrete raceways. They measure up to 400 m (1313 ft) long by 9 m (28 ft) wide. Depth of the water is 1.3 m (4 ft). This typical production unit brings in eyed-eggs from the Alps, hatches the eggs, and grows the fish through fry and fingerling stages to food sizes.

Sales are made in Italy, France, and Germany. Sizes of fish sold are

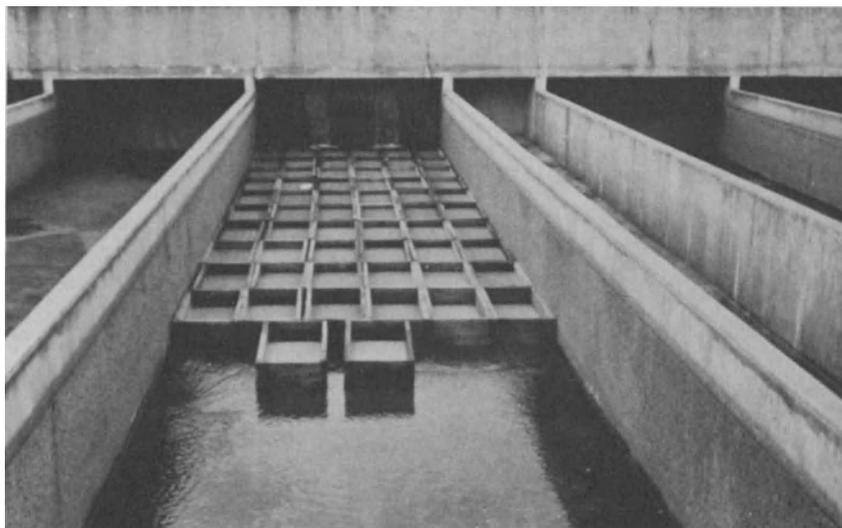


Fig. 11.5. Egg trays used in hatching rainbow trout.



Fig. 11.6. Bailing rainbow trout into mechanical sizing machine.



Fig. 11.7. Mechanical sizing of rainbow trout.



Fig. 11.8. Water transport pipes leading from mechanical trout sizer to different raceways.



Fig. 11.9. Mechanical feeding of rainbow trout.

200–240 g (8–9 oz), in Italy, 180–200 g fish to France² (6–7 oz), and 250–300 g (9–11 oz) to Germany. About 50% of total production is exported. About 90% of the total fish are sold alive and 10% are sold as dressed, iced trout. The live fish are sold through brokers, or to fish markets, who may sell the fish to the ultimate consumer in the round (whole) or dressed.

²Some of these small fish are not destined for immediate consumption but for finishing out in France. See Chapter 12 on France.



Fig. 11.10. Seining earthen trout raceway, trout feeding silos in background.



Fig. 11.11. Loading weighing buckets with trout harvested from raceway.

EUROPEAN EELS (*Anguilla anguilla*)

There are several eel farms in Italy; the first was established in 1969. Some are located in brackish water and others in freshwater. Total output is about 2200 MT annually, and production is expanding rapidly and could double or triple in a few years. Production of 3 kg per m³ (0.187 lb per ft³) is possible under intensive culturing practices. All of the 2200 MT of cultured

eel are produced in northern Italy, while 1800 MT of wild eel are captured in southern Italy. Hence, total domestic production is about 4000 MT. In addition, about 4000 MT of live eel are imported from France, Greece, Algeria, and other countries. Several hundred metric tons of deep frozen eels are also imported from the USA and Japan and New Zealand. Hence, total supply is in the nature of 8200 MT (9036 ST) annually. However, because of inadequate distribution channels and techniques, about 3000 MT of the domestically produced eel are exported to Germany from northern Italy and the imports are brought into southern Italy for consumption. The main demand for eels is in southern Italy while there is only limited demand in the northern part of the country.

About 90% (2000 MT) of the cultured eel is produced in brackish water and only about 200 MT in freshwater. Planning calls for an additional 1500 MT of brackish production by 1990 and 300–500 more metric tons of freshwater production by 1980.

The elvers (larvae eels) are secured mainly from the western coast, such as a 45 km (30 mi) area north of Naples. Elvers are captured in November, March, and April. In December, January, and February the water is cold and they do not migrate.

The elvers are transported from the catching area to freshwater and brackish water (Valli-culture or lagoons) culturing areas in northern Italy. Average size is 7 cm (3 in.) with a weight of about 0.16 to 0.20 g (5500 per kg or 2500 per lb). They are stocked directly in the extensive, brackish water of the Valli-lagoons at the rate of between 2500 and 6500 per ha (1000 and

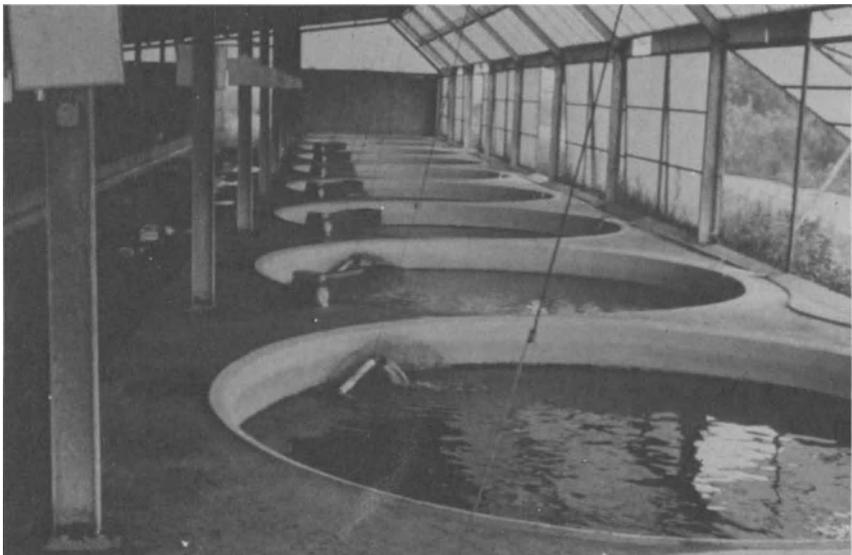


Fig. 11.12. Elver rearing tanks from 0.1 to 5 g sizes.

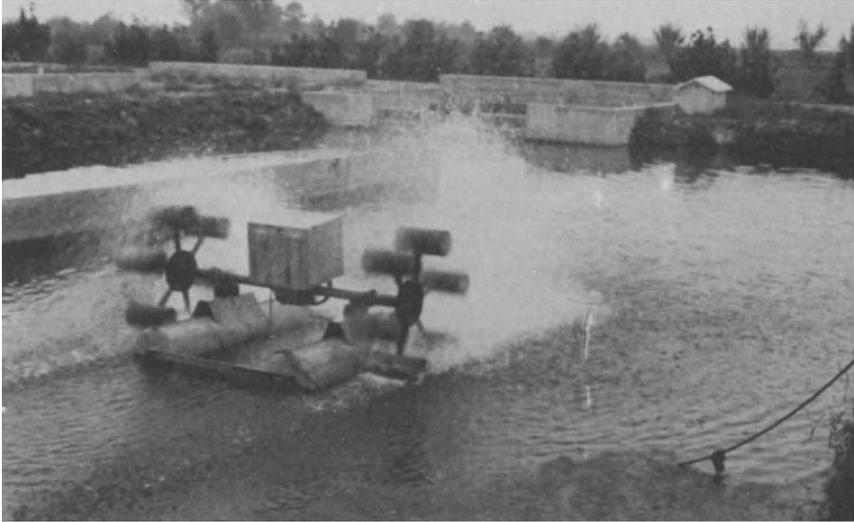


Fig. 11.13. Paddle wheel aeration of springwater prior to use in eel pond.

2600 per acre) depending on water quality and degree of intensification of production. No food is fed during the grow-out stages.

Elvers for intensive freshwater culturing are placed in round concrete tanks about 5 m in diameter (15 ft) and $\frac{1}{2}$ m (18 in.) deep. Stocking is at the rate of 80,000–100,000 per tank. Water is constantly circulated through the tanks. The elvers are raised in these tanks until they are about 2 g in weight. During the 0.2 to 2.0 g cycle, they are fed worms, finely ground fish meal made into a paste, and finely chopped sea fish. At about 2.0 g weights, the black eels are transferred to rearing or finishing ponds. After stocking these ponds, in which water is circulated and aerated, the fish are fed fish meal paste and fresh raw fish.

The elvers are fed 6–10% of body weight daily. This declines to about 1% at harvest weights.

Mortality of the fish is about 50% during the 0.2–2.0 g cycle and an additional 50% of the remainder during the 2.0 g to finish sizes of 200 g maximum for males and about 350 g for females. From elvers to maturity takes three growing seasons in northern Italy. Hence, to produce 100 MT of eels requires about 400,000–500,000 fish. To secure this many live adults requires nearly 2,000,000 elvers, or about 310 kg (682 lb) of larval fish. To produce all of the 2200 MT of cultured eel in Italy requires about 7 MT of elvers.

Elvers prices were about \$18 per kg (\$8.20 per lb) in 1975. This means that each elver costs about \$0.003. With a 25% survival rate, each fish at harvest would thus cost about \$0.0125. Prices paid to producers for the 150–200 g males and 200–400 g females in 1975 ranged between \$4.50 and

\$6.00 per kg (\$2.05 and \$2.73 per lb). This price was about three times higher than that paid for live trout.

Retail prices for mature live eel ranged between \$7.46 and \$8.95 per kg (\$3.39 and \$4.07 per lb).

One typical intensive eel farm has 9 different pond segments in production with more under construction. Each segment is 60 m long, 18 m wide, and 1 m deep (194 ft long, 58 ft wide, and 3 ft deep) (see Fig. 11.14). Freshwater comes from a well at a constant temperature of 13°C (55°F). Production is 2 MT per segment or 18 MT total. This is at a production rate of about 2 kg per m³ (3.4 lb per yd³). With experience, intensity is expected to be doubled.

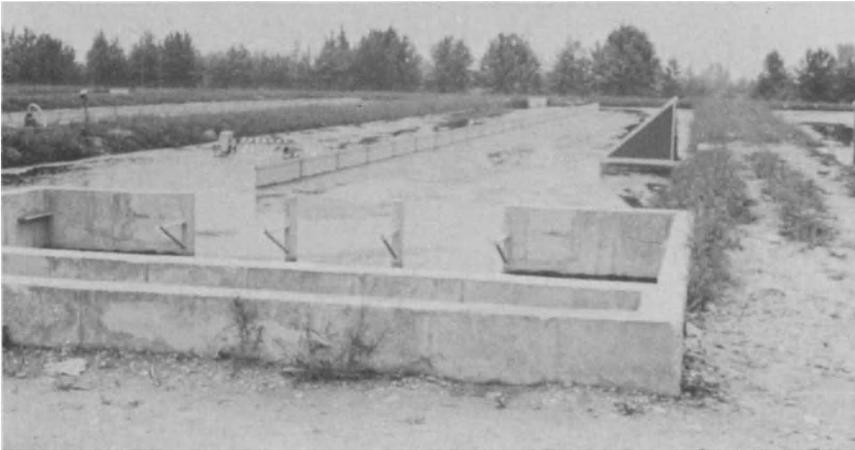


Fig. 11.14. Eel recirculation pond showing catch basin and feeding station.



Fig. 11.15. Eel recirculation pond under construction.

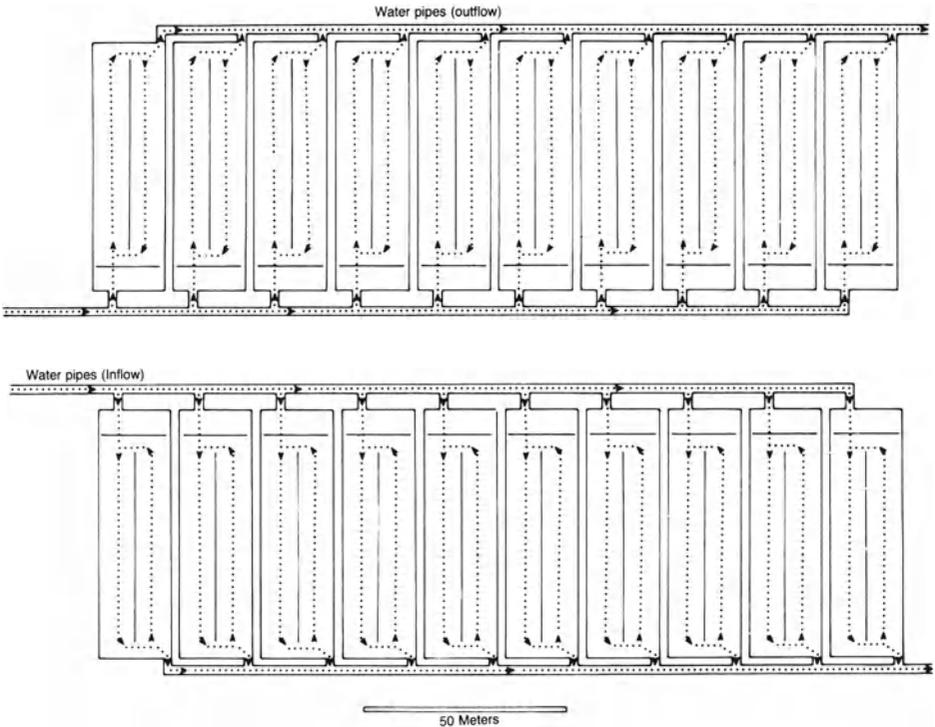


Fig. 11.16. Example of intensive eel culturing farm.

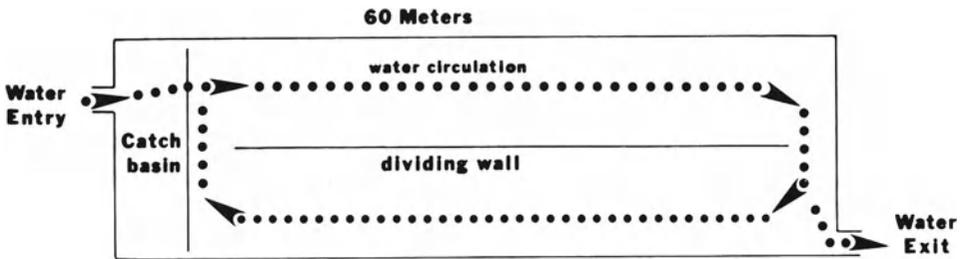


Fig. 11.17. Detail of Italian eel pond segment shown in Fig. 11.16.

BLACK BULLHEAD (*Ictalurus melas*)

There is limited production of black bullheads in Italy. One or two farms established in 1971 produce about 100 MT annually. Small amounts are consumed locally, but the major market is reported to be to fee fish-out

ponds or lakes. Prices received are about \$2.10 per kg (\$0.95 per lb), which is considerably higher than live trout price.

Drs. P. Ghittino and E. Vigliani (1975) believe that one of the major factors restricting catfish farming of the black bullhead (*Ictalurus melas*) and brown bullhead (*Ictalurus nebulosus*) and/or other catfish species which might be used is an existing federal law. An act (March 2, 1931, No. 442) in Italy forbids any trade of live catfish. This act was passed when the species were regarded as extremely noxious to fish fauna living in Italian waters and also without any redeeming value. Until this act is eliminated, catfish farming will remain small.

CARP (*Cyprinus carpio*)

Carp is not a popular food fish in Italy. Therefore there is no commercial production by specialized producers. Before the advent of specialized weedicide sprays, the rice farmers in the Po Valley of northern Italy commonly grew carp in conjunction with rice production. With the discovery of modern weedicides, rice farmers discovered that the value of the additional rice produced using sprays was much higher than having reduced rice yields and producing carp as part of the rotation. Hence, joint production of rice and fish has nearly stopped. A few rice producers still set aside a few hectares of rice for joint production with fish. This is solely to have some protein food for their workers. In 1975, fish yields of 30–35 kg of fish per ha could still be found in isolated fields. Total volume of such production would certainly be less than 5 MT.

BRACKISH WATER CULTURE

It is reported that ancient Romans were able to maintain and raise some marine fish along the Italian coast. They probably learned methods of primitive fish farming from the Etruscans who in turn learned it from the Phoenicians. The practice of brackish water culture in fenced lagoons is quite ancient along the North Adriatic coast around Venice and the Po River delta (Ghittino 1975). About 40,000 ha (100,000 acres) are utilized for fish culture. In addition, the federal government is constructing a 12,000 ha (30,000 acre) facility in Valli de Comacchio south of Venice. When completed, brackish water culture will be conducted on 52,000 ha (130,000 acres).

There are four main species of fish cultured. These are: (1) mullets (*Mugil cephalus*, *Mugil auratus*, *Mugil chelo*, and *Mugil saliens*), (2) sea bass (*Dicentrarchus labrax*), (3) gilthead (*Sparus auratus*), and (4) European eel (*Anguilla anguilla*).

These fish generally belong to the euryhaline group which can tolerate a high degree of salinity. They exhibit a seasonal or life cycle of migrating from sea to freshwater and vice versa. The inward or initial migration



Fig. 11.18. Harvesting carp from rice field.



Fig. 11.19. Brackish water culturing ponds near Venice.

usually consists of young fish, and the second or outward migration of more or less adult fish returning to the sea to breed or to avoid colder, shallow waters in the lagoons.

Young fish either enter the fenced lagoons, which permit entry but not exit, or are caught in nets by specialized fishermen who, in turn, sell them to owners of lagoons. Descending fish are caught by special traps, which are

made of concrete and aluminum screens. In addition, some lagoons can be almost emptied at low tide and then pumped nearly dry to expedite fish harvesting.

Water salinity in cultured lagoons ranges from 10 to 30 ppm. Water temperature ranges from a low near the freezing point to a high of more than 30°C (86°F) in summer. In winter, it is often necessary to pump additional seawater into the lagoons to keep temperatures above the critical point for some of the young fish. Average depth ranges from 70 cm to 1 m (2–3 ft).

Young estuarine fish are bought to stock cultivated lagoons. The last estimate of the amount spent for stocking fish was in 1954 at \$250,000 (De Angelis 1954).

Italian brackish water fish culture is extensive. Production of 150 kg fish per ha (134 lb per acre) is considered satisfactory. The Italian fish market requires mullets and sea bass of 300–1000 g (11–35 oz) which requires 3–5 years, gilthead of 150–400 g (5–14 oz) requiring 1–2 years, and adult silver eel averaging 400 g (14 oz) and requiring 7–9 years.

With a water area of 40,000 ha and an average yield of 150 kg per ha, the total brackish water production is 6000 MT (6612 ST). This volume should expand by over 30% when the new federal project is completed. Composition of these 6000 MT between species is not known. Estimates indicate that it is approximately equally distributed among the four species.

At present, few or no artificial foods are fed in brackish water culture. If artificial foods can be successful, feed production could reach 2.5 MT per ha, for an increase of 1567%. This means total production might reach 90,000 MT.

Scientific advancements underway indicate production will be intensified in the near future. For example, fingerlings are currently being prophylactically treated with formalin baths for external parasites prior to stocking the lagoons. Survival rates have increased to 80% in treated fish, compared to 20–30% in untreated fish. In addition, sea bass and giltheads have been successfully hatched and grown under artificial conditions. The incentive for artificial reproduction is the high value of the fry. In 1975, 2–3 cm (1 in.) sea bass fry were selling for \$0.15 each. Similar sized gilthead fry were selling for \$0.45 each. One breeding and spawning plant is now in production to produce fry.³ The goal is to produce 8,000,000 fry annually. The plant is jointly sponsored by federal government and private capital. The difficulty in raising fry has been the need to feed the larval fish phytoplankton and zooplankton. Hence, it was necessary to develop an economical way of culturing large quantities of phytoplankton and zooplankton before fry could be raised economically.

³S.I.R.A.P. (Industrial Society for the Reproduction of Artificial Fish), 30100 Pellestrina, Venice, Italy. (Italian)



Fig. 11.20. Gilthead hatching tanks.

OUTLOOK

Italy still offers opportunities for increased cultured fish production in rainbow trout, eel, catfish (bullheads), and brackish water species. Fish farmers and professional fisheries experts predict that rainbow trout production could, with favorable prices and control of viral hemorrhagic septiemia (VHS), increase by 15–20% above the 1979 level of 19,900 MT (21,890 ST). This increase would result from fuller use of existing freshwater flows and could amount to 3300 MT (3637 ST). The author also predicts, by intensifying production per unit of water flow, total production could increase by 40–50% or an additional 9715 MT (10,706 ST). This would result in average production per unit of water flow increasing from an average of no more than 143 kg of production per liter of flow per second to at least 210 kg (increasing from about 10 to 30 lb of production per gal. per min). Additional increases might result from better disease controls. Hence, it is conceivable that trout production could increase from 19,900 MT (21,890 ST) to 29,000–30,000 MT (31,958–33,060 ST).

Increases in eel culture are indicated by the fact that only in the 1970s was freshwater culture begun. The present cultured volume of 2200 MT might, with favorable price relationships, increase tremendously. A projected forecast of 8000–10,000 MT appears a possible achievement.⁴

⁴Extensive eel culture, which was used in brackish waters, expanded rapidly between 1965 and 1977. In 1977 a new parasitic disease infected the eels in these waters which resulted in 90% losses. These parasites had not invaded eels in freshwater culture between 1977 and 1981, and if they do, disease controls will be easier than in the extensive brackish water areas.



Fig. 11.21. Mechanical raceway cleaner.



Fig. 11.22. Mechanical noisemaker to frighten away predator birds.

Catfish (bullhead) production is, at present, almost totally prohibited by the 1931 law. Removal of this restrictive law could well result in a new major fish species for culturing. Total production would be limited only by market acceptance and price relationships.

Brackish water production of the mullets, sea bass, and gilthead is increasing under existing conditions. A 30% increase over the present level of 6000 MT is expected by an ongoing federal project. In addition, if artificial foods can be successfully fed and production per given volume of water intensified, production could increase more than 15-fold, or to over 90,000 MT (nearly 100,000 ST).

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France

FISH AND OTHER AQUATIC SPECIES

Black eels

Brown trout (*Salmo trutta*)

Carp (*Cyprinus carpio*)

Coho salmon (*Oncorhynchus kisutch*)

Crayfish (*Astacus leptocylus*)

European eels (*Anguilla anguilla*)

Mullet (*Mugil cephalus*)

Polish crayfish

Rainbow trout (*Salmo gairdneri*)

Sea bass (*Dicentrarchus labrax*)

Shrimp

Turkish crayfish

France

RAINBOW TROUT (*Salmo gairdneri*)

The rainbow trout industry of France, not yet having reached maturity, is still undergoing rapid expansion. For example, in 1965 total production was less than 3000 MT. In 1974 production reached 15,000 MT and then reached 18,000 MT in 1979. The index of production changed from 100 in 1965 to 501 in 1974 (Table 12.1), increasing production 401% in 10 years.

In 1975 there were 700 trout farmers in France. However, about 200 of these buy fish weighing about 160 g each (6 oz) and, in a few weeks, increase their weight to market size of 180–200 g (about 7 oz). While technically these finishers may be considered to be fish farmers, it may be more realistic to consider them as fish “jobbers.” Their aim is to increase weights by 20 to 40 g (1 to 1½ oz) and resell the fish to hotels, restaurants, and retailers at a much better price. They buy in large quantities and sell in small quantities.

Of the remaining 500 *bona fide* trout farmers, most are small producers averaging between 10 and 20 MT of production per year. It is estimated that 50 large farmers account for one-half of total production.

However, of these 500 farmers, about 150 farmers raise only part of their stock and buy the remainder for growing-out. These 150 farmers act a dual role of fish farmer and jobber. Hence, only about 350 of the 700 enterprises do not perform some marketing role.

Production Regions

Trout culturing is unequally distributed throughout France. The French divide the country into eight regions. These are: (1) North, (2) East, (3) Parisian Basin, (4) Normandy, (5) Brittany, (6) Southwest Central, (7) Southeast, and (8) Pyrenees (see Fig. 12.2).

In 1972, Brittany was the largest trout producer of any region in France. Its production was 3068 of a total 11,595 MT. This was 26.4% of total production (Table 12.2). Other regions with high production were North (16.7%), Normandy (14.7%), Southeast (12.4%), and Pyrenees (11.1%).

The northern half of France, where trout production began, represents approximately 70% of total production while the southern half accounts for about 30%. The southern half is an autonomous region and exchanges little of its production with other regions. Nearly every producer has a distinct

TABLE 12.1. CHANGES IN PRODUCTION OF RAINBOW TROUT FOR FOOD FISH IN FRANCE, 1965–1979

Year	Index	Metric Tons	Production	
				Short Tons
1965	100	2,992		3,298
1966	148	4,418		4,870
1967	201	6,006		6,620
1968	238	7,108		7,835
1969	262	7,827		8,628
1970	308	9,206		10,148
1971	352	10,516		11,592
1972	388 ¹	11,595 ²		12,781
1973	451	13,500 ³		14,877
1974	501	15,000 ³		16,530
1975	535	16,000 ⁴		17,632
1976	434	13,000 ⁴		14,326
1977	468	14,000 ⁴		15,428
1978	602	18,000 ⁴		19,836
1979	602	18,000 ⁴		19,836

¹Indexes for 1965–1972 secured from Desplanques *et al.* (1972).

²Production data for 1972 in metric tons secured from Desplanques *et al.* (1972), and then indexes for 1965–1972 were used to compute metric tons of production for 1965–1971.

³Metric tons for 1973 and 1974 secured from Tessier (1975).

⁴Data from Cancellieri (1981).

local market, or markets, for his production. In the northern half of France, including Brittany, Normandy, North, East, and Parisian Basin regions, production is exchanged between regions. Their excess production during different times of year is sold at the National Market at Rungis in Paris. Their contributions to this National Market are growing. In 1965 only 688 MT were committed, while in 1971, 1655 MT or 21% of their production was committed. The size of enterprises also varies between northern and southern France. One study (1) concluded that northern France produced about two-thirds of production by only about one-third of the producers, while



Fig. 12.1. Large trout farm (1000 MT) for rainbow trout.

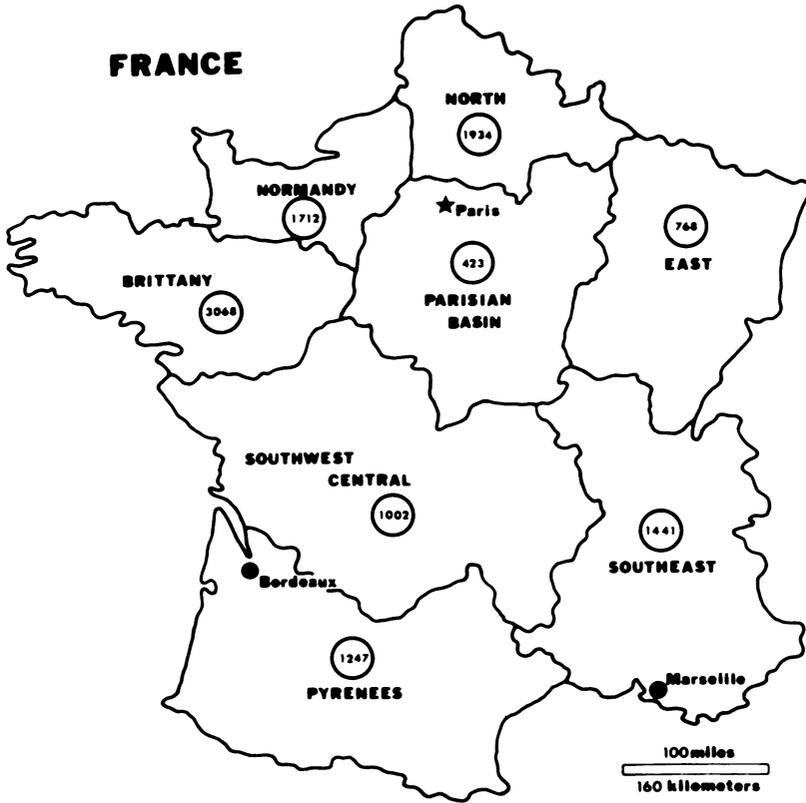


Fig. 12.2. Production of rainbow trout by areas in metric tons, 1972.

southern France had nearly two-thirds of the producers and produced only slightly more than one-third of total output. Fish producers with production greater than 10 MT per year represent more than half the producers in Brittany, North, and Normandy. The average volume of production per producer in Brittany was 66 MT, North 43 MT, and Normandy 32 MT. The average for all other regions is about 15 MT.

Because of the distinct nature of the two areas, northern and southern France, producer prices in southern France are semi-independent of the National Market at Rungis in Paris. In general, their prices are higher by at least the cost of transportation from the northern part of France, and usually bear some premium. This is particularly true when seasonal shortages occur in the North.

In the northern half of France, trout prices at both producer and consumer levels vary more widely. This is due to more concentrated production with more seasonality in production. The regions of northern France which affect production most and have the widest swings in seasonal production rates

TABLE 12.2. ESTIMATION OF ACTUAL TROUT MARKETS IN METRIC TONS BY REGIONS OF FRANCE, 1972

Region	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1972	% of Total
Brittany	50	110	277	449	521	483	358	198	205	119	144	154	3068	26.4
Normandy	86	118	162	237	193	177	130	118	116	122	122	131	1712	14.7
North	162	134	124	125	102	124	141	206	195	210	226	185	1934	16.7
Parisian Basin	14	14	36	49	65	52	22	45	38	29	25	34	423	3.6
Southwest Central	32	50	55	62	81	90	140	183	116	61	59	73	1002	8.6
East	36	48	60	72	76	80	80	84	60	52	44	76	768	6.6
Southeast	67	77	96	102	134	163	181	233	160	70	74	84	1441	12.4
Pyrenees	43	55	65	77	82	112	168	203	116	142	124	60	1247	11.1
France	490	606	875	1173	1254	1281	1220	1270	1006	805	818	797	11,595	100.0

Source: Desplanques *et al.* (1972).

are Brittany and Normandy. These two regions accounted for 41.1% of all France's production in 1972. However, all of northern France, which also includes the North, East, and Parisian Basin regions, accounted for 68% of production.

Low prices occur in most years at the National Market at Rungis in Paris during the April–May–June period, which corresponds to peak periods of marketing for both the Brittany and Normandy areas. Highest prices usually occur in the December–January–February period, which also corresponds to the low months of marketing for both the Brittany and Normandy regions.

Table 12.2 gives monthly marketing of trout in metric tons for each of the eight regions of France. For 1972, these two regions accounted for 41.1% of total French production. However, during the three months of April–May–June, they reached peak levels, and during December–January–February reached their lowest levels. During April they sold 58.5% of the French total; 56.7% in May; and 51.5% in June. By comparison, during December they accounted for only 35.8%; 27.7% in January; and 37.7% in February (Table 12.3).

The North region was somewhat of an equalizer by having different low and high marketing periods. This region's low period of marketing was in April–May–June when Brittany and Normandy flooded the market. However, this was not sufficient to stem the tide, and prices fell on the central market. The effects of all three of these regions are shown in Fig. 12.3. An even clearer presentation is shown in Fig. 12.4, which gives average percentages of production for Brittany, North, Normandy, and France for the lowest and for the highest three months of marketing. The difference between lows and highs for Brittany was 365%, for Normandy, 91%, and for North, 79%. For all of France, marketing during the peak months of June–July–August was exactly 100% greater than during low months of December–January–February.

These data show clearly that Brittany was the arch villain in price swings, that Normandy was a culprit, and that North was a fledgling hero. While it is easy to point an accusing finger at both Brittany and Normandy for causing low prices, the reader should also realize the cause of these wide fluctuations in marketing. In both Brittany and Normandy a disproportionate share of annual production must be sold in April, May, and June before water shortages occur in the summer and water temperatures increase. As temperature increases, the oxygen-carrying capacity of the remaining water flow decreases, and fish numbers must be reduced. During these months, fish prices are depressed in northern Paris markets and fish from Brittany move to other countries as well as to southern France. By August, the temporary glut of food-sized fish is over and a temporary shortage of the right sizes occurs. During August and September, imports, chiefly from Italy and Denmark, are made.

TABLE 12.3 MONTHLY RELATIVE IMPORTANCE OF THE PRODUCTION OF EACH REGION IN PERCENTAGE OF TOTAL TROUT MARKETING, FRANCE, 1972

Regions	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	The Year
Brittany	10.2	18.2	31.7	38.3	41.3	37.7	29.3	15.6	20.2	14.8	17.6	19.3	26.4
Normandy	17.5	19.5	18.5	20.2	15.4	13.8	10.6	9.3	11.6	15.1	14.9	16.5	14.7
North	33.1	22.1	14.1	10.6	8.1	9.7	11.6	16.2	19.4	26.1	27.6	23.2	16.6
Parisian Basin	2.9	2.3	4.1	4.2	5.2	4.1	1.8	3.5	3.8	3.6	3.1	4.0	3.6
Southwest Central	6.5	8.2	6.3	5.3	6.5	7.0	11.5	14.4	11.6	7.6	7.2	9.2	8.6
East	7.3	7.9	6.9	6.1	6.1	6.3	6.6	6.6	6.0	6.5	5.4	9.6	6.6
Southeast	13.7	12.7	11.0	8.7	10.7	12.7	14.8	18.4	15.9	8.7	9.0	10.6	12.4
Pyrenees	8.8	9.1	7.4	6.6	6.5	8.7	13.8	16.0	11.5	17.6	15.2	7.6	11.1
France	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Computed from Table 12.2.

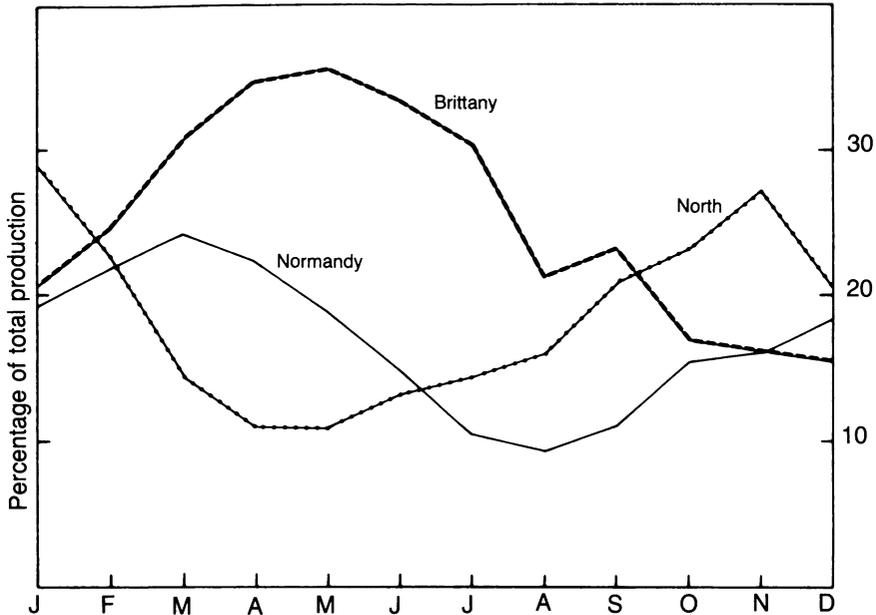


Fig. 12.3. Relative importance of the three major rainbow trout production areas by months, France, 1972.

Imports and Exports

France has long been a deficit country in regard to rainbow trout production. For example, in 1960, 1905 MT were imported and only 158 MT exported, resulting in a deficit of 1747 MT (Table 12.4). Then, from 1962 to 1968 imports declined. Beginning in 1968, imports and exports increased, and a large annual deficit of trout occurred each year. For the five years of 1970–1974, the deficit was 1058 MT annually. This amounted to an average deficit of 8.8%.

During the six year period 1968–1973, a total of 8741 MT (9633 ST) of rainbow trout was imported into France (Table 12.5). These imports had a total value of \$13,552,000. On a yearly basis, 1457 MT (1605 ST) worth \$2,258,666 were imported. Exports amounted to 282 MT (311 ST) annually, worth \$464,000. These figures indicate that France had a deficit of 1175 MT (1294 ST) of rainbow trout annually. In spite of French exports selling for more than French imports on a per kilogram basis, the annual outflow of money in dollars was \$1,794,666.

Observing France's trout export and import locations is interesting. In 1973 and 1974 the chief country for exports was Belgium (Table 12.6), which accounted for 89% of total exports. This is contrary to the belief of many French fish farmers that chief markets are West Germany and

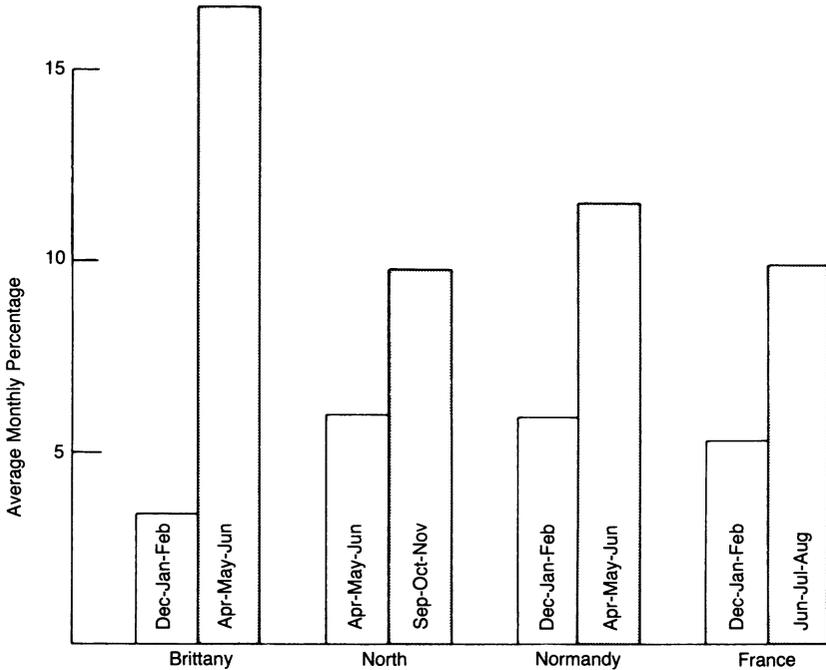


Fig. 12.4. Average percentages of low and high three months trout marketing periods for three districts and for France, 1972.

TABLE 12.4. PRODUCTION, IMPORTS, EXPORTS, DEFICIT, AND TOTAL SUPPLY OF RAINBOW TROUT IN FRANCE FOR THE 15 YEAR PERIOD, 1960–1974

Year	Production	Imports	Exports	Deficit	Total Supply
Metric Tons					
1960	NA	1905	158	1747	NA
1961	NA	1780	187	1593	NA
1962	NA	36	2	34	NA
1963	NA	481	10	471	NA
1964	NA	468	12	456	NA
1965	2,992	565	22	543	3,535
1966	4,418	433	65	368	4,786
1967	6,006	520	68	452	6,458
1968	7,108	1287	60	1227	8,335
1969	7,827	1425	43	1382	9,209
1970	9,206	1000	380	620	9,826
1971	10,516	1037	333	704	11,220
1972	11,595	1983	406	1577	13,172
1973	13,500	1979	466	1513	15,013
1974	15,000	2167	1290	877	15,877

Source: 1961–1974 production data secured from Table 12.1. For 1960–1969 export and import data from Desplanques *et al.* (1972). Data for exports and imports for 1970–1974 secured from Anon. (1971–1979).
NA: Not available.

TABLE 12.5. IMPORTS AND EXPORTS OF RAINBOW TROUT IN METRIC TONS, TOTAL VALUE IN DOLLARS ANNUALLY, AND PRICE PER KILOGRAM AND POUND, FRANCE, 1968-1973

Year	Imports (Metric Tons)	Value in Dollars (1000)		Price		Exports (Metric Tons)	Value in Dollars (1000)		Price	
		Per kg	Per lb	Per kg	Per lb		Per kg	Per lb		
1968	1287.2	1622	0.57	1.26	0.57	60.7	106	1.74	0.79	
1969	1423.7	2093	0.67	1.47	0.67	44.0	90	2.04	0.93	
1970	1023.7	1781	0.79	1.74	0.79	379.9	680	1.79	0.81	
1971	1037.7	1785	0.78	1.72	0.78	333.3	520	1.56	0.71	
1972	1982.2	2815	0.65	1.42	0.65	406.9	521	1.28	0.58	
1973	1986.4	3456	0.79	1.74	0.79	466.0	867	1.86	0.85	
Totals and averages	8740.9	13,552	0.70	1.55	0.70	1690.8	2784	1.65	0.75	

Source: Anon. (1974). Original data secured from Customs Service.

TABLE 12.6. EXPORTS AND IMPORTS OF RAINBOW TROUT BY COUNTRIES, FRANCE, 1973 AND 1974¹

Country	1973 (MT)	1974 (MT)
Exports from France		
Belgium-Luxembourg	407	1161
West Germany	9	62
Andorra	26	21
Others	24	46
Totals	466	1290
Imports to France		
Italy	1480	1742
Denmark	262	283
Belgium-Luxembourg	170	92
Norway	18	22
Ireland	17	12
Others	32	16
Totals	1979	2167

¹Data secured from European Trout Federation Office, Treviso, Italy.

Switzerland. Seventy-five percent of all imports came from Italy, the primary source of imports, in 1973. In 1974, this increased to 80%. Denmark accounted for more than one-half of the remainder.

Trout Prices

The 1975 farm price of trout in southern France averaged about \$2.20 per kg. Depending on location and local demand, this price was for live fish delivered within a radius of 100 km (62 mi), or fish at the producers' pond, with an extra charge made for icing, dressing, and packaging. However, some retailers furnish their own packaging materials. If the producer furnished packaging and boxes, about \$0.20 per kg (\$0.09 per lb) was added on. In southern France, only the very large producers sell outside the local areas. Large producers may sell directly to dealers in Belgium and other countries.

Producer prices in southern France bear little relationship to Paris prices. Southern prices are strongly affected by tourist influx between April 1 and September 1, some producers selling more than 80% of their annual output during these five months. Southern prices are reasonably stable throughout the year.

Producer prices in northern France are generally 10–15% below those found in southern France. The average producer price in northern France in 1975 was about \$2.00 per kg (\$0.90 per lb). The price in northern France is usually determined by the National Market at Rungis in Paris.

In 1971, total production of rainbow trout in northern France from the regions of Brittany, North, Normandy, Parisian Basin, and East was 7329 MT. The National Market at Rungis, Paris, handled 1679 MT of this

amount, or 22.9%. In 1972, production from the five regions was 7905 MT. Estimated sales at the National Market were 2004 MT or 25.4%. These data indicate the relative and increasing importance of that market.

In southern France during 1975, farmer-jobbers were buying trout at \$2.20 per kg (\$1.00 per lb) delivered to their ponds. They, in turn, sold about 80% of their finished fish to hotels and restaurants, and 20% to retail stores in small quantities a few weeks later at about \$3.33 per kg (\$1.51 per lb) for dressed fish. On a heads-on, dressed-out basis, this compares to \$2.73 per kg (\$1.24 per lb).

The retailers, in turn, sell the \$2.13 per kg (\$1.24 per lb) dressed fish to restaurants or homemakers at an average price of \$4.13 per kg (\$1.88 per lb).

There is a small but growing fee fish-out market for producers. Most fee fish-out enterprises are located in a general area south of Paris, but some are scattered throughout central France. It is estimated that 5–10% of total production is sold to fee ponds for recreational fishing. Trout producers' prices for these fish averaged about \$2.65 per kg (\$1.20 per lb) in 1975. Catch-out price at the fee fish-out pond was \$4.35 per kg (\$1.98 per lb), which is higher than retail prices of \$1.88. Additionally, the fee fish-out price was for fish in the round, whereas retail price was for dressed fish.

Marketing Channels

Marketing channels for rainbow trout sold in France are remarkably different from those found for most products. The typical picture is farmer to wholesaler to retailer to consumer. Producers sell French-produced trout directly to farmer-jobbers, wholesalers, hotels, and restaurants, and the ultimate consumer (Fig. 12.5). The farmer-jobbers also sell directly to all levels, including wholesalers, hotels, restaurants, and the final consumer. No information is available concerning relative volumes sold at each step. Imports usually go directly to French wholesalers.

Farm Examples

Case 1. Of the approximately 14,000 MT of rainbow trout produced in France, only about 200 MT are produced in brackish water. About one-half of total brackish production comes from the Méditerranée Pisciculture S.A. farm at Salses near the Spanish border. A brief discussion of this operation will enable the reader to understand some problems faced by French producers in using brackish water for rainbow trout production. Mr. Jouy, the owner, started this farm in 1972 and is still working at removing obstacles and problems associated with the site.

Freshwater supply is from a stream which goes underground about 10 km away and then surfaces at the fish farm from the bottom of a cliff. The oxygen content of the resurfaced water is only 5.5 ppm. Hence, artificial oxygenation is necessary to raise oxygen content. The terrain is so level that mechanical rather than gravity aeration must be used. Maximum use of the

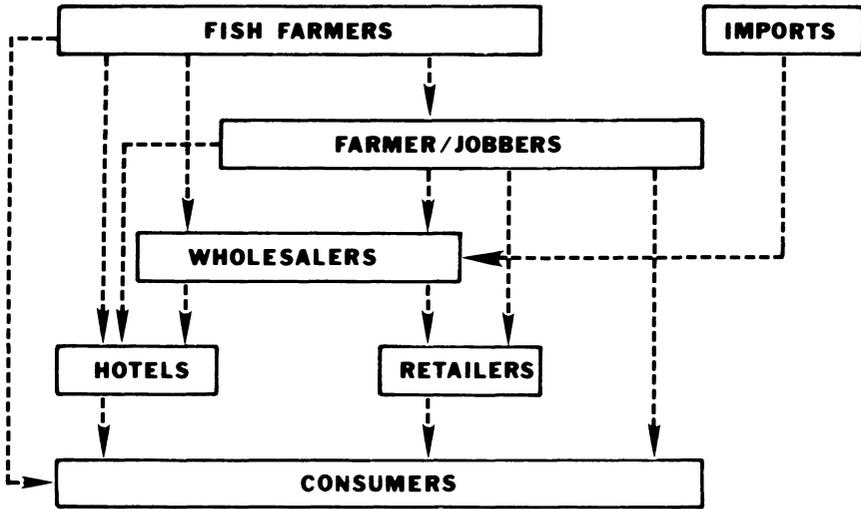


Fig. 12.5. Marketing channels for rainbow trout in France.

freshwater flow has not yet been attained. Existing plans call for a substantial increase in production. The freshwater flow is 1000 liters per sec (15,849 gal. per min) with a constant temperature of 17.5°C (63.5°F). Thus, there is a temperature limitation on use of the water. In summer months, production is limited by being able to use the water only until the temperature increases 4° to 5°C (8°F). Thus, year-round production is restrictive since only limited volumes of fish may be stocked in the summer.

Some of the freshwater is used to dilute salt water brought inland from the bay area. The salt water reaches a temperature of 26° to 27°C (80°F) in summer. Freshwater is added so that the brackish water has a salt content of 20–21 ppm. The mixed brackish water is cold enough for production only between December 15 and May 15, or for five months.

Trout can be raised from hatching to market sizes of 200 g (7 oz) in about 10–12 months. On a 12-month schedule of growth, eggs must be hatched about May 1, reared in the newest freshwater until December 15, and then transferred to the brackish water for growing-out before the next May.

All trout are sold in the round (undressed) to retailers within a 100 km radius (62 mi). There is no relationship to the central market price in Paris, and prices are fairly stable throughout the year.

Another enterprise producing rainbow trout in brackish water is found just south of Bordeaux on the Atlantic Ocean side of France. As is true for the Mediterranean side, the brackish water is too warm for trout production during the months of June–September. Hence, 100 g fingerlings (3½ oz) are brought in to be fattened to a market size of 250 g (8 oz). The production period is about three months. Salinity of the water varies from 18 to 30 ppm. These fish are produced in old salt beds which have been in fish culture since 1750.



Fig. 12.6. Tidal water gate for saltwater culture of fish.

Production costs are higher in brackish water than in freshwater. For example, feed costs increase about 40% due to the need to add a binder and greater loss of feed which dissolves faster in brackish water. This additional feed cost amounts to about 17¢ per kg (\$0.08 per lb). The technicians working with brackish water culture believe that higher production cost can be recovered in the marketing system by emphasizing the pink, fleshy color and the firmer texture of the product. There is also the possibility of differentiating the product by selling different sizes of fish. These might be retail sizes of 200 g (7 oz) for portions, family sizes of 400 g (14 oz) for restaurants, and 600 g sizes (21 oz) for smoking.

There are two ways of maintaining oxygen levels in brackish water culture. With either method, tides are relied upon to exchange the water twice daily. If fish are not intensively stocked, no supplemental aeration may be necessary. One way of providing necessary supplementary oxygenation is with mechanical aerators. The second method is to provide for a reservoir which is higher than the fish cultural ponds. At high tides the reservoir is filled. Between high tides, water is released from the reservoir into the cultured ponds. This system requires an extensive, expensive system of levees and water gates, however. In some parts of France such systems already exist.

Case 2. One of the largest, if not the largest, trout enterprises in France is near Mezos, France, south of Bordeaux. The enterprise consists of two different production units. One unit hatches the eggs and raises the fry to about 50 g each (nearly 2 oz). Then the 50 g fingerlings are transported to the grow-out unit several kilometers away.

Trout eggs for hatching are imported from different countries in order to spread out the production cycle so that harvesting and marketing will be more uniform throughout the year. Eggs are imported from the USA, Australia, and Denmark. Eggs produced in France are also used. Hatching

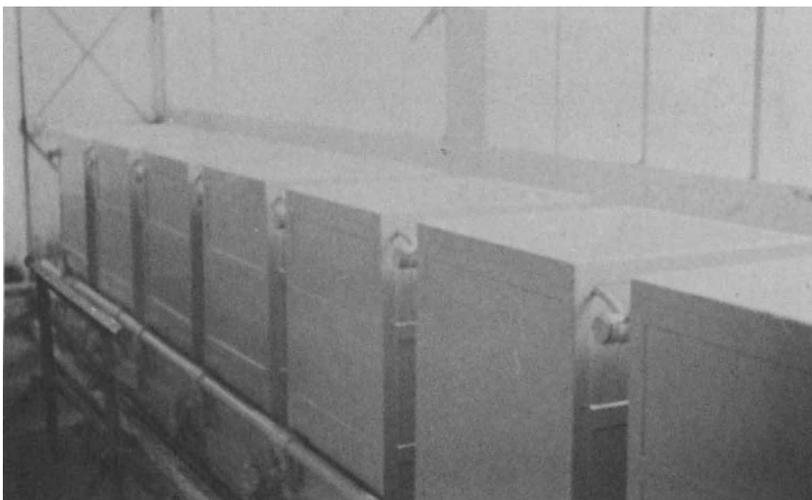


Fig. 12.7. Rainbow trout egg hatching equipment.

takes place every month but June and July. The water source for hatching the eggs is a spring having a water flow of 350 liters per sec (5550 gal. per min). The spring water is a constant 13°C (55°F).

One month after hatching, the fry are moved to rearing raceways. These raceways are supplied by a separate spring-fed stream; the temperature of raceway water varies from a low of 9°C to a high of 15°C (48° to 59°F). In 6 to 8 months the fry reach an average size of 50 g (nearly 2 oz). The fish are graded for size twice during this period. The fry and fingerlings are fed 6 to 8 times daily by mechanical feeders. All other work is performed by four workers.

After the fish reach 50 g they are transferred to the grow-out unit several kilometers away. Water supply for this operation comes from a large spring having a flow of 3000 to 6000 liters per sec (47,564 to 95,128 gal. per min). The water flows through 13 lines of raceways. Each line is divided into 5 segments, or 65 segments *in toto*. Each segment is 1 m deep, 8 m wide, and 60 m long (3 ft deep × 26 ft wide × 194 ft long). The fish are grown from 50 to 200–250 g (nearly 2 to 8 oz) in 4 to 4½ months. During this time they are mechanically graded twice by size. At harvest, they are sold in the round or dressed and packed in ice. Sales are made throughout France to wholesalers. Direct export sales are also made to supermarkets in Belgium and Switzerland.

Production efficiency is very high at this farm. Output of trout per worker per year ranges between 70 and 80 MT.

At this facility a quick freezing plant was completed in 1976 and was the first specialized quick freezing trout operation in France. The plant is

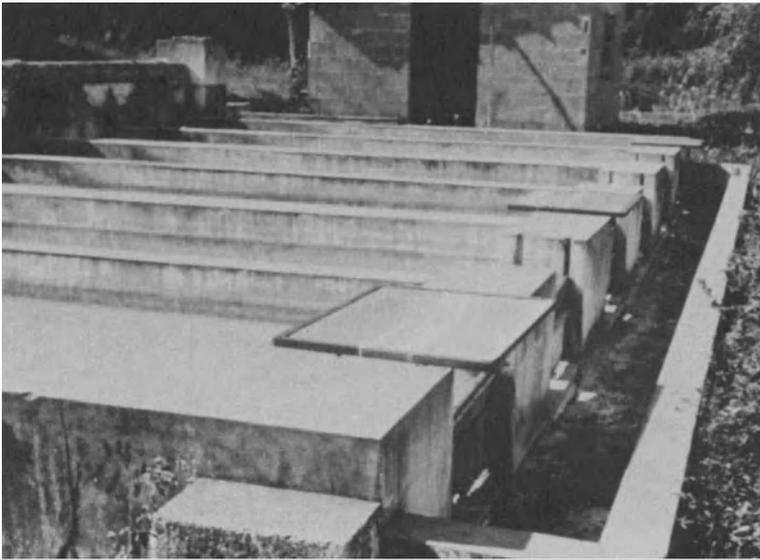


Fig. 12.8. Fry rearing troughs.

capable of processing, storing, and marketing several thousand tons of trout annually.

Case 3. One rather typical enterprise was visited in central France. This fish farmer had three different farms: one to hatch eggs and produce fry; one to rear fry to fingerling size; and one to complete the grow-out process.

At one time, this farmer raised his own brood stock and produced his own eggs. He then shifted to importing one-half of his eggs from Denmark. He



Fig. 12.9. New frozen trout processing plant under construction.

recently shifted entirely to imported eggs from Denmark. He remarked that it was cheaper to buy all eggs than to produce his own. He buys 1 million eyed-eggs annually during the January 15 to May 15 period. Eggs are purchased in units of 200,000 at a time. From the 1 million eggs, 850,000 fry are obtained. A hatching tray is divided into 4 compartments, each holding 10,000 eggs, for a total of 40,000 eggs per tray. After hatching, the yolk fry go by gravity to the holding tank under the tray.

From the holding tank, fry are placed into rearing tanks, each 7 m long, 1.5 m wide, and 0.5 m deep (22 ft × 5 ft × 18 in.). Each rearing tank holds 30,000 fry. These fry are then grown to a maximum length of 6 cm (2½ in.).

At 6 cm, the fry are transported to the second farm. This farm has a sufficient number of raceways to rear the fry to 10 cm (4 in.). A raceway is divided into three segments, each of which is 30 m long, 3 m wide, and 0.5 m deep (92 ft long × 3 ft wide × 18 in. deep).

After reaching 10 cm, fingerlings are transported to the grow-out farm for rearing to market sizes varying between 150 and 220 g (5.5 and 8 oz).

This farm (all three units) is designated as a disease-free, certified farm. Hence, sales prices for fingerlings are higher than noncertified farm prices. However, prices for food fish remain competitive with other producers. Sales of fingerlings from this farm during September 1975, were priced at \$8.70 per kg (\$3.95 per lb) for 7 cm (4¼ in.) fish. This amounted to about \$0.033 each. Prices at noncertified farms were \$5.16 per kg of fish (\$2.35 per lb), costing about \$0.02 per fingerling.

This farmer sells 100 MT (110 ST) annually. Fish, when sold, vary from 150 to 220 g (5.5 to 8 oz). The larger fish of 180–220 g are sold to local fish



Fig. 12.10. Overhead aeration from canal leading from a river.

markets and restaurants. Some are sold live and some in the round. Fifty metric tons are sold at an average price (in 1975) of \$2.98 per kg (\$1.35 per lb).

About 48 MT were sold live to fish farmers who also played the role of jobbers. These were the smaller fish of 150–180 g which sold for \$2.64 per kg (\$1.20 per lb).

Two metric tons were sold to fee fish-out ponds. Since there are none locally, they were transported about 200 km (132 mi) to middle France. Prices here were the same as to local jobbers, \$2.64 per kg (\$1.20 per lb).

Feed conversion from time of hatching to market size was 1.8 to 1. Feed cost was \$0.69 per kg (\$0.31 per lb).

Case 4. One of the nicest, but by no means the largest, fish farms visited by the author was in Brittany. This farm was owned by an elderly gentleman more than 80 years of age. Daily work was performed by one hired man, but during busy times, such as grading, an additional man was hired. Production was 50 MT (55 ST) per year.

The farmer had no pollution, had disease-free spawning stock, produced all his own eggs, and raised only his own fry and fingerlings. He had no disease problems and only minimal parasite problems.

This farmer had his own private spring which had a normal water flow of 300 liter per sec (4755 gal. per min). The lowest flow ever encountered was 180 liters per sec (2853 gal. per min).

Water temperature at the spring was 9°C (48°F). The temperatures of the discharge waters after being used in the fish farm were never lower than 6° or 7°C (44°F) in winter and never exceeded 21°C (70°F) during the worst heat wave.

Eggs are produced from January 15 to February 15 using 700–800 female spawners and 200–300 male breeders. Egg output averages 1.5 million annually. From these he sells between 200,000 and 400,000 fingerlings annually and 750,000 food-size trout. The survival rate is between 65 and 76%. His 12 to 15 cm (5 to 6 in.) fingerlings in 1975 sold for \$0.08 to \$0.09 each. The remainder of the fish, about 50 MT, were sold at 200–250 g sizes (7–8 oz). About 50% were sold locally through fish markets or to a nearby fish freezing plant. This plant freezes mostly saltwater fish. The remainder were sold through the central market in Paris.

Case 5. This involves perhaps one of the most interesting trout enterprises in France, located in central France.

Water supplies at this farm are furnished by springs having a total flow of 1000 liter per sec (15,840 gal. per min). The spring water is a constant 10.5°C (51°F). Two parts of recirculated water are used for each part of new spring water. Hence, total water flow is 3000 liters per sec.

Eyed-eggs are bought from northeastern French producers. Five and one-half million eggs are purchased during the November–February period. Production time, from hatching to market size, averages 16 months. Survivability during the rearing and growing-out stages to market weights

averages 56% of the eggs. The fish are marketed between 160 and 200 g (6 and 7 oz) to fish jobbers who add 20–40 g (1–1½ oz) of weight per fish. Eighty percent of their production is marketed between April and August to coincide with the tourist season in the area. In this area, producer trout prices do not follow the seasonal low prices of April–June of the National Market in Paris.

Maximum use is made of aeration, and production per unit of water flow was the highest found on any trout farm visited in Western Europe by the writer. Production was 555 kg of fish per liter of freshwater per sec (78.4 lb per gal. per min). Disease problems were minimal and mortality was less than that of many farms where only a fraction of his output per unit of freshwater was attained.

Additional labor efficiency was high. Production per worker averaged between 70 and 80 MT per year.

Production Costs

In nearly all, if not all, trout-producing countries, the major cost is for feed, and this is true for France. In 1975, feed costs for different feeds in 20,000 kg (44,000 lb) trucklots varied from a low of \$333 per MT (\$367 per ST) for 45% protein feeds for fish between 100 and 300 g (4 and 11 oz) to a high of \$378 per MT (\$417 per ST) for 50% protein feeds for young fry. Fish pellets for other stages of growth ranged between these two figures. A feed



Fig. 12.11. Intensive aeration of trout water.

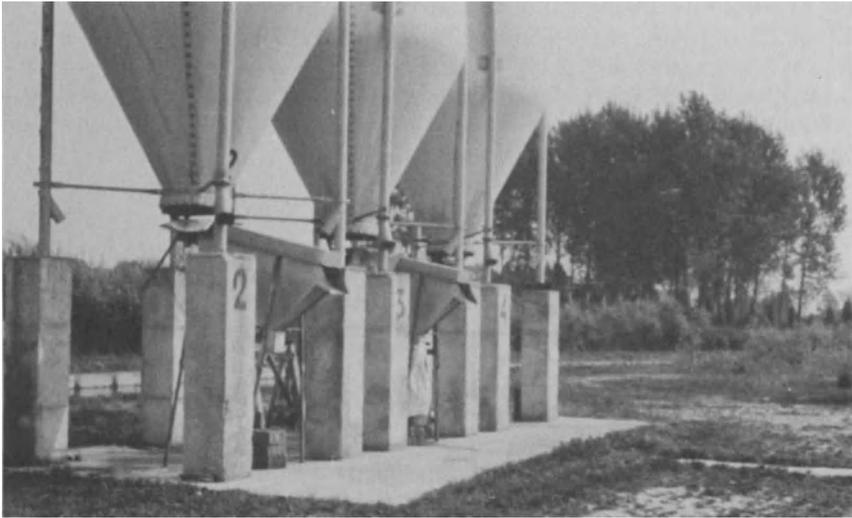


Fig. 12.12. Feed storage bins for trout feed.



Fig. 12.13. Mechanical feeding of trout from both sides of feeder.

conversion of 1.7 kg of feed per kg of growth resulted in an average cost of about \$0.58 per kg (\$0.26 per lb) for feed. This amounted to about 36% of total production cost.

From discussion and data secured from interviewing numerous trout producers, rather consistent figures for cost of production by areas appeared. In 1975, total costs of producing trout in France, including feed, labor,

fingerlings, and fixed overhead costs, ranged between \$1.38 and \$1.83 per kg (\$0.63 and \$0.83 per lb). The lower figure of \$1.38 per kg was representative of larger, more efficient producers and average size producers in Brittany. The higher figure of \$1.83 per kg was for the smaller, less efficient producers outside Brittany. A mean cost of \$1.60 per kg (\$0.73 per lb) would probably be representative of the average producer.

Outlook

In 1979, rainbow trout production was hovering around 18,000 MT annually (19,800 ST). Estimates by French trout producers and specialists suggest production could increase by 10 to 20% before all existing freshwater of the proper temperature and purity, including seasonal production, would be used.

This projected increase does not take into account possible increases from fish disease control. The worst disease is viral hemorrhagic septicemia (VHS), which may be restricting total production by 15%. In addition, some farmers have problems with infectious pancreatic necrosis (IPN), which affects young trout.

Moreover, if all producers were able to increase output per unit of freshwater flow to the maximum possible, production might well increase by 50–60% (see later section on "Hydrologic Information"). In addition, if brackish water culture expands, there may be no foreseeable limit on this type of production. There are thousands of hectares of brackish water area in France which could conceivably be converted to production. Present techniques result in 4 to 20 MT per ha (1800 to 9000 lb per acre). Among



Fig. 12.14. Rainbow trout produced in brackish water on the way to market.

these four possibilities, it would appear possible for trout production to at least double in the foreseeable future.

BROWN TROUT (*Salmo trutta*)

Brown trout are not commonly grown in France as a food fish. However, there is a large demand for brown trout fingerlings for restocking rivers and streams. The number of fingerlings stocked could not be determined. However, there are approximately 4,200,000 licensed anglers, many of whom fish primarily for brown trout. Hence, the number of fish stocked could be somewhere between 50 and 100 million fish.

CARP (*Cyprinus carpio*)

There is one intensive carp producer in France. He feeds his fish and fertilizes his ponds, and is reputed to be the largest producer of carp in the country. His total production of 225–250 MT is produced from 200 ha of water. Average production is 1.25 MT per ha (1.1 ST per acre).

The remainder of carp producers are extensive enterprises, using no feed and little or no pond fertilization. The number of these producers is unknown, but may number several hundred. On the extensive-type operations, production is estimated to be about 180 kg per ha (160 lb per acre).

Total cultured carp production is difficult to determine. No government studies or data are available, and discussions with different individuals who are extremely knowledgeable about France's cultured fish industry resulted in widely varying estimates of total production, hectares of production, and area of consumption. The most pessimistic estimate of carp production was 5000 MT (5510 ST). The most optimistic estimate indicated 14,000 MT (15,428 ST), and the most common estimate was 8000–10,000 MT (8816–11,020 ST). Since total production is a function of total hectares of water area and yields per hectare, it was only natural that these estimates also varied widely.

Estimated consumption ranged from 80% of some unknown quantity exported to West Germany and 20% consumed in France, to 80% consumed in France and 20% exported to West Germany. Data secured in West Germany for carp imports from France for the 1970–1975 period indicate that even the most conservative estimate of production and exports to West Germany was too high. Annual imports from France during these years varied from a low of 300 MT to a high of 792 MT. (See Chapter 8 on West Germany.) Areas of production are shown in Fig. 12.15.

More solid estimates indicate that very few farmers make their living solely from carp production. Production and sale of carp are supplementary farm enterprises. There was general agreement that many fingerlings were sold for sports fishing and that nearly all carp food fish were sold at the end of three summers of growth at slightly more than 1 kg of weight.



Fig. 12.15. Carp (*Cyprinus carpio* L) areas in France, 1975.

EUROPEAN EELS (*Anguilla anguilla*)

There were only three intensive eel farms in France in 1975, and all three were discontinuing operations. Reported reasons for discontinuance were relatively low domestic eel price and technical production problems, such as high mortality during the 0.2 to 20 g growth period.

A general statement is that the French have no preference for eels. Most of the wild catch is exported to Italy, Belgium, Holland, and West Germany. Approximately 90% of the total catch, about 8000 MT (8816 ST), is exported. This is divided into 4000 MT caught in freshwater, 3000 MT in brackish waters of the French Mediterranean, and 1000 MT in brackish waters on the Atlantic side of France. Because of the abundance of wild eel, prices are low. In spite of these factors, there are several enterprises either planned or in process to culture eel extensively (no feed). One such project is near Guerande where extensive culture is planned on old salt beds. Eel culture is also conducted at Croisic near Nantes.



Fig. 12.16. Saltwater culturing ponds and feeding stations for eel.

Culturing techniques call for feeding freshly ground redworms during the first three weeks after the elvers are captured. Then in brackish or salt water, the eels are gradually converted to fish fillets. In freshwater, a binder can be added to artificial foods, and after the first 3 weeks, finely ground fish meal can be fed. Feed conversion with mackerel is about 5:1, while feeding other raw fish results in about a 7:1 ratio. During the first season of growth, the eels may grow from 0.2–0.4 g elvers to 20–30 g black eels. At the end of the second season, eels of 150–200 g can be expected.

One intensive farm visited used salt water in its intensive operation. The ponds were 1000 m² and 1 m deep (10,760 ft² and 39 in. deep). Each pond produced 1.2 to 1.5 MT (1.3 to 1.4 ST), for a total output of 10 to 12 MT per ha



Fig. 12.17. Seining harvesting channel in earthen eel culturing pond.



Fig. 12.18. Mechanical loading of eel catch from harvesting channel in earthen eel pond.

(25 to 30 ST per acre). Each pond had 5 m³ (176 ft³) (1322 gal.) of saltwater flow per hr. Each pond also was stocked with a few sea bass (*Dicentrarchus labrax*) and mullet (*Mugil cephalus*). These fish feed on the eel excreta.



Fig. 12.19. Harvested eel being transported to holding tanks.



Fig. 12.20. Holding tanks for harvested eel.

COHO SALMON (*Oncorhynchus kisutch*)

There is only one coho salmon farm in France. It is operated by the federal government as a pilot demonstration farm. Production in 1975 was between 40 and 50 MT. In 1976, production was forecast at 120 MT. It is believed that between government and private individuals, production could reach 3000 MT. Part of existing production is used for stocking streams and part for food fish.

CRAYFISH (*Astacus leptocylus*)

Crayfish are a gourmet item in France and command a premium price. In addition to the capture of an unknown quantity of wild crayfish, about 1300 MT are imported. About 80% of this volume is imported from Turkey and 20% from Poland and Eastern Europe. Domestic production from six cultur- ing enterprises is estimated at 10 MT annually.

The largest crayfish enterprise in France was visited. This farm has 4 ha of water divided into 32 ponds. About 10 MT (11 ST) of crayfish are in various stages of culture.

This farmer cultures Turkish crayfish which mature in 2–3 years, as compared to 5–6 years for the Polish crayfish. Several hundred thousand juvenile crayfish are produced annually. Each female produces 50–100 eggs. Shrimp pellets are fed exclusively. Average weight of food-sized crayfish sold is 40 g or 25 per kg (11 per lb). The producer price in 1975 was about \$6.50 per kg (\$3.00 per lb), or \$0.26 per crayfish. Crayfish sold for propaga-



Fig. 12.21. Dip net for harvesting crayfish.

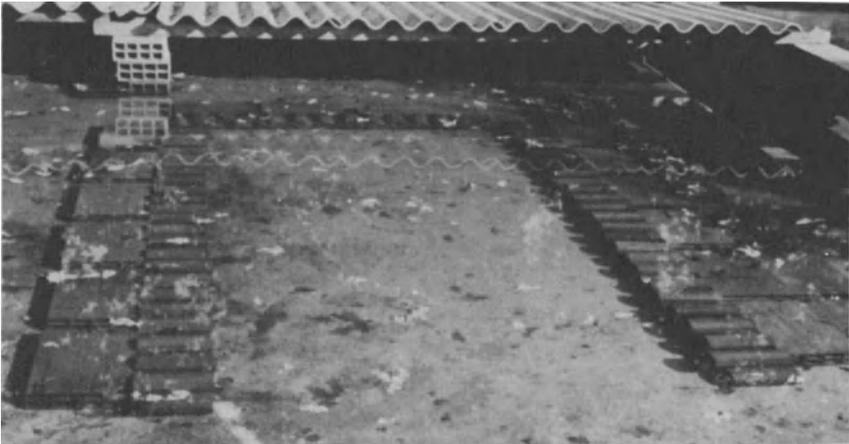


Fig. 12.22. Intensive culture of crayfish in terra cotta pipes.

tion purposes are, of course, higher priced. With imports of 1300 MT and a price of \$6.50 per kg, the minimum amount spent for imports is about \$8½ million annually.

It is essential that each crayfish have its own quarters. Hence, each pond is furnished with thousands of terra cotta pipes about 20 cm long and 6 cm in diameter (8 in. × 2½ in.). In the more intensive, cultured ponds there can be as many as 40 crayfish and 40 terra cotta pipes per m² (10 ft²), which necessitates stacking the pipes three and four high. These resemble a hotel with each dweller looking out of his private picture window. With production of this intensity, there can be an annual gross return of \$10.80 per m²



Fig. 12.23. Cultured crayfish, the end product.

every two or three years. This calculates out to \$108,000 per ha (\$43,725 per acre).

HYDROLOGIC INFORMATION

One measurement of management effectiveness is the volume of trout which can be produced per unit of flowing water. In the USA, Buss and Miller (1971) state that in one heavily aerated hatchery in Pennsylvania, production of more than 589.6 kg per liter per sec (82 lb per gal. per min) of water flow was attained. They said that this was far above the accepted maximum of 360–396 kg per liter per sec of water (50–55 lb per gal.). While there is no recommended minimum, it would appear that a production rate of one-half of the maximum could be attained to increase the effectiveness of a given water flow.

In West Germany, the commonly accepted standard is that 100 kg of production should result from a flow of 1 liter per sec (13.8 lb per gal. per min). This would appear to be about 28% of the maximum potential.

In Denmark, the production rate is normally about 200 kg of production per liter of water flow per sec (27.8 lb per gal. per min). This result is 100% better than the West German level, but is still only 56% of the maximum potential. Growers in Denmark admit that they do not stock their waters at the maximum rate, but understock because sometimes in winter the streams feeding the ponds freeze over and water flow and oxygen levels drop.

In Italy, where the trout waters never freeze and minimum temperature is 12°C (54°F), a high production rate is 143 kg of production per liter per sec (19.9 lb per gal. per min). While this rate is better than for West Germany, it is only 40% of the maximum possible.

In southern France, one average trout enterprise producing 50 MT of trout annually uses only spring water which does not freeze in winter. This farmer produced at the rate of 278 kg per liter per sec of water flow (38.6 lb per gal. per min).

At a second trout farm in central France, 550 MT were being produced from spring water. Approximately one-third of total water in the system was freshwater and two-thirds was recirculated. Maximum aeration was used. Production rate was 555 kg of fish production per liter of freshwater per sec (76.5 lb per gal. per min). Disease problems were minimal, and mortality was less than that of many farms where only a fraction of this output per unit of water was attained.

These latter examples indicate that production of rainbow trout in Western European countries, where stream flow is not restricted by freezing in winter and water recirculation in summer still permits the water temperature to remain low enough, has not attained its maximum production volume. If maximum use were made of trout waters, production could double in Italy and increase by significant amounts in France and Spain.

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Spain

FISH SPECIES

Atlantic salmon (*Salmo salar*)

Brown trout (*Salmo trutta*)

Carp (*Cyprinus carpio*)

European eel (*Anguilla
anguilla*)

Largemouth bass (*Micropterus
salmoides*)

Northern pike (*Esox lucius*)

Rainbow trout (*Salmo gairdneri*)

Tench (*Tinca tinca*)

Spain

RAINBOW TROUT (*Salmo gairdneri*)

Cultured fish destined for sale for food use is a relatively recent development in Spain. There was little or no production before 1965. In 1975 there were 112 private fish farmers producing between 5000 and 6000 MT (5510 and 6612 ST) of rainbow trout. By 1979 production had reached 9000 MT (9900 ST). The total volume of rainbow trout eggs produced for all purposes was 100 million compared with 3 million Atlantic salmon (*Salmo salar*) and 6 million brown trout (*Salmo trutta*). All of the production of rainbow trout is consumed domestically; there are practically no exports or imports of commonly cultured freshwater fish.

The rainbow trout spawn in the October–March period and after reaching about 6 cm (2½–3 in.), fingerlings are placed into concrete raceways for growing out. A small proportion of the trout are grown in earthen ponds.

All fish are fed pelletized foods. Fish are harvested at about 200 g (7 oz), although a few are raised to 2 or 3 kg sizes (4½–6½ lb). These latter are for smoked fillets. Nearly all of the 200 g fish are sold in the round, packed in ice. Average production time from egg laying to the 200 g size is about 15 months.

The majority of rainbow trout is sold by the farmer directly to buyers for fish markets. The fish market in turn sells directly to the final consumer.

Fish farms exist in all parts of the Iberian Peninsula but the majority are located in the northern half of the country. The ideal farm is located close to a large spring but many farms are using river water. In 1975 there was little or no fee recreation fishing, but some farmers were in the planning stages of initiating fee fishing outlets for the public.

OTHER FRESHWATER FISH

Other than rainbow trout, there is not commercial production of freshwater cultured fish destined for immediate food consumption. However, the state has 23 fish hatcheries in production. These hatcheries produce a variety of fish for restocking river and stream beds. In 1974 the restocking program was as follows:

Species	Number of Fingerlings
Brown trout (<i>Salmo trutta</i>)	4,648,150
Rainbow trout (<i>Salmo gairdneri</i>)	3,707,562
Largemouth bass (<i>Micropterus salmoides</i>)	<u>1,005,000</u>
Carp (<i>Cyprinus carpio</i>)	838,500
Atlantic salmon (<i>Salmo salar</i>)	363,800
Northern pike (<i>Esox lucius</i>)	162,000
Tench (<i>Tinca tinca</i>)	7,000
Other	<u>36,790</u>
Total	10,768,802

MARINE CULTURE

Cultivation of marine fish in Spain is only in its beginning phases. In 1975 there were two private groups experimenting with Atlantic salmon culture (*Salmo salar*). One of these was located at the mouth of the river Arosa in Villagaracía province and one at the mouth of the river Ortigueira in La Coruña province. Both of these projects were still in the experimental phases and salmon culture can be said to be still noncommercial. Salmon at these two sites are produced in saltwater net enclosures. Eggs and fingerlings are produced in freshwater for stocking in these pens.

EUROPEAN EEL (*Anguilla anguilla*)

There is no culture of the European eel in Spain. An undisclosed volume of wild eel is caught annually, and these are consumed domestically. There is no exportation of elvers or adult eel and no importation.

OUTLOOK

Production of rainbow trout for food started only about 1965 in Spain. In 15 years, production had reached 9000 MT. Water limitations may check production at about the 10,000–12,000 MT limit. Additional production can also be attained by intensifying production per unit of flowing water. The domestic market has readily accepted rainbow trout and can probably expand to accommodate increased production.

There is also a predicted future for salmon culture. However, commercial production may never exceed several hundred metric tons annually.

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Portugal

FISH SPECIES

Atlantic salmon (*Salmo salar*)

Brown trout (*Salmo trutta*)

Carp (*Cyprinus carpio*)

Rainbow trout (*Salmo gairdneri*)

Steelhead trout (*Salmo irideus*)

Portugal

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

As in Spain, culturing fish for food use is a relatively recent development. All production began only within the past 15 years. In 1976 there were only four private individuals culturing rainbow and brown trout. The area of production is in northern Portugal in Paredes de Coura, Vila Conde, Manteigas, and Viseu. About 250 MT (276 ST) of trout, nearly all of them rainbow, are produced annually. All production of trout is consumed domestically. There are practically no exports or imports of freshwater cultured fish of food sizes.

The trout spawn in the November–February period. In addition to domestic egg production, about 1.5 million rainbow trout eggs are imported. The fry are raised in concrete troughs until they reach about 6 cm (2.5 to 3 in.). They are then stocked in concrete raceways for growing-out.

All fish are fed pelletized foods. Trout harvested at about 200 g (7 oz). Nearly all the 200 g fish are sold in the round, packed in ice. Average production time from hatching to the 200 g size is from 12 to 15 months, depending on water temperatures.

Nearly all trout is sold by the farmer directly to retail fish markets which sell to the final consumer. Hence the marketing channel is very direct.

In 1976 there were few or no fee fish-out operations. However, this type of outlet is being discussed.

CARP (*Cyprinus carpio*)

In 1976 there were several carp farms in Portugal. Total production was estimated at 50 MT (55 ST).

Carp spawn in the March–May period and are then raised in earthen ponds. Farming is extensive, which means that few or no feeds are fed. After about 2 to 3 years the carp reach their market sizes of about 1 kg (2.2 lb) and are sold directly to homemakers or to retail fish markets.

MARINE CULTURE

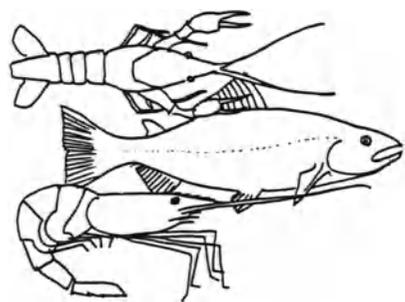
Cultivation of marine fish centers on steelhead trout (*Salmo irideus*) and Atlantic salmon (*Salmo salar*). However, production cannot be said to be truly commercial. About 500,000 steelhead trout eggs and 300,000 Atlantic salmon eggs are imported yearly for restocking streams leading to the ocean. Production of both species combined is less than 100 MT (110 ST).

OUTLOOK

It has been predicted that production of cultured fish will increase at least 20% in the next 10 years and that this increase will be essentially in rainbow trout. It is difficult to predict the expansion of marine fish culture since it is not really commercial at present. With marine cultured fish, much depends on price relationships and price levels of the same and other species of wild marine fish. An increase in the price of salmon and steelhead trout would be conducive to expansion of culturing.

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United Kingdom

FISH AND OTHER AQUATIC SPECIES

Carp

Crayfish

Crucian carp

Crustacea

Dover sole

Eels

Koi

Mirror carp

Molluscs

Orfe

Rainbow trout

Salmon

Tench

Turbot

Ornamental fish

United Kingdom

Shawn R. Prescott

Fish farming in the United Kingdom has progressed dramatically in the last decade so that today the U.K. ranks about sixth in Europe for farmed fish. Total production was about 4400 MT in 1980 and 5200 MT in 1981 (Anon. 1981). Regrettably, however, the majority of the production is concentrated on one species, viz., rainbow trout. Nevertheless, the interest in farmed fish, actively encouraged by the media, is now extending the commercial horizons into such species as: salmon, Dover sole, turbot, eels, crayfish, and carp.

A characteristic of this latter development is the entry of many large companies looking for diversification that have the capital, technical expertise, and marketing abilities which any "new frontier" industry must have in order to achieve maturity.

The government has several research laboratories working with the industry to overcome the biological problems, disease, marketing, and related problems. These laboratories are working more effectively than in the past in close liaison with the industry, and seminars are now a regular part of the curricula for the industry.

Specialized areas of mutual interest are emerging, for example, the Shellfish Assoc. of Great Britain, which brings together in an annual conference all parties interested in the production of molluscs and crustacea. Trout farmers have also their own association and Scotland has its own now specialized Fish Farmers Union under the aegis of the National Farmers Union.

Compared with the diminution of the natural Fishing Industry the production of farm fish is a mere fraction of what would be needed to replace the drop in the fish landings; however, the industry is in a position to exponentially increase production in the coming decade.

RAINBOW TROUT

The number of producers was estimated to be about 160 in 1978 in the United Kingdom, of which about one-third were in Scotland (Lewis 1980). The majority of the producers are only small-scale ones; they sell their fish at the farm gate or to local hotels and restaurants. Production in 1979 was

about 4415 MT, and planned production for 1980 was 6001 MT (Lewis 1980), but any statistics are suspect as many small "hobby" producers keep incomplete records.

Trout producers have, however, been forced by pressure of the market to organize themselves to produce better quality fish, available at a size and weight that the supermarket and other large buyers require, and to plan their production in such a manner that the fish are available on a year round basis.

It appears that about 15% of the farms produce two-thirds of trout production. These farms, which are larger, are increasingly being run on typical big business lines with costings planned down to the last detail and contract marketing at preagreed prices often to large retail outlets.

Certain trends are emerging which parallel in many respects the dynamics of the poultry industry of the 1950s and 1960s. These are the division into specialized production of eggs and fingerlings and the dominance in certain areas of a more successful producer who sets standards and will purchase production of other producers at a guaranteed price, subject to a standard of quality which is laid down and delivery at specified times.

Problems in Rainbow Trout Farming

- (1) Disease has been a major problem. Despite intensive efforts by the government laboratory in Weybridge and in Scotland by the disease laboratory of Sterling University, one very large multinational industry had to close down a very large farm due to the ravages of infectious pancreatic necrosis (IPN). However, certain producers of eggs are certified disease-free, and gradually with the spread of both positive and negative information and pressure from the insurance companies, it is possible to foresee a major reduction of the problem.
- (2) Rating is a problem on buildings and other installations, due to a "no-man's-land" attitude of national and local government toward fish farming. The fish farmer, unlike his agricultural cousin, finds himself rated on his assets in the same way as an industrialist. Bearing in mind the vagaries of all forms of farming, including fish, and the slow cash flow relative to manufacturing, this is patently unfair. Despite many representations made to government, etc., and notwithstanding the platitudes of the functionaries whenever they appear on the printed page or in other media, nothing has been done to rectify the matter, despite decade and more during which the matter has been raised on many occasions. Recently the National Farmers Union has taken up the matter, but it is doubtful that the matter will meet with a high degree of priority.
- (3) Lack of cooperation in marketing, especially among a large number of smaller farms, means wide variation in quality standards, erratic supply, and no dynamic advertising to educate the consumer. The

average family either has never eaten trout or has done so only once or twice a year in a restaurant.

At the same time, the Danish Fish Producers have an aggressive marketing policy and there is considerable possibility of a sustained campaign on the United Kingdom market by the Danish producers, with the possibility of creating for these producers a leading position as have the Danish producers of bacon. It is also difficult to persuade leading chain supermarkets to stock and promote trout unless quality, quantity, and delivery year round can be assured, and no single producer can do this alone. United Kingdom Trout Farmers will have to learn to cooperate rapidly if the market and their share of it are to increase to meet their full potential.

SALMON

Salmon in the United Kingdom are farmed in cages in sea lochs after the smolts have adapted to salt water by an acclimatization process. Unilever, through its Marine Harvest Operation, pioneered commercial salmon farming by this method in the U.K., and after many trials and tribulations, has brought it to profitable fruition. Today there are several companies such as Fitch Lovell, Booker McConnell, etc., in production or about to get involved. Production is increasing rapidly and the product is well accepted, so that other large firms in the industry such as Barons Smoked Salmon are actively pursuing plans to build their own production units. Production figures currently are estimated to be 1000 MT per annum with an estimated production of 5000 MT per annum by the mid-1980s.

Production

Production of salmon in the U.K. is almost totally confined to Scotland. Sites have risen from 1 in 1969 to 47 in 1980 (sites include saltwater and freshwater units). Total tonnage produced was 538 MT (598 ST) in 1980; shortage of smolts appears to be a limiting factor in increasing production. Smolt production was 1,418,000 in 1980 compared with 834,000 in 1979, an increase of 70%. These figures show a rising trend of some magnitude and should show up in considerably increased production for the 1980s. Using standard industry loss estimates, the 1980 smolt production should produce 1530–2250 MT (1700–2500 ST) of salmon (Munro and Waddell 1981).

Problems

Red tides have caused heavy losses of salmon in certain areas so that a special group is now studying the subject. Suitable sites are becoming scarcer as cage farming requires good, unpolluted water, away from commercial and leisure traffic, with some protection from the elements in the form of hills or other natural barriers preventing ravages to the farm from

storms as well as tides. Access to the site is essential for servicing the farm and marketing the produce. The suitable areas are mainly to be found on the west coast of Scotland, but the best of these are now unavailable, and while there are undoubtedly other sites to be developed, they will soon be at a premium.

DOVER SOLE AND TURBOT

Government laboratories have led the way in research in this field and the results are now looking more encouraging for commercial exploitation. Farms are already in limited production, viz., at Huntersdon, Oban, and the Isle of Man, and other companies and individuals have serious plans to move into this field within the next couple of years. In particular the planned units envisage the use of the heated effluent of power plants. The WFA (White Fish Authority, government body) research unit at Huntersdon has just been given permission to enlarge its production to 10 MT per annum. No figures are available for the commercial production but it is quite realistic to look for 500 MT plus per annum by 1985.

EELS

Eel production was confined until very recently to the collection of elvers for export to other countries, principally in mainland Europe such as Holland. These are collected mainly from two areas, the Severn estuary and its tributaries and Loch Neagh in Northern Ireland. In the last couple of years, however, lured by the potential of very large profits (30% net return on sales is theoretically possible) from successful rearing to adults, a few large companies, including a major brewer, have entered the market for growing out the elvers using heated power plant effluent. This farming could possibly show the greatest future growth of all fish farming in the United Kingdom.

CRAYFISH

There is a growing interest in this exotic species, especially as its demands are relatively unexacting. However, most interest at this stage appears to be confined to individuals and farmers who are experimenting with low level production. The potential, especially for export to the nearby French market, is large, but marketing will be difficult unless worthwhile quantities become available. Current production is estimated at about 100 MT per annum, all for export.

Cultivation and Harvesting

Cultivation consists of buying a quantity of breeding stock and placing them in a large unused lake or large pond. An indigenous self-reproducing

population will usually take 4–5 years to establish itself. The population eats detrital matter for the most part, or decaying vegetation. After the fifth year, harvesting by draining down the ponds can be commenced, making sure to leave a sufficient quantity of adults for reproduction.

CARP

At least 4–5 carp farms have emerged in the last few years despite the fact that the growing season is confined to about 5 months of the year and that the market is still a small ethnic one in the United Kingdom. One or two of these farms produce mirror carp and crucian carp for stocking of lakes and commercial ponds.

Carp cannot be produced to table size in 5 months in the U.K., and the warm summer months are the only ones with a temperature suitable for any growth at all. Thus, it takes two or more seasons to produce table size fish. The potential here could be much larger if the growing season were increased to 12 months a year by using the warmed effluent of a power station, and it may well be that this will shortly be done by one of the producers.

OTHER SPECIES

Several producers of ornamental fish exist throughout the country, producing under controlled or natural conditions such specials as koi, carp, tench, orfe, etc. Figures are almost impossible to obtain, but most of them are sold out for long periods in advance and, by all information available to the author, most do better out of their production financially than the majority of trout farmers.

OUTLOOK AND CONCLUSIONS

Two magazines devoted exclusively to fish farming have emerged in the last four years, viz., *Fish Farming International* and *Fish Farmer*. Also, under pressure from the needs of the industry, diploma courses in practical fish farming for young people wishing to pursue a career in this field are now offered in Hampshire and Scotland. These facts point to a growing awareness of the needs of the emerging industry as well as an appropriate response to these needs in developing the information and training which are prerequisite to successful development of the industry.

In addition, the service side of the industry is beginning to organize in terms of engineering supplies, tanks, and all the paraphernalia (pumps, valves, electronic warning devices, heat exchangers, automatic feeders, air diffusers, etc.) needed by a young and growing industry. Previously this was lacking. Employment in the industry in Scotland is now estimated to be about 1000, whilst in England and Wales it is probably between 1500 and 2000. The holding of regular seminars plus greater interest due to falling

natural catches will almost certainly ensure that the total production of all farmed fish by the end of the current decade will be 20,000–30,000 MT per annum. The most important requirements to ensure this end are, in the opinion of the author:

(1) Appropriate legislation to remove certain anomalies and thus set the climate for large-scale production and to protect the riparian rights of farmers.

(2) National and cooperative marketing policies to educate the consumer and compete against other food in the market.

(3) The protection by River Boards and other appropriate authorities against pollution of natural water, if necessary by severe penalties toward offenders.

SOME GOVERNMENT RESEARCH LABORATORIES

Lowestoft (England) Shellfish Research Laboratory.

Conway, N. Wales, WFA (White Fish Authority). Shellfish Laboratory—reproduction of oysters and prawns.

Weymouth (England) MAFF Ministry of Agriculture and Fisheries Laboratory. Research into fish diseases.

Plymouth (England) Marine Biological Laboratory.

Torry, Aberdeen, Scotland, Fish Processing Laboratory.

Dunstaffnage, Scotland, Scottish Marine Biological Laboratories.

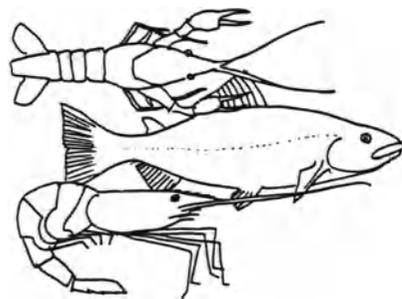
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Ireland

FISH SPECIES

Atlantic salmon (*Salmo salar*)

Brown trout (*Salmo trutta*)

European eel (*Anguilla
anguilla*)

Rainbow trout (*Salmo gairdneri*)

Trash fish

Ireland

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

Culturing of rainbow trout for food consumption in Ireland began about 1965. Since then the industry has grown slowly. In 1975 there were only 6 fish farms with total production between 500 and 600 MT (550 and 660 ST). Of this amount only 50 MT were consumed domestically and nearly all the remainder was exported. Of the estimated 500 MT exported, over 95% went to Great Britain and limited quantities to France.

The reason so little trout is consumed domestically is that traditionally the Irish are a meat-eating people. Beef, mutton, and lamb constitute major portions of the diet. When the Irish eat fish it is a saltwater species, the cost of which is only about one-half the rainbow trout price.

The typical trout farm is fed by river or stream waters rather than from springs. The rivers are described as "racy." This means that the water flow varies considerably, depending on rainfall, and may vary from lethargic to torrid Niagara currents. This makes it difficult to locate a farm in order to take advantage of gravity flows without subjecting the farm to periodic flooding.

Each farm generally performs all steps in the fish culturing system. They raise spawners, produce eggs, hatch them, raise the fry to fingerlings, and grow them out to food market sizes. Water temperatures vary from a low of 5° to 7° C (41° to 45°F) in winter to a seasonal high of 14° to 16°C (67° to 71°F) in summer. The normal spawning period is from November through February. The normal hatching month is March. After hatching, the fry are grown to about 7 cm (2.5 in.) in concrete tanks and are then stocked for grow-out in Danish type earthen ponds. No mechanical aeration is used. After hatching, a period of about 18 months is required for the fish to reach market size because of the cold water. Since most fish are exported, this means market sizes are essentially those demanded in Great Britain (170 to 220 g, or 6 to 8 oz). This size is also in demand in France. The fish are sold in the round (whole and ungutted) and are iced for delivery. They are

sold directly from farms to importers, who are usually wholesalers in London, Manchester, or Wales.

All fish are fed artificial foods. Fry are fed pellets having 48 to 50% protein content. However, during the grow-out process a much cheaper feed containing only about 35% protein is fed.

Considerable effort is made to ensure low cost production because of low prices. This is shown by the type of earthen ponds used and cheaper feeds. In 1975 the farm price was estimated at \$1.54 per kg (\$0.70) per lb).

In addition to the 500 to 600 MT, there are some rainbow trout stocked in enclosed public ponds for sports fishing. In 1975 there were three such ponds or lakes stocking a total of only 50,000 fish.

The Irish government is conducting some experimental raising of rainbow trout and Atlantic salmon (*Salmo salar*) in brackish water and seawater. However, there is no commercial production of these two species by private growers at present.

In addition to rainbow trout production, there is a governmental restocking program for brown trout. An estimated 1 million one-year-old fish averaging about 110 g (4 oz) are stocked annually in public waters and by angling clubs. Anyone can fish free of charge without a license in either the public or angling club waters for freshwater fish. However, salmon fishing requires a license.

Because of the good fishing available in public waters, there is no demand for fee fish-out facilities. Hence there are no fee fish-out lakes or ponds in Ireland.

EUROPEAN EEL (*Anguilla anguilla*)

There is no culturing of eel in Ireland, although there is commercial fishing for this species. The amount of catch is unknown, but may total 1000 MT (1110 ST). Certain inland waters have very high eel production. For example, Lough Neagh, which covers 35,000 ha (87,500 acres), produces 700 MT per year. This amounts to about 20 kg per ha (about 20 lb per acre).

The government, in order to maintain the commercial catch of eels, has a restocking program. Elvers (migrating young eels) are captured in some of the infertile waters and transported to more fertile inland waters.

Adult eels are commonly caught in nets as they migrate downstream. Domestic consumption of eels is small and nearly all of the estimated 1000 MT are exported. Exports go mainly to France, Great Britain, and West Germany, with minor quantities to Holland and Denmark.

OUTLOOK

The outlook for the Irish cultured fish industry is for continued growth in production of rainbow trout. Within 10 years, production is estimated to

nearly double to 1000 to 1200 MT from the present 500 to 600 MT. While it is possible for some salmon production to occur in seawater, the outlook is for very minor quantities of production. This is largely due to the lack of trash fish for feeding.

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Poland

FISH SPECIES

Bream

Common carp

Coregonids

Cyprinids

Eel

Freshwater fish

Pike

Roach

Trout

Poland

Marian Leopold

Total surface area of Polish inland waters amounts to about 470,000 ha (1,161,000 acres). In this about 305,000 ha (753,000 acres) are represented by lakes, 104,000 ha (251,000 acres) by rivers and dam reservoirs, and 60,000 ha (145,000 acres) by ponds. The most important users of these waters are State Fish Farms and the Polish Anglers Association. State Fish Farms use over 91% of total lake area and 86% of total pond area. The Polish Anglers Association uses 70% of total area of rivers and dam reservoirs and 6% of total lake area. Additionally, the Polish Anglers Association has the rights to carry out sport fishing on the majority of lakes managed by the State Fish Farms.

Apart from the foregoing, there are in Poland a various number of small and very small water bodies (small lakes, ponds, pools, old riverbeds, quarry lakes, etc.) which are not included in official records although they are of significant fishery value, especially for recreational fishery.

More or less intensive fish farming is carried out on a large scale by State Fish Farms, mostly upon lakes and ponds (Lake Fish Farms and Pond Fish Farms). In Poland both lake fishery and pond fish farming have a long tradition, dating back to the Middle Ages. This is especially true of pond farming and still affects its economic and production results. At present, the traditional division between pond and lake fish farming is becoming less and less visible, mostly due to the introduction of new biotechniques and forms of fish culture. Nevertheless, this discussion will treat fish farming in Poland according to the traditional division.

POND FISH FARMING

Common Carp

The main species cultured in ponds is common carp, which constitutes almost 100% of total pond fish production. Carp farming is carried out in a two or three year production cycle.

Culture. In Poland conditions for carp culture are rather unfavorable. Nevertheless, carp production in Poland steadily increases. For the period



Fig. 17.1. A typical fishpond.

of 1957–1978, carp production increased by 4.35% annually. Pond fish production in Poland is presented in Fig. 17.2. As is seen, carp production is characterized by significant variability in particular years; coefficient of variability amounts to 30.2%. These variations result, most of all, from climatic conditions. For instance, maximal difference of production of almost 8000 MT (8800 ST) which was noted between two successive years, 1977 and 1978, resulted from a significant difference of average annual temperature in 1975 and 1976. On a national scale this difference reached 2°C (3.6°F), being even higher in some regions of the country. Unfortunately, it is obvious that using even more modern biotechniques of fish culture would not diminish fluctuations of fish yield because of such great differences in average temperatures in particular years.

Improved Biotechniques. In spite of the problems cited, pond production in Poland is characterized by increasing production, mostly due to the introduction of improved biotechniques of fish culture. In this case, basic operations are attempts to prolong the growing season. Favorable natural climatic conditions last only 150–160 days. For comparison, length of the growing season in neighboring Czechoslovakia is 6 months and in Yugoslavia 8 months. Prolongation of growing season is achieved mostly by earlier artificial hatching and rearing of carp stocking material in special rearing units (hatcheries). These operations are also connected with attempts to improve the production of carp stocking material, as regards both quantity and quality. Unfortunately, climatic conditions favor neither quantitative nor qualitative production of carp stocking material.

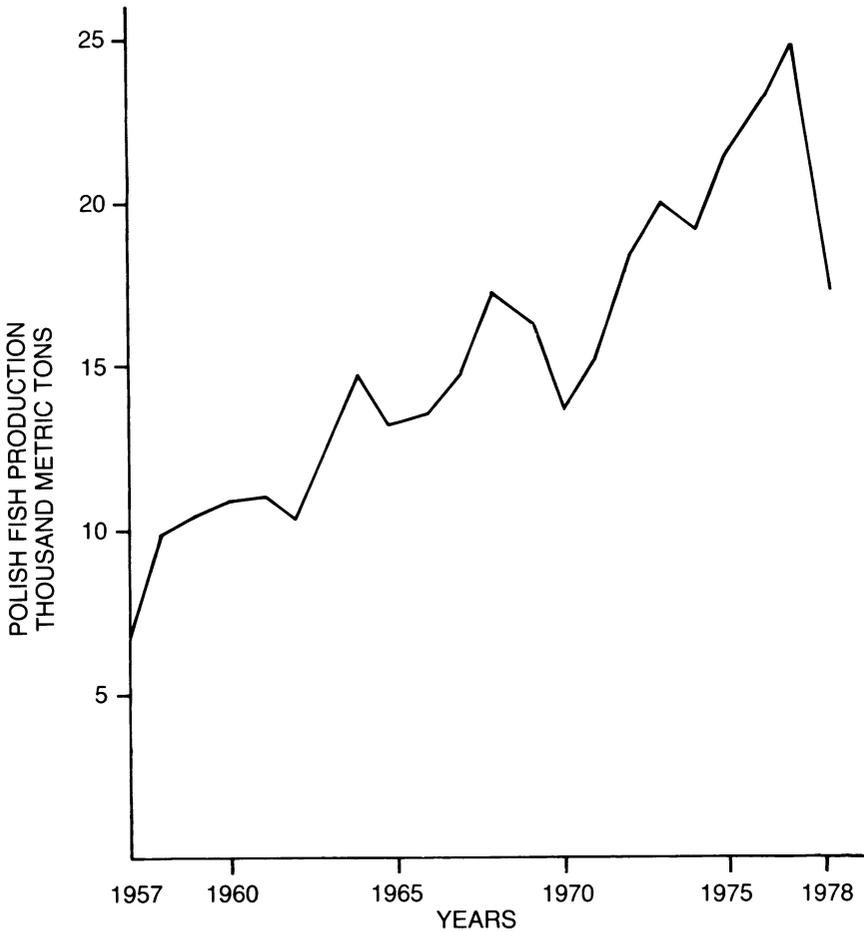


Fig. 17.2. Carp pond production in Poland in the period 1957–1978.

The State of Pond Production

The other unfavorable factor affecting pond production of carp in Poland is the state of production basis, i.e., the state of ponds. Pond carp culture is carried out by State Pond Farms which were created after World War II as a result of land reform and nationalization of large private land estates. The size of these pond farms varies between 300 ha and 1500 ha (740 and 3705 acres). Apart from the rare, newly constructed (post-war) farms, area of the existing pond farms is certainly not an optimal one, neither as regards the organization of production nor the organization of work. In most cases, area



Fig. 17.3. The so-called "plastic-covered tunnel." This type of facility is commonly used for earlier artificial spawning of carp and pre-rearing of carp stocking material. Its application prolongs the growing season.

of particular farms was established depending on the number of ponds in the given region. Large and compact farms are scarce; on the contrary, dispersion of ponds within particular farms is rather characteristic.

There are several reasons for such a situation, but the basic one is the historical background of pond culture in Poland. Ponds constructed tens or even hundreds of years ago occupy the largest area of the existing farms. Numerous farms operate ponds constructed in the 13th and 14th centuries. Significant development of pond culture in that period was connected with religious reasons (three days of fast in a week), and rather high profitability of fish production compared to other forms of agricultural production (mostly due to very cheap labor). As a rule ponds were constructed within large agricultural (land) estates, and they were never treated as the main branch of production. Fish culture in the Middle Ages was considered not only as a side branch of agriculture, but also as a fashionable and pleasant activity. Frequently ponds were constructed in order to make the landscape more attractive. Hence, they were usually small and scattered.

In the more recent period, i.e., before World War II, rapid development of pond culture was connected with favorable tax policy protecting fish culture, as also with exceptionally favorable relations between price of fish and

price of feeds. Nevertheless, this development was based mainly on small pond complexes. A lot of new ponds were constructed, but in most cases no attention was paid to their quality.

As a result, pond production basis in Poland is significantly dispersed, as regards both single ponds and their complexes. A pond complex is understood here as a group of several ponds which are more or less integrated spatially and receive water supply from the same source. Taking into account the total area of State Pond Farms, over 36% of this area represents 74% of the total number of pond complexes, with the average area of one pond complex being only 43.7 ha (108 acres). Of these, almost 19% of the total number of pond complexes have fewer than 12 ha (30 acres). Each farm usually possesses a number of such small complexes, which as a rule are also significantly dispersed. It is obvious that their proper management is rather difficult.

Additionally, many fishponds or pond complexes were often constructed upon poor soils, and based on rainfalls or small streams. Disturbances of water balance, drainage of meadows and fields, and water pollution aggravate the problem. Over 70% of the total number of pond complexes, which represent almost 50% of the total area of State Pond Farms, are situated within catchment areas not exceeding 100 km² (62 m²). This fact constitutes a basic reason for significant differences between pond water surface area and pond area. In reality, pond water surface area constitutes in Poland about 70% of total pond area.

Value of Ponds

Because of the foregoing reasons, many pond complexes do not fulfill the practical demand of rationally and efficiently managed fish farms. On the other hand, due to several reasons, their liquidation cannot be undertaken. Apart from the value of fish production and its economic profitability, several significant nonmeasurable factors connected with the existence of fishponds are taken into account, such as:

- (1) Value of ponds as an element of complex management of water resources (retention of water, antiflood role, etc.)
- (2) Value of ponds as an element of local management of water resources (breeding of waterfowl; cattle watering and washing; local irrigation of grazing fields, cultivated lands, vegetable gardens or orchards; antifire reservoirs, local industry; and domestic purposes)
- (3) Value of ponds as an element of protection, preservation, and shaping of the natural environment (control of eutrophication in the receiving waters, recultivation of wastelands, formation of rich habitats for the development of wild fauna and flora, etc.)
- (4) Value of ponds as an element of various other non-production benefits (recreational activities, direct contact between man and nature, esthetic value of ponds—especially as regards landscape, etc.)

- (5) Value of ponds as an element of local economic activation (utilization of poor soils and bare lands, increase of people's income, by-production of agricultural farms, etc.)

Fish Production Yields

Coming back to fish production, it must be said that despite these main factors restricting pond culture in Poland, its general development is rather good. In more favorable 1977, average yield of market (table) carp in Poland amounted to 900 kg/ha (792 lb/acre). For its climatic zone this result is very good, the moreso that it represents the average value for the total area of State Pond Farms. Many farms in the same year obtained carp yields of 2000 kg/ha or more (1760 lb/acre). Significance of these results becomes even more pronounced if we take into account that in Poland general policy in the field of pond culture is *not* to intensify production at all costs, but rather to utilize—as much as possible—natural food resources of ponds. This policy considerably decreases protein requirements of fish culture. Studies have shown that it is possible to increase carp pond production to over 5000 kg/ha (4400 lb/acre), but this would require considerable use of high-protein feeds, which are not too abundant in Poland.

Methods of Intensification of Production

Taking into consideration the discussed state pond production basis, it may be said that methods of the intensification of carp pond culture in Poland (both those already introduced into practice and those postulated) represent a different approach from those in most other countries. To be more specific, intensification of carp production in ponds is based on the improvement of natural food resources of ponds and their better utilization by fish. This is achieved by:

- (1) Use of relatively cheap (compared to feeds) mineral fertilizers. Fertilization is carried out in such a way as to stimulate the development not only of natural food basis, as such, but also of particular groups of food organisms in the most desired periods
- (2) Utilization of various organic wastes as pond fertilizers, especially for the production of stocking fish
- (3) More effective utilization of natural protein resources of fishponds. Use of low-protein, carbohydrate feeds (mostly grain) in carp culture improves utilization of natural food resources by carp. At the same time carp feeding on natural food are better able to utilize artificial carbohydrate feeds
- (4) Improvement of stocking rates and methods. This is achieved, for instance, by polyculture of carp with plant feeding fish, or stocking with bigger carp. Carp fry of bigger size utilize particular food organisms much better than fish of low individual weight, etc.
- (5) Prolongation of the growing season both of food organisms and of fish.

This is achieved, for instance, by filling the ponds in autumn instead of spring and earlier stocking with heavier fry obtained in artificial conditions (hatcheries with thermal regulation or utilization of heated effluents; refer to Fig. 17.3)

- (6) Introduction of a two-year water cycle in farms characterized by water shortage. In this system water is drawn off from ponds every two years

It should be noted that in the last two instances ponds which are normally used as fry or wintering ponds can instead be utilized as market fishponds.

Justification of such an approach to the intensification of pond culture results also from various studies (Leopold 1979, 1981). It was shown that by applying proper management methods it is possible to obtain 2500 kg/ha (2200 lb/acre) of fish yield without intensive feeding, i.e., using only 360 g of raw protein and *no* animal protein per kg of carp production.

LAKE FISH FARMING

Commercial Fishery

In contrast to many other countries, in Poland commercial fishery is carried out on almost the whole area of lakes. Additionally, most of the lakes are also exploited by recreational fishery.

In the case of Poland the term "commercial fishery" is more a traditional one than the real one. Lake fishery management is rather intensive, and a whole system of complex management methods used in the lakes, and especially intensive stockings, allow for stating that commercial fishery in Poland should be regarded as "lake fish farming."

Possibilities and Aims of Lake Fish Farming

In Poland possibilities of lake fish farming are connected with the character of Polish lakes, their current state, and changes taking place in lake environments. On the other hand, aims of lake fish farming result from multiple economic and socioeconomic requirements, as discussed later.

Size. Over 300,000 ha (741,000 acres) of Polish lake area are represented by small and very small lakes. Surface area of the biggest Polish lake (Lake Sniardwy) is only 12,000 ha (29,640 acres). Lakes bigger than 500 ha (1235 acres) constitute only 1% of the total number of Polish lakes, and 36% of the total area of lakes. Over 90% of the total number of Polish lakes, and one-third of the total area, are small water bodies, with surface area up to 100 ha (247 acres). Lakes in Poland are not only small but rather shallow—70% of the total number of lakes are less than 20 m deep (65 ft); of these, 50% are less than 10 m (40 ft) deep.

Type. Limnologically, over 50% of lakes in Poland are eutrophic water bodies. The remaining are either mesotrophic or of the pond type. Hence, Poland has a number of fertile lakes, with high production potential.



Fig. 17.4. A typical small Polish lake.



Fig. 17.5. A typical bigger Polish lake.

Regional Concentration and Favorable Management. Polish lakes are mostly concentrated in a few lake districts (Fig. 17.6), constituting in some regions 10% of total lake area. Consequently, fishery management of lakes is significantly facilitated. Small unit area of particular lakes, which does not favor traditional fishery, is most favorable for more or less intensive fish farming in lakes. This results from several facts: small lakes are much more controllable than the large ones; they create possibilities of adopting various methods stimulating fish production; and management measures

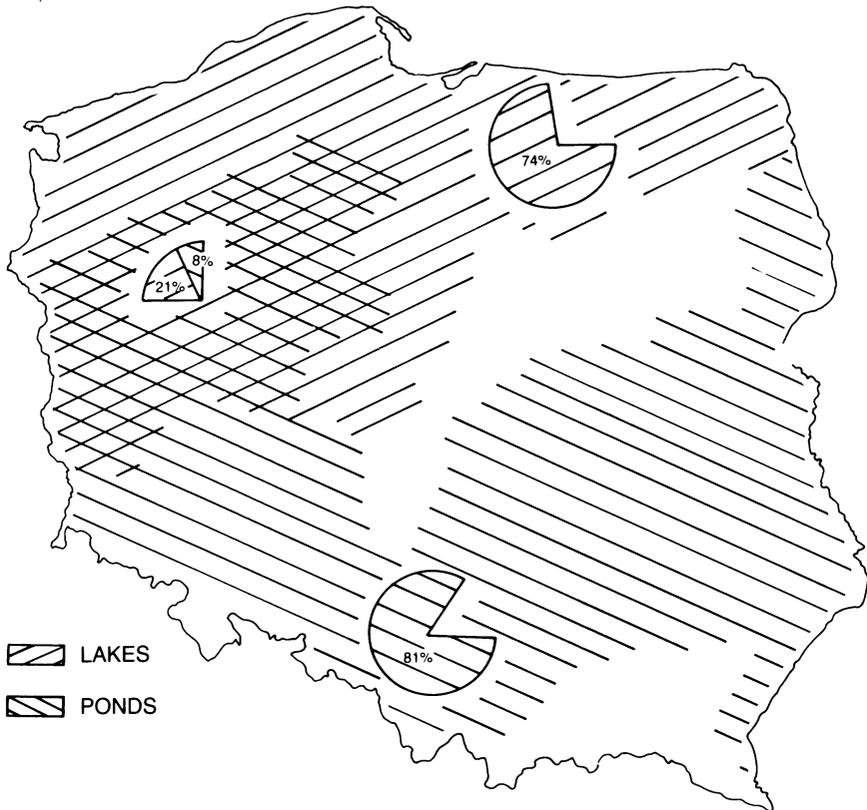


Fig. 17.6. Distribution of lakes and ponds in Poland. Circles represent percentage of lake (or pond) area in the given region in relation to the total lake or pond area for the whole country.

undertaken upon small lakes are much more effective than upon large lakes. The latter statement refers most of all to the common practice of stocking, as also to more effective fish catches.

For instance, eel lake farming is extremely effective in Poland. Nevertheless, analyses of long-term data from 450 Polish lakes (with total area of 117,000 ha (289,000 acres) showed that eel stocking rates in lakes up to 100 ha (247 acres) (artificial stocking with elvers) are higher by 32% than in lakes over 500 ha (1235 acres) of area, with eel yields being 36% higher in the first group of lakes compared with the latter. It was also shown that eel catch per unit of effort is by 31% higher in lakes up to 100 ha than in lakes over 500 ha of area.

Small Lakes. Very small lakes, of a few or at most some tens of hectares, are used for intensive lake farming, in most cases for carp lake farming.



Fig. 17.7. Winter, under-ice lake catches.

Proper adaptation of lakes for carp farming results in carp yields of some hundreds of kg per ha, i.e., at the level similar to less intensive carp pond culture. At the same time costs of carp lake farming are significantly lower than in cases of pond culture, mostly as regards investment and operating costs, especially costs of feeds.

Changes in Lake Environments. In the case of Poland, a shift from traditional lake fisheries to lake fish farming is also connected with progressing changes taking place in the lake environment as a result of anthropopression. Apart from pollution of waters by the industry, we deal with progressing eutrophication of lakes. Lake eutrophication results in the deterioration of environmental conditions for fish, mostly for species characterized by high oxygen requirements. In most cases natural reproduction of these species is significantly inhibited. On the other hand, conditions for fish growth, and especially fish food resources, are favorable. Hence, it becomes necessary to stock fish in the lakes. This refers most of all to more valuable fish species, such as coregonids. The less valuable species, such as some cyprinids (bream and roach, for instance), are able to reproduce (sometimes too abundantly) also in the conditions of advanced eutrophy. In fact, abundant development of bream and roach is frequently cited as a specific symptom of the eutrophication process.

Trends of Commercial Fish Catches

The regularities occurring with environmental changes are illustrated by Fig. 17.10 and Table 17.1, which present general results of commercial



Fig. 17.8. Sorting of eel caught in a lake fish farm.

TABLE 17.1. LAKE PRODUCTION DYNAMICS AND ITS CHANGES

	1957 - 1979		1957 - 1961		1975 - 1979		c/b in %
	Metric Tons	%	Metric Tons	%	Metric Tons	%	
			b		c		
Total	7206	100	5958	100	8570	100	143.8
Artificially stocked fish	1250	17.4	679	11.4	2116	24.7	311.6
Bream and roach	3503	48.6	2749	46.1	4366	50.9	158.8
Other fish species	2453	34.0	2530	42.5	2088	24.4	82.5
Pike	522	7.2	643	10.8	320	3.7	49.8
Eel	457	6.3	287	4.8	660	7.7	230.0



Fig. 17.9. Acclimation of stocking material (coregonids) to ambient temperature before its release to the lake.

fishery management in lakes. Trends of particular fractions of commercial lake fish catches are totally clear (Fig. 17.10). General increase of total lake fish production is based mainly on increasing yields of bream and roach, as well as increasing yields of fish artificially stocked, whereas yields of other fish species decrease. Hence, lake fish production in Poland reflects coupled effects of progressing eutrophication on the one side and more intensive lake management on the other. This effect is even more visible if we take into account that the average catch of artificially stocked species comprises 38.1% of the coregonid species (i.e., fish characterized by high environmental requirements) and 25.6% of eel. Production of fish based on artificial stockings increases along a parabolic curve (Fig. 17.10). For instance, in the fifth year of the analyzed 23 year period, increase of catches from artificial stockings amounted to 1.8% in relation to the multi-year average for the

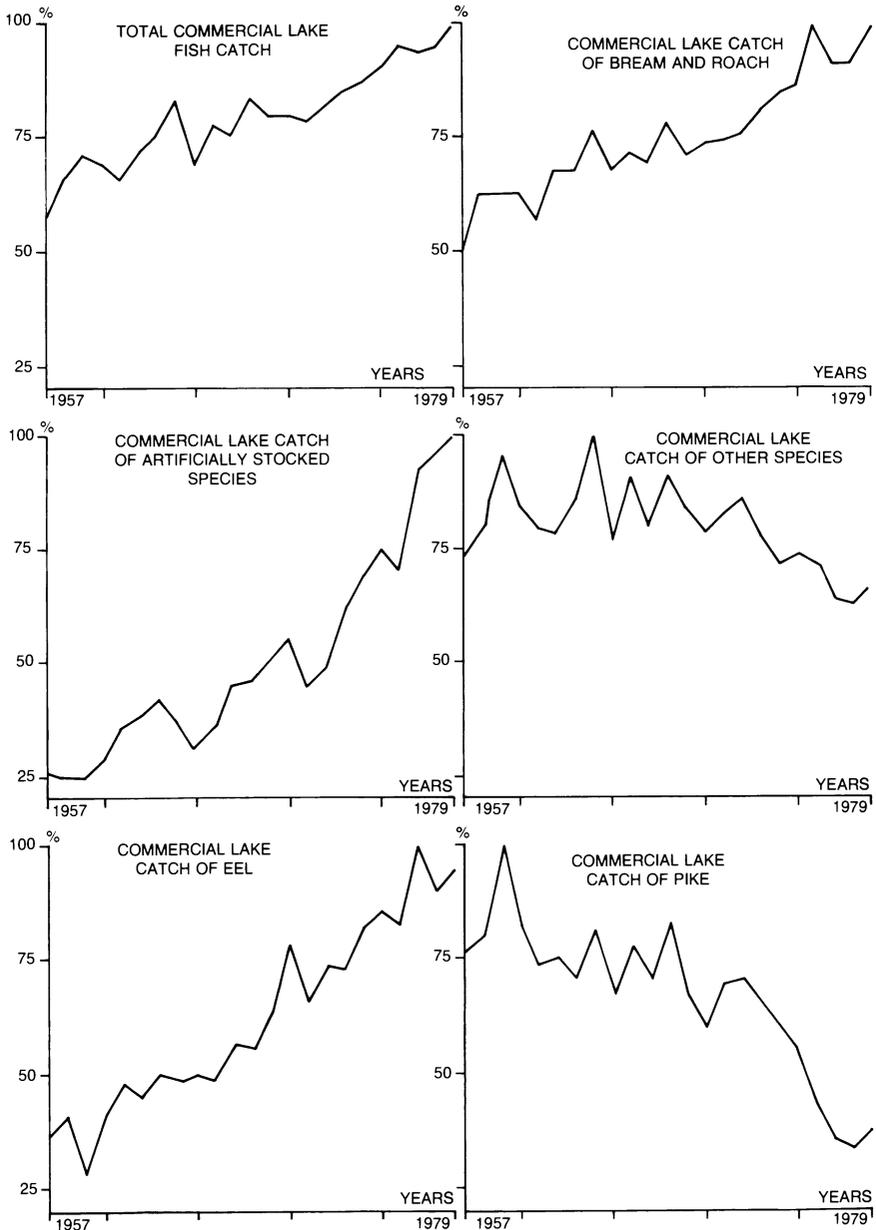


Fig. 17.10. Trend of commercial lake catches and their fractions in the period 1957–1979. In order to make the trends more clear, catches are presented on a uniform percentage scale. In each case, 100% represents maximal value noted in the whole period, with other values recalculated accordingly. Absolute numbers of commercial lake catch and its fractions are given in Table 17.1.

same period, whereas in the twentieth year it reached 11%. In contrast to artificially stocked fish and roach and bream, other fish species are more affected by progressing eutrophication than by the compensating management measures. Hence, their yields decrease along a convex parabola. In other words, their production reached a maximum in the ninth year of the period under study, and has decreased steadily ever since. For instance, in the tenth year this decrease was only 0.4% in relation to the multi-year average, but it reached 3.5% in the twentieth year. As seen in Fig. 17.10, this decrease is especially pronounced in the case of pike. It should be added, however, that pike is also intensively exploited by recreational fishery.

Numerical values illustrating these trends of lake fish production are presented in Table 17.1. This table contains average multi-year (1957–1979) yields, and the relation between yields in the first and the last five years of the analyzed 23 year period.

Lake Management Stimulates Production

Stimulation of Commercial Production. Dependence of commercial lake fish catches on human activities stimulating fish production is much greater than would result only from the increase of total fish catches, or from catches of artificially stocked species. This statement results from the fact that lake fish farming affects positively production of all fish species, and not only of those which are directly the subject of this farming. In reality, without human activities in this field, lake fish production would constantly decrease. Hence, lake management not only increases fish production in lakes, but also compensates for its decrease that would otherwise occur as the effect of various negative impacts upon aquatic environments.

To exemplify the fact let me refer to the results obtained on four small lakes, the biggest of which has the area of only 35 ha (86 acres). The lakes have been adapted to carp farming. As a result carp yield reached 132 kg/ha (117 lb/acre) but at the same time there was an increase of the yield of other fish species from 46.4 kg/ha to 170 kg/ha (41 to 151 lb/acre). Similarly, eel stockings have a general positive effect: eel production in lakes is positively correlated with the production of other fish species.

Increase of Recreational Fisheries. As was mentioned before, without proper management of lakes, fish production would show a decreasing trend. This potential decrease is connected with increasing anthropopression upon lakes. Apart from progressing water pollution and eutrophication, mention can be made here of the increasing impact of recreation activities on lakes, such as recreational fishery. It is doubtful that recreational fishery significantly affects the fish stock. In Poland development of recreational fishery is very rapid. The number of anglers belonging to the Polish Anglers Association increased from 150,000 in 1957 to over 730,000 in 1979, the average annual increase being 26,400 anglers (Fig. 17.11). As shown by some preliminary studies, 37.4% of the total number of angling

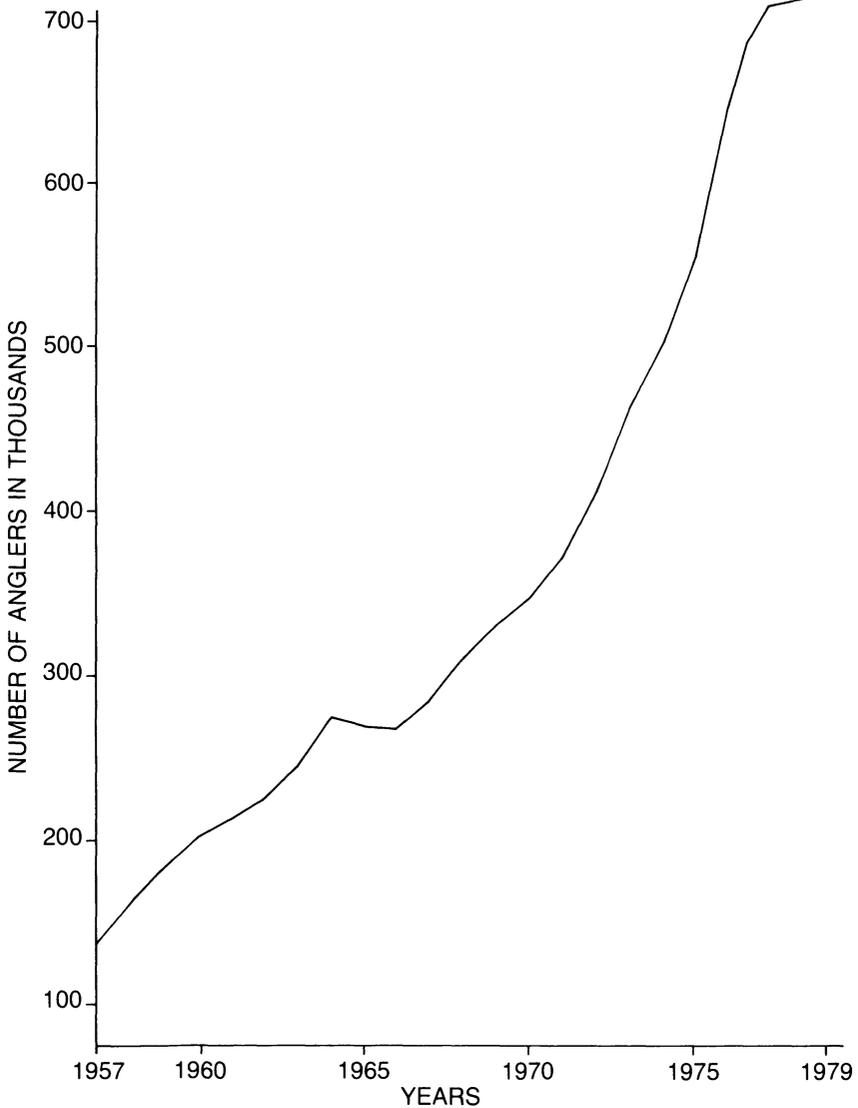


Fig. 17.11. Number of anglers—members of the Polish Anglers Association—in the period 1957–1979.

days annually is spent upon lakes. Hence, it may be assumed that lake fish catches constitute about 37% of total recreational fish catch. With the average number of anglers in the period 1957–1979 amounting to 372,600 and average annual catch per angler of 54.3% (119 lb), it may be estimated that recreational catches from lakes reached in this period the average level

of 7500 MT (8250 ST). Even if we assume that the average annual catches by anglers decreased in the more recent years, it still appears that in 1979 the level of recreational catches in lakes must have been at least the same as of commercial catches obtained by State Fish Farms. Consequently, it may be stated that fish yield in Polish lakes is at least 50–60 kg/ha (44–53 lb/acre). It is obvious that in the climatic conditions of Poland it would not be possible to sustain such yields in the long run if only traditional lake fisheries were relied upon.

Lake vs. Pond Production

In fact, the level of total lake fish production (commercial and recreational catches) in Poland is only slightly lower than total pond fish production. Although pond culture is characterized by broader possibilities and more rapid development, it is less economical than lake fish farming, at least due to high capital and feed requirements of pond culture. In view of this, it is not surprising that in Poland lake fish farming is of high significance, and its various forms are constantly improved.

Cage Culture

Within these various forms of lake fish farming attention should be given to cage culture. In Poland there are two basic forms of cage culture in lakes: culture in cages based entirely on artificial fish feeding, and culture in the illuminated, drifting or floating cages without any fish feeding. The first form is mostly connected with the fattening of table (market) fish, whereas the latter is used for the production of stocking material. The latter form is based entirely on natural food resources of lakes, i.e., on zooplankton which are attracted to cages by artificial light or water movement. This form is basically used for rearing of coregonid stocking material; its biotechniques have been worked out and are being widely adopted. On the other hand, fattening of fish in cages (trout, common carp) is not promoted due to its visible negative impact upon water environment (pollution) and unfavorable economics.

Similarly, more intensive forms of trout culture, i.e., those totally independent of natural food resources, are not much promoted, mostly due to their significant protein requirements. At present, trout production in Poland is about 1000–1500 MT (1110–1650 ST) annually. Trout production is carried out in more or less the same range by the state and by small, private producers. In fishery records this production is partly included in pond and partly in lake fish production.

FISHERY MANAGEMENT OF RIVERS AND DAM RESERVOIRS

About 1000 MT (1110 ST) of fish are caught annually in rivers and dam reservoirs by fishery cooperatives (operating upon some Polish rivers) and

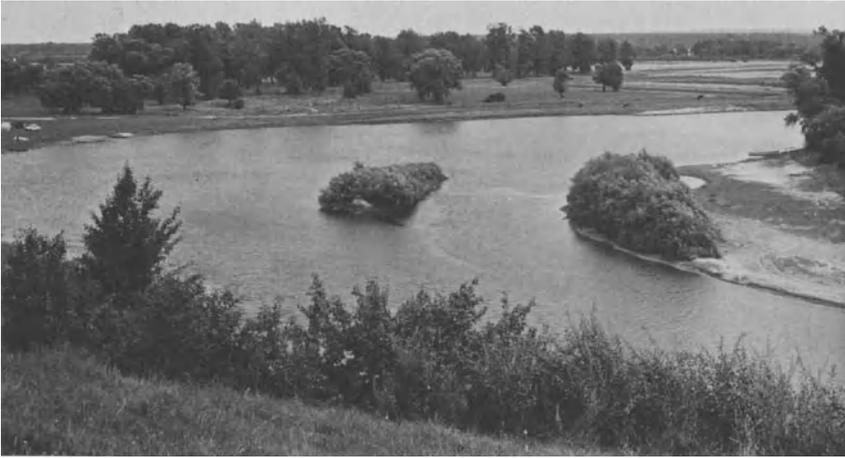


Fig. 17.12. A typical Polish lowland river.



Fig. 17.13. A stretch of lowland stream.

as a result of selective catches undertaken by the Polish Anglers Association. Apart from this, all fish production of rivers and dam reservoirs is taken by individual anglers in the form of recreational catches. Despite significant pollution of Polish rivers, it is estimated that recreational catches from rivers and dam reservoirs amount to about 10,000 MT (11,100 ST) annually with average fish yield being at the level of 100 kg/ha (89

lb/acre). Fishery management of rivers and dam reservoirs is practically restricted to stocking and to regulating catches, the latter being carried out only on a highly limited scale. Lowland fish species dominate the catches obtained from rivers and dam reservoirs.

OTHER FORMS OF FISH CULTURE

Other forms of fish culture are of no significance in Poland. However, brief mention can be made here of cage culture carried out on a limited scale in rivers, heated effluents, and inshore marine waters. Apart from the rearing of stocking material in cages placed in heated effluents, the other forms are neither promoted nor developed, due to the previously discussed reasons.

SOME REMARKS ON THE ECONOMICS OF FISH FARMING IN POLAND

Difficulties of Estimation

Profitability. Traditional unlimited demand for freshwater fish, together with multiple values of fishery management, results in the Polish socioeconomic system of fish farming being broadly developed and promoted. This promotion refers not only to the process of undertaking fish farming by various farms, but also to the prices of various subsidized production means (for instance, feeds), as well as to the prices of the final product, viz., the fish. Consequently, it is very difficult, and sometimes even impossible, to estimate the real profitability of fish farming.

Economic Efficiency. Apart from socioeconomic conditions, economic efficiency of fish farming is also dependent on the existing natural conditions and on the form of fish culture and its intensity. Hence, any estimation of average costs of production and their structure, made for pond or lake farming, or for selected fish farms, would not be of any real value. Additional difficulties are created by progressing irregular changes of the cost of basic production means, for instance of energy and feeds, as well as of the investment costs. Furthermore, in most cases even apparently insignificant modifications of fish farming technology and its biotechniques can significantly affect the economic efficiency. In practice, any analysis of production costs made for the given case of fish farming would necessitate extensive comments and explanations, which still would not give a full picture. On top of that, economic calculations made by particular farms are rather differentiated due to the fact that bookkeeping in Polish farms is not adapted for direct assessment of the costs of fish production, being instead a synthetic balanced bookkeeping, with structure of costs according to the kind.

Measuring Economic Efficiency with Unit Protein Requirements

Partial solution to the problem (although not fully satisfactory) is the use of protein requirements per unit of production as a measure of the economic efficiency of various forms of fish farming and levels of its intensity. This approach is applicable to more developed forms of fish farming. Apart from lake fish farming, and some forms of pond fish culture, protein requirements are strictly connected with the level of production. They also constitute a significant item of the costs. Obviously this approach does not take into account various other items of the costs, but it seems rather justified in view of the progressing shortage of protein resources. Comparison of protein requirements for various levels of the intensity of fish farming and its various forms allows also for undertaking optimal decisions in this field, i.e., to choose such forms that would give maximal fish production at minimal use of proteins, and especially of animal protein. Possibilities of such decision-making are quite well illustrated by Table 17.2. This table refers to various forms of pond carp culture, characterized by different levels of production and well developed biotechniques of farming. Traditional management measures cited in this table are mineral fertilization and use of carbohydrate (cereal) feeds. Measures applied at a level higher and/or different from the traditional one are underlined (see the remarks in Table 17.2).

Operating Costs Increase Faster Than Unit Production Decreases. It is well known that fixed costs per unit of production decrease along with increasing levels of production. Nevertheless, this decrease does not com-

TABLE 17.2. PROTEIN REQUIREMENTS OF VARIOUS FORMS OF CARP POND CULTURE

Case No.	Fish Production kg/ha	Protein Use in g/kg of Fish		Remarks
		Raw Protein	Animal Protein	
1	950	213	none	traditional feeding and fertilization
2	1059	237	none	traditional feeding and fertilization
3	1300	280	none	traditional feeding and fertilization
4	1466	314	none	traditional feeding and fertilization
5	1627	360	none	<i>intensive traditional feeding</i>
6	2376	360	none	traditional feeding and <i>intensive fertilization</i>
7	1220	614	254	traditional feeding and <i>feeding with pellets</i>
8	1280	885	262	<i>feeding with pellets</i>
9	3154	1023	338	<i>intensive feeding with balanced pellets</i>
10	4400	1547	758	<i>intensive feeding with high-protein pellets</i>
11	2122	129	none	traditional feeding and <i>fertilization with sewage</i>

pensate for increasing operating costs, as the latter increase at a rate at least equal to or higher than the increase of protein use. As seen from Table 17.2, this statement refers most of all to the use of pelleted feeds. Rough estimation showed that in case no. 9 and 10, unit cost of 1 kg of carp production was more than twice as high as in case no. 3. Relatively high economic efficiency is noted in case no. 6 and 11, in which carp production is intensified by the stimulation of natural productivity of ponds. This method is also highly economical with respect to the use of feeds (compare case no. 5 and 6).

Carp Cage vs. Pond Culture. In the context of feeds, mention can be made of carp cage culture. This method of carp production is highly unsatisfactory—in order to produce 1 kg of fish it is necessary to use over 1000 g of raw protein on the average, using over 50% of animal protein.

In Polish pond culture average use of raw protein (originating mainly from cereal feeds) is 280–360 g per kg of fish production. Fish meat contains about 15% protein on the average. Hence, to produce 1 kg of protein, it is necessary to use from 1.9 to 2.4 kg of raw protein. This level is more or less similar to milk and poultry production (2–4 kg of raw protein in feed per kg of protein produced), and significantly lower than for pork (4–5 kg) and beef (6–8 kg) production. In view of this, promotion of carp farming in Poland, and especially of carp pond culture, is totally understandable.

Trout Pond vs. Cage Culture. Adopting the same approach based on protein requirements, trout culture in ponds and enclosures is considered to be more effective than trout culture in cages. In the first case average protein use per kg of trout is about 800 g, whereas in cage culture it amounts to over 1100 g, using 70% of animal protein. Similarly, unit cost of trout production in cages is about 50% higher than in ponds and enclosures.

Economic Calculations in Relation to Environment

Intensive Fish Farming. In intensive forms of fish farming, especially cage culture, economic calculations as a rule do not embrace all costs connected with the deterioration of specific environmental values, or the devastation of natural environment.

Lake Fish Farming. Taking into account protection of the environmental as well as the economic efficiency, fish farming in lake is certainly a most specific form of fish production. Protein requirements of lake fish farming are extremely low, and this form is usually highly effective from the economic point of view. Even at relatively high levels of farming intensity, viz., when some food is supplied from the outside and fish yields reach up to 800 kg/ha (713 lb/acre), protein use is very low and does not exceed 100 g per kg of fish. Less intensive forms of lake farming, which are based on heavy stocking with properly selected species and specific management of the lake biocenosis, do not require any artificial fish feeding. Additionally, these forms of lake farming usually have a beneficial effect on the environment

(for instance, as a result of better utilization of nutrients and natural food resources of the lake, the control of weed fish development).

Labor

Most forms of lake fish farming are characterized by high labor requirements. Nevertheless, unit costs of production are still lower than in all other forms of fish culture.

Lake vs. Pond Efficiency: Profits from Recreational and Commercial Fishery

It should also be noted that the effects of lake fish farming are reflected not only by commercial fish catches, but also by recreational catches. In other words, the real economic efficiency of lake fish farming is even higher. For instance, in 1957–1979, average annual eel catch from lakes managed by commercial fishery amounted to 790 MT, viz., 457 MT from commercial catches and 334 MT taken by anglers. At the same time eel is stocked only by commercial fishery. Hence, real profitability of eel stocking is about 70% higher than would result from the effects of just commercial fishery. Taking into account recreational catches, it may be stated that unit cost of fish production in lake farming is about one-half that of pond culture.

Socioeconomic Value of Aquatic Recreation Depends on Lake Fishery Management

Abundance of fish in Polish lakes, development of recreational fishery, and the role of lake fishery management in the protection of aquatic environments constitute important factors favoring the development of recreation connected with an aquatic environment. High socioeconomic value of this recreation and its development are also strictly connected with the development of fishery management in lakes.

OUTLOOK

Fish Production and Consumption

At present fish production in the inland waters of Poland is at least 40,000 MT (44,000 ST) annually. About 60% of this value is obtained from commercial fishery; the rest represents recreational fish catches. Part of this production is exported. National consumption of freshwater fish per capita is about 1 kg (2.2 lb) annually, and thus is rather high.

Lake Fishery Management: Development, Maintenance, and Promotion and Basic Rules of Allocation

Production of inland fish in Poland is a rather important branch of food production, and the demand for freshwater fish is very high. In view of the significant area occupied by lakes in Poland, as well as the high

economic efficiency of lake fish farming, in recent years special attention has been paid to the development and promotion of lake fishery management. In contrast to ponds, which are almost exclusively controlled by State Pond Farms, lakes in Poland are used by several groups. Furthermore, lake water resources (as also pond water resources) are characterized by multiple nonfishery values. Hence, any further development of lake fish farming is strictly connected with an introduction of some basic rules of lake allocation. The aims of such allocation are to increase fish production on the one hand and to maintain multiple values of water resources on the other, with attention being paid to conflicts between various users of lake water resources.

General outline of such allocation has recently been worked out by the Inland Fisheries Institute in Olsztyn, and was presented at the International Consultation on Fishery Resources Allocation organized by the FAO/UN in Vichy, France, in the spring of 1980. According to this outline lakes are divided into several categories, with priorities of lake use (or the main function of particular lakes) defined for each category in the following manner:

- (1) *Lakes which are or may be used as resources of drinking water, or as a supply of water for the food industry.* The main function of these lakes is to supply clean water. Consequently, water resources of these lakes must be maximally clean and any other possible use of lakes (such as utilization of fishery resources) must be subordinate to this function. These lakes should not be used either for recreation or angling. The only permissible use is a more or less extensive fishery management, and only on condition that it is subordinate to the main function. In other words, some commercial fishery may be introduced but only in cases when it might improve water quality, being used as a tool for the control of some fish populations. Upon this type of lakes it is necessary to introduce strict rules of environmental protection.
- (2) *Lakes having the character of nature reserves, or with special natural values, which can constitute specific "genetic banks" for the disappearing species of plants or animals.* The main function of these lakes is their preservation in a maximally unchanged state. All other uses should be maximally restricted and totally subordinate to this function. Depending on which component of the environment is the most valuable one, it may be possible to allow for highly restricted use of these lakes by commercial fishery, recreation, or angling. Taking into account fishery resources, we will at most deal here with extensive fishery management, whereas recreation and angling may be permitted only according to the regulations and rules valid for strict nature reserves.
- (3) *Lakes used for the regulation of water budgets in the region.* These lakes are characterized by changeable water level as they are used for

water storage in the period of high waters. If these lakes are also used as drinking water supply, or by the food industry, they must automatically be treated as the first category. If not, they can be fully used for recreation, angling, or commercial fishery, and there are practically no strict requirements as to the quality of water, so that intensive fish farming may also be introduced (cage culture included).

However, in view of conflicts existing between intensive commercial farming and recreational use of waters, as well as between recreation and angling, these lakes should be allocated in three different ways. If they are to be used for intensive fish farming, their use for recreation must be restricted, whereas angling may be totally free. If the lakes are to be used for general recreation, both commercial fishery and angling must be restricted. If the lakes are allocated for angling, their use for general recreation must be restricted. These lakes may additionally be used as sources of water for agricultural purposes.

- (4) *Lakes considered as attractive for water recreation as such and/or used for this purpose.* The main function of these lakes is the possibility of their use for general recreation connected with an aquatic environment. This function does not exclude proper management of fishery resources and their use by commercial fishery (with the exception of highly intensive forms, of the character of fish culture). It is also possible to use these lakes for angling. Nevertheless, recreation may restrict the latter two ways of lake use (i.e., commercial fishery and angling). Theoretically, water resources allocated for recreational use may be used by other users. In practice, however, recreation connected with an aquatic environment creates several conflict situations and thus leads to significant risks, for both commercial fishery and recreational fishery.
- (5) *Lakes allocated for angling.* In this case the main function of lakes is their use by anglers. Use of these lakes for general recreation should be restricted. It is possible to introduce commercial fishery, provided that it will be subordinate to the main function. Its role will be practically restricted to the regulation of the fish stock (introduction of valuable species, and exploitation of species not used by anglers). In lakes of this type there are practically no conflicts as recreation as such is restricted, whereas commercial fishery improves conditions for angling.
- (6) *Lakes in which commercial fishery and fish production are the main functions.* All other uses of waters should be subordinate to this function. This function does not exclude—depending on the intensity of fish farming—limited use of these lakes by other users, especially by anglers. Any other use of these lakes cannot, however, affect their use by commercial fishery. Hence, the extent to which other uses are permissible must be defined by the main user, i.e., by commercial fishery. This extent will obviously depend on the intensity of fish farming—the higher the intensity the lower the possibility of lake

use by other users. In the case of highly intensive fish farming, there are no possibilities of other water uses whatsoever.

Differentiation of Commercial Fishery from Lake Fish Farming

It is obvious that with such allocation of lakes, lake fish farming and the forms of commercial fishery will be highly differentiated. In this context, the following types of commercial lake management can be distinguished:

- (1) *Extensive management with restrictions.* In this form of fishery management, production is not stimulated by any management measures, and fishery exploitation may be restricted. Such a type of management is undertaken on lakes in which any more intensive form of fishery management is permissible, usually on those lakes which are utilized by other users, i.e., for other purposes than fisheries. For this type of commercial fishery management, the manager should possess considerable knowledge on:
 - (a) The needs of these other users.
 - (b) The lake ecosystem and its functioning. In the case of lakes used by others, the timing and range of proper intervention into the ecosystem (so as to fulfill frequently divergent requirements of these users) are very difficult and require a really good knowledge of the given ecosystem.
- (2) *Extensive management without restrictions.* Just as in case no. 1, this type of management does not permit the stimulation of fish production by any measures, but fishery exploitation is totally unrestricted, except for existing laws and regulations. This type of management is undertaken on water bodies used by other groups, as well as on lakes in which due to some reasons more intensive management would not be economically feasible. Most frequent reasons justifying this type of commercial fishery are low resource requirements, known decrease of production possibilities of the given lake, and/or already known restrictions of fishery management possibilities.
- (3) *Extensive-intensive management.* In this type of management certain measures stimulating fish production are used, and fish exploitation is not restricted. It is undertaken on all water bodies in which fishery management is of similar significance to other forms of lake use, as well as on water bodies in which fishery is of primary importance but its more intensive form is not justified due to some reasons, such as, for instance, shortage of certain resources. This type of fishery management is characterized by moderate resource requirements.
- (4) *Intensive management with restrictions.* This type of management allows for all possible measures stimulating fish production and restricted fishery exploitation. It is undertaken in cases when high density of the fish stock is necessary for other users, for instance, in case of water bodies allocated for angling, or else when the fish

stock is used in order to ameliorate the environment. This type of management is characterized by very high resource requirements.

- (5) *Intensive management without restrictions*. In this type of management there are no restrictions as concerns various measures stimulating fish production, nor as concerns exploitation. This type of management is undertaken on lakes in which commercial fishery production is decisively of primary importance. Use of these lakes by other users is restricted. Intensive management is characterized by very high resource requirements. In reality, this type of lake fishery may be treated as lake fish culture.

Broad introduction of these schemes into practice will certainly not allow for any outstanding, spectacular increase of freshwater fish yield, but it will assure its constant, long-term increase. Furthermore, it allows for maintaining multiple values of water bodies, compensates for possible losses due to water pollution and eutrophication, and liquidates conflicts between various users of lakes. Hence, it seems the most appropriate and feasible solution on a long-time scale, as well as for further development of fish farming.

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Czechoslovakia

FISH SPECIES

Barbel (*Barbus barbus*)

Bighead carp (*Aristichthys nobilis*)

Bream (*Abramis brama*)

Brook trout (*Salvelinus fontinalis*)

Brown trout (*Salmo trutta* m. *fario*)

Carp (*Cyprinus carpio*)

Chub (*Leuciscus cephalus*)

Eel (*Anguilla anguilla*)

Grass carp (*Ctenopharyngodon idellus*)

Grayling (*Thymallus thymallus*)

Huchen (*Hucho hucho*)

Leather carp (variation of *Cyprinus carpio*)

Maraena (*Coregonus lavaretus*)

Minor or naked carp

Mirror carp (variation of *Cyprinus carpio*)

Peled (*Coregonus peled*)

Perch (*Perca fluviatilis*)

Pike (*Esox lucius*)

Pike-perch (*Stizostedion lucioperca*)

Rainbow trout (*Salmo gairdneri*)

Rapacious carp (*Aspius aspius*)

Roach (*Rutilus rutilus*)

Sheatfish or wels (*Silurus glanis*)

Silver carp (*Hypophthalmichthys molitrix*)

Tench (*Tinca tinca*)

Trout

Wild fish

Phytophagous fish

Pond culture

Salmonoid culture

Czechoslovakia

*Jan Vacek*¹

Background

Pond fish culture in Czechoslovakia has nearly 900 years of tradition. The first fish ponds date back to the 10th and the 11th centuries in Bohemia and Moravia. The greatest development was in the 16th century when complex fish farms were built in Bohemia and Moravia and water surface area was estimated to be more than 120,000 ha (296,400 acres). During the 18th and 19th centuries, cultivation became more intensive, resulting in a reduction of water area by 50% with converted ponds being used for pastures and crops. After this time, pond area gradually declined so that by 1933 there were only about 42,000 ha (103,820 acres) in Bohemia and 5915 ha (14,610 acres) in Moravia. Following this period came the first state fish farms.

After World War II administration of state farms for pond fish was vested in the Ministry of Agriculture. In 1967 the State Fishery Branch was formed to head up 24 state fish farms. At the same time two independent state farms were formed in Slovakia.

The total water area of reservoirs including rivers is estimated at 135,000 ha (333,450 acres). Of this area, 52,030 ha (128,514 acres) are in ponds. The State Fishery Enterprise comprises 41,380 ha (102,209 acres) or 79.5%. Headquarters are in the town of Ceske Budejovice. More than 50,000 ha of ponds (123,500 acres) are in Bohemia. Besides the State Fishery Enterprise, exploitation of fish ponds is by two state fish farms in Slovakia, the Czech and Slovak Angling Associations, Agricultural Cooperatives, state farms, municipalities, etc. However, because the predominant share of waters is under the State Fishery Enterprise with better control over intensification, production, and marketing, future increases in output depend on this agency.

Fishery exploitation of running waters and artificial lakes lies essentially with the Czech and Slovak Angling Associations. From a total of 83,170 ha (205,430 acres) of such waters, 43,000 ha (106,210 acres) are utilized by the Slovak Angling Association in Slovakia and 28,500 ha (70,395 acres) by the Czech Angling Association (Bohemia and Moravia).

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The remaining water is used by the State Fishery Enterprise, Fisheries Research Institute, Fishery High Schools, etc.

The development of angling and all-round exploitation of running waters began before World War I. Associations of fishing clubs started in 1923. By 1933 more than 500 fishing clubs were registered. After World War II, the Czechoslovak Angling Association was formed and when the federation law was passed in 1969, two separate Czech and Slovak Angling Associations were founded. Interest in angling is shown by growing numbers of registered anglers. In 1965, 120,000 anglers were registered, but by 1978 these numbers were more than 200,000. Statistical studies indicate future growth.

Development of Production

Reliable statistics are available after 1953 when amalgamation of fish farms was completed. Fish production started to intensify. This was due primarily to tying in technology with a combination of fish (carp) and duck culture. The development of fish and duck culture and their contribution to production of animal protein for human consumption is shown in Table 18.1

Since the area of ponds fluctuates only within a very narrow range, total marketable production is due almost entirely to intensification. According to statistical data, fish production increased 140% between 1953 and 1978. In the last 10 years, duck production has increased 102%. In several State Fisheries duck production reached higher levels than fish production. Since 1953 there has been a 410% increase in production of animal protein for human consumption per hectare of cadastral area. In the past 10 years, important technological changes in duck breeding have come into use. The average annual increase in total fish production and animal protein from fish and duck production averaged 4.3 and 9.7% per year, respectively.

In published data, the catch by anglers is not given because this catch and consumption are outside the marketplace. Statistics of the Czech and Slovak Angling Associations indicate that total catch by anglers in 1978 reached 3500 MT (3850 ST), an increase of about 30% from 1970.

Biotechnology

Technology of fish production is tied up with traditional Czechoslovak pond fish culture, some aspects of which have not changed for a long time. Notable among these is the reliance on production of natural foods in ponds for the nutrition of fish. These relationships between fertilization and natural food production were fairly well determined by 1900. Hence, natural nutrition is the basis of fishing culturing.

To aid in increasing productivity per ha, artificial feeds are also given. In comparison with some European countries (Hungary, East Germany, Yugoslavia, Bulgaria, Belgium, etc.), Czechoslovakia achieves high production with smaller shares of artificial feeds, while at the same time

TABLE 18.1. FISH AND DUCK PRODUCTION AS SOURCE OF ANIMAL PROTEIN FOR HUMAN CONSUMPTION, CZECHOSLOVAKIA, 1952-1978

Year	Total Fish Production (MT)	Duck Production (MT)	Fish Production	Hectare Growth Rate in kg Duck Production	Animal Protein for Human Consumption (Fish and Duck Production in kg/ha)
1953	5,620	95	136.2	2.0	10.7
1954	5,540	220	132.7	5.5	10.8
1955	5,100	420	124.8	10.4	10.8
1956	5,400	520	130.1	12.8	11.4
1957	6,400	790	153.6	19.4	14.0
1958	6,980	960	169.5	23.8	15.7
1959	7,820	1,190	187.2	29.1	17.7
1960	7,560	1,870	182.4	46.1	19.3
1961	8,840	2,220	213.4	54.5	22.6
1962	9,160	2,310	219.3	56.3	23.3
1963	9,500	3,000	228.1	73.1	25.9
1964	10,620	3,660	251.3	88.2	29.4
1965	8,890	4,610	210.8	110.6	28.8
1966	10,160	4,860	239.1	116.5	31.7
1967	10,798	5,201	256.6	125.6	34.1
1968	12,173	5,908	288.1	142.5	38.4
1969	11,949	5,266	287.5	126.4	36.5
1970	10,454	7,444	252.5	176.6	39.6
1971	12,056	7,967	287.1	189.8	43.7
1972	12,590	7,811	301.7	186.8	44.5
1973	12,339	8,479	295.2	198.1	45.3
1974	13,114	8,136	315.4	195.7	46.6
1975	13,631	9,526	328.3	229.4	51.5
1976	14,301	9,538	347.3	231.7	53.2
1977	15,060	9,959	363.9	240.6	55.5
1978	13,470	10,630	326.4	257.5	54.6

achieving conspicuous increases in carp production with additional applications of feeds per ha.

Data for the 1971–1978 period show some of these relationships. Year to year fluctuations are influenced by climatic changes, nutritional relations, etc.

	1971	1972	1973	1974	1975	1976	1977	1978
Feed in kg per kg of carp produc- tion	1.49	1.53	1.72	1.65	1.70	1.63	1.70	1.80
Inputs of feeds in kg/ha	429.3	461.9	481.4	489.7	524.9	526.8	582.9	580.1

In addition to fish (and duck) culture, pond culture serves several other functions such as retention of water and utilization of water for agriculture, industry, and outdoor recreation. In these special cases, production and economic effectiveness are related to needs of the national economy.

Differences in intensity of farming result in classification of ponds into five groups.

(1) High intensity fish farming

(2) Average intensity farming

(3) Lower intensity of farming (technological and economic limits)

(4) Lower intensity of farming (preference for outdoor recreation)

(5) Ponds with specific utilization (water to be used for irrigation, sugarbeet factories, etc.)

In the first group, yields of over 1000 kg/ha (890 lb/acre) are achieved, in the second group, yields of 300–400 kg/ha (267–356 lb/acre) are achieved. In the remaining three groups requirements for technological, economic, and specific uses result in less intensification of farming.

As indicated earlier, traditional methods rely on fertilization. Phosphorus and nitrogen mineral fertilizers are applied as well as organic manuring. Application of mineral fertilizers is increasing as ponds with average or lower intensity of farming are subject to improved hygienic regulations. Serious problems also arise from water runoff bearing nutrients from other farm land that drain into ponds. Owing to the configuration of the terrain, nutrient runoff from arable land is more prevalent than in the majority of European countries.

Application rates of fertilizers and organic manuring follow:

	lb/Acre	kg/ha
Lime	347	390
Phosphorus fertilizers	27	30
Nitrogen fertilizers	20	23.2
Organic manuring	1603	1800

The preceding data represent average levels of input in the State Fishery Enterprise. In ponds with intensive farming, inputs of fertilizers are substantially higher.

Amelioration. While fish production is improved by use of both feeds and fertilizers, there are other factors which ameliorate more efficient intensification of culturing. Among these are installation of diversion ditches, cutting of weeds in ponds, enlargement of water area, summer and winter drying of ponds, and cultivation of pond bottoms. Possibilities for improvement also include additional building modifications (installation of feeding silos, aeration of water, control of chemical and biological composition of water). All contribute to more efficient technology and permit further intensification.

In Czechoslovak pond culture the following species are cultured for food:

- (1) Carp (*Cyprinus carpio*)
- (2) Tench (*Tinca tinca*)
- (3) Rainbow trout (*Salmo gairdneri*)
- (4) Pike-perch (*Stizostedion lucioperca*)
- (5) Pike (*Esox lucius*)
- (6) Maraena (*Coregonus lavaretus*)
- (7) Grass carp (*Ctenopharyngodon idellus*)
- (8) Silver carp (*Hypophthalmichthys molitrix*)

Also found in small numbers are sheatfish (*Silurus glanis*). Growing in importance are peled (*Coregonus peled*) and bighead carp (*Aristichthys nobilis*).

The most important fish cultured, by far, is the common carp (*Cyprinus carpio*) which accounts for over 90% of production. Increased production of several species is adversely influenced by intensification (mainly pike, pike-perch, rainbow trout, and maraena). While common carp is predominant, it is expected that there will be increased use of both mirror and leather (variations of *Cyprinus carpio*) carp.

Technology of Carp Culture

Extensive possibilities for improving culture remain in the sphere of incubation of eggs and fry and in fingerling and yearling production. Technological measures exist for the preparation of spawning fish which are affected by climatic conditions. Technology of artificial spawning and culturing of carp fry and fingerlings in special devices with thermal waters are being introduced on a large scale. Meanwhile, production of carp yearlings is adversely affected by the inflow of nutrients from agricultural soils. Eutrophication of waters in ponds is accompanied by fluctuating pH values and alkalinity with resulting negative effects on cultured yearlings. For the improvement of the water environment, application of amelioration, aeration of water, and other measures are coming into use.

Stock fish culture and production of marketable fish are carried out in rearing and fattening ponds. Three year rotation of fish is predominant and

marketable fish achieve individual weights of about 2 kg (4.4 lb). When a two year rotation is followed, the yearling fish are stocked directly to fattening ponds and reach weights of 1–1.5kg (2.2–2.9 lb) at the end of the second year. Two year rotations are utilized only to a limited extent, but gradual application of processing fish into different forms gives future possibilities to the utilization of smaller sized carp.

Species Cultured Besides Carp

Tench (*Tinca tinca*). Commonly produced in polyculture with carp. Growing marketable production is stimulated mainly by requirements for export. Production of marketable fish reached 400 MT in 1978.

Rainbow Trout (*Salmo gairdneri*). In Czechoslovakia, two main technologies of trout production are used:

- (1) Polyculture with carp in suitable ponds
- (2) Fattening in monoculture with utilization of special devices (cage culture, raceways, etc.). Contemporary marketable production amounts to 500–600 MT annually (1978–1979).

Pike-perch (*Stizostedion lucioperca*). Supply does not match demand of the market. Marketable production amounts to 17 MT per year. Increased production can be achieved by utilization of ponds with limited intensity of farming and by application of monoculture.

Pike (*Esox lucius*). Fluctuation or even decline of the yields is affected by similar factors as in the case of pike-perch (eutrophication of water, etc.). Total annual marketable production fluctuates around 30 MT. Future expansion of pike production depends on the selection of suitable ponds and improvement of technology of yearling culture.

Maraena (*Coregonus lavaretus*). These had been imported and successfully acclimated by the end of the 19th century. They are commonly produced in polyculture with carp. In spite of increasing intensity of farming, marketable production of maraena is gradually growing and in 1978 reached 360 MT.

Peled (*Coregonus peled*). Peled is evaluated as a good prospect for growing. It has been tested in polyculture with carp. In suitable ponds, stocking of peled with carp enabled total fish production to increase by 20–40% without additional inputs.

Phytophagous Fish

Acclimation of phytophagous fish is concentrated on the grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*), and to a lesser extent on the bighead (*Aristichthys nobilis*). The best conditions for culture and breeding are in the regions with warmer climate

(Southern Moravia, Southern and Eastern Slovakia). Marketable production of phytophagous fish fluctuates around 90 MT and is affected mainly by outcome of technology of yearling culture.

RIVER MANAGEMENT

Attention is drawn to the exploitation of rivers and artificial lakes by means of angling. Composition of wild fish affects predominantly the selectivity of angling, pollution, amelioration of waters, and limitation of natural spawning.

Angling is oriented mainly to species, their production in hatcheries and other devices, and then stocking in water reservoirs. Anglers catch the following species of fish mainly:

- (1) Carp (*Cyprinus carpio*)
- (2) Pike (*Esox lucius*)
- (3) Pike-perch (*Stizostedion lucioperca*)
- (4) Wels (*Silurus glanis*)
- (5) Tench (*Tinca tinca*)
- (6) Bream (*Abramis brama*)
- (7) Eel (*Anguilla anguilla*)
- (8) Barbel (*Barbus barbus*)
- (9) Rapacious carp (*Aspius aspius*)
- (10) Chub (*Leuciscus cephalus*)
- (11) Roach (*Rutilus rutilus*)
- (12) Perch (*Perca fluviatilis*)

Fish, other than common carp, account for only 10–11% of production. In the future, major expansion should be in trout and polyculture of phytophagous fish with carp.

Among salmonoids, these species are the most attractive ones:

- (1) Brown trout (*Salmo trutta m. fario*)
- (2) Rainbow trout (*Salmo gairdneri*)
- (3) Brook trout (*Salvelinus fontinalis*)
- (4) Grayling (*Thymallus thymallus*)
- (5) Huchen (*Hucho hucho*)

Anglers have an increasing interest in the exploitation of artificial lakes, special ponds, river arms, and other water reservoirs which have formerly been underutilized. In selected artificial lakes, fishing by means of seines and ground nets is sometimes practiced. The role of net fishing is limited insofar as supplying the market (60–70 MT annually). The major problem is the low economic efficiency of this kind of activity.

Another specific problem area is angling in artificial lakes which have the main purpose of supplying drinking water. Fish used for food for predatory fish are stocked as one component in the biological self-purification of water. In these types of waters, only limited angling is carried out.

MARKETING, HOME CONSUMPTION, AND EXPORTS OF FISH

Imports of fish from abroad and the supply of domestic marketable production influence the distribution and sale of fish in the home market. Imports fluctuate in the range of 50,000–60,000 MT annually. About 80% of imports are frozen, and are then further processed into various fish products. Possibilities of increasing imports of fish are adversely affected by increases in world market prices due to technological and economic limits of the world catch. For these reasons, efforts have been made to increase domestic production. However, in spite of increased domestic production in Czechoslovakia, consumption of home-produced fish meats accounts for only 17–20% of total fish consumption.

Annual consumption of fish meat per capita amounts to 5.5 kg (12.1 lb) or 6.4 kg (14.1 lb) including additional components during processing. The domestic share of consumption is 0.95 kg per capita (2.1 lb) and 1.15 kg (2.5 lb) including the catch from anglers. Elasticity of demand for fish is smaller than for other meats such as beef, poultry, and pork.

Reliable statistics of Czechoslovakia fish exports were published after World War I. The greatest amount of fish production exported was about 1935 when it reached more than 1000 MT (1100 ST). More extensive exports began about 1956. Most exports go to West Germany and Austria. After 1960, tench exports began to develop rapidly with Italy as the main customer. During the 1970–1975 period, exports increased from 800 MT to more than 1600 MT annually. Carp is the most important fish exported, secondly minor or naked carp. They are usually delivered on a live weight basis.

RESEARCH AND TECHNICAL INNOVATION

Fisheries research is concentrated on the solution of technological, technical, and economic aspects of two main kinds of fish culture:

- (1) Traditional fish culture in ponds, whether monoculture or polyculture
- (2) Fish culture in special devices (cage culture, raceways, etc.) with partial utilization of thermal waters

Point 1—Considerable attention is centered on the analysis of intensification and substitution of inputs, mainly in relation to limited resources of concentrated feeds. Technology of feeding and fertilization, aspects of genetics, ichthyopathology, technical innovation, and economic efficiency of fish production are being analyzed.

Point 2—Methods of increasing production by means of intensive fish culture with utilization of thermal effluents are being studied. Water from cooling reservoirs of electricity power stations is commonly utilized with recirculation.

Fish culture with utilization of thermal water has many interactions with the traditional pond fish culture. Devices with thermal water are

specialized mainly in the production of fry and fingerlings, which are further cultured in ponds. Pond culture is the existing leading method at present and this will probably continue. Analysis of technical and technological aspects of fish culture in thermal waters is still in experimental stages.

Genetics, Breeding, and Ichthyopathology

Genetics studies are oriented to aspects of reciprocal breeding, heritability of scaly covering, heterosis, etc. Methods for identification of genotypes by means of transference analysis were developed and used in the practice.

In relation to ichthyopathology, methods for diagnosis and therapy of infectious, parasitic, fungous, and other fish diseases are being solved. Considerable attention is concentrated on the etiology of spring viremia and prevention of diseases in salmonoid culture with high intensity farming. Impact of spring viremia on carp yields is a very serious one and improvement of prevention and therapy contributes to better technological and economic outcomes.

Hydrobiological research solves biological aspects of water management including the role of fish stock in improving the quality of drinking water. For the explanation of connections and interactions among individual particles of the nutritional chain, mathematical modeling is used. In water reservoirs, used as sources of drinking water, possibilities of fisheries exploitation from the standpoint of the national economy are analyzed.

Technical Innovation

Limited production of special machinery and technological devices complicate technical innovation. Devices are frequently used separately without versatile utilization of all parts of technology. Innovation is directed to the following parts of technology:

- (1) *Fishing the pond*—Utilization of seines and bag nets in catch basin prevails. According to foreign experience, fishing in basins outside ponds (below dam) is also practiced. Building of devices for fishing outside ponds is, however, limited due to the large investment. Higher requirements for manpower and changeability of conditions of fishing forms hinder the all-round application of electrical fishing. Growth of the productivity of labor was achieved by utilization of pneumatic dip nets for emptying the seine of fish. In artificial lakes and ponds during the summertime, fishery exploitation is practiced with the help of seines, ground nets, and experimental application of electrical fishing.
- (2) *Transport of fish*—For the transport of live fish, trucks with transporting tanks are used mainly and, in limited extent (deliveries for export), railway also. Application of narcotics during transport of live fish is not widely used. Impact of liquid oxygen on the biological

- functions of transported fish and costs of transport are analyzed.
- (3) *Wintering the fish*—Construction of wintering ponds is accompanied by high investment costs over 1,000,000 Czechoslovak crowns per ha and by considerable requirements for water supply (inflow, chemical composition, etc.). Wintering with very dense fish stocks is practiced utilizing aeration.
 - (4) *Feeding and fertilization*—Special boats for feeding large ponds permit decreases in input of labor. Mechanization of feeding is based partially on the application of foreign conclusions (German Democratic Republic, Hungary). Special boats help the growth of productivity of labor at the time of fertilization by utilizing automatic fertilizer dispensers.
 - (5) *Maintenance of ponds*—Enlargement of water area is carried out by versatile machines (bulldozers, etc.). Special machines for amelioration have not been developed, yet. Liquidation of weeds is usually mechanically accomplished, but there are increasing applications of herbicides.

Intensification of fish culture and increasing the supply of marketable production will require improvements in technology of fish processing.

ECONOMIC ASPECTS OF FISH CULTURE

In the sphere of economics, possibilities and requirements for highest efficiency of fish production are analyzed predominantly. Attention is also paid to the optimization of organizational structure and to economic aspects of fish culture with utilization of thermal water.

Economics of Pond Fish Culture

In pond fish culture as in aquaculture the natural conditions must be considered as the basis for efficient intensification of production. There are substantial differences between mentioned branches regarding the possibilities of adaptability and changeability of economic conditions.

Among the most important economic conditions which affect efficiency of intensification of production in pond fish culture are:

- (1) The distance of ponds from the fish farm buildings
- (2) The dispersion and mutual isolation of ponds
- (3) Size structure of ponds

Great distances, dispersion, and isolation of fish ponds do not allow complete introduction of measures, which can provide bases for the increase of technological and economic levels of production in agriculture.

Economic studies reveal that intensity of farming decreases with increasing distances of ponds from the fish farm. Unfavorable impact of distances can, however be compensated for partially by greater area of ponds.

In practice, seven different size groups of ponds are distinguished:

- | | |
|-----------------|------------------|
| (1) Up to 1 ha | (5) 20.01–50 ha |
| (2) 1.01–5 ha | (6) 50.01–100 ha |
| (3) 5.01–10 ha | (7) Over 100 ha |
| (4) 10.01–20 ha | |

From the standpoint of expedient utilization of labor and means of production, it is possible to recommend economic measures that result in the decrease of the distant and greatly dispersed smallest ponds (while maintaining integrity of drainage area of ponds). The best economic outcomes and highest intensity of farming have proved to be the fifth size group (20.01–50 ha).

Intensification of pond fish culture is accompanied by gradual change in cost structures. With increasing intensity of farming, share of labor costs decreases while material expenditures and maintenance increase (see Table 18.2). For the analysis in Table 18.2, 38 ponds with growth increments between 700 and 2000 kg per ha were chosen.

Average cost structure in Czechoslovak pond fish culture can be demonstrated by the selected statistical data in Table 18.3.

TABLE 18.2. CHANGES IN COST STRUCTURE WITH INTENSIFICATION OF POND FISH CULTURE

Cost Item	Cost Structure	
	1971 (%)	1975 (%)
Feeds	51.0	43.8
Fertilizers	10.9	4.1
Depreciation	3.3	2.5
Maintenance	5.4	12.5
Labor	8.9	6.0
Transport, repairs, etc.	7.4	8.9
Other cost (mainly material)	13.1	22.2

TABLE 18.3. AVERAGE COST STRUCTURE IN CZECHOSLOVAK POND FISH CULTURE

Cost Item	Cost Structure 1978 (%)
Feeds	35.4
Fertilizers	4.3
Depreciation	4.1
Maintenance and other material expense	14.7
Labor	9.5
Other costs	6.1
Direct costs	73.1
Transport, repairs, etc.	10.9
Total direct costs	84.0
Overhead charges	16.0

By means of mathematical modeling, structural changes of production costs in respect to the different relations of unit prices (per kg) between feeds and fish (carp) were derived. Outcomes of modeling of discrete relations are introduced in the survey in Table 18.4 and Fig. 18.1.

In the selected set of ponds (Set I), the price of feed is decreased per kg from 3 Kcs (Czechoslovak crowns), i.e., relation 1/4, to 1.20 Kcs (relation 1/10). This results in a decrease of total direct costs from 4200 Kcs to 2940 Kcs together with downward movement of share of feeds in the cost structure from 50 to 28.57%. Higher average intensity of farming (Set II) with comparable intervals gives decreases of total direct costs from 6300 Kcs to 4095 Kcs while the share of feeds in the cost structure decreases from 58.33 to 35.90%. In Czechoslovak pond fish culture, the unit wholesale price of concentrated feeds (pellets, etc.) corresponds approximately to 25% of the unit wholesale price of carp (relation 1/4).

Rate of return in carp culture (net return in relation to total costs) amounts to 4–5%. Net return per ha of cadastral area is between 800 and 1000 Kcs. In the Czechoslovak pond fish culture, there is one person employed in the State Fishery enterprise per 15 ha of cadastral area. Average production of one employee in the State Fishery Enterprise is more than 140,000 Kcs (total gross production).

TABLE 18.4. MODELING OF STRUCTURAL CHANGES OF PRODUCTION COSTS IN RELATION TO UNIT PRICES (PER KG) BETWEEN FEEDS AND CARP¹

Total Direct Costs (Kcs/ha)	Set I Average Growth Rate 525 kg/ha		Set II Average Growth Rate 925 kg/ha	
	Share of Feeds from Total Direct Costs (%)	Price Relations of Carp/Feeds (1=12 Kcs)	Total Direct Costs (Kcs/ha)	Share of Feeds from Total Direct Costs (%)
10,500	88.00	1/1	17,325	88.85
7,700	72.73	1/1.5	12,425	78.87
6,300	66.67	1/2	9,975	73.68
5,460	61.54	1/2.5	8,805	69.14
4,900	57.14	1/3	7,525	65.12
4,500	53.33	1/3.5	6,825	61.54
4,200	50.00	1/4	6,300	58.33
3,967	47.06	1/4.5	5,892	55.45
3,780	44.44	1/5	5,565	52.83
3,627	42.11	1/5.5	5,298	50.45
3,500	40.00	1/6	5,075	48.28
3,392	38.10	1/6.5	4,886	46.28
3,300	36.36	1/7	4,725	44.44
3,220	34.78	1/7.5	4,585	42.75
3,150	33.33	1/8	4,462	41.18
3,088	32.00	1/8.5	4,354	39.72
3,033	30.77	1/9	4,258	38.36
2,984	29.63	1/9.5	4,172	37.09
2,940	28.57	1/10	4,095	35.90

¹Price of feed is varied from 12 to 1.2 Kcs per kg.

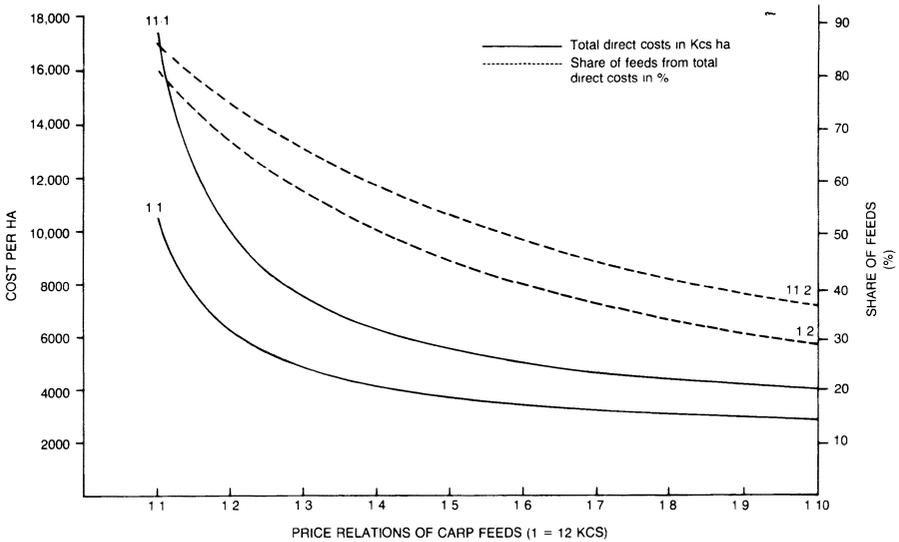


Fig. 18.1. Structural changes of costs in respect to different price relations of carp/feeds.

Economic Aspects of Trout Culture

Trout culture with rainbow trout (*Salmo gairdneri*) is practiced mainly by means of cage culture. Useful volume of cages fluctuates between 30 and 40 m³ (377 and 430 ft³).

Analysis of trout culture in cages reveals low investment requirements and high level of the productivity of labor and intensity of production. However, rate of return is commonly lower than in carp culture. Price relations between feeds and marketable production affect economics of trout culture to a greater extent because fattening in the cages is not based on the utilization of natural food.

Cost structure of trout culture in cages is affected mainly by calculation of expenditures for stock fish. When yearling trout are sold for cage culture from special fish farms, purchase is calculated as a separate cost item. Simultaneous production of fish stock and marketable fish in the same farm leads to the distribution of expenditures on the fish stock to the various cost items. Cost structure for cage culture from two different trout farms is as shown in Table 18.5 and 18.6.

For an evaluation of economic efficiency of trout culture in cages, a system of economic indicators is used, expressing intensity of production, productivity of labor and profitability of production.

	1973	1974
(1) Purchase of stock fish		
Intensity of production		
Stock density in number · m ⁻³	185	230
Weight of stock in kg · m ⁻³	2.77	3.45
Yield in kg · m ⁻³	33.33	31.25
Marketable production in kg · m ⁻³	30.56	27.80
Marketable production in MT		
per 1 employee	8.2	8.0
Marketable production in Kcs		
per 1 employee	229,515	222,560
Rate of return, %	2.80	
(2) Own production of stock fish		
Stock density in number · m ⁻³	80–100	100–120
Weight of stock in kg · m ⁻³	1.85	1.90
Yield in kg · m ⁻³	10.30	11.90
Marketable production in kg · m ⁻³	8.45	10.00
Marketable production in MT		
per 1 employee	8.7	10.2
Marketable production in Kcs		
per 1 employee	241,116	283,764
Rate of return, %	2.43	

TABLE 18.5. COST STRUCTURE FOR CAGE CULTURE FOR PURCHASED STOCK FISH

Cost Item	Cost Structure	
	1973 (%)	1974 (%)
Feeds	40.65	34.22
Purchase of stock fish	23.50	28.82
Other material expenses	2.35	3.24
Repairs, maintenance	0.59	1.10
Depreciation	7.64	9.98
Labor	12.69	14.93
Transport	1.76	1.16
Overhead charges	10.82	6.55

TABLE 18.6. COST STRUCTURE FOR CAGE CULTURE FOR OWN PRODUCTION OF STOCK FISH

Cost Item	Cost Structure ¹	
	1973 (%)	1974 (%)
Feeds	75.61	56.94
Purchase of stock fish	—	—
Other material expenses	2.66	1.35
Repairs, maintenance	0.44	1.35
Depreciation	11.09	6.13
Labor	9.76	33.62
Transport	0.44	0.61
Overhead charges	—	—

¹Excluding overhead charges.

TABLE 18.7. FIXED MARKET PRICES OF FISH BASED ON WEIGHT

Species	Czechoslovak Crowns per kg of Live weight	
	Wholesale Price ¹ (Per kg)	Retail Price ¹ (Per kg)
Carp (<i>Cyprinus carpio</i>)		
first category	13.50	15.00
second category	11.25	12.50
third category	6.80	7.00
Tench (<i>Tinca tinca</i>)	11.25	12.50
Pike (<i>Esox lucius</i>)	18.00	20.00
Pike-perch (<i>Stizostedion luciperca</i>)	22.50	25.00
Maraena (<i>Coregonus lavaretus</i>)	11.25	12.50
Wels (<i>Silurus glanis</i>)	18.00	20.00
Grass carp (<i>Ctenopharyngodon idellus</i>)	13.50	15.00
Silver carp (<i>Hypophthalmichthys molitrix</i>)	10.80	12.00
Bighead (<i>Aristichthys nobilis</i>)	10.80	12.00
Eel (<i>Anguilla anguilla</i>) over 250 g	31.50	35.00

¹To determine price per pound, divide wholesale or retail price per kg by 2.2.

PRICE OF FISH

In Czechoslovakia, fish is sold at fixed prices. In respect to the utilization of marketable production, wholesale and retail prices are introduced at this point. Marketable production of carp is divided into three categories, determined mainly by the weight of fish (see Table 18.7).

OUTLOOK

According to the data from various forecasting studies, growing consumption of animal protein, fruits, and vegetables is predicted. Gradual increases of world prices of fish and various fish products attest to the economic benefits of the growth of home fish production. Long-range planning data anticipate upward movement of consumption of home fish from 0.95 kg or 2.1 lb (1978) to 1.50 kg or 3.3 lb (1990) per capita per year.

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European USSR

FISH SPECIES

Atlantic salmon (*Salmo salar*)

Baltic sturgeon (*Acipenser sturio*)

Bass

Bester (hybrid cross of sturgeon) (*Huso huso* ♀ × *Acipenser ruthenus* ♂)

Bream (*Abramis brama*)

Carp

Chum salmon (*Oncorhynchus keta*)

Common carp (*Cyprinus carpio*)

Common or northern pike (*Esox lucius*)

Crucian carp (*Carassius carassius*)

Cyprinidae

Grass carp (*Ctenopharyngodon idellus*)

Great sturgeon (*Huso huso*)

Herring

Inconnu (*Stenodus leucichthys*)

Native catfish

Pike-perch (*Lucioperca lucioperca*)

Pink salmon (*Oncorhynchus gorbuscha*)

Rainbow trout (*Salmo gairdneri*)

Salmon

Silver carp (*Hypophthalmichthys molitrix*)

Starred sturgeon (*Acipenser stellatus*)

Steelhead (*Salmo iridius*)

Sterlet sturgeon (*Acipenser ruthenus*)

Sturgeon

Trout

Ukrainian or bleak carp (*Alburnus alburnus*)

European USSR

Akiro Homma and Hiroshi Shibukawa¹

Estimates of the freshwater catch from inland fisheries in the USSR range from 500,000 to 850,000 MT annually (551,000 to 937,000 ST). The Caspian Sea area accounts for about 30,000 MT (430,000 ST) of the higher estimate. The catch is increasing each year. Most of the catch is from natural waters. However, to maintain and increase the catch has meant limiting catches by species and sizes, creation of fish ladders around dams, creation of spawning areas and artificial hatching, and release of young fry and mature fish.

Sturgeon, trout, and carp are the major species being managed. Silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idellus*) from China have been introduced and are cultured in a limited way. Fish farming is generally limited to pond culture, mainly in the Ukrainian Republic. Carps are the major species. These include common carp (*Cyprinus carpio*), bleak carp (*Alburnus alburnus*), bream (*Abramis brama*), and crucian carp (*Carassius carassius*). The main species for culturing is probably the Ukrainian or bleak carp. There are plans to greatly increase cultured production, which presently is in the neighborhood of 200,000 MT (220,000 ST). In addition some rainbow trout (*Salmo gairdneri*), native catfish (not identified), and a hybrid of sturgeon called Bester are cultured.

About 70% of all pond production involves carp. There is considerable emphasis on creating new hybrid strains of carp for culturing and managing by crossing native and foreign species. Some of this work dates back 300 years. Research is aimed at increasing production by breeding for better growth rates, resistance to diseases, adaptability to cold water and higher survivability. These are goals for silver and grass carp also.

During the fifth 5-year plan it was decided to culture fish intensively in the heated water effluents from thermal electrical power plants. There were 10 to 12 of these possible production areas in 1974. Carp are grown in the summer and rainbow trout and sturgeon in the winter. Feeds fed to carp in intensive culture contain no animal protein and 3 to 4% fat content. Feed conversion is 4 units of feed to 1 of fish weight. Even with this conversion

¹This chapter is based on a fact-finding tour made by the authors in 1976.

rate, production cost is less than in Japan, where the feed conversion is better but the feed ingredients are more expensive.

Production of carp in ponds is about 2 MT per ha (1787 lb per acre). Plans call for increasing yields to 5 MT per ha (4468 lb per acre) by using fertilizers, minerals, and artificial food supplements. In one area, yields of 3 MT per ha are reported.

The Ukrainian or bleak carp (*Alburnus alburnus*) has superior growth in the colder waters. At the end of the first year the fingerlings range between 70 and 100 g (3 and 4 oz); the average is 1500 g (54 oz) after 2 years, 2500 to 2700 g (89 to 96 oz) after 3 years, and 3500 g (125 oz) after 4 years. The males mature in 3 years and the females in 4 years.

To achieve maximum production per hectare of pond water, polyculture is being promoted. This means that top water, bottom feeders, and mid-water feeding fish are raised together. A typical stocking density would be 7000 carp, 2000 to 2500 grass carp, 50 silver carp, a few pike-perch (*Lucioperca lucioperca*), and 30 to 50 catfish per hectare. It can be seen from these stocking figures that grass carp are playing an important role in cultured production.

Rainbow trout play only a minor role in fish farming, and production is not large enough to be listed in official statistics. They are cultured in the winter discharge waters of several electrical generation plants and are grown in netted boxes $3 \times 4 \times 1.5$ m ($10 \times 13 \times 5$ ft). In 10 months they reach market sizes of 150 to 200 g (5.5 to 7 oz). Production may be 100 MT (110 ST) annually. There is also one experimental hatchery using concrete raceways. This hatchery has 1200 m² (about 12,000 ft²) and production is 20 kg per m² (4.1 lb per ft²). Total production of this hatchery is 24 MT (26 ST). The goal is to double production per unit of water surface.

The inland freshwater catch in 1973 is shown in Table 19.1. The catch of carp is important, as well as herring. World sturgeon production, of which the USSR accounts for 95%, totals about 20,000 MT (22,000 ST). About 90% of the USSR catch comes from tributaries of the Caspian Sea. The sturgeons taken by fishermen are great sturgeon (*Huso huso*), Baltic sturgeon (*Aci-*

TABLE 19.1. INLAND FRESHWATER CATCH, USSR, 1973

Fish	Metric Tons		Total (1000s)
	Caspian Sea (1000s)	Other Areas (1000s)	
Cyprinidae	8	181	189
Common or northern pike (<i>Esox lucius</i>)	1	14	15
Catfish	3	11	14
Bass	1	29	30
Sturgeon	—	20	20
Herring	373	—	373
Salmon	—	28	28
Others	3	179	182
Total	388	462	851

penser sturio), starred sturgeon (*Acipenser stellatus*), sterlet sturgeon (*Acipenser ruthenus*), and Bester, a hybrid cross.

Biological minimum sizes for *Huso huso* are between 100 and 150 kg (220 and 330 lb). Adult females contain 500,000 to 800,000 eggs. These fish are taken in the Don and Volga rivers and tributaries. However, after maturing sexually the sturgeons grow much larger.

Biological minimum-sized Baltic sturgeon (*Acipenser sturio*) weigh between 15 and 40 kg (33 and 88 lb) and produce 150,000 to 300,000 eggs. They are caught in the Volga and Don rivers and in the Black and Mediterranean seas.

Biological minimum-sized starred sturgeon (*Acipenser stellatus*) weigh between 10 and 20 kg (22 and 44 lb) and female adults produce 150,000 to 200,000 eggs. They are found in the Volga and Don rivers and tributaries.

Because of plans to build four hydroelectric dams on the Volga (one already completed) and also dams on the Don River, scientists have concentrated on the methods of maintaining and increasing fishing populations, particularly of sturgeons. To do this means not only construction of fish ladders to enable fish to by-pass the dams, but also knowledge of the reproduction cycles and maintenance of hatcheries. They found that the *Huso huso* lays eggs in April and the small fish hatched go downriver in June. The *Acipenser sturio* lays eggs in April and goes downriver in September. The *Acipenser stellatus* lays eggs in June and the small fish go downriver in October.

At the sturgeon hatchery near Volgograd, which was founded in 1960 and contains 50 three-hectare ponds (371 acres), eggs are taken from natural sturgeon, hatched, raised to 13 to 15 cm (5 to 6 in.), and released. In 1972, 6 million sturgeon were released. These were 60% *Acipenser sturio*, 40% *Acipenser stellatus*, and a few *Huso huso*. After stripping the fish, using pressure only, the eggs are placed in hatching trays and at temperatures of 8° to 10°C (46° to 50°F) are hatched in 9 to 10 days. After hatching, the fry are placed in the hatchery ponds where they feed on natural foods. Stocking density of fry varies from 40,000 per ha (16,000 per acre) for *Huso huso* to 60,000 to 70,000 for the other two species (24,000 to 28,000 per acre). From the egg to 7 to 8 g sizes (0.25 oz) survivability of the *Acipenser stellatus* is between 55 and 60%. For *Huso huso* survivability is 40 to 42%. Survivability of the *Acipenser sturio* was not obtained but it must be high because the return rate from natural waters is 50%, compared to 20 to 30% for the *Acipenser stellatus* and 10% for the *Huso huso*. When the fingerlings reach a length of 13 to 15 cm (5 to 6 in.), they are released. This is called the "cigarette" stage and they weigh only 6 to 10 g (0.25 to 0.33 oz). It takes 42 to 45 days from spawning to release.

The number of sturgeon passing the Volga River dam in 1972 was 800,000. Plans call for an increase to 1,600,000. By the year 2000 production is planned to increase from 20,000 MT in the Caspian Sea to 50,000 MT (22,040 to 55,100 ST). Of these, *Huso huso* will account for 20% with each of

the other two species accounting for 40%. To achieve this goal, plans call for hatching and releasing 10 to 15 million *Huso huso* one-year-old fish, 130 to 135 million *Acipenser sturio*, and 290 to 300 million *Acipenser stellatus*. The sturgeon reach biological minimum size in 15 years and have a lifespan of 30 to 50 years.

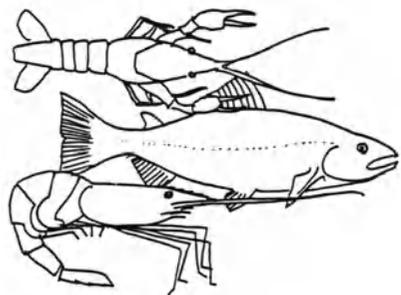
For about 15 years a hybrid cross called Bester has been produced. Adult female *Huso huso* eggs are fertilized with milt of male sterlet sturgeon *Acipenser ruthenus*, a sturgeon which is smaller and does not migrate down the rivers to the Caspian Sea. The advantage of these is the reduction of maturing from 15 to 8 years. In 1972 production of Bester was still in a pilot stage. In 1974 production was 225,000 fish.

Sturgeon fishing is prohibited in both the Caspian Sea and the waters of the Volga dam. Fishing is permitted only in other parts of the main rivers and tributaries.

Other species being cultured for release in natural waters are: (1) inconu, *Stenodus leucichthys*, which lives only in the Caspian Sea and the Volga River and nearly became extinct before scientists aided in its recovery; (2) Atlantic salmon (*Salmo salar*)—about 3 million are raised and released annually into the Black Sea and Baltic Sea; and (3) *Salmo iridius*, which is released in the Black and Asov seas. About 80,000 are released annually.

Experiments are being conducted with steelhead (*Salmo iridius*) imported from Canada, chum salmon (*Oncorhynchus keta*), and pink salmon (*Oncorhynchus gorbuscha*).

The major barrier to increased aquaculture production in the USSR is water quality—mainly water temperatures, which limit species and, for coldwater fish, necessitate long growth periods. Various carps will continue to be the mainstay in Ukrainian pond culture. Use of warmwater effluents from power plants can only play a minor role in increasing total production although relatively large increases in noncarp species are possible.



Hungary

FISH AND OTHER AQUATIC SPECIES

Asp (<i>Aspius aspius</i> L.)	Percidae
Barbel (<i>Barbus barbus</i> L.)	Pike (<i>Esox lucius</i> L.)
Bighead (<i>Aristichthys nobilis</i> Rich.)	Pike-perch (<i>Stizostedion lucioperca</i> L.)
Brown trout (<i>Salmo trutta m. fario</i> L.)	Rainbow trout (<i>Salmo gairdneri</i> Rich.)
Chinese carps	Silver carp (<i>Hypophthalmichthys molitrix</i> Cuv. et Val.)
Common carp (<i>Cyprinus carpio</i> L.)	Sterlet (<i>Acipenser ruthenus</i> L.)
Cyprinidae	Tench (<i>Tinca tinca</i> L.)
Ducks	Trout
Grass carp (<i>Ctenopharyngodon idellus</i> Cuv. et Val.)	Wels (<i>Silurus glanis</i> L.)
Hybrid of sterlet (<i>Acipenser ruthenus</i> L.) × hausen (<i>Huso huso</i> L.)	

Hungary

Karoly Pinter

Hungary is a typical landlocked country in Central Europe in the Carpathian basin. Due to its being landlocked and its distance from the seas, the population has become accustomed to freshwater fish which are available through domestic production. The other dominant factor in the development of Hungarian fish farming is that the majority of fish indigenous to or introduced in the Carpathian basin belong to the families Cyprinidae and Percidae, which are warmwater fish.

Management and control of the fishery sector is with the Wildlife and Fisheries Department of the Ministry of Agriculture and Food. The administrative work based on the Fishery Act and the management and development of productive activities are both carried out by this department.

During the most recent three decades, the Hungarian fisheries sector has undergone major changes, as indicated in Fig. 20.1. This figure also indicates the share of different fishery activities of the overall production volumes. The two major fields of production are natural water fish capture activity and pond farm fish production; these two areas are closely related.

The fishing rights belong to the state on all the natural waters of the country, about 130,000 ha (313,000 acres). These rights are then granted by the state—on the basis of given conditions—to organizations which are considered to be most suitable for the utilization of a certain water area. The organizations utilizing natural waters may be the following types: state farms, agricultural cooperatives, fishery cooperatives, research institutes, and the Hungarian National Angling Union. Anglers are entitled to use waters not constituting the area of anglers' organizations as well. The only exceptions to this system are the intensively utilized water reservoirs and backwater areas.

The data in Fig. 20.1 also indicate that fish captures from extensively used natural waters have also increased steadily. It should be noted here that in accordance with the Hungarian statistical system, the anglers' catches have risen sharply with the rapid increase of sport fishing activities. Fisheries management and production in natural waters are also affected adversely in Hungary by drainage and rising pollution levels. This tendency can only be countered by stocking more and more fish into the waters in the course of years. Production of fish for stocking is the task of the pond farms.

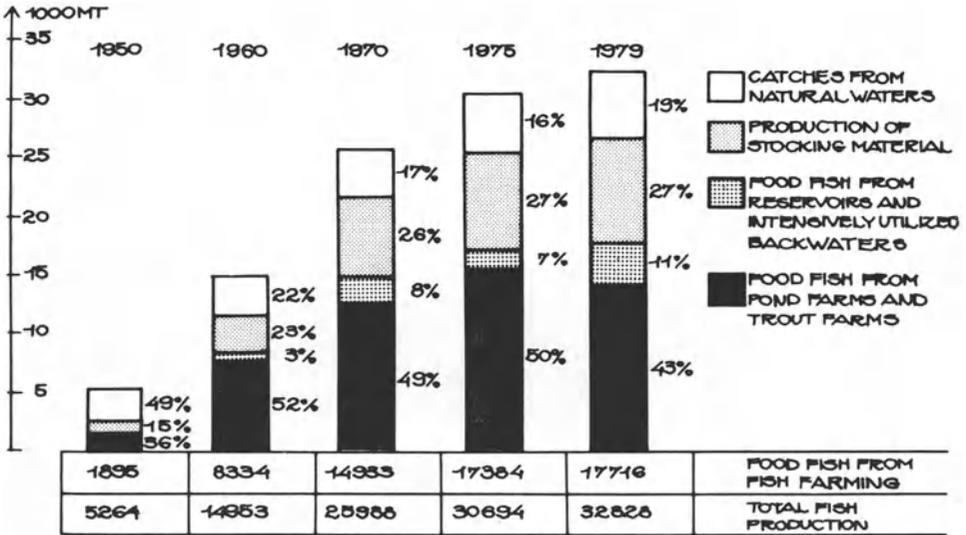


Fig. 20.1. Development of fish production in Hungary.

POND FARMING

The production of common carp (*Cyprinus carpio* L.) is the most important area of fish farming in Hungary. Climatic and topographical conditions in the country are particularly advantageous to the development of pond farming; thus as early as the end of the 19th century, people had begun to construct fishponds. Many fishponds were constructed after 1950. The general approach here was to construct fishponds on areas which are very difficult to use for other farming purposes. As a result, most of the fishponds were constructed on the worst, frequently sodic soils.

The total pond area in operation is about 20,000 ha (48,200 acres). Fishponds may be found mostly on state farms with mixed farming and in agricultural cooperatives. On these farms there is a separate enterprise for fish production, which is, however, closely associated with the other farm enterprises, primarily with the crop production enterprise which supplies the cultured fish with feeds.

As in other Central European countries, the principal fish in pond farming is common carp. Production is generally subject to 3-year cycles. Its rationale is that in the first year fingerlings of 25–35 g are produced, in the second year footlings of 200–300 g, and in the third year, food fish above 1 kg (2.2 lb) body weight are produced.

The 2-year production cycle is less commonly used. This system is useful in certain years as a supplementary system. In this scheme, in the first year fingerlings of 80–100 g are produced and in the second year food fish under 1 kg (2.2 lb) weight are produced.

The production of supplementary fish species together with carp is also practiced. These include the predatory fish, like pike-perch (*Stizostedion lucioperca* L.) and wels (*Silurus glanis* L.), in the first instance, and tench (*Tinca tinca* L.), which helps to better utilize the available nutrients. The share of supplementary fish species in the stock of a given pond is not more than a few percent.

The successful introduction of Chinese carps involved important changes in Hungarian pond farming. The acclimatization program started in 1963 with these species:

- grass carp (*Ctenopharyngodon idellus* Cuv. et Val.)
- bighead (*Aristichthys nobilis* Rich.)
- silver carp (*Hypophthalmichthys molitrix* Cuv. et Val.)

In general, these are herbivorous fish.

The main objective of this venture was to find a way to better the utilization of the natural nutrients proliferating in the ponds and to be able to increase yields without alterations in the feeding methods. (It is to be noted here that the main principle of feeding in pond farms in Hungary is to enable the ponds themselves to produce the animal protein required for the fish by means of various fertilization methods, and that only cereal grains should be applied externally.) A survey carried out in the years 1973–1978, which extended to 60% of the pond farms and to 80% of the pond areas of the country, indicates that the three herbivorous species are used in production by pond farms with widely different yield-levels (Table 20.1).

Pond farms stock their ponds with carp and herbivorous species in highly different proportions. The composition of the stocking population is determined by natural conditions and by market requirements. The stocking pattern itself involves to some extent alterations in the technology applied. This is illustrated by the varied picture of production composition on farms which reached the highest yields over a 5-year period (Table 20.2).

With the widespread introduction of polyculture (common carp and herbivorous fish), a pond farm model has been developed as illustrated in Fig. 20.2. The figure visualizes farming activity which encompasses the entire production cycle in which the marketing of both food fish and stocking material is of great importance. A complete production cycle can only be found on certain larger fish farms; there is a strong tendency toward specialization.

Specialization is in its most advanced stage in the phase of reproduction. About 30% of hatching is concentrated in the Warm Water Fish Hatchery at Szazhalombatta.

In addition to the previously mentioned pond farm fish species, the farm units specializing in reproduction are also concerned with fish which play a major role as stocking material for natural waters. In this way, induced propagation methods are applied for pike (*Esox lucius* L.), sterlet (*Acipenser ruthenus* L.), asp (*Aspius aspius* L.), and barbel (*Barbus barbus* L.) as well.

TABLE 20.1. OCCURRENCE OF THE FOUR MAIN SPECIES IN THE STOCK COMPOSITION OF POND FARMS OF DIFFERENT YIELD-LEVELS

MT/ha	Yields lb/Acre	Common Carp	Frequency of Species in Percentage of Pond Farms	Silver Carp	Number of Investigated Pond Farms (1973-1978)
			Grass Carp	Bighead	
0.5	457	100	35	11	111
0.5-0.8	457-732	100	67	37	118
0.8-1.1	732-1005	100	64	42	104
1.1-1.4	1005-1280	100	69	41	46
1.4	1280	100	74	46	39
Percentage of the 4 main species in total pond farm production (1978)		70.1	3.1	10.1	13.6

TABLE 20.2. PRODUCTION COMPOSITION OF POND FARMS WITH HIGHEST YIELD-LEVELS

Pond Farms	MT/ha	lb/Acre	Common Carp	Production Composition by Species in Percentage	Others
				Grass Carp	Silver Carp
A	1.76	1610	78	4	10
B	1.78	1628	75	0	25
C	1.78	1628	100	0	0
D	1.83	1673	95	0	5
E	1.99	1820	92	5	0
F	2.12	1948	88	4	8
G	2.23	2039	59	17	24
H	2.49	2277	81	2	15

OUTPUT I.

PRODUCTION

OUTPUT II.

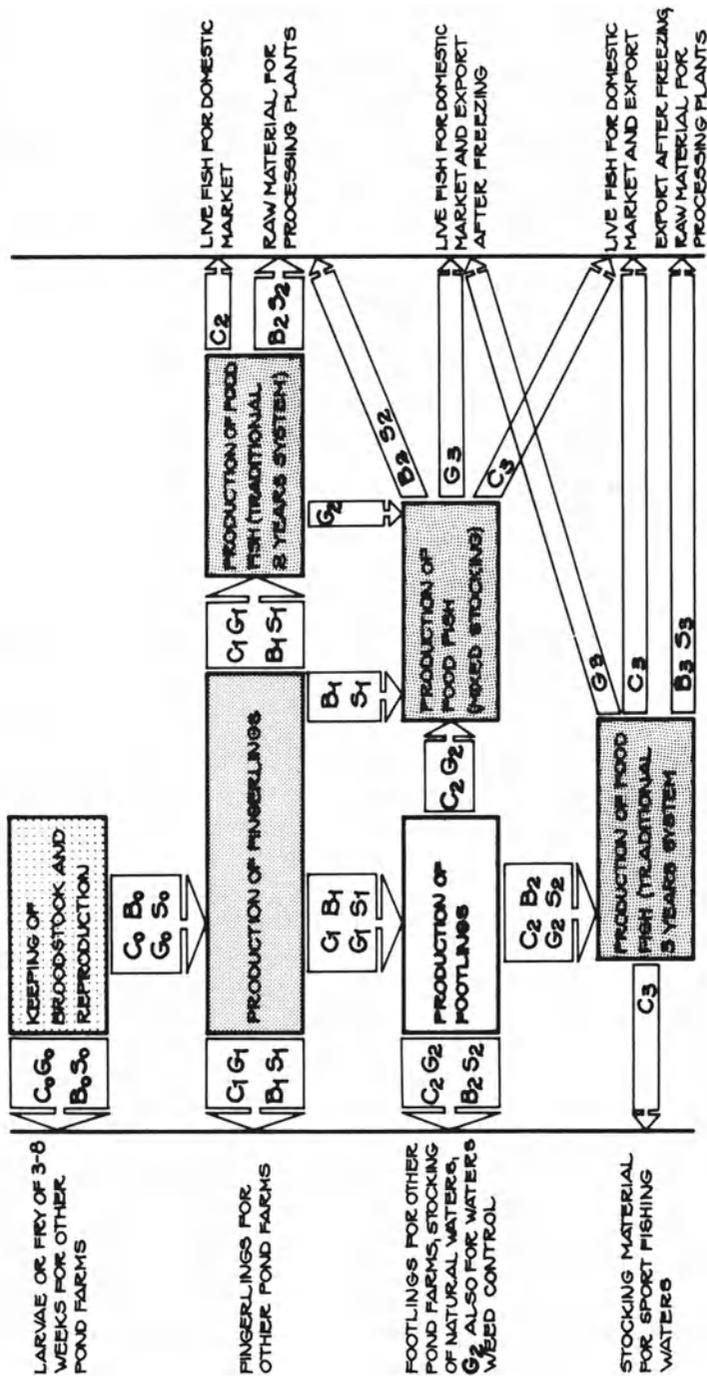


Fig. 20.2. Scheme of pond farming systems practiced in Hungary.

Certain pond farms undertake duck production too. Subsequent to a brief initial rearing period, young ducks are kept on the ponds, whereby the problem of pond fertilization by duck droppings is also resolved. On the pond farm of the Fisheries Research Institute at Szarvas the fish-cum-duck production system is completed with agricultural rotation as well.

TROUT FARMING

Trout farming in Hungary does not belong to the traditional fish production areas. Until 1976 only two minor trout farms were operating in the country. Their task was to supply food fish for the domestic market and partly to provide stocking material for various natural water areas. The one really large-scale trout operation was established only in 1976. This farm is supplied with water from an adjacent bauxite mine. The major species here is rainbow trout (*Salmo gairdneri* Rich.), but smaller quantities of brown trout (*Salmo trutta m. fario* L.) are also produced as stocking material for sport fishing waters. Production on this farm attained 280 MT (309 ST) in 1979.

FISH PRODUCTION IN WATER RESERVOIRS

Fish production-related activity in water reservoirs is in all cases of secondary importance since the primary purpose of water utilization from the reservoirs imposes restrictions on fishery possibilities.

For reservoirs (the so-called one-year storage facilities) the same technology has been developed as for pond farm fish production. For these reservoirs, the ancillary facilities necessary for fishery utilization are designed at the outset: first of all, the internal drain-off canal system, the external or internal fishing pits, fish screens preventing fish from escaping, land level-



Fig. 20.3. Combination fish with duck culture. Courtesy of Dr. Shigeru Arai.



Fig. 20.4. Concrete canal for mechanized fish harvesting on the state farm of Bikal.

ling over the reservoir area, or perhaps smaller fish storage ponds.

The water level in these reservoirs is considerably reduced by the end of the productive season and the residual water may be removed to facilitate harvesting.

The fish yields attained and the profitability of production are roughly the same as for traditional pond farming.

Recent land protection legal provisions compel reservoir constructors to pay a fine as land redemption for the area removed from agricultural usage. The amount paid is progressively higher depending on the quality of the land in question. The only way to reduce this cost is to design supplementary fishery facilities for the reservoirs. In this case 50% of the penal land redemption tax is cancelled. These central measures are expected to lead to a larger number of reservoirs built in the future being utilized for intensive fish production.

Currently, the major part of the installed reservoir area is suitable for only traditional, extensive natural water-type fishing and for angling. The fishing rights over certain water reservoirs are now granted for use by the state to the Hungarian National Angling Union. These reservoirs primarily serve recreational purposes; commercial fishing is carried out in them occasionally, controlling overstocking. Water reservoirs for the exclusive use of anglers also contribute to the profitability of fish production by purchasing large amounts of footlings (yearlings) for restocking from state-owned and cooperative pond farms.

UTILIZATION OF BACKWATER AREAS

Large-scale river draining operations have a double effect on fisheries. The drainage of large food areas has led to a reduction of fish breeding grounds, and, consequently, to an impoverished fish stock in rivers. This setback could only be partially and minimally counteracted by extensive backwater fish production and sport fishing activity. Over the recent two decades—parallel to the rising construction costs of traditional pond farms—the fishery cooperatives operating over backwater areas have, however, recognized the possibility of using the different backwater areas for much more intensive fish production than hitherto practiced. The widespread development of sport fishing has also had a constraining effect. Sport fishing demanded ever larger areas for its own purposes: fishery cooperatives were entirely ousted from certain waters, while in other areas the commercial fisheries activity was restricted by the stock regulation.

The replacement of lost productive areas by the construction of new pond farm units encountered obstacles: fishery cooperatives did not have sufficient funds for development of extremely expensive pond farms. On the other hand, formerly the major role in the production pattern of these cooperatives was fishing in natural waters; they had therefore no land areas suitable for pond construction and no possibility to purchase such areas, due to restrictions on the commercialization of landed properties.

Backwater sections in flood areas and on protected riversides have basically different features and possibilities from the viewpoint of fisheries utilization.

The backwater areas in floodplains are in connection with the main riverbed for a shorter or longer time during the year. The development of an intensive pond-like production technology cannot be undertaken over these water areas. It is advisable, however, to develop them in such a way as to make them more suitable for anglers compelled to quit the waters taken under intensive utilization and to provide adequate recreational possibilities over these waters. By dredging, a part of the backwater areas can be communicated with the main riverbed for a longer time of the year even at low water levels. In this way, the role of these areas in the resupply of the main water course with fish can be restored and the costs involved of restocking rivers can be substantially reduced. In the implementation of related investments, the commercial fisheries, angling and wildlife protection bodies and authorities should, however, play their proportionate financial roles.

The majority of backwater areas along protected sides may be made suitable for intensive fish production. Intensification requires different levels of technical improvement in different areas, but it generally includes the following aspects:

- (1) Technical conditions should be provided for safe, economical drain-off and replenishment possibilities, independent of the water level available in the main water course.

- (2) Conditions for internal water management and water control required by high level fish farming should be created, i.e., internal drain-off canals, fishing pits, embankments.
- (3) In certain cases, the construction of fish storage ponds, wintering ponds, and granaries might become necessary.

The average implementation cost of the preceding specified investments is 60,000–100,000 Forints¹ per ha (\$1050–\$1760 per acre) in comparison with the average investment requirements of 200,000 Forints per ha (\$3500 per acre) for traditional pond farms. On the other hand, the backwaters are much more difficult to operate and manage than traditional pond farms.

Only backwaters with special endowments can be drained off perfectly. Consequently, the aeration, freezing, and cultivation of the waterbed are impossible. Since backwaters are used for water storage purpose too, water retention and removal can only be carried out in accordance with or subordinated to the interests of water management and agricultural water usage. The quality of feeding water supply also varies largely. All these factors combine to give a much shorter lifetime and less suitability for intensive fish farming.

Currently, about 1100 ha (2650 acres) of backwaters are under intensive fish production in Hungary. Over about 90% of this area food fish are produced from footlings (yearlings) by polycultural method. On about 10% of the total area footlings (yearlings) are produced through stocking with fingerlings. This latter method is only typical of water difficult to protect against fish poachers; its importance is expected to decline in the future.

Indicators for traditional pond farming and intensive utilization of backwaters are compared in Table 20.3. The production year 1977 is used because in 1978 there were considerable production losses on most of the pond area as a result of adverse weather and fish sanitation conditions. Since mainly footlings (yearlings) were affected by this setback, the national pond farm averages were reduced for 1979 as well. The use of data from 1977 proved to be more amenable as this year is more typical of real conditions.

As shown in Table 20.3 common carp plays a decisive role in the production pattern of pond farms, whereas herbivorous species are predominant in backwaters. The other species are composed of predatory species and tench in the stocking of both ponds and backwaters. At the time of harvesting, in the case of backwaters, the “others” category also includes different wild fish which could not be captured in the previous season and were able to winter.

Two-thirds of the yield on pond farms—in accordance with stock composition by species—originates from the feeds applied, while for backwaters the yields are mostly determined by natural foods, with the added stimulating effect of fertilizers.

¹The artificial official exchange rate is 23 Forints per dollar. Since this rate is artificially maintained, “real” costs in dollars may not be realistic.

TABLE 20.3. NATIONAL LEVEL COMPARISON OF MAJOR PRODUCTION INDICATORS BETWEEN FISHPONDS AND INTENSIVELY UTILIZED BACKWATER AREAS (Model year: 1977)

Indicators	Fishponds	Backwaters
Stocking rates (kg/ha)	422	488
within this: common carp,	314	223
herbivorous fish,	98	257
others	10	8
Harvesting (kg/ha)	1305	1301
within this: common carp,	946	476
herbivorous fish,	334	749
others	25	76
Total yields (kg/ha)	883	813
within this: natural and		
fertilizer-induced yields	295 (33.4%)	497 (61.1%)
yield on feeds	588 (66.6%)	316 (38.9%)
Amount of feeds for production		
of 1 kg total yield (in starch		
value kg)	2.3	1.3

Note: 1 kg equals 2.2 lb and 2.47 acres equal 1 ha.

The expected wider application of intensive backwater utilization in the years to come will induce a response in the production pattern and economics of traditional pond farms. Because food fish are produced almost exclusively in backwaters, the necessary stocking materials are to be produced in traditional pond farms. In the framework of this progress toward specialization, the pond farms will increasingly be able to use proportionally larger pond areas for the more profitable production of fry, fingerlings, and footlings.



Fig. 20.5. Selective harvesting in a cooperative pond farm.

FISH PRODUCTION IN CAGES

Fish are produced in cages only on an experimental scale in Hungary. The reason behind this is that complete feeds are required even for common carp in the case of cage culture. The price of high animal protein content feed-stuffs is so great that it makes carp farming in this way uneconomical.

The experiments are concerned with fish species which are demanded by export markets or which meet special needs in the domestic catering industry. The best results thus far have been with wels (*Silurus glanis* L.) and with the hybrid of sterlet (*Acipenser ruthenus* L.) \times hausen (*Huso huso* L.). The technological development is aimed at performing fish production even in water areas which presently serve primarily angling purposes.



Fig. 20.6. Experimental cages on a backwater near the fisheries research institute at Szarvas.

OPERATIONAL ECONOMICS

In Table 20.4, a model calculation is provided for the operational economics of the two major fish farming methods: traditional pond farming and intensive backwater fishing, both food fish production. To facilitate comparison, yield was assumed to be 1 MT for each hectare (915 lb/acre). The theoretical character of the model should be emphasized since it assumes the entire quantity of footlings (yearlings) used for stocking to be obtained from external purchases. This alternative is rare in common practice, but as illustrated in Fig. 20.2, the pond-raised stocking material for natural waters has an appreciable marketing possibility. If this item were reckoned

TABLE 20.4. MODEL CALCULATION FOR OPERATIONAL ECONOMICS¹
(1980 PRICES)

Indicators	Traditional Pond Farm		Intensively Utilized Backwaters	
	(1000 Fts/ha) ²	%	(1000 Fts/ha) ²	%
Costs				
stocking	12.1	36.0	10.0	40.0
feeds	10.2	30.4	4.0	16.0
other materials	2.5	7.4	3.5	14.0
labor and public rates	2.3	6.8	3.0	12.0
depreciation, maintenance, administration, and other fixed costs	6.5	19.4	4.5	18.0
Total costs	33.6	100	25.0	100
Price proceeds	39.0		30.2	
Return	5.4		5.2	

¹Based on 1 MT of production per ha or 915 lb per acre.

²The artificial official exchange rate is 23 Forints per dollar. "Real" costs may be inaccurate if this rate is used.

with at on-farm production costs rather than at purchase price in the calculations, production costs would decline.

The difference in fish species composition between the two methods of fish farming is reflected in *variable costs*.

Stocking costs are affected to a smaller degree because the price of herbivorous footlings is almost the same as that of common carp. (It should be mentioned here that after the first production year the price of herbivorous fingerlings is about three times the price of carp; this is because due to changing climatic conditions the reproduction of herbivorous fish can only be safely performed in certain specialized farms. Besides, the rearing requires more care and more labor input, and the development of these fish species is less rapid than that of common carp. Essentially the high production costs arising in the first production year continue to be reflected in the second one; they are only slightly reduced by lower feed usage rates.)

Feed costs vary widely between traditional pond farming and intensive utilization of backwaters. The cost-saving feature of producing herbivorous fish arises only here. In terms both of absolute figures and of percentage ratios the other material costs are higher in the case of intensively utilized backwaters. This is mainly due to higher fertilizer use which is necessary with higher shares of herbivores in production.

Labor costs are also higher in backwater operations because, despite lower amounts of feeds being used during the production season, feeding must be carried out regularly. The manpower required to apply fertilizers is of similar magnitude to that in pond farming. On the other hand, harvesting in the fall in backwater areas is a more difficult task. Backwaters cannot be drained off completely, harvesting is protracted, and the mechanization of the operation is almost impossible.

The level of *fixed costs* for backwater operations is lower because the depreciation ratio is minimal due to the usually smaller extent of site improvement and installations and to the use of less machinery equipment.



Fig. 20.7. Mechanized harvesting and fish sorting on the state farm of Hortobagy.

Total production costs are substantially higher for traditional pond farming; but the attainable level of *price proceeds* is also higher. In calculating price proceeds, delivery to the domestic market through the wholesale trade company was taken into account. The discrepancy in price proceeds between the two methods of production is because herbivorous fish are marketed at a price appreciably lower than in case of common carp.

MARKETING

The utilization of marketing possibilities plays a decisive role in the economics of fish farming. The different marketing possibilities have an effect on production technologies and on the structure of production by fish species and year groups.

Stocking materials are mostly marketed through direct deliveries between fish farms, frequently on the basis of package contracts concluded several years in advance. In marketing stocking materials, generally there is appreciable competition among the demands of fish farms, natural water fisheries, and angling associations.

This market is less affected by export possibilities, because the amount of export-ready stocking material is limited by the state. The price of stocking material of predatory fish is relatively stable but the prices of common carp and herbivorous species are greatly variable from year to year due to the effects of supply and demand.

Fish in Hungary cannot be considered as a regularly consumed foodstuff. A representative datum is that the amount of fish sold during the days preceding Christmas corresponds to the total turnover in fish of two other normal months.

As an overall indication the per capita annual fish consumption from domestic production amounts to 1.8 kg (4 lb). This quantity is increased by the annual per capita consumption of 0.9 kg (2 lb) of saltwater fish from import sources.

The total fish consumption is thus extremely low but within this level the

consumption of freshwater fish is relatively outstanding on the international scale.

Carp is in particularly high demand by the population because the special fish dishes of the Hungarian cuisine are usually prepared from this species. Carp is mainly commercialized as live fish in containers. Carps above 1 kg (2.2 lb) weight are rated as a first class commodity.

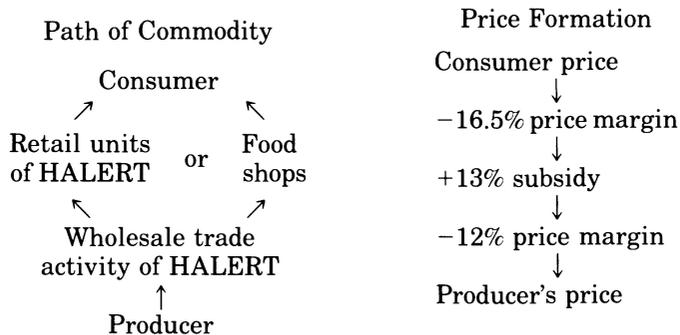
The herbivorous fish species are less sought after on the domestic market. Their increased marketing turnover can only be expected after improvements in the capacity of fish processing plants producing kitchen-ready products.

At the present moment the demand for predatory fish (wels, pike-perch) captured from natural waters or produced as supplementary fish by fish farming cannot be matched by production. The consumer price of these species is about 2.5 times the price of carp. The same applies to the price of trout, although in this case the high price is a result of high production costs rather than of excessive demand.

In marketing fish the producer has a choice among several channels in order to reach higher profitability. Fish commodity prices in Hungary are not directly controlled; they belong in the free price category. Yet in spite of this, supply and demand conditions have only limited influence on price trends. The major limiting factor results from the size of farms. The operational size of pond farms belonging to the state-owned sector is very large—i.e., the State Farm of Hortobagy operates about 5000 ha (11,000 acres) of pond area.

The large producers offer their fish crop to one single wholesale trade company (HALERT). About 50% of all produced food fish are commercialized via this company.

The price margin for wholesale and retail trade is centrally controlled. At the same time, in order to keep consumer prices down, the state provides a 13% subsidy (consumer price promotion) on farm raised carp and herbivorous fish. Price margins and levels of subsidies are calculated on the basis of consumer price. The producer price paid to the farms is therefore calculated backwards in the following manner:



Consumer prices are subject to seasonal variations. Thus, for example, the consumer price of first class carp in May–June–July is on average 50% higher than in October. The farms therefore which undertake the delivery of their fish in the summer season may attain quite high prices. On farms where the necessary technical conditions are available, the amount of fish to be captured during a selective harvest in summer is kept in mind beforehand at the time of stocking in springtime. On other farms the current economic conditions are taken into consideration in order to decide about the summer harvesting—with its difficulties, risks, higher price possibilities but also lower production volume.

The preceding specified commercial channel, in view of its predominant role, has a decisive effect on possible consumer prices attainable through marketing by other existing channels.

There is, however, a possibility of realizing a part of the retail trade plus wholesale price margins within the fishery enterprise or at least within the given state-owned or cooperative farm itself. This is made possible through the following schemes:

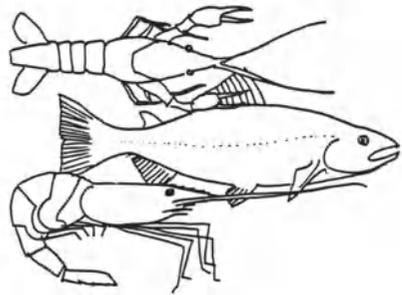
- (1) The farm operates its own fish processing plant for which the raw material is obtained from its own fishery enterprise at given accounting prices or purchased from other farms without the mediation of wholesale trade. These prices are higher than those paid by the HALERT Company, whereby larger profits are obtained in the fishery and in fish processing enterprises of the farm, mainly from the distribution of the 12% wholesale trade price margin.
- (2) The farm operates its own fish selling shop or a catering trade establishment, e.g., a fishermen's inn. The internal accounting prices follow the same pattern as in the preceding case. The profit increment is distributed between the farm's fishery and retail trade or catering trade enterprises.
- (3) The fish of the farm are marketed directly for the state-managed catering trade enterprises without the mediation of the wholesale trade. This possibility is extremely limited because the catering trade requires the continual delivery of small lots and it is easier for the wholesale trade company to meet this demand.

The price proceeds of farms are appreciably enhanced by marketing fish for export. These possibilities are, however, limited, particularly for the most important product—live carp. First the increased quality requirements of the external markets have to be fulfilled, and second, the customs system of the Common Market is unfavorable to Hungarian fish exports in most of the year. In the case of live carp the most important external market is the German Federal Republic (West Germany). In recent years high amounts of export deliveries could be reached in markets in the Middle East with frozen herbivorous fish.

Fish farms are not endowed with export rights. The Hungarian fish exports are undertaken by foreign trade companies.

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Asian USSR

FISH AND OTHER AQUATIC SPECIES

Abalone	Pink salmon (<i>Oncorhynchus gorbuscha</i>)
Algae (edible)	Pollock
Char	Salmon
Chum salmon (<i>Oncorhynchus keta</i>)	Scallops
Cod	Shellfish
Coho salmon (<i>Oncorhynchus kisutch</i>)	Silver salmon
King crab	Sockeye salmon (<i>Oncorhynchus nerka</i>)
Masu salmon	Sturgeon
Molluscs	Tanner crab
Northern seaweeds	Whitefish

Asian USSR

Clinton E. Atkinson

Aquaculture in the Soviet Far East is completely different from that taking place in European Russia. The area itself is extremely broad, extending from east to west for about 7500 km (5000 mi). Although there are a number of large modern cities (Vladivostok, Khabarovsk, Irkutsk, etc.), the population density as a whole is low—probably comparable to that of the state of Alaska. However, the climate is the factor that has discouraged the development of pond culture in Siberia and the Soviet Far East. The winters are severe and, except for the Sakhalin and Primora regions, the ponds are covered with ice for 4 to 6 months of the year and the growing season is short.

The marine environment is similarly severe and it is difficult to develop an extensive marine aquaculture program. Again with the exception of Sakhalin and the Primora regions, the entire coast of the Soviet Far East is affected by the flow of cold currents along the coast, originating in the northern Bering Sea (and some from the Arctic Ocean) to form the Oyashio, Okhotsk, and Liman currents. Generally the water is too cold to grow the common forms of fish and shellfish cultured in the more temperate waters of other countries.

In very recent years the Soviet scientists have begun a series of studies on the development of mariculture along the Pacific coast of the USSR, especially in the warmer waters of Primora (e.g., Peter the Great Bay) and Sakhalin. Although much valuable work has been done by the scientists of the Pacific Scientific Institute of Fisheries and Oceanography (TINRO) at Vladivostok and five branch laboratories, recent success of the Japanese and others in the culture of scallops, abalone, king and Tanner crab, the northern seaweeds, etc., has done much to encourage a re-examination of the potential of mariculture in the Soviet Far East. In the past 10 years, plans have been developed to establish production farms for kelp and other seaweed and probably for scallops and other shellfish as well (Ayushin and Chigirinsky 1976). Romanycheva and Sal'nikov (1979) also refer briefly to mariculture of edible molluscs and algae in the seas of the Soviet Far East. One of the plans calls for the saltwater rearing of salmon in pens in the Primora District, especially in the areas of industrial development where cooling water would be available from thermal or nuclear power stations:

It is estimated that about 23,000 to 25,000 MT of salmon can be produced by pen culture by the year 2000, or about 6–8% of the total amount of salmon from the Soviet Far East (Chigirinsky 1978).

Although mariculture and pond culture have not been developed in the eastern part of the Soviet Union, the results from “fish ranching” (i.e., the taking of spawn, incubation, and releasing the young in the rivers and lakes to grow) have been outstanding. Also associated with the work of the hatcheries have been innumerable experiments on the transplantation and acclimatization of various species of fish to new waters. Although a list of species used in these transplants is not available, much of the effort has centered around sturgeon, whitefish, and salmon. Perhaps the most spectacular of all these experiments has been the mass transplant of millions of pink and chum salmon eggs to the Murmansk region and the establishment of a new run of Pacific salmon in the eastern Atlantic and northern seas.

SALMON¹

Although several earlier investigators had expressed concern for the future of the salmon runs to the Amur River, I.I. Kuznetsov was the first to take active steps to protect the natural spawning runs of salmon and to propose artificial propagation, “. . . which, when there is an excess of spawners on the grounds, can provide a real addition to natural reproduction.” Mainly as a result of his efforts to maintain salmon runs in the Far East, measures were taken in 1924 to establish catch quotas, protect spawning grounds, regulate fishing seasons, and undertake artificial spawning. Thus in 1927–1928 the first salmon hatcheries were built at Teplovka Lake (tributary to the Amur River) and at Lake Ushkovskoye (tributary to the Kamchatka River). Later a third hatchery was built on the Bidzhan River, tributary to the Amur River and about 100 km (62 mi) from the hatchery at Teplovka Lake (Atkinson 1960).

It is interesting to note the growth in the production record for chum salmon (*Oncorhynchus keta*) at Teplovka Lake. There has been an increase of 200 to 300% between the pre-war (1928–1937) and the war and post-war (1938–1952) periods, or from an average of 12.5 to 23.2 million eggs and 8.1 to 20.4 million fry released. At the same time, however, the neighboring Bidzhan hatchery began to experience difficulty in obtaining sufficient eggs to operate. This was blamed specifically on local development and poaching.

The hatchery at Lake Ushkovskoye produced mostly sockeye (*Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*), and a few chum salmon. A production level of 20 to 26 million eggs was maintained before World War II. Afterwards, however, the run suffered a catastrophic decline, dropping

¹The portion of the text describing the propagation of Pacific salmon in the Soviet Far East has been taken almost *verbatim* from *Salmon Aquaculture in Japan, the Koreas and the USSR*, prepared by the author (Atkinson) 1976.

from 16 million eggs in 1947 to only 3.9 million in 1952. The criticism at the time was directed toward failure to maintain the facilities in proper operating condition; but whatever the cause, the hatchery has now been rebuilt and is in full operation.

The Japanese also built a number of salmon hatcheries in the southern part of Sakhalin and the Kurile Islands during the latter part of the 1920s. By the beginning of World War II a total of at least 12 hatcheries were in operation with a total capacity of 170 million eggs. The average annual take by the Japanese hatcheries, however, was only about 73 million eggs (Chernyavskaya 1964).

Between 1946 and 1960 the 12 existing Japanese hatcheries were improved, and an additional 12 new hatcheries were built between 1955 and 1960. Together they provided a total capacity of 265 million eggs for Sakhalin and 100 million eggs for the Kurile Islands. By 1964 there was a total of 25 hatcheries in operation in Sakhalin and the Kuriles—20 in Sakhalin and 5 on Iturup Island (Kuriles).

The relative size of the hatcheries was described by Chernyavskaya (1964) as follows:

No.	Capacity
7	Fewer than 10 million eggs
12	10–20 million eggs
6	Over 20 million eggs

In 1959 all hatcheries (except for three on Iturup Island) had rearing ponds. Subsequently, several of the more inefficient hatcheries were abandoned, others have been modernized and enlarged, and new ones have been built. At the present time, there are a total of 17 hatcheries operating on Sakhalin, three on Iturup Island (Kuriles), four on tributaries of the Amur River, and one on a tributary to the Kamchatka River.

In 1958 the young were fed for 2 or 3 months at 10 of the hatcheries before release. Traditionally, the food used was ground, frozen fish waste (pollock, cod, etc.), supplemented at times with fish meal; no meat products were used. In recent years, the food used at the Soviet hatcheries has shifted from the traditional minced fish to a modern, pellet-type food, containing a balanced mixture of protein (50 to 60%), fat (10 to 16%), and carbohydrate (up to 20%), and supplemented with the necessary vitamins and other essential food elements. In general, the new pellet-type diet for the young salmon has proven to be about 25% more efficient than the former diet of minced fish and fish meal (Kanid'yev and Gamygin 1978).

Both Tables 21.1 and 21.2 show the rapid growth in production by the USSR hatcheries since 1962. In Sakhalin, for example, the numbers of pink (*Oncorhynchus gorbusha*) and chum salmon fry released almost doubled in the 10 year period—257 million fry released in 1962 and 468 million in 1971 (Rukhlov 1973A). Further, according to Doroshov, the total number of salmon fry released by the hatcheries in the Soviet Far East increased from

TABLE 21.1. NUMBERS OF YOUNG SALMON RELEASED FROM SAKHALIN HATCHERIES, 1962-1971 AND 1978

Species	(In Millions)											
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1978	
	Region											
Pink salmon	East Sakhalin	44.7	15.7	81.1	38.4	88.1	78.3	191.1	108.2	191.1	87.3	250.2
	Southwest Sakhalin	23.4	11.4	43.3	10.2	32.6	30.1	47.9	18.8	48.7	7.5	36.8
	Gulf of Aniva	29.2	17.3	36.7	31.6	17.6	36.0	42.9	16.7	40.5	17.2	35.6
	Total	97.4	44.4	161.1	80.2	138.3	144.4	231.9	143.7	280.3	112.0	322.6
Chum salmon	East Sakhalin	80.0	108.1	105.1	201.3	185.5	169.9	93.3	186.9	116.9	188.3	133.9
	Southwest Sakhalin	75.2	78.3	69.5	112.6	93.9	102.6	97.7	115.3	100.3	143.3	133.9
	Gulf of Aniva	4.5	12.7	0.2	4.4	18.6	3.1	—	20.0	1.2	24.7	21.2
	Total	159.7	199.1	174.8	318.3	298.0	275.6	191.0	322.2	218.4	356.3	289.0
Total, pink and chum salmon	257.1	243.5	335.9	398.5	436.3	420.0	472.9	465.9	498.7	468.3	611.6	
Percentage chum salmon of total	62	82	52	80	68	65	40	60	44	76	47	

Source: Rukhlov (1973A, 1982).

Note: Minor discrepancies noted in chum salmon totals for 1963 and 1964.

TABLE 21.2. TOTAL NUMBERS OF SALMON RELEASED FROM HATCHERIES IN THE SOVIET FAR EAST, 1970–1974 AND 1978

Species	1970	1971	1972 (In Millions)	1973	1974	1978
Pink salmon (<i>Oncorhynchus gorbuscha</i>)	423.1	206.3	398.8	269.4	457.1	467.9
Chum salmon (<i>Oncorhynchus keta</i>)	218.4	446.6	351.6	413.7	336.8	391.2
Sockeye salmon (<i>Oncorhynchus nerka</i>)	—	—	9.3	—	9.1	—
Coho salmon (<i>Oncorhynchus kisutch</i>)	—	—	3.2	10.3	4.8	—
Total	641.5	652.9	762.9	693.4	807.8	859.1

Source: McNeil (1976)—Personal communication from Dr. S.I. Doroshov, former Chief, Laboratory of Acclimatization and Aquaculture, VNIRO, Moscow, and now Associate Professor, University of California, Davis.
1978 totals from Rukhlov (1982).

some 642 million in 1970 to 808 million in 1974. More recent data from Rukhlov (1982) indicate the total number of young salmon released in 1978 (not including either sockeye or coho salmon) was 859 million.

Note that the salmon hatchery production of the USSR and Japan is of about the same magnitude. The real difference is that the Japanese effort is almost exclusively on chum salmon while that of the Soviets is almost equally divided between pink and chum salmon. Further, the combined hatchery production for the Soviet Union and Japan has now reached a level of nearly 2.5 billion salmon fry for release each year. According to the present Soviet plan for the development of salmon hatchery production in the Far East, some 3 billion fry will be released annually from the hatcheries on Sakhalin by the year 2000 (1.9 billion pinks, 900 million chums, 65 million masu, 55 million coho, and 50 million sockeye). The same plan calls for an additional 1 billion salmon fry to be released from hatcheries in the other regions of the Far East (Rukhlov 1982).

The Soviet scientists have made a number of studies of the rate of adult return from fry released, both by extensive marking programs and by simple comparison of the numbers of fry released to actual count of the numbers of adult returns to the local fisheries and the hatchery. Although Kanid'yev *et al.* (1970) gives a coefficient of return for the 1956–1963 brood years of 0.21 to 0.62%, these returns do not include the high seas catch of the Japanese or the more distant catches of the Japanese and Soviet coastal fisheries. It would appear that the estimate of 1.3% for autumn chum salmon at Teplovka hatchery (Levanidov 1954), or the estimate of 1 to 3% (rarely 5%) for Sakhalin pink and chum salmon (Chernyavskaya 1964), would still be a more accurate estimate to use. This is borne out by a more recent study made by Rukhlov (1980) in which he determined that the coefficient of return of chum salmon from Sakhalin hatcheries, 1964–1978, averaged 0.27–0.28% (range 0.01 to 1.76%) and for pink salmon, about 2.0–2.3% (range 0.3 to 8.7%), for hatchery and wild fish combined—the returns of hatchery fish were a little higher than for the wild fish. (e.g., in

one example, 2.1% for hatchery and wild fish combined compared with 2.7% for hatchery fish only, and in another example, 4.3% for hatchery and wild fish combined and 4.7% for hatchery fish only).

Based upon hatchery costs given by Kanid'yev *et al.* (1970), some attempt has been made to estimate Soviet costs of salmon hatchery production. For example, we may consider the cost of 197,800 rubles to produce 131,900,000 fry for release in 1959–1963, a return of 1 to 3%. At the present U.S. exchange rate (U.S. \$1 = 0.719 rubles), the average cost per adult return would be from \$0.07 to \$0.21 per fish. The cost return ratio for 1968 (i.e., 1 million fry for release at a cost of 1506 rubles) gives a similar cost of the adult returns. There are problems here, however, in trying to compare costs between the two economic systems. Until more information is available on just what is included in the hatchery costs, these figures should be used with caution.

Kanid'yev *et al.* (1970) also give the results of an interesting study by V.Ya. Levanidov on the relationship between the size of young chum salmon and the survival from char predation. He has been able to show that the larger the young chum salmon, the better the chance of survival. Levanidov has also been able to demonstrate a similar relationship between the survival of young chum salmon and fish-eating birds.

Although somewhat out-of-date, the following notes obtained during a visit to the Soviet Far East in 1959 may be of help in understanding some of the operational detail of the salmon hatchery program of the USSR.

Khabarovsk Region (Amur River)

There are apparently three hatcheries now operating on streams tributary to the Amur River: Teplovka Lake (Bira River), Bidzhan, and Udinsk (built in 1959–1960 on the Amgun River). In 1959 the Teplovka hatchery had (in some years) handled between 40 and 55 million eggs and the Bidzhan hatchery about 12 million eggs. The new hatchery at Udinsk was being designed with a capacity of 25 million eggs.

The hatchery at Teplovka Lake is located about 138 m (450 ft) above the outlet. The area of the lake is 0.5 ha (1.3 acres), with a maximum depth of about 4 m (12 ft) and an average depth of 1.5 m (5 ft). The water supply for the hatchery comes from springs with an average monthly temperature of 3.2°C (38°F) in winter and 6.8°C (44°F) in the summer (Vasil'ev 1954A).

The outlet stream is about 5 km (3 mi) in length, flowing into the Bira River and then into the Amur. The young fish migrating out of the lake are counted by a trap placed in the outlet stream.

The collection of eggs usually begins in October at the Teplovka hatchery. The adult salmon, after removal of the eggs or sperm, are sold for human food—a practice similar to the one followed in Japan.

The eggs are incubated in trays placed in troughs. By February the eggs hatch and the young are held in the hatchery until free-swimming. The

young fish are then released into the lake where they feed upon chironomids and other natural foods.

The Teplovka hatchery was the first hatchery established in the Soviet Far East and over the years has probably been the most successful. The average return from fry released has been about 1.3%, more than 6 times the 0.2% from natural spawning.

Sakhalin Region

The hatchery at Kalinin (southwest Sakhalin) was built in 1925 and was operated by the Japanese until 1939. After World War II the fishing industry, including hatcheries, was placed under the jurisdiction of the Sakhalin Fishing Authority (SAKHALIN-RYBPROMA). Under its direction the water supply and ponds at Kalinin were rebuilt in 1951, and new houses and a garage were added in 1952–1954, as well as a new hatchery building in 1959–1960. The hatchery at Kalinin has probably been one of the most successful hatcheries of the Sakhalin group and is a favorite site for tests and scientific studies.

In 1959 the hatchery was operating on an annual budget of 300,000 to 400,000 rubles a year. The supervisor was a trained economist and the hatchery technicians were all university graduates trained in fish culture. The results of the hatchery operations are not usually published but are reported only to the Sakhalin Fishing Authority.

The Kalinin hatchery handles both chum and pink salmon. In the first year of operation after the war (1951) the hatchery took 5 million eggs. In 1958 the quota was set at 21 million eggs; the hatchery took 28 million eggs. The new hatchery building increased the capacity of the hatchery to 33 million eggs in 1959. The capacity was further increased in the latter part of the 1960s. For example, in 1967 a total of 48.6 million fry were released from Kalinin and in 1968, 55.8 million.

The water supply for the Kalinin hatchery comes from a spring, is filtered through sand and gravel, and is carried into the hatchery through a covered flume. The water temperature is about 4°C (39°F) in the winter and 9°C (48°F) in the early fall. The water supply does not freeze in winter.

The salmon are trapped at a weir located a short distance above salt water. Chum salmon are taken from August until the beginning of October, and pink salmon slightly earlier (i.e., from early August until the latter part of September). The fish are spawned at the weir and the eggs are washed and taken to the hatchery to water-harden.

The eggs are picked after one or two days and placed on standard hatchery trays (about 0.09 m² and 0.95 cm deep or 1 ft² and 0.375 in. deep) with about 1500 chum eggs or 2000 pink eggs on each tray and 10 trays stacked together. The stacks of trays are placed in concrete troughs, built into the floor of the hatchery but similar in design to those used in Japan and the United States. The Soviet technologists reported an average of 1.5% egg mortality at time of "pick-off."

After the eggs are eyed and just before hatching, the stacks of trays are transferred to raceways (about 10 m long, 1.34 m wide, and a water depth of 25 cm or 33 ft, 4.4 ft, and 10 in.). The bottoms of the raceways are covered with about 6 cm (2 in.) of gravel. When the young hatch they drop through the screens on the bottom of the trays and enter the gravel.

Several weeks before transferring the eggs to the raceways, the gravel is washed and sterilized with calcium chloride at the rate of 10 kg per m² (2 lb per ft²).

At the time of the visit in 1959, the young fish were fed ground fish waste (pollock, cod, etc.) by placing the food on shallow trays suspended about 5 cm from the bottom. The trays were made of wood and the food was placed on the tray about 1.5 to 2 cm deep. About 1.5 to 2 kg of food were placed on each tray twice a day, or at a rate of 5 mg per fish at the beginning of feeding to about 20 mg per fish at the end. Some fish meal is used to supplement the ground fish diet.

Although unconfirmed, it is believed that the Soviet hatchery technologists have now developed a more efficient way of feeding the young fish and a better formulated food (Frolenko 1964; Kanid'yev *et al.* 1970).

Cooperative Programs

Because of the decline in the salmon runs and the growing restrictions on the salmon fisheries adopted by the Japan-USSR Northwest Pacific Fisheries Commission, in 1962 Japan proposed to establish in the Soviet Far East a series of salmon hatcheries operated jointly by the two countries. Finally, on June 8, 1975, the two governments agreed to establish such a station on an appropriate river in southern Sakhalin. Subsequently there has been a series of meetings between Japanese and Soviet hatchery experts, and they now have agreed to construct a joint salmon hatchery on the Pioner River (southwest Sakhalin).

Although a number of details must still be worked out, tentative plans call for the construction of a hatchery in 1977 and for completion and operation in 1978. The hatchery will have a capacity of 30 million eggs (25 million chum, 3 million pinks, 1 million silver, and 1 million other). The estimated cost of about \$6 million will be shared equally by the two countries.

Also, in December 1972 the first Japan-USSR Joint Symposium on Aquaculture of the Pacific Ocean was held in Tokyo, and subsequently annual symposia have been held alternately in Japan and the USSR. These symposia have been organized by Tokai University (Shimizu) and VNIRO (All-Union Scientific Research Institute of Marine Fisheries and Oceanography) (Moscow). Although the papers cover a broad field of subjects related to fish culture and ocean farming, many are either directly or indirectly related to salmon aquaculture. For example, it is in these seminars that problems of disease and genetics have been discussed (Shikama 1973; Altukhov 1973).

It was at one of the meetings of the Japan-USSR Joint Symposium on Aquaculture (Tokyo and Sapporo, Japan, 1976) that the concept of a four-nation aquaculture symposium was conceived with participation of scientists from Canada, Japan, the USSR, and the United States and particular attention on the biology and culture of salmon in these four countries. The first meeting of the group, the Conference on Pacific Salmon, was held in South Sakhalinsk (Sakhalin Island) in October 1978, and a second meeting, the North Pacific Aquaculture Symposium, was held in Anchorage (Alaska) and Newport (Oregon) in August 1980. Future meetings are planned to be held every two years in one of the four countries.

Finally, there have been continuing exchanges of experts, data, and other materials related to salmon propagation between the countries. Kanid'yev *et al.* (1970) refer to such an exchange.

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Republic of Korea

FISH AND OTHER AQUATIC SPECIES

Abalones	Largemouth bass (<i>Micropterus salmoides</i>)
Agar agar	Laver
Alaska pollocks	Loach (<i>Misgurnus anguillicaudatus</i>)
Blue crab	Mackerel
Bluegill (<i>Lepomis macrochirus</i>)	Mollusks
Carp (<i>Cyprinus carpio</i>)	Octopuses
Catfish (indigenous) (<i>Parasilurus asotus</i>)	Oysters
Channel catfish (<i>Ictalurus punctatus</i>)	Pearl mother shells
Cockles	Rainbow trout (<i>Salmo gairdneri</i>)
Crucian carp	Sea breams
Crustaceans	Sea fish
Dulse	Sea mussels
Eel	Seaweeds
Goldfish	Shortnecked clams
Grass carp (<i>Ctenopharyngodon idellus</i>)	Shrimp
Hard clams	Silver carp
Japanese eel (<i>Anguilla japonicus</i>)	Wild eels
Kelp	Yellowtail

Republic of Korea

Koo-Byong Park

In recent years aquaculture production in Korea has shown a phenomenal increase. In the decade from 1965 to 1974, production increased from 73,705 MT (81,223 ST) to 340,324 MT (375,250 ST) or by 362%. Aquaculture, particularly shallow sea aquaculture, is contributing significantly to food production and the earning of foreign exchange in Korea.

This rapid increase in the aquacultural production, however, was not achieved by a rapid expansion of fish culture but by a rapid increase in the production of seaweeds and mollusks cultured in coastal shallow seaways. The most important products in terms of quantity are seaweeds such as laver, dulse, agar agar, and kelp, being followed by mollusks such as oysters, hard clams, shortnecked clams, cockles, sea mussels, abalones, pearl mother shells, and octupuses. In 1974 the production of seaweeds amounted to 244,795.4 MT, accounting for 71.9% of the total aquacultural production. The production of mollusks was 95,353.2 MT, accounting for 28.0%. The remaining aquacultural production consisted of 168.9 MT (186 ST) of fish and 5.4 MT of crustaceans, such as shrimp and blue crab.

These figures show that the production of cultured fish is negligible in Korea, although a number of species of fish have been and are being cultured (Table 22.1).

History of fish farming in Korea, with the exception of common carp farming, is short, and most fish farming is still in the pilot stages. Freshwater fish such as carp, eel, and rainbow trout are species cultured in Korea (Table 22.1) Farming of these species and some others will be briefly discussed.

TABLE 22.1. PRODUCTION OF CULTURED FISH BY SPECIES, KOREA

Species	Metric Tons				
	1970	1971	1972	1973	1974
Carp	3.0	6.4	24.5	29.3	44.5
Eel	9.4	157.6	5.9	35.7	85.0
Loach	—	—	—	—	15.7
Rainbow trout	3.4	7.1	15.4	6.1	—
Grass carp	—	0.6	1.8	0.3	0.8
Goldfish	0.2	1.6	1.5	2.4	4.7
Others	22.9	21.0	17.1	13.7	18.2
Total	38.9	194.3	66.2	87.5	168.9

Source: Anon.(1971-1975).

CARP (*Cyprinus carpio*)

Carp culture in Korea has a history of hundreds of years. There is a historical record which suggests that carp were cultured as early as in the beginning of the third century. However, carp farming for commercial sale began about 50 years ago under the Japanese regime with the establishment of a public hatchery.

At the present time, carp farming is practiced all over the country. Although many carp farms are scattered throughout the country, the scale of most farms is small as reflected in the small total production of carp. In 1974 the total production of carp, including wild carp caught in natural water, was 149.8 MT, of which 105.3 MT or 70.3% were wild. It should be noted that a considerable part of the wild carp catch was produced in government-run public hatcheries and released in natural waters as fry.

Three different methods are presently used in culturing carp in Korea, namely: (1) stillwater culture; (2) running water culture; and (3) cage culture. Among these, method (1) is the oldest and most common method. Only two carp farmers use method (2). Method (3) was introduced recently, and a couple of carp farmers have adopted this method.

In the stillwater method, ponds and reservoirs are used. Ponds are built with concrete or earthen walls. In carp farms with adjacent streams or rivers, ponds are designed so as to keep a small quantity of water flowing through ponds by gravity.

Since there is a large number of reservoirs for irrigation of rice fields, and many other reservoirs for power generation or multi-purpose uses which can be rewardingly stocked with carp, Korea has favorable conditions for adopting stillwater carp culture methods. These reservoirs, however, are not fully utilized yet. In many instances carp farming in reservoirs is extremely extensive, allowing the carp to feed on natural feeds.

In recent years, under the UN Korean Upland Development and Watershed Management Project, a large number of irrigation-fish ponds have been newly constructed, and some of them have already been stocked with carp fry. In addition, stocking reservoirs and ponds with carp has been encouraged by strong government support. Fry produced in public hatcheries and purchased from private hatcheries have been supplied free of charge to carp farmers. The government purchase fry of 3 to 4 cm (1 to 2 in.) for about \$0.08 each to deliver to carp farmers. The Chosen Daily is, at the present moment, undertaking a "Raise Fish Where There Is Water" campaign, supplying free carp fry under the auspices of the Office of Fisheries.

Some carp farmers specialize in producing seedlings. But many carp farmers produce eggs and fry for their own use. In regard to the stocking rate, carp fry of 3 cm (1 in.), for example are released in stillwater ponds at the rate of about 6 per m² (less than 1 per ft²). In running water ponds, carp yearlings of 10 to 13 cm (4 to 5 in.) are stocked with a higher stocking density.

In feeding carp, finely hulled wheat, trash bread, oil cake, silkworm pupae, fish meal, and vegetables are widely used in Korea. Doughy, pasty

feed compounds made of these stuffs is prepared at each carp farm. No mass-produced commercial feeds are available.

There is a good market for carp in Korea, so no carp farmer suffers from overproduction. Instead, carp production lags behind growing demand. Prices of carp received by farmers per kilogram range from about \$1 to \$3 (\$0.45 to \$1.35 per lb), whereas the average price of sea fish does not exceed \$0.20 per kg (\$0.09 per lb). This means that carp are valued at more than five times the average value of captured sea fish. Market sizes of carp vary from 500 g to 1 kg (1 lb to 2.2 lb). It takes about two years from hatching to produce market size carp.

Primary consumers of carp are sightseers who visit the fish farms. Carp are cooked and served at these farms. Slice raw fish or pepperpot soup of carp is popular with sightseers, but most sightseers prefer the former to the latter. For Korean tastes, raw fish goes well with beer or white liquor. Since, however, it is believed that carp as well as many other freshwater fish are intermediate hosts of the liver fluke, many people do not eat raw fish. A recent study by Dr. Seh Kyu Chun of the Pusan Fisheries College indicated that carp are not an intermediate host of liver fluke. If this is proved to be true through further studies, the demand for raw carp will increase.

Carp are also demanded for medicinal uses in Korea. It is said that when pregnant women eat carp they can have babies with pretty white skin, and that eating carp is conducive to the recovery of health after delivery. According to one of the most famous Oriental medical books, Huh Joon's *Tongueui-Bokam* (Oriental Medical Thesaurus) published in 1613 in Korea, the flesh of carp is efficacious for jaundice, morbid thirstiness, dropsy, etc., and the gall bladders of carps heal amaurosis and strengthen one's sight.

The demand for carp as sport fish has been growing rapidly. Carp stocked in fee-fishing ponds are caught with tackle and bait by the consumer. These carp are free when the consumer pays an entrance fee of \$2 to \$4 although the total catch is limited to 1 to 2 kg (2.2 to 4.4. lb). At fee-fishing ponds where the entrance fee is not paid or only a small sum is paid, the consumer has to pay a fee of \$2 to \$3 per kg (\$0.91 to \$1.36) for carp caught. The entrance fee and the fee for carp caught vary, depending on the distance between fishing ponds and population centers. Carp are often co-stocked with crucian carp in fee-fishing ponds.

In view of conserving the stock of freshwater fish, the Office of Fisheries recently prohibited fishing of wild freshwater fish in many natural inland waters. This had increased and will increase the demand for cultured carp as sport fish.

Profitability of carp farming in Korea varies greatly from farm to farm. Although it is difficult to obtain reliable cost-benefit data on many carp farms, it seems that there are carp farmings which are relatively profitable. For example, data obtained from a carp farm in Yangbuk-myon, Yangsan-kun, Kyongsang-nam-do which adopted the running water culture method showed the profitability of carp farming as presented in Table 22.2.

The full cost of production per kilogram can be calculated by adding 15% for interest on the capital investment. The price received was 2.80 per kg

TABLE 22.2. COST-BENEFIT DATA ON CARP FARMING IN A 693 M² RUNNING WATER POND, YANGSAN-MYON, YANGBUK-KUN, KYONGSANG-NAM-DO, KOREA, 1975

Item	(\$)	(%)
Capital investment		
value of land	210	14.2
construction of pond	1260	85.8
total	1470	100.0
Operating costs		
carp yearlings	200	10.3
feeds	1120	57.5
labor	480	24.6
maintenance and repairs	6	0.3
other	100	5.1
depreciation ¹	49	2.2
total	1955	100.0
Income	4800	
Profit	2845	
Ratio of profit to:		
operating costs		1.46
operating costs— depreciation excluded		1.50
gross income		0.59

¹ Life of 30 years for pond.

(\$1.27 per lb). Thus a relatively high profit on investment can be obtained. If facilities were fully utilized, more profit could be obtained. This carp farm produced only about 2 MT in 1975, but it can produce as much as 20 MT per annum.

However, this is not to suggest that all the carp farms in Korea are invariably profitable. Profitability varies between carp farms and from farmer to farmer according to the suitability of the site and efficiency of operations. There are many unprofitable carp farms. For example, data obtained from a carp farm in a suburb of Pusan, which produced 2.5 MT of market-size carp in 1975 in a 5035 m² (1.5 acre²) stillwater pond built of concrete, showed that the cost of production (including the depreciation cost and interest for capital investment) exceeded \$4 per kg (\$1.82 per lb), but the average price received was \$2.60 per kg (\$1.18 per lb). It seems, however, that if carp farms are properly managed, most carp farmings can obtain favorable returns on investment.

JAPANESE EEL (*Anguilla japonicus*)

Eel farming in Korea began in the late 1960s with experimental culture. Since the beginning of the 1970s heavy demands from Japan for elvers have stimulated an increased interest in eel farming and brought an eel farming boom.

Eels are widely cultured in Korea at present, but the annual production of cultured eels is highly variable, reflecting that eel farming in Korea is not yet an established industry (Table 22.3).

In 1974 the total production of eels, including wild eels caught in natural

TABLE 22.3. PRODUCTION OF CULTURED EELS BY PROVINCE AND YEAR, KOREA

Province	1970	1971	Metric Tons		
			1972	1973	1974
Kyongki-do	—	—	0.6	9.5	8.1
Kangwon-do	—	—	—	—	—
Chungcheon-buk-do	—	—	—	—	—
Chungcheon-nam-do	—	—	—	1.5	15.3
Kyongsang-buk-do	—	—	1.0	1.4	1.8
Kyongsang-nam-do	—	—	—	—	2.0
Cheonra-buk-do	—	—	3.3	20.3	51.6
Cheonra-nam-do	9.4	157.6	1.0	3.0	6.2
Cheju-do	—	—	—	—	—
Total	9.4	157.6	5.9	35.7	85.0

Source: Anon. (1971–1975).

waters, was 145.8 MT, of which the cultured eels accounted for 85 MT or 58%. Eel farming in Korea is characterized by the production of seedlings for exports. Culture of eels through to market size is practiced rather incidentally in some eel farms. Since no technique of artificial breeding of eels has been developed, eel farming has to be based on young elvers collected when they reach river mouths. These young elvers are domesticated to eat artificial feeds and reared for 2 to 3 months and then exported as seedlings.

In the southern part of South Korea, young elvers averaging 0.12 g and 4 cm (1.5 in.) are caught in river mouths from February to May, while in the northern part smaller ones are caught. These elvers are stocked in ponds for 2 to 3 months as already mentioned. During this feeding period, they reach 10 cm (4 in.) in length. On the other hand, the time required for eels to reach market size of 200 to 300 g (7 to 11 oz) is about 2 years.

Two different methods of raising eels (i.e., stillwater culture and circulating filter system) are used in Korea. The stillwater culture is the most common method in raising both elvers and market-size eels.

In stillwater ponds water is aerated by splashier paddles (water wheel). During the spring and early summer when the water temperature is not high enough, eels are raised in covered ponds filled with heated water.

Eel farming by the circulating filter system was introduced in the early 1970s, and only a few eel farmers adopted this method. This is the most intensive fish farming method in Korea. To enhance the growth rate of elvers, it is necessary to keep a high average water temperature. Hence in the circulating filter system the pond is covered with a greenhouse built of angle iron frames and polyethylene or canvas covers. Pond water is heated by pipes, which are laid on the pond bottom, through which hot water is circulated. Dirty water in the culture pond is pumped into the filter pond to be cleaned, and then returned to the culture pond. Culture pond water is constantly aerated by an aerator and splashier paddles.

In the height of summer, when the water temperature outside the greenhouse rises above 25°C (77°F), the warmwater circulating filter system is transferred into the running water system. In some eel farms, elvers in the

greenhouse pond are moved into stillwater ponds, which are constructed on the same farm, during summer.

Main feeds used by Korean eel farmers are flesh of fresh mackerel and compound feed imported from Japan. Powdered compound feed is mixed with finely chopped flesh of mackerel to make a thick paste feed. In the early stage of feeding, other feeds can be fed to elvers and these include oysters and small earth worms.

There is a large export market for both elvers and market-size eels, and the eel has a very high commercial value. Until the end of the last century, Koreans had an aversion to eels because of their snake-shaped unacceptable appearance, and no Korean tried to catch eels for food use. Consequently rivers of Korea teemed with wild eels at that time. It was reported that the stock of eels was so abundant in those days that Japanese fishermen who first engaged in eel fishing in Korea could easily catch as much as 300 kg (660 lb) each in a day. After the turn of the century, however, Koreans came to like eels as their tastes were gradually changed by association with Japanese who liked eels. This led to an overexploitation of wild eels. Demand for eel as a food fish in domestic and foreign markets has steadily grown, and eels are highly prized, not only as a delicacy, but also as excellent health food. These combined effects have made eels the most expensive fish. The farm gate prices of cultured eels of market size reach about \$8 per kg (\$3.64 per lb) in the domestic market. Compared with the price of beef, it is about twice as expensive. Prices of cultured elvers exported to Japan and Taiwan are much higher. The ruling prices in 1976 ranged from about \$44 (an average weight of 10 g each) to \$80 (an average weight of 20 g each) per kg (\$20 to \$30 per lb). Quantities and values of exported cultured eels for a three year period are shown in Table 22.4.

Until 1971 Japan was the only importing country of Korean eels, but in 1972 Taiwan began to import them also. Eel exports to Taiwan sharply increased in 1974 and 1975. The quantity and value of eels exported to Taiwan in 1975 amounted to 71,047 kg (156 ST) (54% of the total export) and 51% of the total export value of eels.

A cost-benefit ratio is calculated in Table 22.5 based on data obtained from an eel farm in Roksan-myon, Kimhae-hun, Kyongsang-nam-do, which produced about 2 MT of elvers by the circulating filter system in 1975. Although a relative bumper crop was harvested on this farm, the cost-benefit ratio was not high. This was mainly due to the unusually low export price of eels in 1975.

Cost of production per kilogram can be calculated in Table 22.5 by computing interest at 15% per annum for capital investment. Cost of production was about \$19 per kg (\$8.64 per lb). The average price received per kg was about \$25 (\$11.36 per lb), showing a favorable comparison.

The previous figures, however, by no means indicate that all eel farming in Korea is always profitable. The profitability of eel farming varies greatly

TABLE 22.4. QUANTITY AND VALUE OF CULTURED EEL EXPORTS BY YEAR, SIZE, AND KIND, KOREA

Size and Kind	Quantity (kg) and Value (\$)	1973	Metric Tons 1974	1975
Market size ¹ (under 10 per kg)	Quantity	2,830	5,263	2,386
	Value	11,278	27,175	16,640
	(Unit price)	(3.99)	(5.16)	(6.97)
Under 100 to 400 per kg	Quantity	67,215	109,279	71,328
	Value	4,318,436	2,563,815	1,463,129
	(Unit price)	(64.25)	(23.46)	(20.51)
500 to 2500 per kg	Quantity	11,379	12,726	55,403
	Value	1,847,411	878,573	2,004,298
	(Unit price)	(162.35)	(69.04)	(36.18)
3000 to 6000 per kg ²	Quantity	239	—	—
	Value	127,886	—	—
	(Unit price)	(535.09)	—	—
Processed	Quantity	13,465	2,500	1,500
	Value	83,943	15,230	10,500
	(Unit price)	(6.23)	(6.09)	(7.00)
Others	Value	—	150,000	—
	Quantity	95,128	129,768	130,617
Total	Value	6,388,954	3,634,793	3,494,567
	(Unit price)	(67.16)	(28.01)	(26.75)

Source: Anon. (1973-1975).

¹A small quantity of wild eels caught in natural waters is included.

²Exports of elvers under certain size have been prohibited by the government since 1974 for better use of the limited elver stock.

from year to year. This is due mainly to wide annual variations in export prices and operating costs. Export prices of eels have shown extremely wide fluctuations, as can be seen in Table 22.4. In addition to this, operating costs vary annually to a considerable extent due to the fluctuation in quantity of annual production and total catch of elvers for stocking. Although no published data on the prices of elvers are available, it is known among eel farmers that prices vary greatly from year to year according to the catch. One eel farmer said that the average price of elvers per kg was about \$700 in 1973, \$300 in 1974, \$30 in 1975, and \$400 in 1976 (\$318 per lb in 1973, \$136 in 1974, \$13.60 in 1975, and \$182 in 1976). Annual production of eels varies greatly, too, and is subject to a number of factors. A main risk involved in the production of eel is loss through various diseases and parasites, and in a serious case all the eels under culture may die. In many cases eel farming is uneconomical, and it is regarded as a highly risky industry.

The market demand for elvers and market-size eels seems to continue to increase. Unfortunately, however, there is a narrow limitation in the expansion of eel farming since the arrivals of elvers to river mouths are limited. The exact quantity of elvers collected around Korean waters is unknown, but it is estimated that it is, on the average, only about 10 MT (11 ST) per annum. Culture of market-size eels should be encouraged rather than simply exporting elvers as seedlings.

TABLE 22.5. COST-BENEFIT DATA ON CULTURING 2 MT (2.2 ST) OF ELVERS IN A 660 M² (7102 FT²) POND USING THE CIRCULATING FILTER SYSTEM, ROKSAN-MYON, KIMHAE-KUN, KYONGSANG-NAM-DO, KOREA, 1975

Item	(\$)	(%)
Capital investment		
construction of pond	7060	—
construction of greenhouse	4800	—
construction of cold storehouse	1200	—
refrigerator	2400	—
water heating system	6000	—
generator	5000	—
feed cooking equipment	1100	—
aerator	1300	—
total	28,860	—
Operating costs		
young elvers	8000	23.8
feeds	3320	9.9
labor	9840	29.3
maintenance and repairs	1286	3.8
fuel	2000	5.9
electric power	1200	3.6
chemicals	600	1.8
rental fee for land	400	1.2
taxes	3200	9.5
miscellaneous	1200	3.6
depreciation ¹	2572	7.6
total	33,618	100.0
Income	49,150	
Profit	15,532	
Ratio of profit to:		
operating costs	0.46	
operating costs—		
depreciation excluded	0.50	
gross income	0.32	

¹Lives of pond, cold storehouse, and greenhouse are regarded as 30 years, 35 years, and 8 years, respectively, and that of other equipment varies between 5 and 10 years. Depreciation costs for pond and cold storehouse were figured out by dividing their initial costs by the number of years of their lives; for the greenhouse and other equipment, 10% of initial costs was subtracted before calculations.

RAINBOW TROUT (*Salmo gairdneri*)

Rainbow trout were imported from the United States in the mid-1960s. In 1965 an experimental rainbow trout culture was begun in Kangwon-do with 10,000 eyed-eggs brought from the United States. In 1966 a public hatchery run by the local government was established in Pyongchang-myon, Pyongchang-kun, Kangwon-do, and the hatchery started production of rainbow trout fry to deliver to would-be rainbow trout farmers. Rainbow trout eggs used in producing fry were brought from the United States and Japan (Table 22.6).

TABLE 22.6. IMPORTED NUMBER OF EYED-EGGS OF RAINBOW TROUT BY YEAR, KOREA

Year	USA	Japan	Total
1965	10,000	—	10,000
1966	200,000	—	200,000
1967	800,000	30,000	830,000
1968	500,000	—	500,000
1969	1,972,000	100,000	2,072,000
1970	800,000	100,000	900,000
Total	4,282,000	230,000	4,512,000

Source: Sun Tae Kim *et al.* (1971).

Following a set of experiments, artificial spawning and larval rearing were successful in 1970, providing a strong base for rainbow trout farming in Korea.

The major eel farming province is Kangwon-do. Most rainbow trout farms are also concentrated in this most mountainous province in Korea.

The best water temperature for raising rainbow trout is between 10° and 18°C (50° and 65°F); hence the water temperature should not go much over 20°C (68°F) in summer not fall too low in winter. Sites which satisfy this condition and at the same time assure adequate supplies of water can be found only in limited places in Korea. Because of this constraint, the total area of rainbow trout farming was only 3.19 ha (7.9 acres) in 1973. The number of farmers engaging in rainbow trout farming is limited to about 18 at present. Annual average production of rainbow trout is less than 10 MT (11 ST) (Table 22.1). Total production in 1974 was so small that it was not shown in official statistics.

Running water culture and stillwater culture methods are used in raising rainbow trout in Korea. In both cases, an important source of water is spring water. Using spring water, extremely high or low water temperatures can be avoided. In stillwater ponds a small quantity of pond water is continuously replaced by spring water. In some rainbow trout farms where running water culture is practiced, pumped-up well water is used.

In feeding rainbow trout, farm-made feeds are used. Ingredients of feed include silkworm pupae, fish meal (made of Alaska pollocks in the main), rice-bran, flour, oil cake, and various vegetables. Specially prepared pelleted feed is also used in some farms.

Rainbow trout is an unfamiliar fish for most Koreans, although those who have tasted it soon come to like it. Rainbow trout are consumed by sightseers who visit rainbow trout farms, as was the case with carp. Raw rainbow trout are a most popular dish. They are also demanded as sport fish, and some fee-fishing ponds are stocked to meet this demand.

Rainbow trout is a high-priced luxury fish in Korea. The price of rainbow trout received by farmers was about \$3 per kg in 1975 (\$1.36 per lb). In spite of the high price, demand for rainbow trout has increased and exceeds the present level of production, particularly with those farms situated near population centers.

It is probably too early to talk about the profitability of rainbow trout farming in Korea since such farming is still largely in the experimental stage. Though a few farmers are still skeptical, there is little doubt that it is a promising industry. Its profitability is suggested by a hypothetical cost-of-production schedule prepared by a rainbow trout farmer who is raising rainbow trout in stillwater ponds in Nam-myon, Cheongseon-kun, Kangwon-do and produced about 2000 market-size rainbow trout in 1975 (Table 22.7).

Feed constitutes the major item of cost in rainbow trout farming. The cost of feed accounted for about 92% of the total operating costs in the case shown in Table 22.7. Adequate supplies of suitable feeds at reasonable prices are of special importance in raising rainbow trout.

Full utilization of existing culture facilities and intensification of culture will alleviate the narrow limit on production of rainbow trout from the lack of suitable sites, although a significant expansion of the industry cannot be expected even in the future.

OTHERS

Loach (*Misgurnus anguillicaudatus*)

Korea has native loach with which all Koreans are familiar. A considerable amount of wild loach is caught annually. In 1974 the catch amounted to 214.6 MT (236 ST). Loach farming has been practiced for years, although its contribution to fish farming has been negligible except for 1974, when 15.7 MT (17 ST) of loach were produced under cultured conditions.

Loach are raised in small stillwater ponds. The breeders are collected from wild stock. Techniques of intramuscular injection of frogs' pituitaries are often applied to loaches to induce maturation and spawning, but they are practiced only on a small experimental scale.

Ponds are fertilized with compost or cattle dung to help produce natural feeds. Supplementary artificial feeds such as fish meal, flour, oil cake, and barley-bran are sometimes fed.

TABLE 22.7. HYPOTHETICAL COST OF RAISING 100,000 MARKET-SIZE RAINBOW TROUT VALUED AT 75 MILLION WON¹ (\$150,000)—TIME REQUIRED IS 18 MONTHS; KOREA, 1975

Item	Cost (Won)
Fry (150,000—5 won each)	750,000
Feed (7,500,000 won for raising fry for 6 months, and 30,000,000 won for raising 100,000 rainbow trout for 12 months)	37,500,000
Wage (1 manager, 900,000 won, and 2 assistants, 1,080,000 won)	1,980,000
Electric power and fuel	72,000
Maintenance costs of ponds and hatchery	120,000
Miscellaneous (firewood, chemicals, and others)	360,000
Total ²	40,782,000

¹ 500 won equal approximately \$1.00 (U.S.).

² Total won equals \$81,564.

Loaches are in demand as a food fish as well as bait fish for commercial fisheries, and they are expensive in Korea.

Grass Carp (*Ctenopharyngodon idellus*)

Grass carp were introduced with silver carp from Japan by Dr. InBae Kim of the Pusan Fisheries College in 1963. Experiments with the artificial spawning of grass carp using hormone injection techniques, conducted at the Pusan Fisheries College and the public hatchery in Cheongpyong, Kyongki-do, were successful in 1970. This paved the way for grass carp farming. Since then pilot-scale grass carp farming has been practiced on a few fish farms.

Special consideration should be given to culture of grass carp, for they are herbivorous animals and there is virtually no limitation in the Korean feed supply.

Catfish (*Ictalurus punctatus*)

Channel catfish were imported from the United States in 1972. They have been experimentally cultured in the ponds of the Pusan Fisheries College and public hatcheries.

The low water temperature which lasts for months in the winter season is the greatest difficulty encountered with catfish farming in Korea. Dr. In-Bae Kim says that if channel catfish can survive through the severe winter season in Korea, special attention should be paid to their acclimatization and popularization of their culture.

Although there is an indigenous catfish (*Parasilurus asotus*) in Korea and Koreans admire it as food fish, no attempt to raise it has been made as yet.

Bluegill (*Lepomis macrochirus*)

Bluegills were introduced from Japan in 1970. Some fish farmers are raising them and they are becoming popular as sport fish.

Bass (*Micropterus salmoides*)

Largemouth bass were imported from the United States in 1973. They are presently under experimental culture at the public hatchery in Cheongpyong.

Sea Fish

No appreciable sea fish culture has yet been practiced in Korea. However, seedlings of a few species of sea fish have been produced under culture.

Fry of a couple of species of sea breams of 2 to 3 cm in length are caught in

coastal waters and raised in net enclosures for 2 to 3 months. They are fed with minced low-priced fish. All of them are exported to Japan.

Yellowtail fry were raised by a similar method for the same purpose in the past. However, in 1975 the government prohibited the catching of yellowtail fry with a view to conserving the natural stock of yellowtail.

OUTLOOK

The fact that fish farming requires relatively expensive feeds is one of the most important reasons that it has not achieved a rapid expansion in Korea, while rapid development has taken place in shallow sea culture of seaweeds and mollusks which do not require feeding. In most fish farming, feed constitutes the major item of operating costs, accounting for more than 50%. Furthermore, it is impossible at present to obtain adequate quantities of suitable commercial feeds produced by a centralized mass production system. This is a serious constraint on large-scale fish farming. Therefore, sufficient supplies of commercial feeds fitted for each species at reasonable prices will be of special importance in the expansion of fish farming.

Another major constraint on the expansion of fish farming is related to the construction of ponds. The climate of Korea is characterized by a rainy warm summer and a cold winter which lasts for about three months. It is necessary therefore to build deep ponds with strong walls to prevent flood damage as well as winter kills. Because of this, coupled with high costs incurred in purchasing land for pond construction, heavy capital investments are involved in fish farming. In addition, time required to obtain a return on investment is long. In Korea, where high interest rates prevail, this is one of the most serious constraints. Sufficient supplies of government grants or low interest loans could alleviate this constraint to a great extent. However, these are not likely to be realized in the near future since fish farming, which produces luxury food items or sport fish for the limited demands of a small number of people, cannot receive high priority in the aquacultural development program.

With these constraints, a significant expansion of fish farming in Korea cannot take place in the foreseeable future. This, however, does not rule out the possibility of slow but steady development of fish farming in years to come. It can be stated with certainty that increasing per capita incomes and leisure, which will result from the high growth rate of the national economy, will create new demands for cultured fish as both luxury food fish and sport fish, thus stimulating investors' interests in fish farming.

SPECIAL ACKNOWLEDGMENTS

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Japan

FISH AND OTHER AQUATIC SPECIES

- Amago or amenouo (*Oncorhynchus rhodurus*)
Anchovies
Ayu or sweetfish (*Plecoglossus altivelis*)
Brine shrimp nauplii
Cherry salmon (*Oncorhynchus masu*) (marine)
Chubs (shiners)
Chum salmon (*Oncorhynchus keta*)
Clams
Common carp (*Cyprinus carpio*)
Copepods
Crab
Crucian carp (*Carassius carassius*)
Diatomaceae
Filefish (*Monacanthus cirrhifer*)
Flounder or flatfish (*Paraichthys olivaceus*)
Glass eels (juvenile state)
Grey or jumping mullet (*Mugil cephalus*)
Horse mackerel (*Trachurus symmetricus*)
Iwana or rockling (*Salvelinus pluvius*)
Japanese eel (*Anguilla japonicus*)
Krill
Loach (*Misgurnus anguillicaudatus*)
Mackerel
Mollusks
Mussels
Oyster larvae
Pacific tuna
Plankton
Porgy or black sea bream (*Mylio macrocephalus*)
Puffer (*Fugu rubripes*)
Rabbit fish (*Siganus fuscescens*)
Rainbow trout (*Salmo gairdneri*)
Red sea bream or red porgy (*Chrysophrys major*)
Rotifers
Salmon
Sand eels
Sardines
Seaweed
Shortnecked clam
Shrimp or prawns (*Penaeus japonicus*)
Tilipia (*Tilipia nilotica*)
Yamame or trout salmon (*Oncorhynchus masu*) (landlocked)
Yellowjack (*Caranx delicatissimus*)
Yellowtail (*Seriola quinqueradiata*)
Whales
Whitefish
Landlocked salmon and trout
Salmon and marine trout
Cultured marine fish
Freshwater fish
Shallow sea cultured fish
Trash fish
Other species—freshwater and marine

Japan

*E. Evan Brown
and S. Nishimura*

Fish have been raised by Japanese farmers for hundreds of years. However, production for commercial sale began about 150 years ago. The industry grew slowly until the 1930s when the government placed emphasis on marine harvest. During World War II the government emphasized freshwater culture and production of freshwater fish expanded. After the war the cultured fish industry, though largely ignored by the government, continued to grow. In 1950, output of shallow sea cultured fish reached 48,000 MT (52,896 ST), including mussels, mollusks, and seaweeds, and freshwater cultured fish reached 5000 MT (5510 ST). From 1950 through 1978, the output of cultured marine fish, mussels, mollusks, and seaweeds expanded from 48,000 MT to 917,000 MT (1,010,534 ST) or by 1810% (Table 23.1). This was at an annual rate of 65%. Inland freshwater cultured fish production increased from 5000 MT in 1950 to 90,000 MT (99,180 ST) in 1978. This was a 1700% increase, or an annual rate of nearly 61% (Table 23.1). Marine harvest of wild fish increased 197% during these 28 years, and the inland freshwater wild harvest increased only 119%. In 1950 the cultured fish industry accounted for 1.6% of total production. In 1978, the cultured fish industry accounted for 9.3% of total production. At present, the government is placing renewed efforts into stimulating marine and freshwater culturing, including sea ranching, because the new international 322 km (200 mi) zones reduced Japanese marine catch of several useful species.

The 861,000 MT of shallow sea culture in 1977 represented only 8.0% of total supply, but accounted for 13.8% of total value (Table 23.2). Freshwater cultured fish accounted for 0.7% of supply but amounted to 3.7% of total value. This means that each unit of cultured marine fish was valued at nearly twice the average fish value, while each unit of freshwater cultured fish was valued at nearly six times the average value. These data indicate the emphasis on culturing high-valued species.

FRESHWATER CULTURED FISH

In Japan there are six major species of freshwater fish produced by culturing method, i.e., in ponds or running water enclosures. The pond classification in government statistics is separated into: (1) agricultural ponds, used mainly for agriculture and where the water levels vary consid-

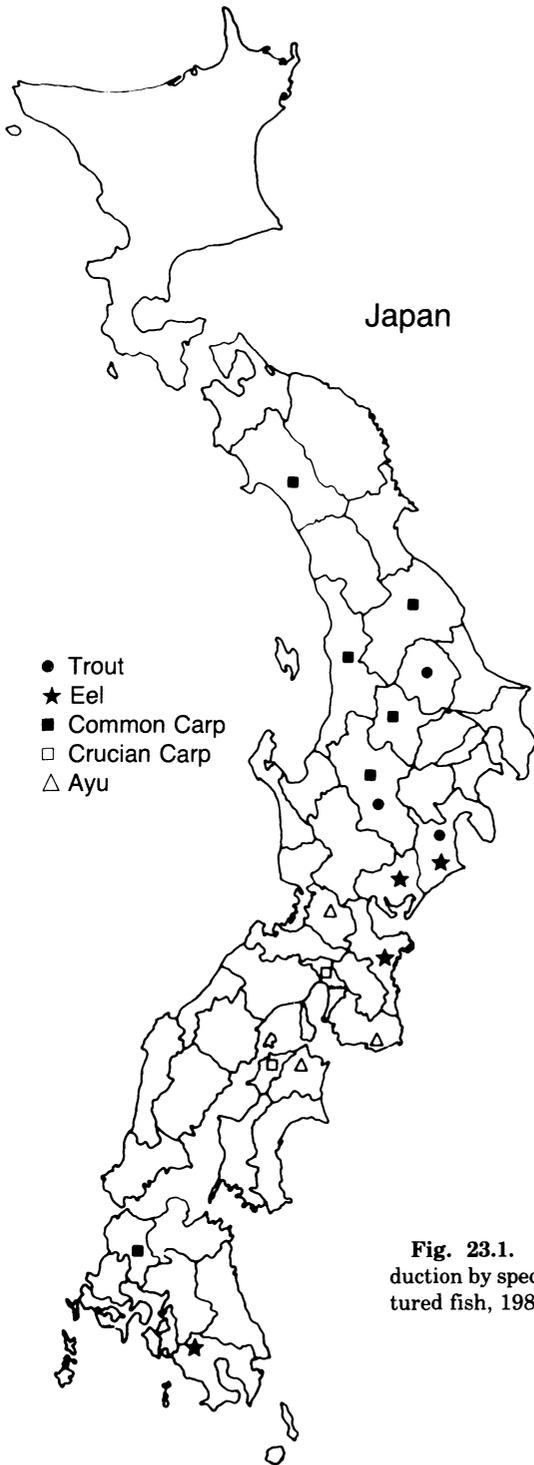


Fig. 23.1. Main areas of production by species of freshwater cultured fish, 1980.

TABLE 23.1. FISH PRODUCTION (NOT INCLUDING WHALES), JAPAN, 1950-1978

Year	Marine Harvest	Shallow Sea Cultured Fish Harvest	Inland Fresh-water Harvest (Wild)	Inland Cultured Freshwater Harvest	Totals
	Metric Tons (1000)				
1950	3255	48	63	5	3,371
1951	2774	88	60	6	3,928
1952	4646	113	53	9	4,823
1953	4387	144	57	8	4,596
1954	4303	145	82	9	4,539
1955	4658	154	82	11	4,905
1956	4487	180	90	13	4,770
1957	5067	244	81	14	5,406
1958	5197	214	78	15	5,504
1959	5567	225	75	15	5,882
1960	5817	284	74	15	6,190
1961 ¹	6287	322	81	18	6,708
1962	6346	362	84	20	6,812
1963	6200	390	85	23	6,698
1964	5869	363	89	30	6,351
1965	6382	380	113	33	6,908
1966	6558	405	103	37	7,103
1967	7241	470	97	42	7,850
1968	7993	522	103	52	8,670
1969	7976	473	112	52	8,613
1970	8598	549	119	49	9,315
1971	9149	609	101	50	9,909
1972	9400	648	109	56	10,213
1973	9793	791	114	64	10,763
1974	9749	880	112	67	10,808
1975	9573	773	127	72	10,545
1976	9605	850	124	77	10,656
1977	9688	861	126	82	10,757
1978	9667	917	138	90	10,812

Source: Anon. (1980A).

¹ Between 1961 and 1965, 87% of the marine harvest came from domestic waters.

TABLE 23.2. DISTRIBUTION AND VALUE OF THE VARIOUS TYPES OF MARINE AND FRESHWATER FISH HARVEST, JAPAN 1977

Distribution of harvest	Volume of Harvest		Value of Harvest	
	(1000 Metric Tons)	(%)	(Million Dollars)	(%)
Marine harvest (wild)	9,695	90.1	8,205	80.6
Shallow sea culture	861	8.0	1,409	13.8
Inland freshwater (wild)	126	1.2	194	1.9
Inland cultured	82	0.7	372	3.7
Totals	10,764	100.0	10,180	100.0

Source: Anon. (1980A).

250 yen = \$1.00 U.S.

erably; (2) specially built ponds of concrete and/or stone with some running water; (3) stillwater ponds, used primarily for fish culturing and with nearly constant water levels; and (4) running water enclosures. In a few cases pens, cages, and nets are used. The six major species raised in the system are: (1) rainbow trout (*Salmo gairdneri*), (2) Japanese eel (*Anguilla*

japonicus), (3) common carp (*Cyprinus carpio*), (4) crucian carp (*Carassius carassius*), (5) ayu or sweetfish (*Plecoglossus altivelis*), and (6) tilipia (*Tilipia nilotica*). In addition to these six, there is some culturing of (1) loach (*Misgurnus anguillicaudatus*), (2) grey or jumping mullet (*Mugil cephalus*), and (3) so-called native trout which are comprised of *Salvelinus pluvius*, *Oncorhynchus masu*, and *Oncorhynchus rhodurus*. These minor species will be discussed in separate sections.

In 1978 of the six major cultured species, a total of 94,774 MT¹ (104,441 ST) were cultured and 35,606 MT (39,238 ST) of wild fish were caught (Table 23.3). Of the total supply of 130,380 MT (143,769 ST), 73% were cultured and raised to market sizes for food. All of the tilipia were cultured, 94% of the eel, 90% of the rainbow trout, 80% of the common carp, 35% of the ayu or sweetfish, and 11% of the crucian carp. By volume of production eel ranked first with 32,108 MT (35,383 ST), common carp second with 29,160 MT (32,134 ST), trout third with 19,029 MT (20,970 ST), ayu or sweetfish fourth with 7185 MT (7818 ST), tilipia fifth with a conservatively estimated 6000 MT (6612 ST), and crucian carp sixth with 1292 MT (1424 ST). The remaining volume of freshwater fish was harvested as wild fish caught in inland freshwaters, although many of these were produced in hatcheries before being released in native waters. Hence, to some extent these wild fish were partially cultured, even if they had not been fed to a finished weight.

In recent years, the volume of freshwater fish cultured has been increasing. For example, common carp production between 1969 and 1978 increased from 13,971 MT (15,368 ST) to 29,160 MT (32,076 ST) for an

TABLE 23.3. VARIETIES AND VOLUMES OF FISH¹ PRODUCED BY INLAND FRESHWATER FISHING AND FROM CULTURED IMPOUNDED WATER AREAS, JAPAN, 1978

Variety	Freshwater Fishing	Cultured Fish	Totals	Percentage Cultured
	Metric Tons			
Trout (<i>Salmo gairdneri</i>)	2,046	19,029	21,075	90
Japanese eel (<i>Anguilla japonicus</i>)	2,068	32,108	34,176	94
Common carp (<i>Cyprinus carpio</i>)	7,378	29,160	36,538	80
Crucian carp (<i>Carassius carassius</i>)	10,751	1,292	12,043	11
Ayu (sweetfish) (<i>Plecoglossus altivelis</i>)	13,363	7,185	20,548	35
Totals	35,606	88,774	124,380	71

Source: Anon. (1980A).

¹Does not include an estimated 6000 MT of cultured tilipia (*T. nilotica*) which has become important in the past five years and for which official statistics are not yet kept.

¹Includes a conservatively estimated 6000 MT of cultured *Tilipia nilotica* for which statistics were not kept.

average yearly increase of 12% (Table 23.4). Trout, during the same 10 years, increased from 10,254 MT (11,279 ST) to 19,029 MT (20,932 ST) for an average yearly increase of 10%. Ayu and eel also increased by 12 and 4% annually, respectively, while crucian carp declined.

Production Methods

Official government statistics classify production facilities by four methods. These are: (1) running water ponds, (2) stillwater ponds (3) agricultural or farm ponds, and (4) nets, pens, or cages (Table 23.5). As can be seen in Table 23.5, running water culture is used for trout, ayu, and common carp. However, there is a world of difference in this classification. The trout and ayu enclosures or raceways may turn over or replace the water every hour while in the carp ponds the water may be replaced only once daily.

The stillwater ponds have only enough fresh water coming in to replace losses. With carp these are simple ponds that may be earthen. With eel they are circulating-filter systems, comparable to running water culture for trout, except the running water is used over and over again. These eel ponds may be inside buildings that resemble greenhouses. The water goes through mechanical and biofilters and is recirculated back to the pond. During circulation, the water is aerated to increase its oxygen content. The major disadvantage of this system is that it has a tendency to encourage the spread of disease. If fish in one production unit become diseased, the system spreads the infection to other production units in which the same water is recirculated.

Agricultural or farm ponds are primarily used for rice production. Crucian carp and some common carp are grown in these ponds. When the rice is nearly mature, the rice fields are flooded prior to harvesting. When harvesting begins, the fields are drained. During this time the flow of water into these ponds may cease. In spite of this limitation, farm ponds are often used for fish production because: (1) investment is minimized compared to other methods, (2) water temperatures are conducive to fast growth of warmwater fish, such as common and crucian carp, and (3) feeding is relatively easy. Disadvantages include: (1) oxygen supply depends on plankton and it is difficult to manage the ponds to maximize plankton growth. Compared to other methods of production, output is low per unit of water. To maximize production, the water supply during the low water season must be at least one-half of the flow of other seasons. As water flow increases in the spring and fall, it must be possible to control water flows so that the plankton growth is not excessively decreased. Also, the mud layer at the bottom of the pond must not be excessive or harvesting becomes difficult unless complete draining can be practiced. Water should be between 2 and 3 m (6 and 10 ft) deep so that in hot weather some cooler water can be found at the bottom of the pond. Otherwise, feeding may have to be curtailed, thus decreasing the rate of gain. The pond should be subject to sunlight for a considerable part of the day so that plankton growth is encouraged. In Japan, desirable pond sizes range from 1 to 3 ha (2.5 to 7.5 acres).

TABLE 23.4. VOLUMES OF CULTURED FRESHWATER FISH PRODUCTION BY SPECIES¹, JAPAN, 1969-1978

Species	Year									
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Japanese eel (<i>Anquilla japonicus</i>)	23,276	16,730	14,233	13,355	14,862	17,077	20,749	26,251	27,630	32,108
Carp (<i>Cyprinus carpio</i>)	13,971	15,865	17,840	23,037	26,406	26,323	28,129	26,239	29,295	29,160
Crucian carp (<i>Carassius carassius</i>)	1,776	1,391	1,209	1,183	1,369	841	966	954	1,007	1,296
Trout ² (<i>Salmo gairdneri</i>)	10,254	10,632	12,749	13,515	15,707	17,631	16,725	16,837	17,617	19,029
Ayu (sweetfish) (<i>Plecoglossus altivelis</i>)	N.A.	3,411	3,941	4,317	4,428	4,712	4,991	5,726	5,735	7,185
Totals	49,277	48,029	49,972	55,407	62,776	65,637	71,560	76,007	80,924	88,774

Source: Anon. (1980A).

¹ Does not include an estimated 6000-10,000 MT of tilapia in 1978 which has become important only since about 1974.

² Includes small amount of trout other than *Salmo gairdneri*.

N.A.—Not Applicable.

With pond culture, feeding should take place near the center of the pond. The water depth should be at least 1 m (3 ft), even in extremely dry weather. The feeding area should be sunny and not subject to strong winds. When the pond is initially stocked, the fish have a tendency to gather near the bank. Hence, feeding should begin the day after stocking and in an area 2 to 3 m (6 to 10 ft) from the bank. Over time the distance can be extended so that the fish are gradually moved to the center of the pond for feeding. The usual practice is to have a walkway extending into the pond with some provision made for stocking a minimum amount of feed at the end of the pier. Special care needs to be given to scattering the feed evenly over the feeding area. In Japan, the usual feeding practice is to feed about 10 times daily from 7 A.M. until 5 or 6 P.M. in running water culture, and about 4 times in pond culture.

Most varieties of cultured fish will stay near the area where they are fed. If they are unable to secure feed at that spot, they have a tendency to move to another part of the pond and may never return to the feeding area, but rely on natural foods. When this situation occurs, growth of fish may be uneven and poor, sometimes with 20 to 40% of the fish being produced without supplementary feeding. This can be a major problem to pond culturists; and the greater the stocking rate (such as in large ponds), the greater is the possibility of this problem arising. Thus, the rate of gain per kilogram of fish stocked may be decreased considerably.

Net, pen, or cage culture is found in many lakes and some rivers. Fish are grown in enclosures anchored in the larger body of water. Usually no effort is made to aerate the water. Instead, water currents within the larger body of water are relied upon to bring a constant supply of fresh water to the net, pen, or cage.

As can be seen in Table 23.5, trout are nearly always cultured in running water enclosures called raceways. Common carp are produced with all systems or methods. Crucian carp are produced in farm ponds, eel in still-water (recirculating) ponds, and ayu in raceways.

Rainbow Trout (*Salmo gairdneri*)

In 1978, cultured production of trout was 19,029 MT² (20,932 ST). The wild catch was 2046 MT (2251 ST). Hence, of the total 21,075 MT (23,182 ST), 90% was cultured. Based on past production records, Nagano, Shizuoka, Gifu, and Tochigi prefectures produced about one-half of the total, while the remainder is accounted for in other prefectures. Rainbow trout are widespread in Japan, being produced on all four main islands. Rainbow trout production is expanding rapidly. For example, in 1969 production was only 10,254 MT (11,279 ST). Thus, in nine years, production expanded 86% (Table 23.4).

In 1978 there were 2007 separate managements in Japan. All of these but

²Includes small amounts of trout other than rainbow.

25 used running water culture methods. Five producers used either cages or nets (Table 23.5). There were 2,914,000 m² or 291.4 ha (720 acres) of water area in rainbow trout production. Production per m² was 6.53 kg (1.3 lb per ft²). This is very intensive production and denoted good management, feeding practices, and proper use of high-quality and large quantities of water per farm.

Trout require a much higher oxygen content in the water than most other fish, so a plentiful supply of cold water with high oxygen content is essential. In general, production is carried out in small concrete-lined units called raceways. Water is secured from deep wells or from mountain streams. Rainbow trout producers utilize running water culture almost exclusively. The advantages and disadvantages of this type of culture follow, respectively:

Advantages:

- (1) The volume of fish produced is generally higher, and more fish can be produced per given area of water surface.
- (2) Ponds or races are smaller in contrast to pond culture, thus easier to manage.
- (3) Few people are required per unit of production.
- (4) Harvesting is easier compared with larger ponds.

Disadvantages:

- (1) A continuous volume of water flow is required during the growing season.
- (2) Essentially the same equivalent volume of water is required during each time period.
- (3) Care must be exercised at all times to ensure that debris carried by the water does not interfere with the water flow.
- (4) The heavy flow of water requires the sides and bottom of the small ponds or races to be of durable material, such as concrete. Thus, construction costs are liable to be higher in comparison with other methods of culture.

In 1978 32,790 MT (36,069 ST) of feed were fed. Nearly all of this was pelleted food (Table 23.6). The average feed conversion for the entire industry was 1.72 meaning 1.72 units of feed fed per unit of output.

TABLE 23.6. TYPE AND AMOUNTS OF FEED FED, BY SPECIES OF FRESHWATER CULTURED FISH, JAPAN, 1978

Type of Feed	Rainbow Trout	Ayu	Common Carp	Crucian Carp	Eel
	Metric Tons				
Fresh and frozen fish	473	53	370	—	9,656
Fresh silkworm pupae	3	—	2,925	3	15
Dry silkworm pupae	62	—	5,437	449	24
Pellets	31,500	11,917	37,043	342	54,165
Other	752	234	2,480	760	3,030
Total	32,790	12,204	48,255	1554	66,890

Source: Anon. (1980A).

The quantity of feed fed to trout varies by size of the fish and temperature of the water. Regardless of the country of production, feeding charts are relatively uniform. A typical example of feeding guides is shown in Table 23.7.

Production Costs. Production costs for cultured rainbow trout are similar to those of Western Europe and the USA. However, wages are usually a more significant cost because output per worker is lower. On only the very large trout farms does production per person reach the output found elsewhere. There are many small producers who produce less than 20 MT (22 ST). Thus, on these farms, productivity may be only one-third of the output per person found on the larger farms in other countries. An example of the typical distribution of costs and returns is found in Table 23.8.

Marketing. In general, rainbow trout as a food fish are not highly regarded in Japan. Even after some 75 to 80 years of culturing, the people still prefer native marine and freshwater species. However, because of inflation and rapidly increasing consumer prices, many Japanese have, in recent years, adapted their diets to include the relatively inexpensive rainbow trout. For example, in 1965, of the total production of 5747 MT (6333 ST), 2122 MT or 37% was exported. At that time, trout was very inexpensive, wholesaling for \$0.75 per kg (\$0.339 per lb) in Tokyo. The export price for frozen and dressed trout was only \$0.81 per kg (\$0.369 per lb) FOB Tokyo. After allowing for processing costs, packaging, and dress-out loss, the export price was less than the domestic price. Nevertheless, the export market had to be used to sell all the trout produced. However, by 1978 the situation had been reversed. Production increased by 221% to 19,029 MT (20,932 ST). However, exports decreased to only 1035 MT (1138 ST) or by 46%. Domestic consumption increased from 3625 MT (3988 ST) to 17,994 MT (19,793 ST) or by 396%. Wholesale prices in Tokyo had increased to \$2.08 per kg (\$0.95 per lb), or nearly triple those prices of 13 years before. Trout were still relatively inexpensive compared to other marine and freshwater cultured fish.

In 1978, 1385 MT (1524 ST) of rainbow trout were sold through the Tokyo Central Wholesale Fish Market (Table 23.9). This amounted to nearly 8% of total domestic consumption. This indicates that the central wholesale fish markets located in the large cities may handle as much as 25% of total production. The major markets for trout are in the large central cities for restaurant use and for sale in supermarkets. The secondary markets are in mountainous, recreational areas and for fee fish-out ponds. While prices have increased rapidly in the past few years, the fish are relatively inexpensive.

While domestic consumption now accounts for 95% of production, compared to 63% 13 years ago, the export market has been important as a stabilizing influence on domestic prices. Exports are rapidly declining, particularly in 1978 and 1979 (Table 23.10). Trout are exported to between 18 and 19 countries annually. The major export markets in 1978 and 1979

TABLE 23.7. QUANTITY OF FEED TO BE FED TO RAINBOW TROUT IN RELATION TO WATER TEMPERATURE AND SIZE OF FISH, JAPAN

Length of Fish (cm)	Length of Fish (in.)	Water Temperature										20 74
		2 36	4 40	6 45	8 49	10 53	12 57	14 63	16 68	18 71		
Less than 2.5	1 or less	2.0	2.5	3.1	3.5	4.2	4.6	5.5	6.3	7.1	7.9	7.9
2.5-5.0	1 - 2	1.7	2.2	2.6	3.0	3.4	3.9	4.4	5.2	5.9	7.5	7.5
5.0-7.5	2 - 3	1.4	1.7	1.9	2.3	2.7	3.1	3.6	4.3	4.8	5.5	5.5
7.5-10.0	3 - 4	1.1	1.3	1.5	1.7	2.2	2.4	2.8	3.3	3.9	4.4	4.4
10.0-13.0	4 - 5	0.8	1.0	1.1	1.4	1.6	1.8	2.1	2.5	2.8	3.2	3.2
13.0-15.0	5 - 6	0.7	0.8	0.9	1.1	1.4	1.5	1.7	2.0	2.2	2.6	2.6
15.0-18.0	6 - 7 1/2	0.6	0.7	0.8	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.0
18.0-21.0	7 1/2 - 8 1/2	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.7
21.0-23.0	8 - 9	0.5	0.6	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.7	1.7
23.0-26.0	9 - 10	0.4	0.5	0.6	0.6	0.8	0.9	1.0	1.1	1.3	1.6	1.6
26 and over	10 or more	0.4	0.4	0.5	0.6	0.6	0.8	0.9	1.1	1.3	1.7	1.7

Source: Chiba (1968).

TABLE 23.8. PRODUCTION COSTS, SELLING PRICE, AND NET RETURNS FOR RAINBOW TROUT, GIFU PREFECTURE, JAPAN, 1978 [40 MT (44.1 ST) OF PRODUCTION]

Item	Production Costs		
	per kg (Cents)	per lb (Cents)	Percentage
Fry ¹	10.0	4.5	5.1
Feed ²	94.0	42.7	47.7
Wages, including bonus ³	50.0	22.7	25.5
Repairs and maintenance	5.2	2.4	2.6
Depreciation	15.2	6.9	7.8
Heat	4.0	1.8	2.0
Interest	15.2	6.9	7.7
All others	3.2	1.5	1.6
Total costs	197.00	89.1	100.0
Selling price (cents)	240	1.09	—
Net returns ⁴	21.8	21.8	—

Source: Anon. (1979C).

¹One million eyed-eggs purchased at \$0.004 each. Survival to market sizes of 100 g was 40%.

²Feed purchased was 67 MT at \$560 per MT (\$508 per ST). Feed conversion was 1.68 to 1.

³Two men employed at \$10,000 each.

⁴Returns to land and management were \$39,800.

were: (1) Canada, (2) Great Britain, (3) Belgium, (4) USA, and (5) Sweden. Export prices are about the same as wholesale prices at the Tokyo wholesale market.

Japanese Eel (*Anguilla japonicus*)

Eels are considered a gourmet fish in Japan and command premium prices. For these reasons culturing of eels began at an early date. During the 1950s and early 1960s as Japan industrialized rapidly, the natural catching waters were restricted by dams and pollution, and the wild catch declined. As prices rose and culturing techniques became known, eel farming intensified with increased numbers of producers and increased production per surface unit of water. In 1955, 4000 MT (4400 ST) were cultured. From then until 1968, production increased rapidly. In 1968 production reached a high mark of 24,000 MT (26,400 ST). In the 1970–1972 period, production declined drastically as a result of various diseases among the fry and the concurrent decline in the catch of natural elvers or glass eels (juvenile state). In 1972 production reached its lowest level with only 13,400 MT (14,740 ST) produced. During the following years, production increased as elvers from Europe as well as those from many other areas were imported.

Market prices followed the supply schedule. Following are the yearly average prices for live eel of 150–200 g from 1970 through 1978 at the Tokyo Central Wholesale Fish Market. Price is in U.S. dollars per kilogram and pound.

	\$ per kg	\$ per lb
1970	4.00	1.82
1971	5.03	2.29
1972	6.36	2.89
1973	5.17	2.35
1974	7.56	2.98
1975	7.92	3.60
1976	7.90	3.59
1977	8.10	3.68
1978	9.36	4.25

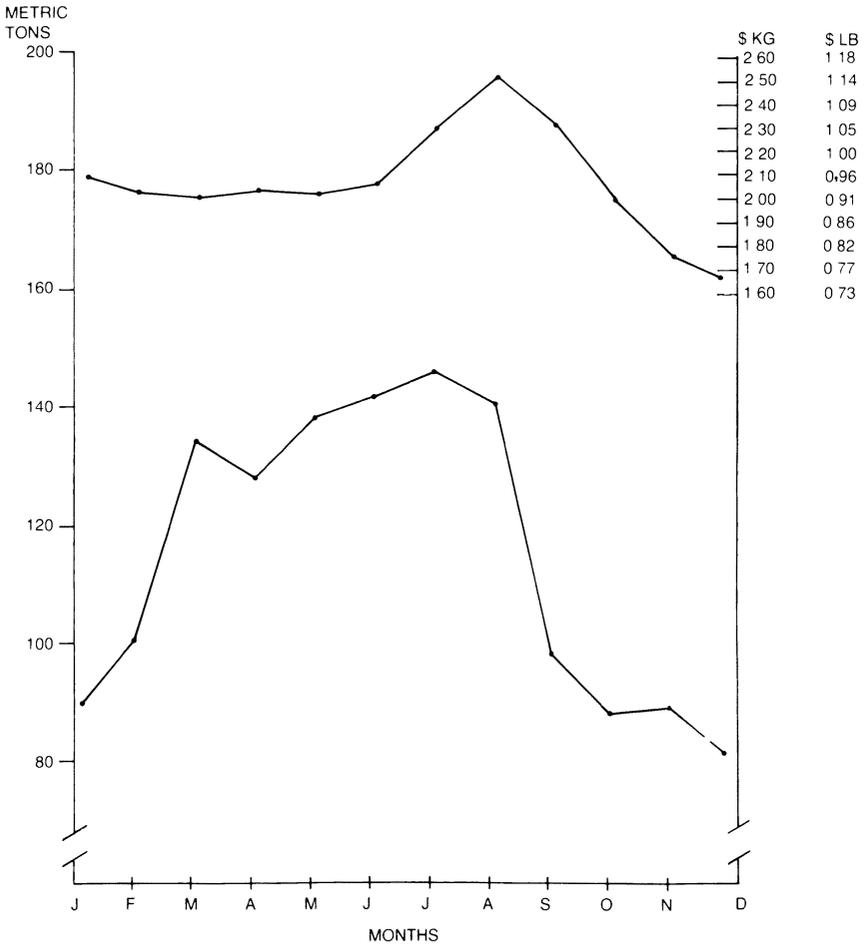


Fig. 23.2. Comparison of average monthly volumes of eel sold and prices paid, Tokyo Central Wholesale Fish Market, 1978.

TABLE 23.9. VOLUME OF RAINBOW TROUT SOLD AND PRICES BY MONTHS, TOKYO CENTRAL WHOLESALE FISH MARKET, JAPAN 1976-1978

Months	Year					
	1976		1977		1978	
	kg	Price in Dollars per kg	kg	Price in Dollars per kg	kg	Price in Dollars per kg
January	70,106	1.64	64,396	2.04	90,268	2.08
February	65,959	1.70	74,647	2.17	101,109	2.00
March	77,047	1.96	86,333	2.45	134,070	1.99
April	72,583	2.12	96,145	2.63	128,120	2.02
May	68,793	2.25	95,660	2.64	138,273	2.01
June	85,575	2.30	110,138	2.49	142,603	2.04
July	99,120	2.45	107,755	2.50	146,591	2.29
August	77,202	2.41	116,750	2.63	141,339	2.51
September	73,965	2.34	92,006	2.50	99,059	2.30
October	69,850	2.09	75,857	2.38	89,828	1.99
November	61,513	2.01	75,913	2.30	90,211	1.76
December	60,965	2.07	71,214	2.14	83,679	1.68
Totals and averages	883,578	2.13	1,067,814	2.44	1,385,159	2.08

Source: Anon. (1972-1978).

TABLE 23.10. RAINBOW TROUT EXPORTS FROM JAPAN BY COUNTRIES, 1972-1979

Importing Country	Years							
	1972	1973	1974	1975	1976	1977	1978	1979
	Metric Tons							
USA	990.8	807.5	848.6	745.6	665.9	497.0	135.1	63.5
Canada	525.3	426.6	623.5	255.1	85.8	381.7	489.3	181.4
Great Britain	533.7	522.6	539.8	553.4	407.0	375.5	160.9	91.9
Australia	64.7	74.2	212.3	1.1	—	—	—	—
Belgium	142.7	221.8	152.6	183.2	113.5	157.3	163.4	38.7
South Africa	16.4	38.3	53.1	60.8	21.3	7.9	—	—
Sweden	15.9	2.3	24.9	27.9	7.0	69.4	55.4	61.7
West Germany	131.5	168.9	22.7	112.0	168.0	77.1	20.0	59.4
Holland	27.7	15.9	20.2	51.0	31.3	14.7	—	—
Others ¹	70.8	67.0	20.5	56.7	108.9	82.1	14.4	4.8
Totals	2519.5	2345.1	2518.2	2046.8	1608.7	1662.7	1035.5	501.2

Source: Anon. (1962-1979).

¹Includes during various years: Hong Kong, Singapore, Philippines, Norway, Switzerland, Italy, Gibraltar, Samoa, New Hebrides, France, Thailand.

The average export price in 1979 was \$2.32 per kg or \$1.05 per lb, with \$1 U.S. equal to 250 yen.



Fig. 23.3. Intensive indoor eel culturing facility.

In addition to smaller supplies affecting market prices between 1970 and 1972, real per capita incomes increased and there was a rapid expansion in demand for frozen and fresh ice-packed fish rather than for the more costly live fish. With rapidly increasing prices between 1970 and 1973, interest in eel culture intensified. Existing producers tried to expand production, new

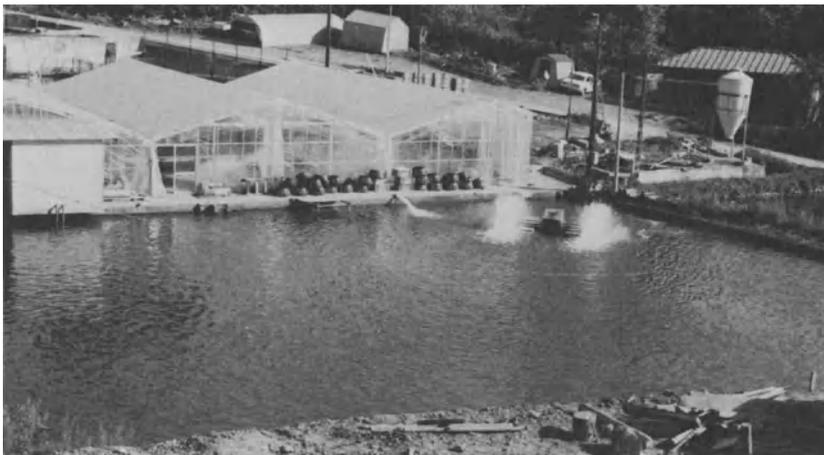


Fig. 23.4. Typical eel culturing farm, with indoor and outdoor ponds, Shizuoka Prefecture.



Fig. 23.5. Eel feeding station, Shizuoka Prefecture.

producers entered the business, and industrial firms started culturing in warmwater effluents. Production units became more capital intensive.

The important problem was the supply and price of elvers. This problem was difficult because the supply of elvers is determined by the catch under natural conditions. Before 1968, if more elvers were needed, they were imported from Taiwan, but in that year Taiwan began culturing eel and exported food-size eels to Japan rather than elvers. In addition, some Japanese firms began exporting Japanese elvers to Taiwan to take advantage of lower production costs. Hence, Japanese elver prices increased rapidly. In



Fig. 23.6. Feeding eel.

1969 elver prices were only \$33 per kg. In the spring of 1973, the price of elvers per kilogram in Japan reached a phenomenal figure of \$1300 (\$590 per lb), or about \$0.43 each.

Import firms went around the world to secure alternative species. France became the main source of supply and accounted for 217 MT (239 ST), or 90% of the 1973 imports. (In the 1977–1979 period, all elver imports declined under 100 MT as the domestic catch increased). Most imported elvers died because of differences in water temperatures and disease. The retail prices of imported cultured eels were lower than the native species; hence, the imported price was as low as \$30 per kg (\$14 per lb). By 1976, eel diseases were widespread in Japan as a result of introduction of new species from more than 10 countries. The major problems became disease control and high feed prices.

Because of problems in obtaining enough elvers and then the introduction of new diseases, domestic production of food-sized eel has been erratic. Production since 1969 has varied from a low of 13,355 MT (14,690 ST) to a high of 32,108 MT (35,319 ST), see Table 23.4. Since total domestic supply is 94% cultured, the supply of wild eels has not been sufficient to moderate rapid price changes brought about by erratic shifts in production volumes.

In 1978 there were 3218 separate managements in the major producing prefectures (Table 23.5). These managements were classified as using essentially stillwater ponds. While this classification is technically correct, there is a world of difference between carp and eel stillwater ponds. The carp pond is exposed to the elements and is fed by a stream or well having sufficient water flow to maintain the pond level with some water flowing out of the pond. In the eel ponds, many are enclosed in plastic types of

greenhouses. The water is usually from wells, heated to the proper temperature, pumped into the greenhouse type of pond, and is recirculated over and over again. Biofilters are used to remove some of the waste materials, and mechanical aerators are utilized extensively. This system is explained in a little more detail under production costs in this section.

A small number of eel farms use running water culture, similar to trout raceways. In 1978, about 11% of the eel farms used running water and 89% used stillwater recirculation systems.

The stillwater farms had a total surface area of 23,743,000 m² or 2374 ha (5864 acres). The farms using running water culture had 1,007,000 m² of surface area (100.7 ha or 249 acres). Production per m² for the stillwater ponds was 0.10 kg (0.09 lb per ft²). Production per m² of running water surface was 2.4 kg (0.48 lb per ft²).

In 1976 Shizuoka Prefecture accounted for 32%, Aichi Prefecture for 19%, Kochi Prefecture for 13%, Kagoshima Prefecture for over 8%, and Miyazaki for 6%. These five prefectures made up 78% of production. The remainder was produced by numerous other minor areas.

A variety of food is fed to eels. However, fish mash makes up 81% of the total, followed by fresh or frozen trash fish with 14%. Other miscellaneous foods made up the other 5% (Table 23.6). In 1978 the feed conversion for all of Japan was 2.1 to 1 or 2.1 units of food per unit of gain. This may appear to be excessive compared to many other cultured fish, but it must be remembered that more than one-third of the diet was other fish. Feed conversion for these other fish may have been 6 or 7 to 1.

Production Costs. The average eel farmer in Japan has 7700 m² of water area (1.86 acres) and produces 10.0 MT (11 ST) of eel yearly. Hence, production per establishment and per person is low. Facilities are costly since land may sell for \$1 million per ha (over \$400,000 per acre).

Production Methods. Production practices call for intensive methods. There are four different methods used. All of them consist of concrete or rock and concrete-walled, running water or pond enclosures. The four methods in order of intensity of production are:

- (1) *Circulating System.* Only a few of these are in use. In experiment, 200 kg have been produced per m² (41 lb per ft²). Water is heated or maintained at a constant 25°C (77°F). Only enough new water is added to replace losses. The recirculated water is filtered by both mechanical and biofilters.
- (2) *Kochi System.* This system takes its name from the prefecture of Kochi on Shikoku Island. About 5% of total production comes from the Kochi system. The eels are kept inside in plastic covered-greenhouses during the entire production cycle. Very little new water is added. Temperatures are maintained at 25°C (77°F). Bacterial action is used in biofilters to clean the recirculated water. Production is 10–15 kg per m² (2–3 lb per ft²). This method is becoming important and may account for 15–18% of total production.

- (3) *Raceway or Semi-raceway System.* This system accounts for about 5% of total production. The water is used once and discharged. Costs are high for maintaining water temperatures. The water exchange rate is about once daily. Production is slightly in excess of the pond or No. (4) system.
- (4) *Pond System.* This is the most common method. The elvers are grown in heated 25°C (77°F) water until they weigh 10 g (½ oz). This indoor pond is about 50 cm deep (18 in.). After about one month they are transferred to a pond 70 cm deep (28 in.) for the second month. They are then transferred to another pond 90 cm deep (36 in.) for two more months. By this time the outdoor pond waters are suitable for stocking and they are transferred to this outdoor pond for grow-out. This pond is also 90 cm (36 in.) deep. They are kept in this pond for 14 months. They are then marketed after about 18 months at 150 to 200 g sizes (5½ to 7 oz). In the last outdoor pond they are often wintered-over outside. The eels throughout this production cycle may be separated by size six or eight times. Hence, labor needs are demanding.

The elvers are fed minced worms for the first two or three weeks and then are gradually shifted to a mash diet containing 55–60% protein. The more mature eels have a mash diet containing 43% protein. A typical diet contains:

Whitefish meal	70%	Salt	1%
Potato starch	20	Minerals	1
Yeast	5	Other	2
Vitamin mixture	1		

Since the pond system is most common, production costs are presented for this system (Table 23.11). These figures are based on farms in the Shizuoka Prefecture. Of the elvers stocked, only about 40% survive to market sizes. The feed conversion is 2 to 1. No raw fish are fed as in some smaller facilities. Fixed costs constitute nearly 20% of total cost. Interest accounts for nearly one-half of fixed cost. The high expenses under variable costs are feed and elvers. Total production cost in 1978 was \$6.30 per kg (\$2.86 per lb). However, the farmer's price was \$8.00 per kg (\$3.64 per lb), resulting in a 27% return or profit per dollar of cost. For these farms, producing 17.4 MT (19.1 ST), total return to management or profit was \$29,512. This is a high income in Japan.

Marketing. Eel as a food was mentioned in archives of 718 A.D. Specialized cooking methods go back 500 years. Eel culturing began in 1879. Among the Japanese, this species of cultured fish is considered highly nutritious and conducive to good health. Hence, the demand is high. However, Japanese scientists have met with only limited success in reproducing the eel elvers by artificial means. The elvers are caught at only a few locations. Elvers are imported from Korea, People's Republic of China, and



Fig. 23.7. Sizing and grading eel.



Fig. 23.8. Sized eel.

Europe in commercial quantities. Very few eels are exported since the Japanese price is the highest in the world. The price fluctuates widely from year to year, depending on the catch of elvers. Formerly, elvers were imported from Taiwan, but in recent years the Taiwanese have been raising the elvers to market sizes and exporting them to Japan. Some Japanese

elvers are exported to Taiwan for rearing there. This is because production cost is less in Taiwan.

Since about 1975 imports of food-sized, cultured eel have become increasingly important. In 1979 in addition to about 35,000 MT (38,500 ST) of domestic cultured production, 13,268 MT (14,595 ST) were imported. Hence, imports account for about 28% of cultured supply. The leading source of imported eel in 1979 was Taiwan. Imports were also made from nine other countries or places.

Eel Imports (MT)	
Taiwan	13,205
USA	17
Guam	14
China	11
Thailand	7
New Zealand	5
Korea	4
Indonesia	3
Hong Kong	1
Egypt	less than 1

TABLE 23.11. PRODUCTION COSTS, SELLING PRICE, AND NET RETURNS FOR 17.36 MT OF EEL PRODUCTION, SHIZUOKA PREFECTURE, JAPAN 1978

Item	Production Costs		
	per kg (Cents)	per lb (Cents)	Percentage (Cents)
Fixed costs			
land and water rent	13.2	6.0	2.1
depreciation ¹	39.2	17.8	6.2
repairs	12.0	5.5	1.9
interest	52.0	23.6	8.3
total fixed	116.4	52.9	18.5
Variable costs			
elvers	144.8	65.8	23.0
feed	242.8	110.4	38.5
heating oil and electricity	60.8	27.6	9.7
treatment costs	22.8	10.4	3.6
expendables	2.4	1.1	0.4
labor ²	40.0	18.2	6.3
total variable	513.6	233.5	81.5
Total cost	630.0	286.4	100.0
Selling price	800.0	363.6	—
Net returns	170.0	77.2	27.0

Source: Anon. (1979A).

¹ 11,240 m² (2.78 acres) of open ponds; 1320 m² (0.33 acres) of heated house; heating equipment; culturing tools; and vehicles.

² Man and wife, family labor.

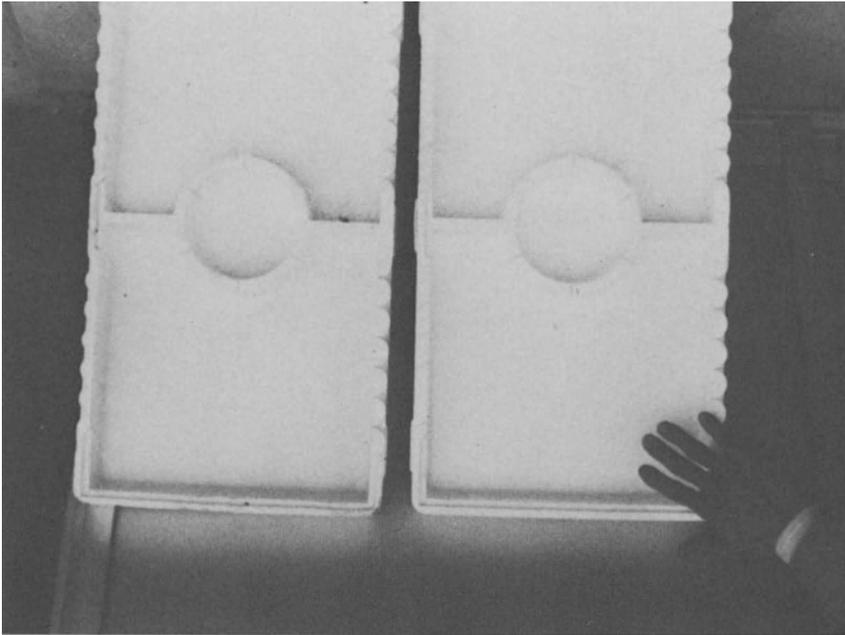


Fig. 23.9. Elver (eel) shipping containers.

The elver catching season in Japan is from December to March. After an 18-month productive cycle, the market-sized eel are ready in the June–October period. However, because of extreme variations in individual growth which may vary by 200 times, eel are harvested and sold throughout the year.

Tokyo is the largest market for eel in Japan. About 40% of all eel are consumed in this one city. Perhaps 15 to 20% of Tokyo's eel comes through the Tokyo Central Wholesale Fish Market. However, the vast majority come from eel distributors selling to fish markets, retail stalls, and supermarkets. Since these sales are of a private nature and prices change rapidly, the volumes and prices at the Central Market are presented (Table 3.12). Prices have been increasing rapidly in the most recent three years for which data are available. By contrast, prices per kg ranged from a low of \$1.78 per kg (\$0.81 per lb) in 1967 to the high of \$9.30 per kg. (\$4.25 per lb) in 1978.

As shown in Table 23.12, volume of eel sold on the Central Market rises in the summer, particularly in July. However, prices do not decline with heavy volumes since more eel are eaten in the summer. In July, one day is set aside as National Eel Day, and one of the traditional meals that day is eel. Hence, prices reach their peak in July in spite of sales increasing.

An unknown but significant share of eel is utilized by the better restau-

TABLE 23.12. VOLUMES OF EEL SOLD AND PRICES BY MONTHS, TOKYO CENTRAL WHOLESALE FISH MARKET, JAPAN 1976-1978

Months	1976		Year 1977		1978	
	kg	Price in Dollars per kg	kg	Price in Dollars per kg	kg	Price in Dollars per kg
January	78,088	8.57	45,304	7.41	42,986	8.37
February	43,980	8.35	42,604	7.90	42,945	8.57
March	57,930	8.70	55,897	8.20	57,868	8.50
April	70,903	8.60	67,788	8.68	59,520	8.49
May	81,900	8.00	85,900	8.73	75,873	8.50
June	99,405	8.70	93,069	8.46	120,884	9.04
July	216,739	8.46	264,231	8.15	223,090	11.34
August	104,024	7.20	117,875	8.07	99,263	10.19
September	63,257	6.21	70,784	7.56	57,231	8.60
October	50,343	6.28	51,853	7.33	49,224	7.89
November	49,644	6.29	49,050	7.40	49,273	8.02
December	56,192	7.20	56,409	8.24	55,583	8.40
Totals and averages	972,405	7.90	1,000,764	8.10	933,740	9.36

Source: Anon. (1972-1978).

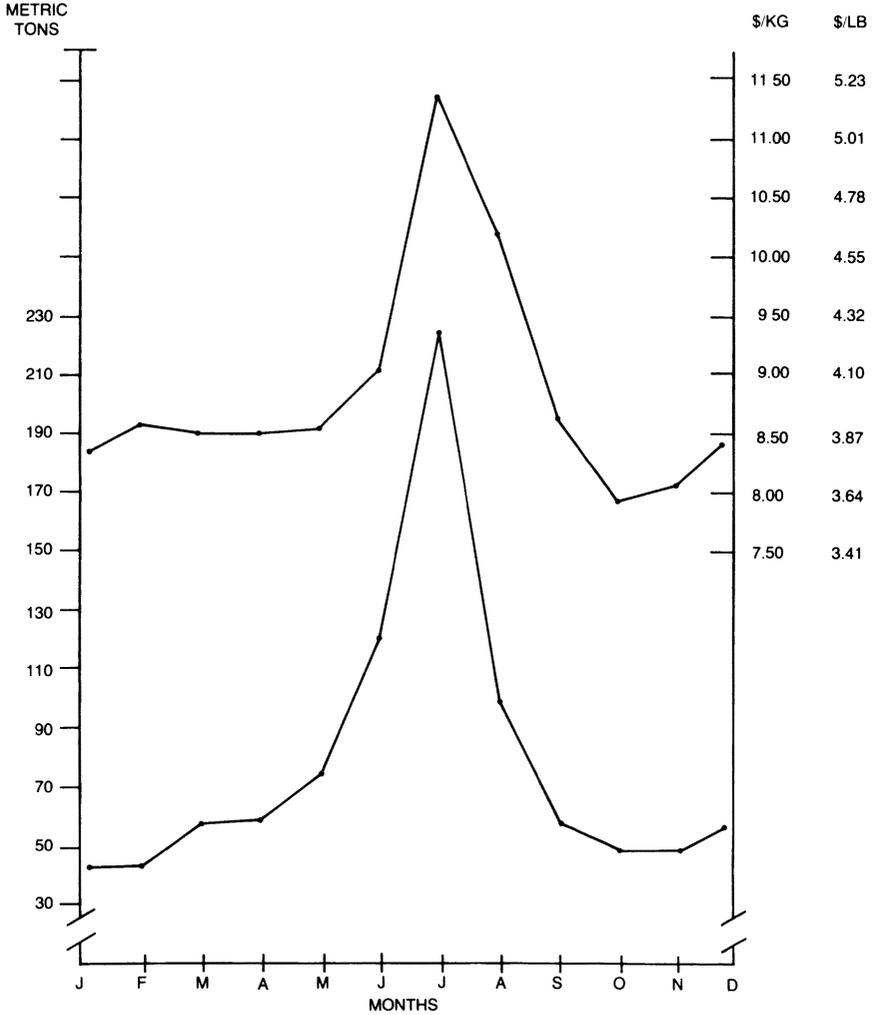


Fig. 23.10. Volumes of eel sold and prices by months, Tokyo Central Wholesale Fish Market, 1978.

rants. Eel can be found frozen in most large supermarkets and in large retail fish stores. The better restaurants use fresh eel. In very recent years, increasing quantities of eel have been sold as a precooked frozen item. This has broadened the demand base for eel. In addition, some eel is canned. Of the major types of freshwater fish cultured, only eel is canned and only eel, trout, and ayu are sold frozen.



Fig. 23.11. Market size eel stored in containers prior to processing.



Fig. 23.12. Processing eel.

Carp (*Cyprinus carpio*)

Common carp is an important freshwater species cultured in Japan. In 1978, a total of 29,160 MT (32,076 ST) were produced by fish farmers. An additional 7378 MT (8116 ST) of wild fish were caught. Eighty percent of the total supply was cultured (Table 23.3).

Cultured production increased rapidly from 1969 to 1973, and then started to stabilize. In 1969 only 13,971 MT (15,368 ST) were cultured. For

the 10-year period, production grew at an average annual rate of 11% (Table 23.4).

The number of carp farmers and water areas is declining while volume of production increases. In 1978, there were over 4046 separate managements located in the major production prefectures alone (Table 23.5). Carp are produced in nearly every type of production system. In 1978, nearly 33% (up from 27% in 1974) of the managements still used running water systems (similar to rainbow trout), 30% used stillwater ponds, 27% used farm ponds, and 10% used cages or nets in lakes. Total surface area of water devoted to culture was 33,941,000 m² or 3394 ha (8383 acres).

Running water culture accounted for 7.6% of the total carp area, but accounted for 15.5% of production. Production per ha was 17.3 MT or 7.6 ST per acre. Production output was 1.7 kg per m² or 0.3 lb per ft².

Stillwater ponds accounted for 12.8% of the total carp area, and accounted for 15.9% of production. Production per ha was 10.5 MT or 4.6 ST per acre. This rate of production, while low by Japanese standards, is two times higher than production in most countries. Production output per m² was 1 kg or 0.2 lb per ft².

Farm ponds accounted for 78% of the total carp area, but accounted for only 32% of production. Production per ha was 3.5 MT or 1.6 ST per acre. Production output per m² was 0.4 kg or less than 0.1 lb per ft².

Net or cage culture accounted for only 1.7% of the total carp area, but accounted for 36 % of production. Production per ha was 184.3 MT or 81.2 ST per acre. Production output per m² was a phenomenal 18.4 kg or 2.9 lb per ft².

Major production areas are: (1) Ibaragi prefecture with 23% of production, (2) Nagano with 15%, (3) Gunma with 10%, (4) Akita with 8%, (5) Fukuoka with 8%, and (6) Tokushima with 6%. These six prefectures accounted for 70% of total production, while about 40 other prefectures accounted for the remainder.

Production per unit of running water surface is not as high as in trout-rearing facilities. This is due to less water flow being used. An example of what can be done with adequate water flow is shown in the following illustration.

Undoubtedly the most intensive fish production rate in the world has been achieved by Mr. Kazuyoshi Tanaka, Annaka City, Gunma Prefecture, Japan. Mr. Tanaka has 16 different ponds and utilizes running water in each. Not all 16 ponds (races) are used to produce food carp; hence, the following discussion is limited to the first pond (race) in the series of 16.

The first raceway has been in fish production for 78 years and is constructed of concrete and stone. The raceway measures 47 m² (505 ft²) of water surface, and the average depth is 1.4 m (4.5 ft). The raceway is stocked with carp fry averaging 85 g each, or less than 3 oz. Gross yield from the 8500 carp stocked is about 10,335 kg (22,738 lb) annually, or 10.3 MT. On a per ha basis, this amounts to a harvest of 2203 MT (982 ST per acre). Deducting the initial stocking weight of 154 MT (62.3 ST) per ha or per acre

equivalent, the net gain in weight would be 2049 MT (920 ST). Feed conversion is 1.3 units of feed fed per unit of fish gain.

The flow of river water into this race varies from 0.1 to 0.5 MT (24 to 120 gal.) per sec during the growing season. The raceway is stocked at the end of March and fed until early November. Harvesting is done by a net, which is drawn the length of the pool, entrapping the fish. Ten people are utilized for this operation, which requires 3 hr.

During times of high water due to rain, the flow of water entering the race is controlled so that the rapid flow does not suffocate the fish. The fish are fed a diet of silkworm pupae, boiled wheat, and fish pellets which contain about 50% fish meal. Feeding commences around April 15 when the water temperature is about 18°C (64°F). The first week the feed is boiled wheat. The second week, fish pellets are added to the wheat ration. After the second week, silkworm pupae are fed along with fish pellets with a little boiled wheat fed in July, August, and September. Starting with the end of September until the end of October, the feeding rate is gradually decreased. No feed is fed during the first two weeks of November until harvesting takes place.

Feeding commences at daybreak, which may occur as early as 5 A.M., and is continued at intervals of 1½ to 2 hr until 11 P.M. Evening feeding is done under artificial lighting. If during the hottest part of the summer the water temperature reaches 33°C (91°F), feeding is discontinued. Feeding is done by tossing the feed in the water in handfuls near the site where the water enters but where the current is not rapid. Feeding is discontinued while the fish are still actively feeding.

Mr. Chiba³ writes that the most important factors of running water culture are: (1) the quantity of running water, which is directly related to the quantity of fish that can be produced; (2) the quality of water, essentially its oxygen content; (3) the need for constant running water, even if it must be circulated artificially; and (4) the temperature of the water, which must be in a range where the species of fish will feed.

Mr. Chiba in reporting his study of Mr. Tanaka's fish farming operation, correlated the flow of water into nine different races with the volume of fish produced per raceway. His analysis is shown graphically in Fig. 23.13. As stated previously, the volume of production is directly related to the quantity and quality of running water. The greater the volume of running water and the higher the oxygen content, the greater the possibility of increasing production. Since in this case study the water flows from one raceway to another, the total volume produced is related to the volume of water at any one point times the number of points (races) where the water is used. More

³The previous discussion of the case study of Mr. Tanaka has been based on two sources of information: Mr. Kenji Chiba's presentation in the book entitled *Fish Culture Seminar, Vol. 1*, supplementary data furnished by Mr. S. Nishimura, Fishery Economist, Freshwater Fisheries Agency, Hino City, Tokyo, and personal data obtained by the authors from Mr. Tanaka in May 1976.

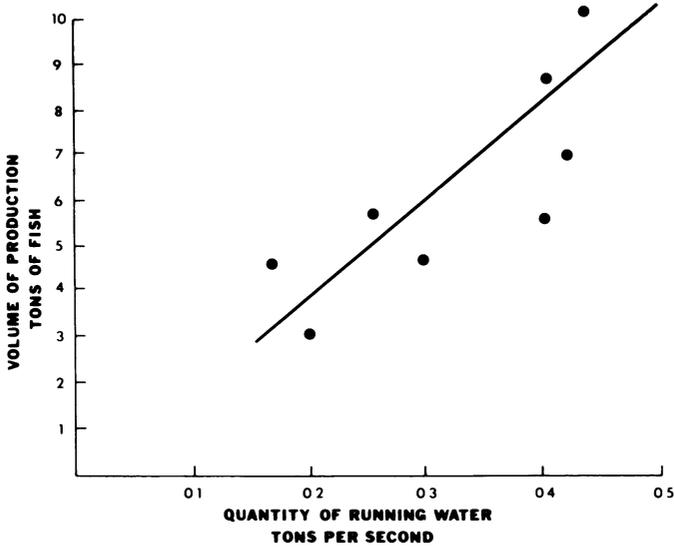


Fig. 23.13. Relationship between running volume of water and volume of freshwater carp production, Tanaka Fish Farm, Gunma Prefecture, 1966. From Chiba (1968).

than 10 MT of fish are produced at the first raceway, while total production from all nine races is over 80 MT. Production decline after the water is used in the first raceway can be expected because of oxygen depletion and lower stocking rates in subsequent races.

Stillwater ponds have only limited water flows, while farm ponds during part of the year may have none, or may even have the volume of the water in the pond reduced. As stated earlier, yields in these types of ponds average 10.5 and 3.5 MT per ha (7.6 and 1.6 ST per acre), respectively. This is very high production per unit of water. The Japanese do this by managing the plankton, which increase oxygen in the water, by mechanical aeration and by proper feeding practices.

Net culture is one of the more interesting methods used to produce carp. Since this type of culture can only be done in the larger lakes, which are limited in Japan, the presence of net culture is confined to a few prefectures having large lakes. Among these is Ibaragi Prefecture, which contains Lake Kasumigura and Kitaura, and Lake Suwa in Nagano Prefecture, where net culture was initiated in 1958. Lake production in these two areas is the major factor why 38% of total production takes place in these two prefectures.

The culturing nets are in the form of a 9 m (29.5 ft) square. The net is approximately 2 m (6.5 ft) submerged. On top of this net, an additional 1 m (39 in.) high net is attached to keep the fish from jumping out. A double net is used on the sides and bottom as a precaution to prevent fish from escaping

in the event one net is broken or torn. The corners of the nets are anchored to the bottom of the lake and connected by a floating walkway. Nine 200-liter (50-gal.) drums are used to float the framework and each net. The usual depth of the lake where net culture is practiced averages about 3 m (10 ft).

The carp stocked are between 10 and 15 cm (4 and 6 in.) long and weigh 70 to 84 g (2½ to 3 oz). The stocking rate is between 3500 and 5000 fingerlings per net set for an average of 320 kg (704 lb) of fingerlings per net. Stocking usually takes place in April and feeding continues for six months. Fish are fed about four times daily for 10–20 min each time. Each net, which includes approximately 81 m² (870 ft²) of water area, yields about 3508 kg (7718 lb) of fish, which is the equivalent of 431 MT per ha (158 ST per acre). The weight gain is 10-fold—a gain of 9 units for each unit of fish stocked. Most producers feed only pelletized fish food, which has over 39% protein content by law. Feed pellets are composed of 50% fish meal, 39% wheat flour, 6% alfalfa, 3% yeast, 1% sodium chloride, and 1% vitamins.

A major finding by the Fishery Laboratory in Nagano Prefecture was that the volume of fish harvested is directly related to the number of fingerlings stocked. They found that a stocking rate of 75 fish per m² (7 fish per ft²) of water is maximum.

A second finding reported by the Fishery Laboratory in Nagano Prefecture is the need to stock uniform size fish. If the size of fingerlings stocked varies as much as 2:1, for example 16 cm and 8 cm, the ending weight may vary as much as 3:1. This implies that the larger fish stocked acquire more than their proportional share of feed.

The Fisheries Agency of Nagano Prefecture has done considerable research of net pond culture during recent years. One of its most interesting, and perhaps most significant, findings is the correlation between average water temperatures in Lake Suwa and growth of carp as measured by the increase in the body weight of fish per day (Fig. 23.14).

Carp take two years to produce to the market sizes of 800–1000 g (29–36 oz). In the first year, spawning takes place about May 1, although this varies from place to place and from year to year. One year later the fingerlings vary from 30 to over 100 g (1 to 4 oz). In the second year the fingerlings are divided into four size groups. Group 1 averages 30 g (1 oz), Group 2 averages 60 g (2 oz), Group 3 averages 100 g (4 oz), and those in Group 4 are over 100 g (4 oz). They are then stocked into grow-out facilities by size about April 1. Group 4, or fish over 100 g, reaches 1 kg (2.2 lb) in the five months from April to August. Fish in Group 3, averaging 100 g each, reach 1 kg in the six months from April to September; those in Group 2, averaging 80 g each, reach 1 kg in the seven months from April to October. Group 1's fish, averaging 30 g each, reach 800 g (28 oz) in the eight months from April to November. The water is then too cold for growth and the fish are wintered-over with minimum feed and reach the market size of 1 kg the following July. An example of typical Japanese water temperatures is shown below (Maebashi-shi, Gunma Prefecture):

	°C	°F
January	Below 8	Below 46
February	Below 8	Below 46
March	8	46
April	13	55
May	17	63
June	22	72
July	29	84
August	30	86
September	25	77
October	20	68
November	13	55
December	8	46

Nearly every producer produces his own eggs, hatches, and raises his own fry and fingerlings. Running water producers try to stock 100 g (4 oz) fingerlings, so they often trade with pond producers. In running water the fish increase their weights by 8–10 times in one year, whereas in ponds, increases of 18–20 times can be obtained. Hence, running water culturists require bigger fingerlings to reach market sizes in one year compared with pond producers. Thus, fingerlings costs are higher for running water cul-

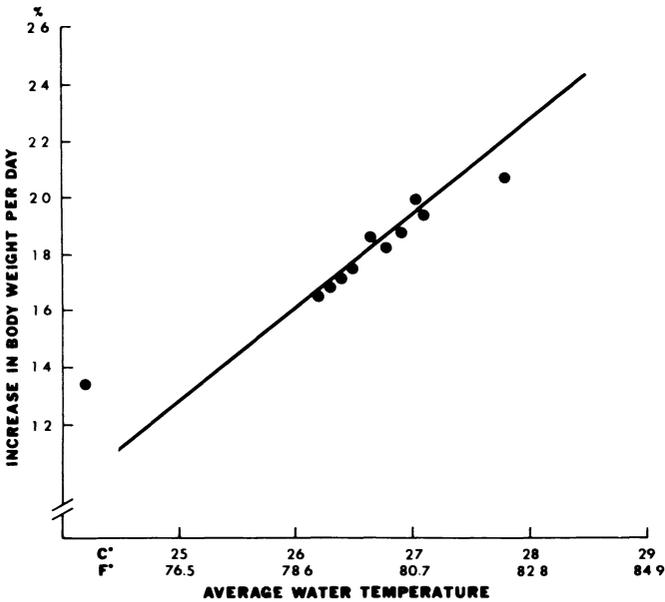


Fig. 23.14. Relationship between average water temperature and rate of growth of carp, Lake Suwa, Nagano Prefecture.

ture. This is offset, however, by their ability to partially or totally harvest a raceway when prices are high, and their average market prices are higher than for pond producers. At harvest time, the pond producers concentrate their pond fish in a smaller feeding enclosure for partial harvesting. However, trapping up to 90% of the fish may require several weeks. To harvest the remaining 10% of the fish, the pond must be drained. Proper sizes for these ponds are between 3 and 5 ha (7.4 and 12.3 acres) and 2 m (6 ft) deep. When ponds are over 2 m deep, the water is dark and proper plankton growth is not possible. The pond culturists have the advantage in labor efficiency. Output of 60 MT (66 ST) per person is possible, while with raceways, output is 50 MT (55 ST) or less.

Production Costs. In 1978, for all of Japan, a total of 48,255 MT (53,177 ST) of feed were fed (Table 23.6). The major food was pellets, followed by dry silkworm pupae, fresh silkworm pupae, fresh and frozen fish, and "other," mainly boiled wheat.

A typical fish diet by months is as follows:

	Wheat %	Pupae %	Pellets %
April	70	10	20
May	50	20	30
June	20	30	50
July	—	70	30
August	—	80	20
September	—	60	40
October	—	50	50
November	20	10	70

Proportions of feed fed vary when prices of wheat, pupae, and pellets change. Pupae cannot be fed alone since they have a high phosphorus content and affect bone deposits. However, the farmers all feed some pupae since they result in a pink flesh which the Japanese consider indicative of high-quality carp. The pupae-feeding of fish results in a dressed-out weight of 60–65%, whereas pellet-fed fish dress out only 50–55%. The pupae contain 58–60% protein, 28% fat, 4% fiber, and 3% ash; compared with 42% protein, 4% fat, 2% fiber, and 12% ash for carp pellet feed.

Production costs of common carp are relatively inexpensive compared with other species cultured. For 1978, total costs were computed at \$1.62 per kg (\$0.738 per lb) for a pen culturing unit requiring two persons, producing 84 MT (92 ST) from 80 pens covering 2000 m² (0.49 acres) (Table 23.13). Feed accounted for over one-half of total expenses. Other major cost items were fingerlings and labor. Returns to management, or net profit, were \$0.379 per kg (\$0.171 per lb). The return above production costs was 23.4%. This example is based on high-quality management in production practices, buying feed, and selling.

TABLE 23.13. PRODUCTION COST OF CARP PER KG (OR PER LB), SELLING PRICE, AND RETURNS OR PROFIT, PEN CULTURE, JAPAN 1978¹

Item	Cost			
	(Cents)	per kg (Dollars)	(Cents)	per lb (Dollars)
Fixed costs				
land and water rent	1.0		0.5	
repairs and depreciation	15.2		6.9	
interest	11.4		5.2	
Total fixed costs	27.6		12.6	
Variable costs				
feed	82.8		37.6	
fingerlings	33.6		15.3	
utilities and fuel	1.0		0.5	
labor	17.1		7.8	
Total variable costs	134.5		61.2	
Total production cost		\$1.621		\$0.738
Selling price		\$2.00		\$0.909
Returns to management or profit		\$0.379		\$0.171
Percentage return (%)		23.4		23.4

Source: Anon. (1979A).

¹Based on production volume of 83.78 MT (92.3 ST) from 80 pens each 5m × 5m × 3 m for total of 2000 m² and using 5413 hr of labor.

Marketing. The consumption of carp in Japan is highly diffused. Of the total supply of 36,538 MT (40,265 ST with 80% cultured) in 1978, the Tokyo area, which accounts for a disproportional share of most fish, accounted for only about 10%. In some of the inland prefectures, consumption of carp is often five times more per person than in Tokyo. This is due to the inability of the inland prefectures to obtain fresh marine fish; therefore, they turn to fresh carp; carp prices are also lower than in the big cities.

In general, carp producers sell to outlets in the local markets near the place of production. This has been the traditional method of distribution, based largely on poor transportation. As transportation improved, the local markets broadened. The major markets are tourist areas in the countryside and local people in carp production areas. Although some carp is sold at large, centralized, wholesale fish markets, the major markets are not at these centers. In general, little carp is sold in very large cities. Hence, city people have not acquired a taste for carp, nor are they accustomed to using it in the home.

The custom of eating carp in the home is not widespread among the younger Japanese. Hence, available data suggest that demand will increase very slowly, principally in response to increases in population and rising incomes of those who have acquired a taste for carp. As in the USA, the modern Japanese homemaker does not like to prepare carp because of the bony nature of the fish.

Carp are not on sale at most retail markets in large cities. Hence, the possibilities of rapid expansion of this segment of the industry depend on a

more efficient distribution system and stimulating consumer acceptance among the younger Japanese. Carp production is widespread throughout Japan and, as a result, the availability of carp would be good in most small cities, towns, and villages.

An example of the decentralized market for carp is shown by the volume handled by the Tokyo Central Wholesale Fish Market (Table 23.14). In 1978, of the total supply of 36,538 MT (40,265 ST), only 0.4% were sold on this market. This is in direct contrast to shrimp, yellowtail, eel, and other species, wherein the Tokyo market is the most important single market.

The consumption of carp in large cities such as Tokyo is lower per person than in rural areas largely because of price. In 1976, for example, consumer price in Gunma Prefecture was \$2.00 per kg (\$0.91 per lb), whereas it was over \$3.00 per kg (\$1.37 per lb) in Tokyo only 65 km (40 mi) away. In the production areas, producers sell directly to restaurants, fee fish-out ponds, and fish dealers. The fish dealer then sells directly to the ultimate consumer. The producer receives about 62% of the consumer price.

By contrast, when carp go to large centralized markets, the producer sells to a local wholesaler or broker who increases the producer price of \$1.00 per kg (\$0.45 per lb) to \$1.17 per kg (\$0.58 per lb). The local wholesaler transports and sells to a wholesaler in the city. This market increases the price from \$1.17 per kg (\$0.58 per lb) to \$1.50 (\$0.68 per lb) for sales to restaurants, other fish dealers, and fee fish-out ponds. For sales to supermarkets and department stores where additional handling is required, the price goes to \$1.83 per kg (\$0.83 per lb). These other fish dealers, fee fishing operators, supermarkets, and department stores sell for about \$3.33 per kg (\$1.51 per lb) to the final consumer. Hence, the producer receives only about 30% of the consumer dollar instead of 62%. The city dweller pays about 70–80% more for the same fish than does his country cousin. Even with these markups, or margins, the city wholesaler cannot make a profit on carp, and always handles eel or other fish as the main source of income.

While carp prices fluctuate seasonally at the Tokyo market—with high prices in June–September and low prices in December–February—the change is not considerable. In the production areas there is the same seasonality, but prices will vary by 25 to 30% from the low months to the high months.

Wholesalers often buy directly at the pond to eliminate some of the middleman's margins. Some marketing cooperatives have been formed to increase marketing efficiency and lower marketing margins, but they have found that, in general, they have the same distribution channels and costs faced by private businessmen.

Two possible answers suggest themselves for the low December–February prices and the high June–September prices: (1) tourists flock to rural carp-producing areas in the summer and eat at traditional restaurants located there; and (2) the volume of carp harvested in the fall increases, which may affect prices negatively.

Since there is a widespread, decentralized market for carp in small cities,

TABLE 23.14. VOLUME OF COMMON CARP (*CYPRINUS CARPIO*) SOLD AND PRICES BY MONTHS, TOKYO CENTRAL WHOLESALE FISH MARKET, JAPAN 1976-1978

Months	Year								
	1976			1977			1978		
	kg	Price in Dollars per kg	per lb	kg	Price in Dollars per kg	per lb	kg	Price in Dollars per kg	per lb
January	22,266	1.98	0.90	16,221	1.90	0.86	13,585	2.52	1.15
February	24,486	1.89	0.86	11,831	1.65	0.75	15,479	2.43	1.10
March	11,915	1.68	0.76	10,464	1.60	0.73	11,027	2.06	0.94
April	8,439	1.76	0.80	10,179	1.69	0.77	8,239	2.18	0.99
May	8,947	1.79	0.81	11,344	1.70	0.85	10,101	2.12	0.96
June	9,201	1.68	0.76	9,998	1.88	0.88	10,020	2.08	0.95
July	9,921	1.66	0.75	11,127	1.94	0.88	11,613	2.07	0.94
August	9,555	1.66	0.75	10,851	1.91	0.87	11,585	2.08	0.95
September	8,069	1.66	0.75	9,047	1.97	0.90	7,781	2.28	1.04
October	9,005	2.04	0.93	7,762	1.96	0.89	6,814	2.10	0.95
November	11,332	2.02	0.92	9,398	2.14	0.97	11,052	2.28	1.04
December	13,444	1.85	0.84	12,887	2.22	1.00	16,456	2.14	0.97
Totals and averages	146,580	1.82	0.83	130,809	1.89	0.86	133,752	2.20	1.00

Source: Anon. (1972-1978).

towns, and villages, carp are not transported long distances for sale. Nearly all of the 46 prefectures produce carp, but fish sold on the Tokyo market come from only eight prefectures. Two of these, Gunma and Ibaragi, account for 90% of sales.

Crucian Carp (*Carassius carassius*)

In 1978, cultured production of crucian carp was 1292 MT (1424 ST). Of this volume, over one-half was cultured in Osaka and Kagawa prefecture. The remaining one-half was produced in about 20 other prefectures.

Crucian carp normally eat plankton, soft natural foods and insects. In Japan three production methods are used. In the most extensive method, the fry are stocked in unfertilized farm ponds and subsist only on plankton and natural foods. In the second method, the pond is fertilized to encourage the growth of natural foods. In the third method, some feeding is practiced. This may be induced by household waste waters being channeled to the pond to supply nutrients and induce plankton growth. The most important supplementary feed is dried silkworm pupae, which is high in protein content. The usual practice is to raise a few common carp and perhaps other fish, such as chubs (shiners), with the crucian carp.

It is common practice to stock rearing ponds with 16–20 g fish ($\frac{1}{2}$ – $\frac{3}{4}$ oz). After about 2 years of culturing, the fish are about 20 cm long (8 in.). Between 2 and 3 years later, the fish reach 30 cm (12 in.) and weigh 500–600 g (1–1 $\frac{1}{4}$ lb). Natural fish take 4 to 5 years to reach the same size.



Fig. 23.15. Recreational fee fishing pond.

The 1000 g (2 lb) cultured fish measure 35 cm or more in length (14 in.) and require 3 to 4 years. Natural fish require 5 to 6 years to reach this size.

The chief markets are for game or fee fish-out ponds, or for restaurants in the city of Osaka. Market size depends on whether they are used in soups, portions, or as filets. The average wholesale fish price at the Osaka Central Fish Market for the first half of 1976 was only \$0.76 per kg (\$0.35 per lb). Price of common carp during the same period of time was \$1.42 per kg (\$0.65 per lb). It is readily apparent that crucian carp have a specialized, low value market and culturing is only conducted in order to get dual use of farm pond waters.

In 1974, there were 299 managements of crucian carp with fish stocked in 603 separate ponds. About 1968 ha of water were used (4861 acres). Production was only 558.9 kg per ha (498 lb per acre).

Ayu or Sweetfish (*Plecoglossus altivelis*)

Ayu are native to Japan. A Dutch scientist in 1846 introduced ayu to the world's learned society. However, they did not become commercially important until about 1908. Ayu are a species of fish found in Japan, Southern Korea, Okinawa, and the mainland Chinese coast. Eggs are laid in September, October, and November, usually in a water depth of 30–45 cm (12–18 in.). Eggs number 10,000 to 100,000 per female. Suitable water temperature for hatching is 14° to 23°C (58° to 74°F), and the number of days for hatching varies from 10 to 24; the warmer the water, the more rapid the hatching. Ayu are cultured most frequently by running water techniques similar to those used for trout. The fry are stocked when they are 5–6 cm (2–2½ in.) long. The fish are sold for consumption at about 75–80 g (3 oz) per fish, or 17–22 cm (7–9 in.).

In 1978, 7185 MT (7918 ST) were cultured. Wakayama and Shiga Prefectures produced about 60% of the total. About 30 other prefectures produced the remainder. Two-thirds of all Japanese fry cultured are captured in Lake Biwa in Shiga Prefecture. Nearly all fry cultured are wild, since it is difficult to reproduce ayu under artificial conditions.

There is a definite relationship between water temperature and growth of ayu (Fig. 23.16). The fish can be produced for sale in about 90 days from the time the fry are stocked. The ideal method of feeding is in running water raceways.

In 1978, a total of 12,204 MT (13,449 ST) of feed were fed to produce the 7185 MT (7918 ST) of cultured ayu (Table 23.6). The feed conversion was 1.5 units of feed per unit of gain. Nearly all the feed was artificially prepared pellets similar to trout feeds. A typical management will consist of 8–12 concrete enclosures with each enclosure containing about 200 m² (2152 ft²). Fresh, aerated underground water from wells 20 to 40 m (60 to 125 ft) deep is added, and the water is recirculated once. Water is exchanged every 2 hr. The temperature range is maintained between 18° and 22°C (64° and 72°F). In each tank or enclosure is stocked 50,000 fry. The fish are fed a 45 to 48%

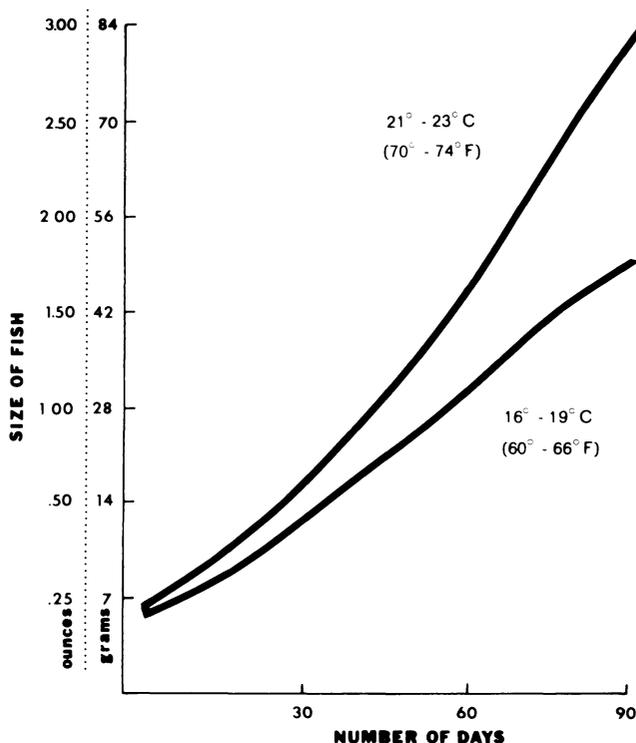


Fig. 23.16. Relationship between growth rates of ayu fish and water temperatures. From Chiba (1968).

protein diet to which cod oil has been added at a 5% weight level. Mortality in 90 days may be only 1%. From each tank or enclosure, 4 MT (4.4 ST) of marketable fish are harvested. Production per m² of water surface area is 20 kg (4.1 lb per ft²). The tanks are about 1 m (39 in.) deep.

Production Costs. The cost of producing ayu is high. Several reasons are cited for this high cost. These are: (1) high cost of fry, (2) high costs of pumping water, (3) low productivity per person employed, (4) high costs of preventing and treating diseases due to intensive stocking, and (5) high insurance.

An example of production costs is presented in Table 23.15. The cost of fry was \$0.064 each. Since the ayu are sold at only about 75 g (3 oz) this makes the fry price large in relation to market weights. The proportion that fry prices constituted of total production cost was 22.3%. This is nearly double the costs of some other species. The example shows a sale price of only \$5.60 per kg (\$2.54 per lb), whereas the Tokyo wholesale price was \$6.92 for the same period. However, most of the ayu on the Tokyo Central Wholesale Fish market are fresh, iced fish, while in Tokushima Prefecture over 80% are



Fig. 23.17. Ayu pond and feeding stations with floodlights for nighttime feeding.

sold frozen. The frozen fish command a lower price than either live or fresh iced fish.

Marketing. Consumption of ayu is highly seasonal. Peak prices are to be found in the April to September period. This period coincides with the tourist season, when Japanese flock to the recreation areas outside the large cities and eat at restaurants. Since most of the ayu are consumed in restaurants, this accounts for the high prices. Most wild ayu are caught by sports fishermen and not sold. Most cultured ayu are sold live or fresh iced to these restaurants by producers or fish wholesalers.

In 1978, 20,548 MT (22,644 ST) of ayu were consumed. Of this volume, 5% were sold on the Tokyo Central Wholesale Fish Market, which was the largest single market for ayu. The highest volumes reached the market during the April–September period when prices were highest (Table 23.16). The consistent high prices for ayu are shown in Table 23.17. In May 1978, the wholesale price was \$9.86 per kg (\$4.48 per lb). These fish came from more than 30 of Japan's 46 prefectures. However, the five prefectures of Wakayama, Tokushima, Shizuoka, Nagano, and Shiga accounted for 85% of the total.

TABLE 23.15. PRODUCTION COSTS FOR
A TYPICAL AYU CULTURING FARM
PRODUCING 45 MT (49.6 ST) OF FISH,
TOKUSHIMA PREFECTURE, SHIKOKU ISLAND,
JAPAN, 1978

Capital investment items	
11 enclosures or tanks each having 200 m ² of surface	
1 building containing 90 m ²	
5 pumps	
22 aerator pumps	
5 wells, 30 m deep	
22 water wheel aerators	
22 automatic feeders	
1 electrical transformer, 150 kw	
44 floodlights	
Fixed costs	
depreciation	\$ 9,600
interest	9,600
repairs	4,000
taxes and insurance	12,000
Variable costs	
fry	38,400
feed	50,400
power	20,000
wages (3 workers)	20,000
medicine	8,000
Totals	\$172,000
Production cost per kg	3.82
Production cost per lb	1.74
Selling price per kg	5.60
Selling price per lb	2.54
Total profit	\$ 80,000.00

Source: Anon. (1978).
250 yen = \$1 U.S.

Tilapia (Tilapia nilotica)

Tilapia is a new species cultured in Japan, starting about 1974. Many earlier attempts had been made to culture *tilapia*, but the ability of the fish to reproduce every few weeks resulted in mostly small fish in ponds, excessive feed cost, and no market for the small fish. The reproduction cycle and problem was brought under control by using running water culture similar to trout raceways, or by creating a current by using paddle wheels. With moving currents, the *tilapia* did not spawn.

The growth of the *tilapia* industry has been phenomenal. From 1974, when production was nearly zero, production had reached an estimated 6000 to 10,000 MT (6600 to 11,000 ST) in 1980. The industry is so new that the Japanese government has not yet started to keep separate production and marketing data. The phenomenal growth has been due to high

TABLE 23.16. VOLUME OF AYU (SWEETFISH) SOLD AND PRICES BY MONTHS, TOKYO CENTRAL WHOLESALE FISH MARKET, JAPAN, 1976-1978

Months	1976			1977			1978		
	Total kg	Price in Dollars per kg	per lb	Total kg	Price in Dollars pr kg	per lb	Total kg	Price in Dollars per kg	per lb
January	5,090	4.08	1.85	9,872	3.28	1.49	1,940	5.10	2.32
February	2,031	4.19	1.90	4,694	3.31	1.50	9,816	4.98	2.26
March	7,791	3.86	1.75	71,073	3.32	1.51	16,926	5.51	2.50
April	33,197	6.13	2.79	124,445	4.64	2.11	47,734	7.32	3.33
May	109,649	5.94	2.70	112,662	6.35	2.89	54,819	9.86	4.48
June	214,359	5.31	2.41	137,613	7.05	3.20	132,122	8.23	3.74
July	262,933	4.75	2.16	189,773	6.41	2.91	202,754	6.90	3.14
August	241,389	4.29	1.95	185,327	6.32	2.87	208,956	7.06	3.21
September	150,526	3.83	1.74	118,773	5.20	2.36	118,980	5.61	2.55
October	61,978	3.08	1.40	54,066	4.67	2.12	36,905	5.88	2.67
November	23,212	3.46	1.57	17,779	4.94	2.25	17,538	5.74	2.61
December	9,311	3.38	1.54	4,864	5.04	2.29	102,856	5.84	2.65
Totals and averages	1,121,466	4.65	2.11	1,030,941	5.74	2.61	951,386	6.92	3.15

Source: Anon. (1972-1978).

prices which result from the flesh of the tilapia having a close similarity to cultured red sea bream, which is in short supply and great demand. Farm prices for tilapia in 1980 varied between \$3.20 and \$4 per kg (\$1.45 and \$1.82 per lb) with a reported return to management above production costs of 35–40%. The wholesalers buy fish-in-the-round from farmers, fillet, and process. Consumer prices as high as \$24 per kg (\$10.90 per lb) are reported.

Tilapia are raised mainly on the southern island of Kyushu where the waters are warmer. The spawners are kept inside in heated waters in the winter. Ponds are stocked in May and harvested in early November. For every 200 g of fish stocked, 1 kg is harvested. Market preferences are for 0.8 to 1.2 kg live weight fish (1.8 to 2.6 lb).

Pelletized fish food traditionally fed to carp is fed. For fingerlings the pellets contain 40% protein. Thirty percent protein feeds are fed to larger fish. Fish pellets contain 10% fish meal, 34% wheat flour, 6% yeast, 10% soybean meal, 15% middlings, 10% rice middlings, 5% alfalfa meal, and a 2% vitamin/mineral mix.

TABLE 23.17. VOLUME OF AYU SALES ON THE TOKYO CENTRAL WHOLESALE FISH MARKET, JAPAN, 1974–1978

Year	Volume of Sales (Metric Tons)	Sales Price per kg (Dollars)	Sales Price per lb (Dollars)
1974	720.3	4.28	1.95
1975	1050.6	4.66	2.12
1976	1121.5	4.65	2.11
1977	1030.9	5.74	2.61
1978	951.4	6.92	3.15

Source: Anon. (1972–1978).

Other Salmonidae

In Japan, in this group are: (1) *Salvelinus pluvius*, commonly called iwana or rockling, (2) *Oncorhynchus masu* (white flesh), commonly called yamame or trout salmon, and (3) *Oncorhynchus rhodurus*, commonly called amago or amenou. These three are all landlocked species.

These three species are cultured only in cold waters in mountainous areas. They have become popular only in recent years, and rapid growth is being experienced in production. They are produced in many prefectures. Unlike rainbow trout, which have never really been accepted, and for which prices are relatively low, these three salmonidae have captured the Japanese imagination, are readily accepted, and command high prices. Sales are to fee fish-out operators and to restaurants and supermarkets located in recreation areas. In 1978, total production was estimated at 2000 MT (2204 ST), while in 1977 the wild catch was 1202 MT (1325 ST).

In 1978 in Gifu Prefecture, producer prices for rainbow trout were \$2.40 per kg (1.09 per lb). Producer prices for these "other salmonidae" averaged \$4.80 per kg (\$2.18 per lb). Returns on profits above production costs were

22.3% for rainbow trout, and a phenomenal 60% for these "other salmonidae." A breakdown of production costs for Gifu Prefecture is shown in Table 23.18.

"Other" Freshwater Cultured Fish

The two cultured species under this classification are: (1) loach (*Misgurnus anguillicaudatus*) and (2) mullet (*Mugil cephalus*).

Loach are cultured in small quantities in Niigata, Aomori, and other prefectures on northeastern Honshu Island. These fish are raised in farm ponds and are similar to crucian carp in their feeding habits. Their food consists of worms, insects, and plankton.

In 1941, production of loach was as high as 1600 MT (1763 ST), but declined to only 450 MT by 1962. Since then there has been a resurgence of production, and volume in 1976 was estimated at 1000 MT (1102 ST). Production declined because of the widespread use of agricultural chemicals, but with bans and strict controls by the government, production is increasing.

Loach are small fish, seldom attaining more than 40 g (1½ oz) in size. They are sold in three sizes. These are: (1) small, between 10 and 15 g (½ oz), (2) medium, 15–30 g (½–1 oz), and (3) large, over 30 g (over 1 oz). In 1976 the small fish were selling for \$0.83 per kg (\$0.38 per lb) and the large

TABLE 23.18. COST AND RETURN DATA PER KG AND PER LB FOR *SALVELINUS PLUVIUS*, *ONCORHYNCHUS MASU*, AND *ONCORHYNCHUS RHODURUS* (OTHER SALMONIDAE) GIFU PREFECTURE, 1978
Based on 30 MT of production.

Item	Costs		Percentage
	per kg (Dollars)	per lb (Dollars)	
Fry	0.40	0.18	13.3
Feed	1.24	0.56	41.4
Wages	0.67	0.30	22.3
Oil and gasoline, power	0.08	0.04	2.7
Repairs	0.07	0.03	2.3
Interest	0.23	0.11	—
Depreciation	0.24	0.11	8.0
Other	0.07	0.03	2.3
Total production cost	3.00	1.36	100.0
Selling price	4.80	2.18	—
Profit	1.80	0.82	60.0

Source: Tachikawa (1979).

Situation: Labor—2 persons @ \$10,000 each.

Pond—2000 m² (15 kg/m²).

Production—30 MT (60 g each—500,000 fish).

Fry—2 million eggs @ \$0.006 each.

Survival—25% from eyed-eggs.

Feed—60 MT @ \$0.62 per kg.

Feed conversion—2:1.

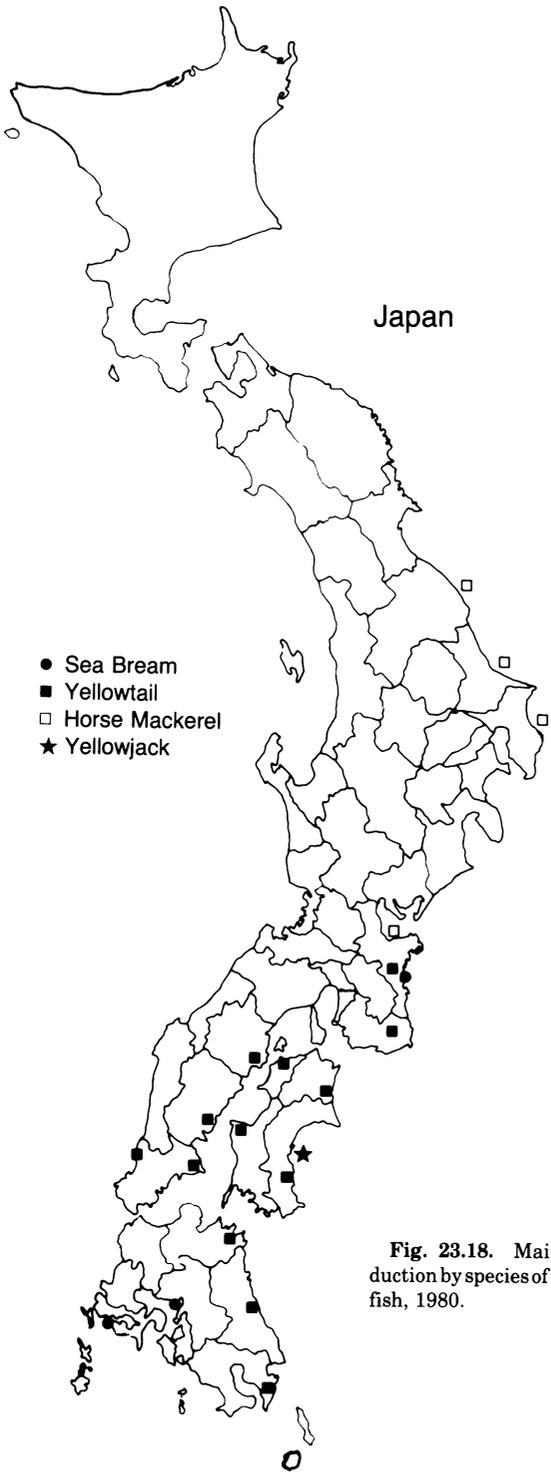


Fig. 23.18. Main areas of production by species of marine cultured fish, 1980.

fish for \$3.33 (\$1.51 per lb). They are sold alive to restaurants in large cities. The different sizes are used in different preparations and are cooked differently. The small ones are used in soup, the medium ones are grilled, and the large ones are grilled and seasoned.

Grey or jumping mullet is also cultured. This fish lives in fresh, brackish, and salt water, but Japanese statistics include the cultured ones under the freshwater classification.

The fry are caught in the sea and raised in the net partition ponds described later under "Yellowtail." The cultured fish are stocked in net enclosures in the mouths of rivers or creeks. No supplementary food is fed. Natural foods consist of marine worms, insects, and plankton. The mullet farmer buys captured fry about 3 cm (1 in.) long in May. In two to three years they are 30–40 cm long (11–14 in.). They are marketed fresh on ice. This is a very inexpensive fish compared to other cultured species, but because most of these fish are marketed through game or fee fish-out ponds, the authors were unable to obtain reliable price information. In 1977, 80 MT (88 ST) were cultured in Aichi and Mie Prefectures. The wild catch was 1043 MT (1149 ST) from rivers, 647 MT (713 ST) from lakes, and 10,445 MT (11,510 ST) from the sea.

MARINE CULTURED FISH AND SHRIMP

At present there are 11 species of marine fish and 1 species of shrimp cultured in Japan. These are: (1) yellowtail (*Seriola quinqueradiata*), (2) red sea bream (*Chrysophrys*), (3) horse mackerel (*Trachurus symmetricus*), (4) yellowjack (*Caranx delicatissimus*), (5) filefish (*Monacanthus cirrhifer*), (6) puffer (*Fugu rubripes*), (7) porgy or black sea bream (*Mylio macrocephalus*), (8) flounder or flatfish (*Paraichthys olivaceus*), (9) rabbit fish (*Siganus fuscescens*), (10) chum salmon (*Oncorhynchus keta*), and (11) cherry salmon (*Oncorhynchus masu*) (red or pink flesh). Shrimp or prawns (*Penaeus japonicus*) are not finfish, but are more important from a volume and income viewpoint than most of the cultured marine fish.

Culture of these fish and shrimp increased from 10,475 MT (11,543 ST) in 1964 to 136,188 MT (150,079 ST) in 1978 (Table 23.19). During these 14 years the annual rate of increase was 92%. This was an even more rapid expansion than for freshwater cultured species. Nearly all of this expansion was due to yellowtail and sea bream, although nearly every species increased in importance.

While volume of production increased 1197%, the number of marine fish farmers increased 609%, from 991 in 1964 to 7036 in 1978 (Table 23.20). This indicates that volume of production per farm also increased. This increase was from 10.6 MT (11.7 ST) to 19.4 MT (21.3 ST), or 83%.

Yellowtail (*Seriola quinqueradiata*)

Yellowtail is the most popular and economically significant cultured fish in Japan. Culturing is mainly along the western coast of Japan south of

TABLE 23.19. VOLUME OF PRODUCTION, BY SPECIES OF CULTURED MARINE FISH¹ AND SHRIMP, JAPAN, 1964-1978 (METRIC TONS)

Year	Species										Totals
	Yellowtail (<i>Seriola quinqueradiata</i>)	Horse Mackerel (<i>Trachurus symmetricus</i>)	Sea Bream (<i>Chrysophrys major</i>)	Yellowjack (<i>Caranx delicatissimus</i>)	Puffer (<i>Fugu rubripes</i>)	Filefish (<i>Monacanthus cirrhifer</i>)	Other Cultured Fish	Shrimp (<i>Penaeus japonicus</i>)			
1964	10,321	—	—	—	—	—	— ²	154	10,475		
1965	14,779	—	—	—	—	—	925	N.A.	15,704		
1966	16,875	—	—	—	— ²	—	815	N.A.	17,690		
1967	21,169	—	—	—	46	—	313	305	21,833		
1968	31,777	—	—	—	63	—	354	371	32,565		
1969	32,722	— ¹	—	—	49	— ¹	375	296	33,442		
1970	43,354	7	454	—	23	62	11	301	44,212		
1971	61,855	57	930	—	15	18	38	306	63,219		
1972	77,059	127	1,380	—	14	39	104	454	79,177		
1973	80,439	378	2,741	— ³	16	40	150	659	84,423		
1974	92,946	619	3,298	48	8	25	140	912	97,996		
1975	92,407	920	4,462	22	9	8	170	936	98,934		
1976	101,786	704	6,572	58	11	2	125	1042	110,300		
1977	115,098	743	8,245	161	15	10	238	1124	125,634		
1978	121,953	809	11,315	177	46	3	701	1184	136,188		

Source: Anon. (1980A).

¹Under "Other."

²Under Yellowtail.

³Under Horse Mackerel.

⁴N.A.—Not Available.

TABLE 23.20. NUMBER OF MANAGERMENTS CULTURING MARINE FISH AND SHRIMP, JAPAN, 1964-1978

Year	Species										Totals
	Yellowtail (<i>Seriola</i> <i>quinqueradiata</i>)	Horse Mackerel (<i>Trachurus</i> <i>symmetricus</i>)	Sea Bream (<i>Chrysophrys</i> <i>major</i>)	Yellowjack (<i>Caranx</i> <i>delicatissimus</i>)	Puffer (<i>Fugu</i> <i>rubripes</i>)	Filefish (<i>Monacanthus</i> <i>cirrhaifer</i>)	Other Cultured Fish	Shrimp (<i>Penaeus</i> <i>japonicus</i>)			
1964	928	—	—	—	— ²	—	— ²	63	991		
1965	786	—	—	—	40	—	126	77	1029		
1966	1038	—	—	—	33	—	36	71	1178		
1967	1285	—	—	—	23	—	66	76	1450		
1968	1556	—	—	—	14	—	103	82	1755		
1969	1904	— ¹	—	—	11	— ¹	167	95	2166		
1970	2278	7	204	—	9	17	11	77	2603		
1971	2675	27	278	—	6	14	19	75	3094		
1972	3060	119	529	—	6	10	23	80	3827		
1973	3246	117	745	— ³	7	8	57	86	4266		
1974	3044	125	987	23	6	8	83	96	4372		
1975	3292	121	1192	24	6	8	85	98	4826		
1976	3809	108	1431	26	8	4	144	105	5635		
1977	3991	147	1781	19	10	3	310	104	6366		
1978	4162	223	2069	25	24	2	412	119	7036		

Source: Anon. (1980B).

¹Under "Other."

²Under Yellowtail.

³Under Horse Mackerel.

Tokyo, on the southeastern coast of Honshu Island, on Shikuko Island, and on the eastern coast of Kyushu.

The history of yellowtail culture dates back to 1928 when experiments were conducted at a site on Shikuko Island. However, it was not until the 1950s when the enterprise started to expand and production became commercial. When fish farming was promoted in the early 1960s by the government, yellowtail farming spread rapidly. During these years, total production was about 3000 MT (3300 ST) per year.

In 1964, the earliest year for which the authors obtained detailed data, there were about 928 separate managements for yellowtail production (Table 23.20). They produced about 10,321 MT (11,353 ST). Production has increased rapidly from then until the present. In 1978, there were 4162 managements, producing 121,953 MT (134,492 ST), Table 23.19. The number of managements grew at an annual rate of 24% while production increased at an annual rate of 77%. While this rapid increase in numbers of managements and production occurred, average production per management increased from only 11.1 MT (12.2 ST) in 1964 to 29.3 MT (32.3 ST) in 1978. Hence average production per management increased 138% or 9.9% per year. Since 12,029 people were employed in producing yellowtail, the average production per person was only 10.1 MT (11.1 ST). This relatively low level of output per person indicates the need for close supervision during production and the relatively high value of the species per unit of sale.

In 1966 there were 5867 different farms or places of production, operated by 1938 managements, or 5.6 places of production per management. In 1978, there were 23,733 different farms or places of production under 3991 different managements or nearly 5.9 places of production per management (Table 23.21). In 1966 there were 3,083,000 m² (762 acres) of surface area devoted to yellowtail culture. Production was about 5.5 kg per m² (1.1 lb per ft²). In 1978, there were 5,537,000 m² (1368 acres) of surface area devoted to yellowtail culture. Production was 22.0 kg per m² (4.5 lb per ft²) (Table 23.21). Hence, production increased by 4 times per surface area. This was possible because of changes in production techniques as explained subsequently.

Production of yellowtail is accomplished in a variety of ways. The oldest technique is in a land enclosure (dike) with sea gates which permit the exchange of water as the tides rise and fall. Hence, there is only partial exchange of water about twice a day. Stocking levels may be only 1% that of net culture. In 1978, there were only nine of these dikes.

The second technique is called net partition. With this technique at least one side of the enclosure is separated from the sea by nets, while the other sides are natural or manmade walls of concrete, stone, or earth. This technique permits better exchange of fresh salt water for culturing. Stocking may be as high as 10% that of the net technique. In 1978, there were 93 of these net partition areas.

The third technique is net culture. Net culture may be divided into

numerous subtypes. These are nets, enclosures suspended below floating rafts, and/or buoys. Rafts may be constructed of wooden barrels, bamboo, or steel. With these systems, the net enclosure is above the surface of the water. The latest method allows the net enclosures to be as much as 30 m (100 ft) under the surface buoys. They are used where there are strong surface currents caused by winds or damaging storms. With net culture, water exchange may be every few minutes and stocking may be 100 times that of the dike method and 10 times that of the net partition method. In 1978 there were 23,635 different net enclosures used. These accounted for 99% of the yellowtail farms, but only 72% of the culturing area.

In 1978, a total of 972,493 MT (1,071,687 ST) of food were fed to produce the 121,953 (134,392 ST) of fish. Hence, the feed conversion was eight units of food to one unit of output. Ninety-four percent of the food fed was sardines, mackerel, sand eels, and other trash fish, and 6% was pelletized feed.

The major catching areas in order of importance are Mie, Kochi, Tokushima, and Kagoshima Prefectures. All other areas accounted for less than ¼% of the stocking catch. Major areas for culturing do not correspond to catching areas since the fry are moved to places with the least pollution, the greatest culturing interest, and to areas of low cost fish food. In 1978, Mie, Kochi, and Ehime Prefectures on the island of Shikuko accounted for over one-half of total cultured production.

In 1978, cultured production of yellowtail was 121,953 MT (134,392 ST) while the wild food catch in 1977 was 26,915 MT (29,660 ST). Hence, over 80% of the total yellowtail consumed is cultured.

Yellowtail grow to 5 to 8 kg (11 to 18 lb) under natural conditions. The market size of cultured fish is 1.0 to 1.5 kg (2.2 to 3.3 lb) in one year, and 2.0 to 3.0 kg (4.4 to 6.6 lb) in two years.

The wild fish spawn from January to August when marine water temperatures are between 16° and 29°C (61° and 84°F). The wild fry are caught in April and May when they are only about 15 mm long (½ in.) and weigh about 1 g (0.035 oz). During May and June, the fry are acclimatized and started on feed in floating net enclosures. They double and triple in size during this adjustment period. In June, they are graded by size and stocked in floating or submerged net enclosures. Feeding rates vary from 50% of body weight for the fry to 7% for those weighing 1 kg and over. By December, some culturists harvest their fish at 1.0 to 1.5 kg while others continue feeding into the second year.

Although spawning and fry rearing have been done on an experimental basis, the cost is still prohibitive. Thus, all fry are from natural stocks. A special license is required to collect and sell the fry to avoid overfishing. The fry usually follow floating seaweeds in the Kuroshio current, which flows from southern Japan to the north. The fry are captured in nets and kept in small floating net pens made of fine mesh synthetic fibers until they are acclimatized to feeding. These pens may vary up to 50 m² (540 ft²) and are from 1 to 3 m deep (3 to 9 ft).

The most important operation initially is to separate the fry by sizes into

TABLE 23.21. NUMBER AND TYPES OF MANagements, NUMBER AND TYPES OF PRODUCTION PLACES, SURFACE AREA OF WATER USED, NUMBER OF EMPLOYEES, FRY STOCKED, AND TYPES OF FEED FED; BY SPECIES OF CULTURED MARINE FISH AND SHRIMP, JAPAN, 1977

Species	Types of Managements				No. of Individual Places		
	No. of Managements	On Land	Extending from Shore	Marine Nets	On Land	Extending from shore	Marine Nets
Yellowtail	3991	7	85	3971	7	93	23,635
Horse mackerel	147			147			339
Yellowjack	19	1		18	13		44
Red sea bream	1781	3	3	1778	4	3	7,869
Puffer	10		4	6	1	4	13
Filefish	3			3			9
Other fish	310	4	8	297	40	10	579
Total fish	6261	15	100	6220	65	110	32,488
Prawns	104	93		11 ¹	206	1	97 ²

Species	Surface Area by Types of Mgmts (1000 m ²)				Metric Tons of Food Fed				
	Total Surface Area	On Land	Extending	Marine Nets	No. of Employees	No. of Fry Stocked	Total	Fish and Other	Pellets
Yellowtail	5537	423	1105	4009	12,029	76,007	972,493	966,218	6275
Horse mackerel	47			47	325	6,823	6,404		
Yellowjack	15	1		14	87	132	2,447		
Red sea bream	1444	89	58	1297	4,310	21,577	105,567		
Puffer	23		21	2	43	55	252		
Filefish	4			4	11	64	85		
Other fish	204	116	2	74	832	5,137	5,371		
Total fish	7274	629	1186	5447	17,637	109,795	1,092,619	966,218	6275
Prawns	3750	3663	8	79 ³	504	118,902	122,284	10,892	1392

Source: Anon. (1979A).

¹Includes 10 listed as "other."

²Includes some listed as "other."

³Includes some listed as "other."

at least small, medium, and large. Without proper sizing, cannibalism takes place and mortalities of 50% may occur in a few days.

The fry are fed minced meat of sand eels, horse mackerel, shrimp, and so on. During the grow-out period, there must be sufficient water exchange to keep the supply of dissolved oxygen over 3 ppm and to wash out feces and uneaten food. Optimum temperatures for growth are between 24° and 29°C (75° and 84°F). The higher and lower critical temperatures are 31°C (88°F) and 9°C (48°F), respectively. Salinity should not be below 16 parts per thousand.

Floating net enclosure must be in locations where violent wave and wind action do not occur. The submersible net enclosures are more suitable to open sea areas. The basic structures of these types of enclosures are shown in Fig. 23.19 and 23.20. Ten to 12 separate net enclosures are usually treated as one management unit.

As stated previously, the diet is predominantly trash fish which have low market values for human food. The small amount of pelletized food used is at least 70% whitefish meal, with 5–10% of gluten as a binder. Other ingredients include vitamin mix and minerals, especially iron and cobalt to prevent anemia. Growth with this feed is not as rapid as feeding minced fish alone, but growth is better when both are fed. The high costs of the pellets has prevented their widespread acceptance and use.

The optimum feeding regime consists of a morning and afternoon feeding. Feeding rates decrease as a percentage of body weight as the fish mature.

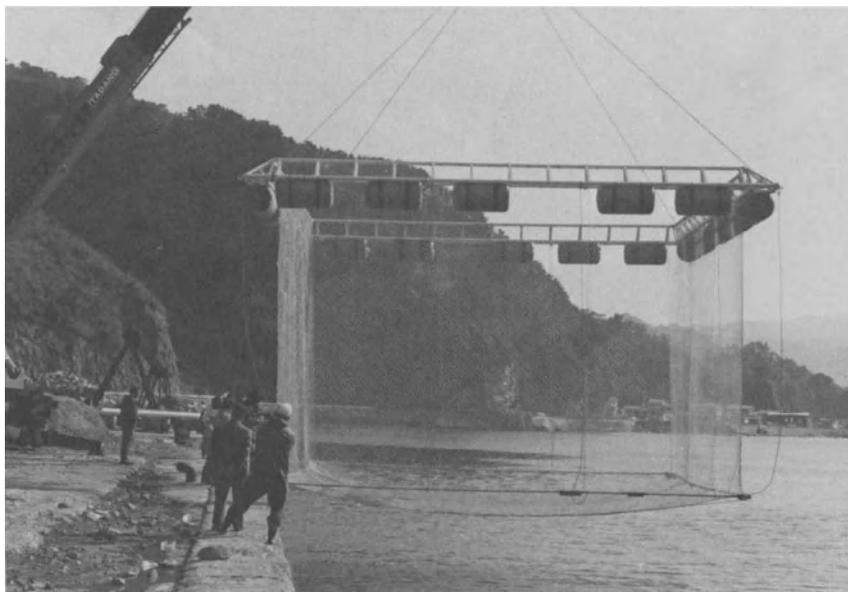


Fig. 23.19. Newly constructed yellowtail cage being lowered into marine waters.

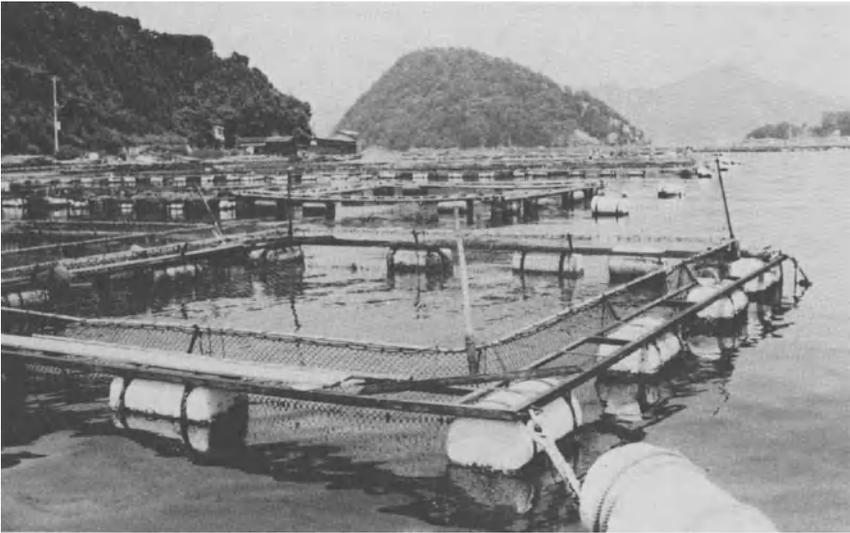


Fig. 23.20. Floating yellowtail cage culture.

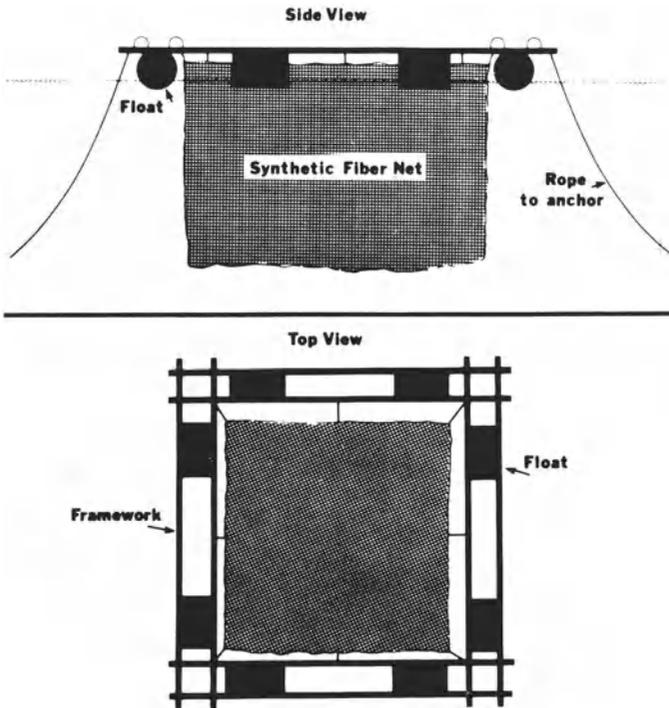


Fig. 23.21. Floating net cage for yellowtail.

The cultured fish ready for the market are harvested with a simple dip net.

About one-half of cultured yellowtail are sold alive, and are then transported to market by boat or truck in iced water. These go to cities in eastern Honshu where natural yellowtail are caught. Nearly all of these ultimately end up in restaurants. The remaining fish are sold as fresh iced fish, either in the round or gutted. These fish go to the western side of Japan or to the areas north of Tokyo where wild yellowtail cannot be caught. About 95% of them ultimately end up in restaurants while about 5% (usually the smaller ones) are sold through supermarkets.

The average producer produces between 10,000 and 20,000 fish weighing 1.0 to 1.5 kg (2.2 to 3.3 lb each). This volume is sufficient to render a middle class income.

It is estimated that future expansion of yellowtail culturing will be small because of government restrictions on the number of wild fry that can be harvested. Hence, hope for further large-scale expansion is in reducing the costs of producing spawns and fry artificially. The main problem appears to be a shortage of suitable food for the newly hatched fish.

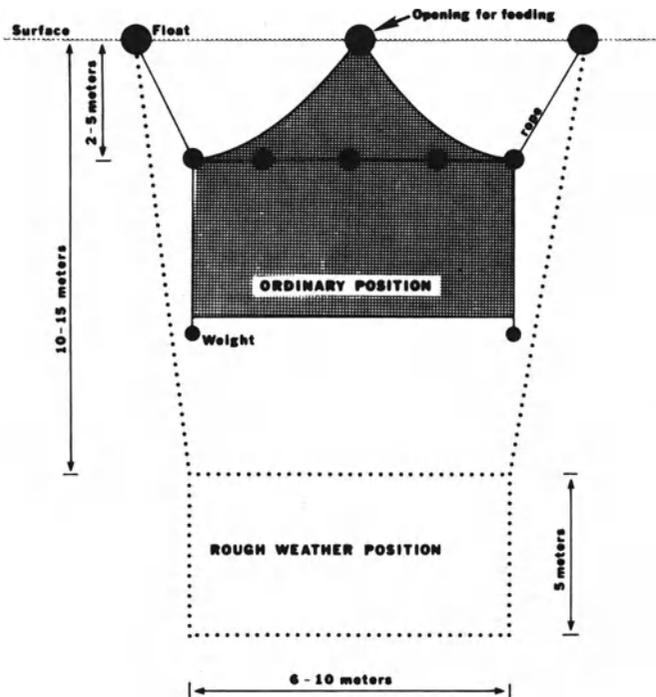


Fig. 23.22. Submergible net cage for yellowtail.

Production Costs. In 1978 the average cost of producing a one-year, May–December yellowtail weighing 1.2 kg (2.6 lb) was \$3.98. The average selling price per fish was \$4.08, giving a net return to large-scale management or net profit of \$0.10 per fish. With an average production per management of 29.3 MT (32.3 ST), this means that the average producer produced 26,917 fish, and made a return for family labor and net profit of \$39,836. Those farmers who can afford to do so often keep their fish for two years. During the second year, growth is 2.8 kg (6.2 lb) instead of the 1.2 kg (2.6 lb) that they gain in one year. Hence, the profit is higher for two-year fish, but cost and returns data are not available.

Marketing. Of the total fish supply of 10,812,000 MT (11,914,824 ST) in Japan in 1978, the six largest wholesale fish markets handled about 20% of the total. These six markets in order of importance are: (1) Tokyo, (2) Yokohama, (3) Nagoya, (4) Kyota, (5) Osaka, and (6) Kobe. The Tokyo market handled more than 40% of the volume of the six largest markets.

For each year from 1974 through 1978, the price of cultured yellowtail was higher on the Tokyo market than for wild fish (Table 23.22). This premium is mostly due to the ability of the fish farmers to harvest and sell to the market when native stocks are low and prices are higher. Even though cultured yellowtail prices are higher on the Tokyo market than wild yellowtail, it is believed that prices of cultured yellowtail are lower on the Tokyo market than elsewhere. This is due to the cultured fish being fatter and containing more oil, which affects the flavor.

Red Sea Bream or Red Porgy (*Chrysophrys*)

Red sea bream, sometimes called red porgy, is the second most important cultured marine finfish in Japan. It is traditionally regarded as a symbol of good fortune. Thus, it is not only a food material but is featured at celebration meals and is a particularly highly valued fish.

Research on the farming of this species had been carried out since 1887,

TABLE 23.22. SALES OF WILD AND CULTURED YELLOWTAIL ON THE TOKYO CENTRAL WHOLESALE FISH MARKET, 1974

Year	Wild Yellowtail			Cultured Yellowtail		
	Metric Tons	Price in Dollars		Metric Tons	Price in Dollars	
		per kg	per lb		per kg	per lb
1970	—	—	—	7,504	1.81	0.82
1971	—	—	—	8,663	1.96	0.89
1972	—	—	—	9,978	1.98	0.90
1973	—	—	—	9,743	2.04	0.93
1974	2019	2.50	1.14	10,875	2.66	1.21
1975	2364	2.56	1.16	11,696	3.95	1.80
1976	1910	3.64	1.65	14,203	3.90	1.77
1977	1061	3.66	1.66	13,739	4.39	2.00
1978	2412	3.23	1.47	11,860	4.27	1.94

Source: Anon. (1972–1978).

and experiments on artificial propagation stem from 1902. However, no successful results were found until 1958 when research on propagation began again; limited success was accomplished in 1962. Since then, farming has advanced quite rapidly and the output of cultured fish has expanded rapidly in recent years.

Prior to 1970, the number and volume of production of red sea bream were reported under yellowtail information. In 1970, there were a total of 204 managements, producing 454 MT (500 ST). Eight years later, in 1978, there were 1781 managements, producing 11,315 MT (12,469 ST).

The 1781 managements in 1978 had a total of 7876 production places with a total area of 1,444,000 m² (357 acres). Hence, the average production was 7.8 kg per m² (1.6 lb per ft²). Only 4 places used the dike method, 3 used net partitions, and 7869 used net techniques. These were described previously under the "Yellowtail" section of this chapter. As was true for yellowtail, the most intensive output per m² of water surface was with net culture because of the better exchange of seawater and resulting higher water quality. The average volume of production per management was only 6.4 MT (7.0 ST). Since 4310 people were employed, the average volume of production per employee was only 2.6 MT (2.9 ST) per person. This indicates the need for close supervision and the high value of the fish per unit of sale. In 1978 there were 21,577,000 fry stocked. The total supply of food fed was 105,567 MT (116,335 ST). Hence, the feed conversion for the 11,315 MT of production was 9.3 units of feed per unit of output. The diet is almost exclusively trash fish.

The three main areas of production are Nagasaki, Mie, and Kumamoto Prefectures. These three areas accounted for about 60% of production in 1978. See the map of Japan (Fig. 23.1) for the location of these three prefectures.

Red sea bream culturing is increasing rapidly. Production expanded from 454 MT in 1970 to 11,315 ST in 1978. However, the natural wild catch is 10,722 MT. Hence, culture production, accounting for an increasing share of the total supply, is about 51% of the total.

Representative costs of culturing red sea bream are shown in Table 23.23. Farm selling prices in 1978 were \$10.20 per kg (\$4.64 per lb). Costs accounted for 84% of the sales dollar. Returns to management were very light at \$1.67 per kg (\$0.76 per lb). Major production costs were seedfish, feed, and labor. On this scale enterprise, returns to management using all hired labor were \$19,552. If family labor had been used, returns to labor and management would have been \$30,089.

Horse Mackerel (*Trachurus symmetricus*)

Horse mackerel is the third most important marine finfish cultured in Japan. Prior to 1970, the volume of cultured production was listed under "other" cultured fish. However, production must have been negligible because in 1970 when separate records were made, production was only

TABLE 23.23. COSTS AND RETURN OF PRODUCING CULTURED RED SEA BREAM PER KG AND PER LB JAPAN, 1978

Item	per kg (Dollars)	per lb (Dollars)	Percentage
Total income	10.20	4.64	100.00
Costs	8.53	3.88	100.00
seedfish	4.42	2.01	51.82
feed	1.45	0.66	17.00
boats	0.23	0.10	2.73
wages	0.90	0.41	10.55
depreciation, repairs,			
insurance	0.34	0.15	3.99
selling costs	0.11	0.05	1.25
interest	0.71	0.32	8.32
others	0.37	0.17	4.34
Return to management	1.67	0.76	16.00

Source: Anon. (1979B).

Based on 9 marine pens, each 66.8 m² (719 ft²), producing 43,183 fish having a harvest weight of 11,708 kg (25,758 lb), employing 3.4 people. Total returns to management were \$19,552. If family labor had been used, returns to labor and management would have been \$30,089.

7 MT (less than 8 ST). However, within eight years, production had reached 809 MT (892 ST), see Table 23.19. Production per management is small. For example in 1977, there were 147 separate managements producing the 809 MT, or 5.5 MT per management (Table 23.20). The 147 managements were using a total of 339 floating net marine enclosures (Table 23.21). These enclosures had a total surface area of only 47,000 m² (505,720 ft²). The average net enclosure covered 139 m² (1496 ft²) of surface area. Production was 2.4 MT per net enclosure for an average output of more than 17 kg per m² (3.4 lb per ft²) of surface area.

A total of 325 people were employed, so production was only 2.5 MT (2.8 ST) per person. Hence, it can be seen that stocking is intensive and labor requirements high.

Total volume of feed fed was 6404 MT (7057 ST) for a feed conversion of 7.9 units of fish feed per unit of fish produced. Production is mainly west of the Tokyo area of the Pacific side of the main island of Honshu. Over one-third of total production comes from Mie Prefecture (see map of Japan, Fig. 23.1).

Fishermen catch 50–100 g (2–4 oz) fry in marine waters for stocking. After only 2 to 3 months of feeding sardines and other trash fish, the horse mackerel are between 200 and 300 g (7 and 11 oz) and are sold as fresh iced fish in the round. They are a relatively expensive fish.

Although production of horse mackerel is increasing and reached 809 MT (892 ST) in 1978, this volume was only a minor contributor to total supply. During the same year, about 87,457 MT (96,378 ST) were caught in marine waters. Culturing accounts for less than 1% of total supply.

Other Cultured Marine Fish

Under this heading are: (1) yellowjack (*Caranx delicatissimus*), (2) puffer (*Fugu rubripes*), (3) filefish (*Monacanthus cirrhifer*), (4) porgy or black sea bream (*Mylio macrocephalus*), (5) flounder or flatfish (*Paraichthys olivaceus*), (6) rabbit fish (*Siganus fuscescens*), (7) chum salmon (*Oncorhynchus keta*), and (8) cherry salmon (*Oncorhynchus masu*).

Yellowjack. Separate statistics were only started for yellowjack in 1974. In that year there were 48 MT (53 ST) of cultured production (Table 23.19). By 1978, 177 MT (195 ST) were produced by 25 separate managements (Table 23.20). Nearly all culturing was in floating marine enclosures or pens. Eighty-seven people were employed, making the output per person only about 1 MT. However, many of these managements produced other species, so the real output per person is higher than this information indicates. The major producing area is Kochi Prefecture on the island of Shikoku. Farmers stock 200–300 g (7–11 oz) wild fish caught by fishermen. They are then fed minced sand eels, anchovies, sardines, and other trash fish. They are raised to a size of 2–3 kg (4.4–6.6 lb) in a period of 12 to 18 months. The fish are considered a gourmet item and are sold to first class restaurants at prices averaging \$10.00 per kg (\$4.55 per lb). Yellowjack production will undoubtedly increase under the double impetus of good prices and ability to continue expansion.

Puffer. Puffer is also a cultured species. Puffer production reached 600 MT (661 ST) a year during the 1959–1961 period along the coasts of the Inland Sea. Since then it has rapidly declined to only 46 MT (51 ST) in 1974. This was due to increases in natural production and imports. Most culturing is for restocking the seawaters.

Spawning begins in May when adults are collected for eggs and fertilization. In 7–10 days the eggs hatch. Hatching waters range between 15° and 19°C (59° and 64°F). When the fry are 5 cm (2½ in.), they are stocked in floating net enclosures or impoundments having seawater exchange. They are fed two to three times daily at 17–25% of body weight. Food is sand eels, minced mackerel, and other trash fish. At 350 g (12½ oz), feeding rates drop to 0.6% of body weight. By the end of December, they average 400 g (14 oz). In January, growth stops because of low water temperatures. They are fed for 2½ years and are sold at 1½ to 2.0 kg (3.3 to 4.4 lb). They are sold live to specialized gourmet restaurants at very high prices. Producer prices range between \$10 and \$20 per kg (\$4.55 and \$9.09 per lb).

The skin, liver, and ovaries of puffer are extremely poisonous and cooks in the specialized restaurants undergo intensive training and are licensed by the government. The Japanese have a saying that “to savor fugu (puffer), one courts death,” and also “honey is sweet, but the bee stings.” In spite of all precautions, some 20–30 Japanese die each year from eating puffer. There are no available statistics of consumption, but a minimum of 1000 MT (1102 ST) are consumed annually.

Filefish. Filefish are another cultured marine fish. They are cultured by only a few individuals and production has declined from 62 to 3 MT annually. They are stocked with other marine cultured fish in small numbers. They eat only marine growth, which adheres to the floating and submerged nets; thus, the nets are kept cleaner, which aids in reducing labor costs of cleaning and replacing nets. They are usually stocked with horse mackerel and red sea bream. Wild fingerlings caught by fishermen are stocked at about 50 g (2 oz). In 10 to 15 months they reach market sizes of 500 to 600 g (18 to 21 oz) and sell for about \$1.50 per kg (\$0.68 per lb).

Porgy or Black Sea Bream. Porgy or black sea bream are cultured used domesticated spawners. They are used for restocking at about 3 cm sizes (1 in.) or are fed out until they reach about 20 cm in length and 250 g (8–9 in. and ½ lb). Porgy consumer prices vary between \$8.00 and \$12.00 per kg (\$3.63 and \$5.45 per lb).

Flounder or Flatfish. Flounder or flatfish are spawned from both domesticated and wild fish. For restocking they are released at 3 cm (1 in.) and for food use are cultured until they weigh 1 kg (2.2 lb). Consumer prices are extremely high, averaging about \$28 per kg (\$12.72 per lb) in Tokyo.

Rabbit Fish. Rabbit fish are cultured for restocking and raising for food. Market sizes are 20–30 cm (8–12 in.). Prices are relatively inexpensive, averaging about \$2 per kg (\$0.91 per lb) at retail.

Total cultured volume of porgy, flounder, and rabbit fish is small, probably less than 100 MT. The greatest interest is centered on flounder. All three species are fed oyster larvae or rotifers starting one day after swimup until the thirteenth day. From day 13 to day 32, copepods are fed. Starting about day 25, the fry are gradually shifted to fish meal paste and at about 10 cm sizes, commercial fish pellets are introduced. All three species are raised in salt water, in net or pen culture, or inland using pumped waters.

Pacific Tuna. Experiments are underway on culturing Pacific tuna. Small wild tuna are captured, kept in pens or nets, and fed out. The reason for interest in tuna is extremely high prices which run \$40 per kg (\$18.18 per lb) in Tokyo.

Chum Salmon and Cherry Salmon. Chum and cherry salmon are also cultured. Chum is the major species. Chum, in addition to being cultured by the government in Hokkaido as part of a sea ranching effort, is also cultured as a food fish. In sea ranching, small fry of less than 1 g were formerly released, but the return was only 1 to 2%. At present, 5 g fish are released and the return is 6–8%. On the east coast of the main island of Honshu, north of Tokyo, there has been no species adapted to the colder waters. Starting about 1975 the Nidriro Fish Company and several farmer cooperatives, with encouragement by the government, introduced salmon as a culturable species. The private company and the cooperatives hatch and sell smolts for culturing in marine pens. Since the water temperature is



Fig. 23.23. Major production areas for prawn culturing, 1980.

marginal during summers, the smolts at about 100 g (4 oz) are stocked by farmers in October when the water temperatures are under 15°C (59°F). They are then grown out until May and harvested at about 1 kg liveweight (2.2 lb). The pens used for culturing are about 10 m² by 5–6 m deep (40 ft² by 15–20 ft deep). Feed is raw fish, moist or dry pellets with small shrimp or krill added to give color to the flesh. Total production is over 1000 MT (1104 ST).

Shrimp (*Penaeus japonicus*)

This species ranges from southern Japan southward to northern and northeastern Australia, eastward to Fiji, and westward to Africa. The shrimp, sometimes called prawns, are common in Asian waters. They dwell in coastal waters of moderate temperature and salinity. The shrimp are attractive in color with alternate cross-bars of brown, blue, and yellow and weigh between 20 and 25 g. They are highly valued for their delicacy. Weights of 130 g (4.6 oz) have been attained. It is a carnivorous species and lives two years.

The northern limit of their range on the Japan Sea side is Akita Prefecture. On the Pacific side it is Miyagi Prefecture. The wild catch in Japanese coastal waters is about 2800 MT (3086 ST), while cultured production was 912 MT (1005 ST) in 1974. The wild catch decreased in the 1960s because of pollution. In the 1970s the various prefecture governments were restocking coastal waters and the catch increased to near the old level of about 3000 MT (3306 ST) by 1974 and then declined to 2440 MT (2689 ST). Cultured production continues to increase.

The smaller, wild prawns are found in the sand beds of the inner parts of bays. As the prawns grow, they move into deeper waters. In the summer, they generally move into shallower waters and in winter move into deeper waters and bore themselves into the sand. The winter catch is small, and, hence, the market price is high.

Prawns are nocturnal and have a long spawning period. Female prawns gravid with mature ova can be seen as early as April 1 off southern Kyushu, and as late as September in the northern limits of their range. The females measure about 15 cm (4 in.) and males about 12 cm (3 in.). Mating occurs during the night. Spawning also takes place at night and usually takes from 3 to 4 min. Fertilization is finished as soon as the ova leave the female body. The ova are slightly heavier than salt water and, hence, sink to the bottom.

In Japan, experimental work began on culturing prawns as early as 1933. However, it was 1963 before techniques were adequately developed so that culturing was economically practical. In 1976, there were more than 100 prawn farms in Japan. They are mainly in the Seto Inland Sea area (Fig. 23.23). They are established on deserted salt beds or on sandy beaches of the inner bays.

The depth of the culture pond is shallow, being about 60 to 180 cm (24 to



Fig. 23.24. Shrimp culturing pond showing water gate leading to the sea.

46 in.), with a flat sandy bed. The turnover of the seawater is done by using floodgates, which permit partial exchange of the seawater twice a day, as the tides ebb and flow. The bed of the pond should be a light colored, slightly reddish sand, since the color of the prawn is said to be affected by the color of the sand and the feed. Prawns with red coloring and clear stripes are most valuable in Japan.

Seed Production. Commercial concrete tanks having capacities of 200 m³ (7000 ft³) or more are common.

To produce prawns within the year, the young prawns must be stocked by the end of May into the finishing culture pond. This means that heated water of about 28°C (82°F) may be required in the early stages of incubation.

In April or May the gravid female prawns must be obtained and at this time must have a dark green ova cluster. They must be collected, shipped in cooled wet sawdust, and placed in the incubation tank before the evening of the day they are captured.

The gravid female prawns spawn during the night while swimming. After 14–15 hr in water temperatures of 25° to 28°C (77° to 82°F), the ova become nauplii. They do not require feeding, but absorb the yolk of the ova and go through repeated ecdyses. Between 20 and 36 hr after the sixth ecdysis they become zoeae.

The zoeae repeat ecdysis 3 times in 4 days and become mysids. During the zoea stage, cultured diatomaceae are placed in the tank for food. Water quality and the quality and quantity of diatomaceae affect the growth rates of the zoeae.

When the zoeae enter the mysis stage, supplemental food can be added to the diatomaceae. The ova and larvae of oysters are sometimes used. The mysis stage takes three days. The first legs develop and they become post-larvae.

In the post-larva stage, they begin actively feeding on microorganisms, and the nauplii of brine shrimp are fed plus minced, shortnecked clam meat. At this point about 25% of new water is exchanged daily in the tank. By P₂₀ the body weight may be 10–20 mg. They are now ready for stocking in the finishing or grow-out culturing pond.

The P₂₀ post-larvae must be placed in the culturing pond by early June to prepare them for the winter market season. An average stocking density of 20 per m² (2 per ft²) of surface area is recommended.

Raising Shrimp. Before stocking the P₂₀ shrimp the pond must have been prepared. After the last crop of adult prawns is harvested, the pond is drained and dried. The sand bottom is turned over to aid in decomposition of organic matter. When all odors have vanished, the sand is usable. New sand is often added to renew the proper culturing characteristics of the pond bottom. The pond is then filled with seawater and small foreign fish and predators are killed by using derris powder.

If the P₂₀ shrimp are stocked in early June at a density of 20 m² (2 per ft²) they can reach market sizes of 20 g by December or January when the water becomes too cold for growth. The young shrimp are fed shortnecked clams. The clams are run through crushers to crack the shells and then dropped into the culturing pond. Other types of feed are sometimes fed, including other shrimp, crab, and young fish. For the serious reader, the authors recommend *Aquaculture in Japan* by Akio Honma (1971) and *Shrimp Culture in Japan* by Kunihiko Shigueno (1975).

Prawns spend most of their time in or on the sand bed at the bottom of the pond. Particular care must be given to avoid pollution. As feeding increases and the size of the prawns increases, the formation of hydrogen sulfide arises. At 2 to 4 ppm the prawns lose their sense of balance and at 2 ppm they die. Pumping is sometimes necessary to assure good water quality. Care must also be exercised in the continuous suppression of foreign fish and predators. A 4 to 5% rotenone mixture is commonly used. Several other chemicals for use are discussed by Honma and Shigueno.

Harvesting and Selling. Harvesting is done by several methods. Among these are the "pound net" and the "pump net." Catching is done at night when the prawns are active. The pound net is a simple trapping device which the prawns enter and which is then lifted out of the water. The pump net is used when the water is cold and the prawns have burrowed into the sand. Jets of water plough the sand bed, forcing the prawns to surface into a trailing catch net. Nearly 100% harvesting can be done by using these two methods.

After harvesting, the prawns are transferred to a cooling tank. The

TABLE 23.24. ELEVEN YEAR HISTORY OF THE UBE SHRIMP CULTURING FARM, UBE CITY, YAMAGUCHI PREFECTURE, JAPAN, 1965-1975

Year	Post-larvae Stocked (1000)	Survival Rate (%)	Average Harvest Weight (g)	Total Harvest Weight (kg)	Average Price per kg (Dollars)	Average Price per lb (Dollars)
1965 ¹	600	50	20.0	6,000	8.33	3.79
1966	870	61	11.0	5,836	6.51	2.96
1967	800	68	13.9	7,520	11.63	5.29
1968	800	71	17.5	8,509	11.41	5.19
1969	800	37 ²	22.1	7,033	15.62	7.10
1970	800	44 ³	18.2	6,268	14.31	6.50
1971	800	79 ⁴	20.9	10,115	12.30	5.59
1972	680	69	25.9	12,430	14.11	6.41
1973	880	39 ⁵	26.6	8,806	15.09	6.86
1974	800	76	27.7	16,103	15.66	7.12
1975	900	53	27.0	12,950	19.20	8.73
Totals and averages	—	59.7	21.08	9,557	13.59	6.18

Source: Anon. (1976C).

¹First year of operation.²Oxygen depletion.³Pollution problem and red tide.⁴Aeration added.⁵Sea grass infestation.

prawns are cooled by slowly lowering the water temperature. When the prawns can barely move and the body color becomes reddish, cooling is stopped. This is usually at 12° to 14°C (54° to 57°F). They are then packed in wet sawdust by size. Each layer of prawns is separated by a layer of sawdust. Sometimes a lump of ice is packed in the middle of the shipping container. Between 2 and 3 kg (4.4 and 6.6 lb) of prawns are packed into each box. The number and weight is recorded on the outside of each box. The prawns are moved to airports or trains by refrigerated trucks. In these shipping containers they can live for 3 to 5 days. At the central auction the prawns are examined for condition and auctioned off to restaurants and fish retailers.

Sales are usually at one of the six largest central fish markets. These are: (1) Tokyo, (2) Yokohama, (3) Nagoya, (4) Kyoto, (5) Osaka, and (6) Kobe. Average prices received by one farm are shown for the 11 years between 1965 and 1975 (Table 23.24). These data indicate the relationship between size of prawns and price, the increasing prices of cultured prawns, and the high value per unit of sale. In 1975, the average price received at this farm was \$19.20 per kg (\$8.73 per lb).

Production Costs. While selling prices of cultured prawns are high, production costs are, too. One example of this is shown in Table 23.25. The farm produced 24,069 kg (26,524 lb) of prawns in 1978. The cost of production was \$23.89 per kg (\$10.86 per lb). Feed was the major cost item. Labor was the second highest expense item. Feed at this farm consists of 40% pellets, 40% other shrimp, and 20% clams. Nearly 8% of the total sales was profit or return to management, which amounted to \$47,897. This indicates the relatively high return to a successfully operated prawn farm.

TABLE 23.25. COSTS AND RETURN OF PRODUCING CULTURED SHRIMP PER KG AND PER LB, JAPAN 1978

Item	per kg (Dollars)	per lb (Dollars)	Percentage
Total income	25.88		100.0
Costs	23.89	10.86	100.0
seed	1.09		4.6
feed	8.57		35.9
wages and benefits	3.93		16.5
depreciation, repairs	2.10		8.8
selling costs	2.56		10.7
interest	2.80		11.7
others	2.84		11.9
Returns to management	1.99		7.7

Source: Anon. (1979B).

Based on farm employing 11.6 people, and using no unpaid family labor, two ponds having surface area of 39,703 m² (9.8 acres) producing 24 MT (26.4 ST). Total return to management was \$47,760.

RESTOCKING

The Japanese have intensive restocking efforts for both freshwater and marine species. For example, in 1978, over 54,000,000 shrimp larvae were

released in marine waters. In the same year, a total of 1,560,870,000 fry were cultured and released. These were as follows:

Salmon and marine trout	112,824,000
Landlocked salmon and trout	130,103,000
Ayu	203,891,000
Common carp	64,165,000
Crucian carp	73,558,000
Eel (adults)	15,968,000
Others	960,361,000

Under "others" nearly every conceivable species found in Japan fresh and marine waters was included (Anon. 1978, 1980B).

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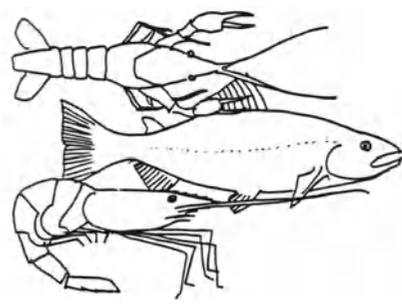
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People's Republic of China

FISH AND OTHER AQUATIC SPECIES

Bighead (<i>Aristichthys nobilis</i>)	Milkfish (<i>Chanos chanos</i>)
Black amur bream (<i>Megalobrama terminalis</i>)	Mollusks
Black carp (<i>Mylopharyngodon piceus</i>)	Mud carp (dace) (<i>Cirrhina molitorella</i>)
Bream (Wuchan fish) (<i>Parabramis pekinensis</i>)	Mullet (Mugilidae)
Bullfrogs	Mussels
Colored carp (koi)	Northern Asian mullet (<i>Mugil so-iuy</i>)
Common carp (<i>Cyprinus carpio</i>)	Octopus
Crabs	Oysters
Crucian carp (<i>Carassius carassius</i>)	Plankton
Crustaceans	Rainbow trout
Diatoms	Scallops
Eel	Sea cucumbers
<i>Elopichthys bambusa</i> (predator fish)	Seaweeds
Freshwater clams	Shellfish
Golden carp	Shrimp
Goldfish	Silver carp (<i>Hypophthalmichthys molitrix</i>)
Grass carp (<i>Ctenopharyngodon idellus</i>)	Snails
Grey or striped mullet (<i>Mugil cephalus</i>)	Snakehead (<i>Ophicephalus argus warpachowskii</i>)
Japan eel (<i>Anguilla japonicus</i>)	Taiwan dojo (<i>Ophicephalus maculata</i>)
Kelp	Tilapia (<i>Tilapia mossambica</i>)
Mandarin fish (<i>Siniperca chuatsi</i>)	Walking catfish (<i>Clarius fuscus</i>)
	Xenocypris (forage fish)

People's Republic of China

Clinton E. Atkinson

From the very earliest times, fish have provided a basic source of food for the Chinese people. Archeological records dating back some 15,000 to 50,000 years provide evidence that grass carp (*Ctenopharyngodon idellus*) were regularly eaten by the "mountain cave dwellers" of that period and skull bones of this fish were used as primitive ornaments. In the next 5000 to 10,000 years, hooks and spears made of bone and net weights of stone and clay were commonly found among the artifacts of this primitive civilization. There is also evidence that the method of preserving fish in salt, for use when food became scarce, was developed during this period.

By the time of the Shang Dynasty (1766 to 1122 B.C.) fishing was a well-developed skill; various types of metal fish hooks and remnants of other fishing gear are frequently seen in museums today.

Shortly thereafter the Chinese rulers of the Chou Dynasty (1122 to 255 B.C.) recognized the need to protect their fishery resources by special closures and other regulations and established an office within the government to exercise control over their fisheries. This was the beginning of our modern concept of fisheries conservation.

Chinese literature is filled with references to the almost sacred position that carp, "the King of Fish," occupied among the early Chinese. The carp was primarily known for its stamina and persistence in overcoming areas of fast water. The carp was said to be the only fish that was able to ascend the famous rapids of the Yangtze River—the Dragon's Gate. Thus when a student ultimately overcame all the obstacles of obtaining the final *Han Lin* degree at school, it was said that he had passed "through the Dragon's Gate." The Chinese ideograph for fish is said to represent a carp with nose pointed upwards in the ascent of a falls. Similarly the Chinese character for wealth and abundance is symbolic of two carp swimming upstream side-by-side. The flying of the carp streamers during boys' day festivities, the "nabori-koi" of Japan, signifies the strength of a carp (koi) swimming upstream and is an ideal for the sons to follow in overcoming the adversities of life.

Over the centuries carp have been closely associated with religious beliefs and ritual. The place of carp in the Oriental religions probably originated in the teachings of Confucius and developed from the knowledge of carp and carp rearing of the Chou Dynasty. However, it is significant that

even at the present time Buddhists of China and other nations in eastern Asia celebrate Buddha's birthday (April 8th) by purchasing young carp and releasing them. Further, the Buddhist goddess of compassion, Kwan-yin, is usually shown as a middle-aged woman carrying a common carp in a basket. Carp also are the subject of worship and ritual in the Shinto faith, especially in their preparation for cooking.

Although some scholars believe that fish culture actually may have originated in one of the more southern Asian countries, there is little question that the high position occupied by the common carp in diet, folklore, and religion, and the advanced civilization of the Chinese people had a strong influence on the development of the fisheries and methods for culturing carp and other freshwater fish.

The origin of aquaculture in China is attributed to Wen Wang, the founder of the Chou Dynasty. Twenty years after his accession to the throne until his death, the last ruler of the Shang Dynasty had Wen Wang confined to an estate in Honan Province (1135 to 1122 B.C.). It was there that Wen Wang built a pond, filled it with fish and made the first recorded reference to their behavior and growth. The fish pond was apparently the source of great pleasure for Wen Wang and much of the early skill in the rearing of fish is said to have originated from his efforts and those of the people working with him.

Although a number of references are found in the early Chinese writings that appeared in the next several centuries, it was not until 460 B.C. that Fan Li, a land-holding official in the ancient kingdom of Yüeh, wrote his *Fish Culture Classic*, which describes in some detail the results of numerous experiments made by Fan Li and others at that time. His observations on the location and size of ponds and principles of stocking and harvest served as a guide for fish culturists for many years and are even applicable today.

It was also during the latter part of the Chou Dynasty that the keeping of carp for pleasure, such as described by Wen Wang, changed to the rearing of carp for food. The sizes of ponds were expanded and earnings from fish culture proved to be exceptionally profitable.

Over the last 70 years the methods established by Fan Li were further refined and expanded. Carp culture in "large water areas" was fully developed during the Han Dynasty (206 B.C. to 220 A.D.) and laws were enacted to protect the fisheries in the larger areas and to govern the use of large fishnets. The use of rice paddy fields for carp culture began during the Three Kingdom Era (221 to 277 A.D.), colored carp appeared during the Tsin Dynasty (265 to 419 A.D.), and methods to transport live fish were developed during the Era of Division between North and South (420 to 500 A.D.).

Laws passed during the T'ang Dynasty (618 to 917 A.D.) were of special significance in the culture of freshwater fish in China. During this period the carp was made a symbol of the royal family and, in effect, became a national treasure. Thus, if carp were taken, either intentionally or accidentally, they had to be released, and if they were taken and sold, the offenders were punished. Because of this action, commercial carp culture was no

longer possible and growers in the coastal areas of the Yangtze and Pearl Rivers turned to the culture of grass carp, black carp (*Mylopharyngodon piceus*), and bighead (*Aristichthys nobilis*) for their income—probably the beginning of “polyculture” in China.

By the time of the Sung Dynasty (960 to 1280 A.D.), methods of collecting fish fry had already been developed in Kiangsi Province and the young fish were being regularly transported into the interior of Kiangsi as well as the neighboring provinces of Chekiang and Fukien. It was also during this period that culturists began experimenting with feeding and hybridization.

The system of polyculture widely practiced in China today was actually developed during the Ming Dynasty (1386 to 1644 A.D.) and much attention was given at that time to problems of sex and species composition, density of fish in a pond, and to methods of pond fertilization. However, for all intents and purposes, this completed the active development of the major aspects of freshwater fish culture in China. Authors have described the next 300 years, or until the end of the Civil War in the 1940s, as a period of stagnation, with some effort made to refine existing technology but without significant new discovery or radical change in culture methods.

Since 1949 a new interest in aquaculture has developed in China. Most critical was the need to provide adequate food for the people, and aquaculture, with all of its history and tradition, played a natural role in such a program. The extensive development of water-use projects on all the major rivers was a most significant development and increased by many times the productive capacity of freshwater fisheries in China. Domestic subsidies of funds and labor, foreign grants, and technical assistance have all contributed much to the reactivation and success of the present aquaculture programs.

In China today numerous fish breeding centers and scientific laboratories have been established to assist the fish culturist in obtaining a higher yield. Hormone-induced spawning has become an integral part of the fish culture program; production is no longer dependent upon the abundance of naturally occurring fry. New species have been introduced (such as *Tilapia*) to form an important supplement to aquaculture production. The aquaculture program has been expanded into the more remote areas of China to provide a welcome addition to the diets of the people in those areas where fish have not been regularly eaten. Perhaps most exciting has been the increase in production of brackish water species, such as milkfish (*Chanos chanos*) and mullet (*Mugilidae*), and in the culture of the truly marine species. It is quite possible that the greatest increase in aquaculture production in the future will come from marine aquaculture.

THE AREA

China has a large number of rivers and more than 1500 of them have watersheds of 1000 km² (380 mi²) or more. Three of the rivers (the Yangtze, Yellow, and Amur rivers) are ranked among the 10 longest rivers in the

world. In addition, there are 130 lakes that exceed 100 km² (38 mi²) in area. The control and use of water has been an integral part of the Chinese civilization from very ancient times. Extensive dykes, irrigation systems, canals, and other projects have been constructed over the past 4000 years, contributing greatly to the natural water resources of the country and providing added incentive for the development of freshwater fisheries and aquaculture in China.

Similarly, China has a long and sinuous coast, extending for a total of about 20,000 km (12,500 mi) and bordered by 4 seas (Po'hai, Yellow, East China, and South China Seas). China's coastline may be roughly divided into two types: north of Hangchow Bay the coast is generally flat and is composed mainly of sand, mud, and silt from the rivers; south of Hangchow Bay, the mountains run close to the shore and the coast is characterized by outcroppings of rock, islands, and large deep-water harbors. Although coastal fishing existed on a fairly large scale as early as 770 B.C., China's economy has historically and traditionally been closely linked with the development of agriculture and freshwater fisheries. Only recently has emphasis been placed on modernization and expansion of the coastal and offshore fisheries and marine aquaculture.

FRESHWATER AQUACULTURE¹

For centuries Chinese fish farmers have learned to rear a variety of freshwater fish that naturally occur in their waters. The common carp, of course, still retains a position of "King of Fish" in China and is a favored item for festive occasions. In terms of production, however, many of the other carp-like fish grow more rapidly, are less susceptible to mortalities and cost less to rear than the common carp. For these reasons, the amount produced of grass carp, black carp, silver carp (*Hypophthalmichthys molitrix*), and bighead far exceeds that of the common carp. A summary of the characteristics of the more common freshwater fish cultured in China is given in Table 24.1.

With the exception of the common and crucian carp (*Carassius carassius*), the fish farmer in China has had to depend upon a supply of eggs and fry collected annually from the rivers and lakes. Because of natural fluctuations in the environment and perhaps other factors, the supply of eggs and the species composition varied widely both within the season and from year to year. The instability of supply has led to the development of a system of polyculture, mixing different groups of fish together according to feeding habits in order to make the best use of whatever fish were available and, if properly managed, utilizing the total productivity of the pond at all trophic levels.

¹ According to the *Yearbook of Fisheries Statistics, Catches and Landings, 1973* (U.N. Food Agric. Organ. 1974), the estimated total inland, freshwater fish catch was 4.6 million MT. Estimates indicate that two-thirds of this amount or 3.0 million MT (3.3 million ST) were cultured. Including the large, but unknown, volume of brackish and marine cultured fish, China produces about two-thirds of the world's cultured fish.

TABLE 24.1. FRESHWATER FISH COMMONLY CULTURED IN CHINA¹

Species	Food Habits	Growth		Maturity Age (Years)	Fecundity (No.)	Egg		Hatching Time hr	Hatching Time °C
		Age (Years)	Length (cm)			Size (mm)	Type		
Grass carp (<i>Ctenopharyngodon idellus</i>)	Herbivore (grass, aquatic plants, etc.)	1	20-25	3-4	100,000-800,000	2.2	Nonadhesive	32-40	26-40
		5	56						
		7	75						
		10	84						
		max	122						
Black carp (<i>Mylopharyngodon piceus</i>)	Shell animals (snails, mollusks, crustaceans, etc.)	1	22-32	6-7	400,000 or more		Nonadhesive		
		2	45-50						
		3	5 kg						
		max	120						
		max	36 kg						
Silver carp (<i>Hypophthalmichthys molitrix</i>)	Plankton (phytoplankton, algae, etc.)	2	30	3-4	400,000-600,000		Nonadhesive		
		3	47						
		4	52						
		5	55						
		7	64						
		max	100						
		Bighead (<i>Aristichthys nobilis</i>)	Plankton (macroplankton, algae, etc.)						
2	22								
3	30								
4	40								
5	45								
7	50								
max	150								
Common carp (<i>Cyprinus carpio</i>)	Omnivorous (Plant and animal forms, organic debris, etc.)	1	10-17	2-3	160,000-380,000	1.5	Adhesive	85-95	20-21
		2	22						
		3	30						
		5	22-25						
		10	35						
Crucian carp (<i>Carassius carassius</i>)	Omnivorous (zooplankton, algae and diatoms, insect larvae, organic debris, mud, etc.)	max	40	4-5			Adhesive	75	22-23
		1	5						
		2	10-12						
		3	18						
		5	22-25						
Bream (Wuchan fish) (<i>Parabramis pekinensis</i>)	Omnivorous (mainly grass and aquatic plants, algae, crustaceans, mollusks, etc.)	max	40	4-5			Adhesive		
		1	8						
		2	14						
		4	22						
		5	25						
		7	33						

(Continued)

TABLE 24.1. (Continued)

Species	Food Habits	Growth		Maturity Age (Years)	Fecundity (No.)	Egg		Hatching Time hr	°C
		Age (Years)	Length (cm)			Size (mm)	Type		
Black amur bream (<i>Megalobrama terminalis</i>)	Omnivorous (mainly algae and other aquatic plant forms, etc.)	10	37	max	max	max	max	max	max
		max	55						
		max	60						
Mud carp (dace) (<i>Cirrhina molitorella</i>)	Omnivorous (diatoms, algae, organic debris, mud, etc.)	1	8-9	max	max	max	max	max	max
		2	20						
		3	25-30						
<i>(Elopichthys bambusa)</i>	Predacious (small fish, etc.)	1	25	max	1,800,000	7	7	7	7
		2	35-40						
		3	42						
		4	55						
		5	71						
		7	75						
		max	200						
Walking catfish (<i>Clarias fuscus</i>) Japan eel ¹ (<i>Anguilla japonicus</i>)	Omnivorous	1	120 g	max	1.5-2	0.2	Adhesive	30	27-29
		max	120 g						
Taiwan dojo ² (<i>Ophicephalus maculata</i>)	Predacious (mainly aquatic animal material, dead or alive, etc.)	max	60	max	max	max	6	45	25
		max	60						
Snakehead (<i>Ophicephalus argus war-pachowskii</i>)	Predacious (small fish, insects, macrozooplankton, etc.)	1	25	max	50,000-60,000	1.0	Nonadhesive	48	25
		2	35						
		4	55						
		max	100						
Mandarin fish (<i>Siniperca chuatsi</i>)	Predacious (small fish, insects, macrozooplankton, etc.)	1	12	max	500,000	2.0	Nonadhesive	72	21-25
		2	20						
		3	25-30						
		max	5-6 kg						

Milkfish ^{2,3} (<i>Chanos chanos</i>)	Vegetation (phytoplankton, algae, diatoms, some zooplankton, etc.)	1 2 max	20-40 40-50 180	3,000,000 7,000,000		
Grey or striped mullet ³ (<i>Mugil cephalus</i>)	Vegetation (phytoplankton, algae, diatoms, some zooplankton, organic detritus, mud, etc.)	1 2 5 max	18 35 55 80	50,000- 60,000	0.7	Nonadhesive 48-120
Northern Asian mullet ³ (<i>Mugil so-iuy</i>)	Vegetation (phytoplankton, algae, diatoms, some zooplankton, organic detritus, mud, etc.)	1 max	13-18 60			
Tilapia ^{2,3} (<i>Tilapia mossambica</i>)	Omnivorous (mainly aquatic plants, algae, diatoms, also macro-zooplank- ton, etc.)	1/3	17-22	80- 500+		4 72-120

¹ Various measurements are best averages available and could differ significantly by environmental conditions (temperature, food, population density, etc.).

² Tropical fish and distribution generally limited to the warmer waters of South China (and Taiwan).

³ Euryhaline.

⁴ Tilapia are mouthbreeders, the male incubates the eggs in his mouth. The eggs are ovoid, 1.8 × 2.3 mm.

⁵ Eels are catadromous, the young eelers captured for rearing when they enter freshwater to feed.

⁶ Airbreathers, male builds floating nest of air bubbles and keeps the eggs in the nest and guards until young are free-swimming.



Fig. 24.1. Harvesting fish (silver and black carp and bighead) from a lake farmed by the Wuhan Freshwater Fisheries Cooperative. The lake has an area of 325,000 m² and a depth in the center of about 5 m. Much of the fertilization is by cattle manure from nearby farms. Production in 1974 was 780,000 kg. Courtesy of K. Kondo, Tokai-ku Fisheries Research Institute, Tokyo.

The fish farmer would also receive from time to time young of the rarer species, either mixed with the other fry or for some reason or other especially abundant in the fry collections. Although some are highly predacious, they are frequently mixed with the other fish if their size and growth rates are compatible. Or, if the market value is high, they may be reared in separate ponds.

Pond Rearing

Although there is great effort being made at the present time to modernize fish culture practices in China, there is still much to be done in the training of the traditional fish farmer in new techniques of pond design, stocking rates, species balance, feeding, and disease. There are still many simple ponds, fertilized by an adjoining pigpen or with the waste from other animals or ducks, trash from kitchen and garden, and nightsoil. From time to time the ponds are cleaned, the rich bottom soil placed on the neighboring fields, the pond sterilized by leaves from the tea bush or other native plants, and restocked. Although these methods have produced fish for centuries, production per pond area is low and generally inefficient by present standards.

Change is not easy but through the work of a series of newly established scientific laboratories, experimental stations and fish breeding centers,

new methods of rearing freshwater fish have been developed and are gradually being adopted by the various communes, cooperatives, and even the traditional farmer. The methods of pond management reviewed here represent some of the aspects of the "new look" in Chinese aquaculture.

Eggs and Fry

Traditionally Chinese freshwater fish culturists have obtained their supply of eggs and fry from two sources: (1) from brood stock kept in ponds on the farm [common and colored carp, goldfish, tilapia, snakehead (*Ophicephalus argus*), etc.] and (2) from wild stock naturally spawning in rivers and lakes (grass carp, black carp, silver carp, bighead, etc.).

Whether from pond or wild stock, spawning is triggered by rain, water temperature, stream flow, water depth, turbidity, and other environmental conditions. The uncertainty of the weather has always been a critical problem for the fish farmer since it controls the frequency of spawning and the total number of eggs and fry available during the season, as well as the time of spawning in relation to the length of the growing season. Modern techniques of hormone-induced spawning have revolutionized fish farming in China by stabilizing the supply of eggs and fry.

Until recently the common carp (and the colored carp and goldfish) were the only species that could be spawned in artificial ponds. The breeder would first prepare a wintering pond 1 to 1.5 m in depth (up to 57 in.) by fertilizing with animal manure up to rates of 300 to 350 kg per 100 m² (6 to 7 lb per ft²) to produce and maintain a healthy plankton bloom. At the appropriate time (perhaps December) the brood fish would be placed in the pond at a stocking rate of about 150 kg per 100 m² (e.g., 100 fish averaging 500 g per fish). The fish are fed an artificial diet in addition to the natural food, adjusting the amount to produce a healthy fish, but not too fat a fish, since fat reduces the number of eggs that are developed in a female.

When the water begins to warm in the spring and the fish show signs of maturity, the brood stock are carefully selected for size, sex, and condition and transferred to special spawning ponds 50 to 100 m² in area and 0.5 to 1.0 m in depth (538 to 1076 ft² and 19 to 39 in. deep). The sex ratio used by the breeders in China varies from 1 female to 3 males, but there are exceptions depending upon the breeder's experience and preference.

The eggs of the common carp are adhesive and, when deposited by the female, cling to aquatic plants or other materials. To collect the spawn the breeder simply suspends bunches of aquatic plants or other fibrous material in the pond, either from poles arranged along the bank or from pieces of wood or rafts floating on the surface and anchored to the bottom. After spawning, the spawn collectors with the eggs are transferred to special containers for hatching and rearing (frequently 10 to 50 m² in area and 15 to 60 cm in depth, or 108 to 540 ft² and 6 to 23 in. deep). During this period the fry are fed a variety of very fine foods (egg yolk, soybean liquor and curd, etc.), or even better, whatever plankton organisms might be available. This

is a critical stage in the rearing of young carp and a mortality of 50% or higher is common. When the fry reach a length of about 2.5 or 3.0 cm (1 or 1.25 in.) they are transferred to rearing ponds or shipped to other areas.

Other fish are suitable for pond culture because of their unique breeding habits. One example is tilapia, which are mouthbreeders—the males collect the eggs, incubate them in their mouths, and shelter the young until they are free-swimming and able to fend for themselves. Another example is the snakehead, which is an airbreather—the males build a nest of air bubbles on the surface of the water among the aquatic vegetation, place the eggs in the nest, and guard them until the young are free-swimming; the nests can be easily collected in a dipper and transferred to nursery containers for rearing.

Unlike the common carp, for many years the only source of supply for fry of grass carp and the other carp-like fish for culture had to be obtained from natural spawning that occurred in the lower reaches of most of the rivers in China. These spawning areas are located in the river channels where the currents and other characteristics are such as to attract the spawning fish. The areas are well known to the professional fry collectors and, at the first indication of eggs or fry in the river, the traps are placed in the water below the spawning area to collect the fry. There are thousands upon thousands of traps that operate along the banks of the rivers and the operations of the fry fishermen, through generations of training and experience, are both practical and efficient.

The most common gear for collecting the young fry are floating traps, triangular in shape, with a round, semi-round, or rectangular mouth, and discharging into a square pen of fine-meshed netting. The nets were formerly made of ramie fiber but are undoubtedly made of synthetic twine at the present time. As might be expected, there is a great variation in size and design of these traps. Generally the length is 4 or 5 m (13 to 16 ft), the mouth 1 to 4 m (3 to 13 ft) in width and depth, and a trap opening 10 to 15 cm (4 to 6 in.), depending upon the size of fry. The traps may be fished singly, in gangs of 4 to 7, with or without wings, and placed at the surface or at depths up to 2 m (6 ft). The traps are operated in the river either from anchored, floating bamboo poles or from poles driven into the bottom.

There are a variety of other types of gear used in the collection of fry, ranging from the common dip nets and push nets to beach seines and permanently installed traps. The species of fish and the spawning usually dictate the best gear to use. For example, mullet fry are usually collected from the estuaries and river mouths where there is little current and the conventional type of trap would be useless.

The nets take a variety of fry that are spawned in the river above. Although the fry can be identified by certain body characteristics, no attempt is usually made to sort the catches by species because of the small size and fragile nature of the fry. Fortunately, however, there are slight differences in the times of spawning for the various species which provides some species dominance in the catch. The size of the fry and the rate of growth

also allow the catches to be partially separated by screening. The resulting collections, whether screened or not, are sold on the basis of a sampling of each lot. The farmer will balance the mixture in his ponds with older fish, if necessary, at a later date and when the fish are hardier and easier to handle.

Formerly, when a sufficient number of fry had been collected, the fry were sold to a middleman (a fry merchant) who would readily travel up and down the rivers contacting the various local fishermen. The middleman operated his business as a monopoly, more or less fixing the price he wished to extort from the culturists, and even on occasion releasing some of the fry when there was a surplus and the price was too low. The fry were usually sold in two basic units: a *wan* of about 10,000 fry or a *bowl* of 800,000 fry. Prices, of course, would fluctuate widely from season to season and within the season in accordance with the numbers available and the demand.

The middleman usually operated a series of nursery ponds in connection with his business, placing the fry in the ponds as soon as possible after collection. These ponds were about 6 or 7 m (13 to 16 ft) in length and breadth, relatively shallow, and shaded in the summer to prevent overheating. The location was preferably near the seashore where brackish water could be mixed with the freshwater in order to reduce the mortality of the young fish.

In the vicinity of Canton the middlemen have specialized in rearing the fry and young fish to a length of about 15 cm (6 in.) before distribution. Over the years fish of this size have proven to be much hardier than the younger fish and can be easily shipped to fish farms throughout China and even distant countries, such as Malaysia, Singapore, etc. The ponds were usually 5 to 6 m long and 30 cm deep (16 to 20 ft long and 12 in. deep) arranged in a series separated by only a low dyke and with enough slope to allow some flow of water. If no gradient was available, the farmers would frequently have to resort to the use of a treadle pump or other means creating some circulation of water in the ponds.

These middlemen/growers sold the young fish in two basic sizes: 7.5 to 12 cm in length (3 to 5 in.) and 12.5 to 18 cm in length (5 to 7 in.). To separate the fish into different size groups, a screen made of bamboo slats is placed in the pond—the smaller fish can escape through the slats and the larger ones are retained for sale. The middleman/grower frequently controlled the growth of the fish by feeding or crowding to obtain the size of best price in the market. Normally all fish were sold within 2 or 3 months of collection.

The shipment of the fry from the middleman to the farmer is made in a number of ways depending upon the distance involved, weather conditions, species, etc. Originally the containers were of rattan or bamboo, closely knit, and treated to hold water. More recently, kerosene tins have been substituted for the knit baskets and have been used where the distances are short. For longer hauls the fry were frequently transported in boats, or "live barges," with holds so constructed that water could circulate continuously through the tanks and without pumps. Because of the extensive network of canals and waterways in the plains area of China, transportation of fry by

“live barge” was the standard method used for many years. The mortality, however, was still high and a loss of 50% was often anticipated by the middleman and the cost of such loss included in the delivered price.

At the present time, the distributors have adopted the familiar method of using plastic bags for transporting fry and young fish, filling the bags with oxygen and placing them in a cardboard carton or other container for shipment. This method is commonly used by culturists throughout the world and has reduced markedly the fry mortality that was formerly experienced by the middlemen.

The most significant advance in the culture of freshwater fish in China in recent years has been the development of hormone-induced spawning in grass carp, black carp, silver carp, and bighead. The first success in the artificial propagation of carp was in 1958 when, with the assistance of Russian experts, silver carp and bighead were induced to spawn by injection of a pituitary extract from carp. Since then, the use of hormone-induced spawning for the cultured carp species has rapidly expanded to fish breeding centers in all the provinces and has gone far to increase and stabilize production of freshwater fish farms.

A recent visit by a group of fisheries experts provides a good description of the artificial breeding techniques now practiced at the Fish Breeding Farm near Shanghai (Anon. 1976).

Brood stock are kept in separate ponds of 3 to 5 mu area²; the species are mixed in these ponds which contain only 10 to 15 brood fish per mu and they receive special care. Spawning of the family fish in this region occurs in May and June when water temperatures are increasing from 18° to 25°C (64° to 77°F). Silver carp spawn earliest followed by bighead, then grass carp and finally black carp. As a species matures, 5 or 6 females and 7 to 9 males are placed in a special cement-lined spawning pond, oblong in shape, 25 m (82 ft) in length, 10 m (33 ft) in width, 1.3 m (51 in.) in depth and with a good flow of water to simulate conditions of natural river spawning sites. To induce spawning, these fish are injected in mid-afternoon with pituitary extract from common carp, or (except for grass carp), a commercial preparation of gonadotropin. (The dosages used range from 2 to 8 mg of dried pituitary extract or 500 to 1000 IU of gonadotropin per kilogram of spawner.) Spawning takes place the next morning about 4:00 or 5:00 A.M. The fertilized eggs are collected in traps at the outlet end of the spawning pond and transferred immediately to special circular incubating tanks about 8 m (26 ft) in diameter. These tanks, constructed of concrete, consist of 2 concentric circular channels which are about 1.5 m wide and 1.5 m deep (57 in.). A good flow of water is maintained in the circular channels by injecting the inflow of water through a series of flanged nozzles protruding along the bottom and directed horizontally around the circle. An adequate flow (0.3 to 0.5 m per sec) is maintained to keep the eggs and developing fry in suspension. The capacity of this size of incubating tank is 30 million eggs (20 million in the outer

² 1 mu = 99.15 m² (approx 1066 ft²).

channel and 10 million in the inner channel). The eggs hatch after one day in the incubation tank but are held there for an additional 6 or 7 days. By this time they are about 6 mm in length and are ready to begin feeding.

The modern fish farm in China consists of a series of specially designed ponds, each serving a certain function. The site of the farm is important and, where there is a choice, it is important that the land have sufficient slope to provide for a natural flow of water from pond to pond. Much attention is also given to water quality (mineral content, alkalinity, etc.) and to exposure to the weather (both sun and winter winds). The selection of a site safe from inundation from floods is perhaps most difficult because of their natural association with water.

Most of the larger ponds are still made of dirt, with banks sloped to minimize erosion and to provide a surface for production of natural food for the fish. Where necessary, the banks of the ponds are strengthened with rock-work. At the present time an increasing number of ponds, particularly those used for spawning, incubation of eggs and the rearing of the very young fry, are being constructed of concrete.

Preparation of the ponds generally follows the traditional methods practiced by fish farmers for centuries. Ponds which have been in use for several years are cleaned during the winter months. Accumulation of organic material is removed from the bottom, and the pond is treated with lime, rotenone, or one of the natural organic poisons (*Camellia*, *Croton*, etc.) to eliminate undesirable predators and other pests. The pond is then left exposed to the sun to "cure" before filling and stocking.

Probably the most difficult phase of freshwater pond culture concerns the proper application of fertilizers, in order to produce the optimum concentration and species composition of plankton organisms to satisfy the food preferences of the various kinds of fish in the pond. Each pond differs in



Fig. 24.2. Series of dirt-banked ponds at Chingphu Provincial Freshwater Fish Farm. Courtesy of K. Kondo, Tokai-ku Fisheries Research Institute, Tokyo.

water quality, mineral balance, and naturally occurring nutrient chemicals and materials. The kinds of fertilizers applied are related to the type of natural food eaten by the fish. The amount of fertilizer needed depends not only on the stocking rate and kinds of fish in the pond, but on weather conditions (i.e., temperature, sunshine, amount of rain, etc.). These same weather factors, in turn, affect the growth and feeding habits of the fish. Too much fertilizer can easily produce a superabundance of plankton which will deplete the oxygen supply and kill all the fish in the pond. There have been endless experiments conducted in China on the proper rates of fertilization of the ponds and the ultimate yield in terms of fish. There is still much to be learned.

Through trial and error the Chinese fish farmer has developed a feel for pond fertilization, based on color and transparency of the water and the growth and behavior of his fish. Most fish farmers still prefer to use organic materials, including pig and cow manure, droppings from ducks or other fowl, nightsoil, rice bran, soybean and peanut meal, and organic compost. Ponds rich in nutrients (or heavily fertilized) are suitable for such fish as silver carp, bighead, common carp, crucian carp, and tilapia, and especially for duck-*cum*-fish and hog-*cum*-fish farms. Ponds low in nutrients, and with an abundance of grass and weeds from nearby fields, should be used predominately for the culture of grass carp. Predator fish (snakehead, mandarin fish, *Elopichthys bambusa*, etc.) should be used sparingly in a mixed culture pond and be provided with suitable forage fish (*Xenocypris* sp., etc.) (Chen 1973).

In the last 10 years, much attention has been given to the use of superphosphates and other inorganic fertilizers to supplement the organic fertilizers or to serve as the sole source of added nutrients. Although the results of experiments show the added production that can be obtained from a pond by using inorganic fertilizers, the Chinese fish farmer still prefers to use organic fertilizers, except in those areas where the supply is limited.

Most of the fish farmers in China plan to harvest their fish by the end of the second year, allowing time to drain their ponds and prepare them for the next season's fry. The very fast growing fish, such as tilapia, are marketed the year round. Silver carp are marketed as soon as they reach the weight of about 500 g (18 oz). The remaining species are usually not ready for marketing until fall, or are even held until the New Year to take advantage of the higher demand and price.

With very few exceptions, polyculture of freshwater pond fish is almost universally practiced in China at the present time and there is almost an infinite "mix" of species available to the fish farmer. There are many factors that influence his choice of "mixes," generally very practical. For example, his decision is based on the kinds of fry available, past successes and failures, projected market demand, various inducements from the commune or the government, etc. Basically, of course, the farmer is concerned with creating the right balance in his ponds, both between species competing for similar food and groups of fish with different food habits, so that he

will utilize the entire productive capacity of a pond. Examples of a variety of mixes of fish are given in Table 24.2.

The same is true in Taiwan. For example, the stocking rate (fry per hectare) for a freshwater pond in central Taiwan is given as: 800 silver carp (7 to 12 cm or 3 to 5 in.); 100 bighead (7 to 12 cm or 3 to 5 in.); 50 grass carp (7 to 12 cm or 3 to 5 in.); 1000 mud carp (5 cm or 2 in.); 2000 mullet (5 cm or 2 in.); and 1000 common carp (2.5 cm or 1 in.). All fry were put into the pond in March or April. In southern Taiwan the stocking rate (fry per hectare) was: 1000 silver carp (10 to 13 cm or 4 to 5 in.); 400 bighead (10 to 13 cm or 4 to 5 in.); 200 grass carp (12 to 15 cm or 5 to 6 in.); 500 mud carp (7 to 10 cm or 3 to 4 in.); 2000 common carp (3 to 4 cm or 1 to 1.5 in.); 2000 crucian carp (3 cm or 1 in.); 2000 mullet (5 cm or 2 in.); 500 walking catfish (5 cm or 2 in.); and 500 snakehead (10 cm or 4 in.). Most of the fish were introduced in February and March, walking catfish in May, and snakehead in June (Chen 1973).

Rice Paddy Culture

Since the early 1950s, the government has encouraged cooperatives and communes to culture fish in rice fields, pointing out the multiple benefits of such ventures. For example, in addition to the added yield from the fields, the fish would eliminate mosquitoes and other insect pests, cultivate the plants by their constant digging, and provide fertilization from their feces. Originally common carp and the related golden carp were used in the paddies, but more recently silver carp, bighead, and snakehead have been proving profitable. Grass carp is not recommended until after harvest and the paddy is lying fallow.

The deep water method of culture is used in the northern provinces of Szechwan, Kweichow, Kwangsi, and Hupeh, where the depth of water in the rice fields may be as much as 0.5 to 0.8 m (19 to 31 in.). The growth of fish in the paddy fields is good; fry about 8 cm in length (3 in.) will weigh 250 to 500 g (9 to 18 oz) within 3 months. The yield of fish from a paddy is reported to be 35 to 75 kg per 100 m² (0.8 lb per ft²).

The shallow-water method is used in Kwangtung and other southern provinces, where the depth of water in the rice fields may be only 6 to 8 cm (3 in.). To allow the fish space to swim and hide, several ditches are dug in a criss-cross pattern in the field, about 20 cm in depth (8 in.) and with pockets 0.6 to 1.0 m deep (23 to 39 in.). Stocking at the recommended rate of 1000 to 1500 fish per 100 m² (0.9 to 1.4 fish per ft²) will produce fish 10 to 15 cm in length (4 to 6 in.) by the time the rice is ready for harvest (Solecki 1966).

Statistics on yield of fish from rice paddies are not known but the amount must be considerable for mainland China. In 1958 one report stated that about 10% of all rice paddies in China were also being used for the culture of fish. Following the pressures of the Great Leap Forward and the Cultural Revolution, the amount is certain to have increased.

TABLE 24.2. SPECIES, SIZE, AND RATE OF STOCKING PER 100 M² OF A POND OF MIXED SPECIES

Grass Carp		Black Carp		Silver Carp		Bighead	
Size (cm)	No.	Size (cm)	No.	Size (cm)	No.	Size (cm)	No.
15-18	2,000-4,000			11-12	8,000-12,000		
15-18	4,000-8,000			8-9	20,000-25,000		
8-12	10,000-25,000			11-12	4,000-5,000	11-12	8,000-12,000
15-18	2,000-4,000					8-9	15,000-20,000
12-14	4,000-6,000					11-12	4,000-5,000
8-12	10,000-25,000	12-14	5,000-6,000	12	4,000-5,000	¹	200-250
		14-15	5,000-6,000			11-12	4,000-5,000
		12-14	5,000-6,000			¹	200-250
		9-12	10,000-15,000				
15-18	2,000-4,000	12-14	400-600	11-12	8,000-12,000	11-12	8,000-12,000
12-14	2,000-4,000	12-14	400-600			²	150-200
8-12	10,000-25,000			¹	50-60		

Source: Anon. (1973).

¹Number not given, weight 500 to 750 g per fish.

²Number not given, weight 500 to 625 g per fish.

Open Water Culture

Production of fish in lakes and rivers, or "fish ranching," has been conducted in China for at least 100 years. Many of the rivers and lakes were owned by the local landlords and held for their own use and development. The yield in 1936, a peak year, was 25 to 30% (about 370,000 MT) of the total landings. Production from fish culture would probably account for 8 to 10% of the amount and the remainder would be from conventional fisheries on the rivers and lakes.

There was little attempt in the earlier years to farm these natural bodies of water. There were regulations, of course, either by the private owners or in a few instances by the government. Unique, perhaps, was the utilization of parts of the canals for fish culture. Weirs were installed in the channels, of bamboo or other material that could be opened to let the boats pass up and down the canal. These fenced areas were stocked with fish which in due time were caught and marketed. The canals (as well as the rivers and flowing lakes) could not be fertilized because of rapid dilution. With the exception of grass carp, the use of artificial foods was limited.

However, the Water Conservation Program of the Great Leap Forward (1958–1960) placed renewed emphasis on the fishery production of the inland waters. During the first two years, 1958–1959, some 47 large reservoirs, 3000 large irrigation projects, and 26,000 small and medium-sized projects were completed—many by local cooperatives and communes and without the use of heavy equipment.

There were many problems, however, in the realization of full reservoir use. Many of the reservoirs were in mountainous areas where little fishing or fish culture had taken place in the past. Also, during construction, little thought was given to the needs of the fishing industry and the bottoms were left with stumps and other debris, restricting the choice of gear that could be used. The first years after completion of the program were disappointing for fisheries.



Fig. 24.3. A bamboo fish fence in a canal showing a central opening, flexible at the top, which allows boats to slip through. Courtesy of K. Kondo, Tokai-ku Fisheries Research Institute, Tokyo.



Fig. 24.4. Harvesting fish from one of the ponds at Chingphu Provincial Freshwater Fish Farm. Courtesy of K. Kondo, Tokai-ku Fisheries Research Institute, Tokyo.

However, in time small areas were cleared in some of the reservoirs to allow fishing with seines and traps. More important were the attempts to stock the reservoirs with fry in order to increase production from the inland waters. The recommended stocking rate was 100 to 150 fish (12 to 14 cm in length, or 5 to 6 in.) per 100 m² (1076 ft²). Grass carp, silver carp, and black carp so introduced were expected to reach an average weight of about 5 kg (11 lb). The yield from these early attempts was disappointingly low, on the average about 8 kg per ha (7 lb per acre) (Solecki 1966).

It would appear from recent reports that many of the difficulties have been overcome. For example, present annual rates of production are: 900 to 1800 kg per ha (800 to 1600 lb per acre) in screened-off sections of rivers and canals; 300 to 450 kg per ha (267 to 400 lb per acre) in natural lakes; and 180 to 300 kg per ha (160 to 267 lb per acre) in reservoirs (Anon. 1974).

Other Freshwater Culture

During the past 20 years the Chinese have conducted a number of experiments with the introduction and culture of various freshwater species. Tilapia were introduced into mainland China from Vietnam in 1958 and are now extensively cultured. Although elvers have been trapped and exported to Japan since 1968, eel culture on a commercial scale was established in mainland China about 1970. Rainbow trout from North Korea, and bullfrogs from Cuba have been introduced into mainland China but the success of the transplants is not known. There no doubt have been other attempts to introduce new species into China (various kinds of oysters,

shrimp, etc.) that have escaped attention in this review. Of interest to culturists are the experimental studies on the rearing of freshwater clams at Chinphu Fish Breeding Farm near Shanghai for freshwater pearl production and to supply food for eels and black carp.

MARINE AQUACULTURE

Development of marine aquaculture in China has not progressed as rapidly as the program for freshwater fisheries. There are three basic reasons for this: the long history and experience of the Chinese fish culturists in freshwater fisheries; the close association with the Water Conservation Programs of 1958–1960 and 1967–1969; and the common interests of the agriculture cooperatives and communes in farming and fish culture. The history of marine aquaculture began about 300 years ago in the Pohai Sea area but expansion was limited by the availability of suitable land.

The potential of marine aquaculture in China is enormous, with some 20,000 km (12,500 mi) of coastline, waters relatively rich in nutrients, and a combination of protected bays and channels to the south and low, flat coastal shorelands to the north. The total marine area suitable for culture has been estimated by several sources to be between 450,000 and 900,000 ha (1,112,000 and 2,223,000 acres), of which 60,000 ha (148,000 acres) were utilized in 1957, 120,000 ha (296,400 acres) in 1958, and 250,000 ha (617,000 acres) by 1959 (Kenji 1962).

Although considerable study by various research laboratories on the life histories and methods of culture of various marine seaweeds, fish, and shellfish was undertaken in the early 1950s, it was not until the Chang-chiang Conference of 1959 that a definitive program of marine aquaculture was adopted. The conclusions and recommendations reached at this conference included six main points. (1) Some important species can be cultured only in salt water. (2) Marine culture does not infringe upon the use of agricultural land. (3) Production from marine aquaculture is more stable than that from freshwater farming and provides a more stable supply of food to the consumer. (4) Seawater is rich in natural food and simplifies feeding with artificial foods. (5) Marine fish fry are abundant and can be easily collected and shipped. (6) Seawater is continually being moved by action of the tides and wind and the supply of nutrients and oxygen is constantly being replenished. As a result, 10 to 15 large culture farms were built by the government for growing seaweed, oysters, sea cucumbers, mullet, shrimp, scallops, crabs, octopus, and mussels (Solecki 1966).

Although the descriptions are not complete, there are apparently four types of marine culture: dyked ponds, fixed net enclosures, floating pens or rafts, and open shore culture.

The fish farms built along the Pohai Sea and in Kwangtung Province provide examples of dyked ponds. These farms consist of a series of ditches built in shallow, natural basins or in the intertidal zone of a suitable beach. The ponds are arranged with a main ditch about 6 m wide and 1.2 m deep (20

ft wide by 4 ft deep) and a series of side ditches separated only by low banks or dykes. The water exchange is controlled by a main gate, 2.5 to 3 m wide (8 to 9 ft) and 1.5 m (5 ft) high, and smaller floodgates at the entrance of each side ditch. The seaward bank of the farm is usually 65 to 90 cm (2 to 3 ft) higher than the maximum tide level. The ponds are usually rebuilt every spring, and before stocking seawater is allowed to circulate freely through the system to thoroughly clean the ponds and stabilize the salt content of the soil. After several cleanings, the ponds are stocked with gravid shrimp, egg-carrying crabs, or fish fry, which are allowed to grow until harvesting in the fall.

Raft culture is basically the same as used in Japan, consisting of a series of bamboo poles tied together by rope or wire in a rectangular shape, and supported by floats of wood, styrofoam, or oil drums. For culture of the various species, ropes are suspended from the bamboo poles with spat or spore collectors fixed to each rope at regular intervals.

Of course, the use of either natural or supplemental food is limited to ponds or pens where the fish are confined and where the food or nutrients are not rapidly dissipated by tidal currents. Organic fertilization (including a wide array of manures, vegetable and animal meals, etc.) is an integral part of the successful culture of milkfish and other marine species and must be used to provide an unidentified "life factor" that helps maintain the natural qualities of seawater. If fresh seawater or organic fertilizers are not added from time to time, the ponds soon become sterile and nonproductive (Lin 1968B).

Care must also be taken in the use of inorganic fertilizers. Surprisingly, the application of superphosphates or N-P-K fertilizers has little effect, if any, on increasing the production of milkfish. In fact, the application of these types of inorganic fertilizers may have a detrimental effect upon the production of plankton and bottom algae in saltwater ponds by stimulating the growth of nano-plankton organisms. These organisms are too small to be utilized by milkfish and multiply rapidly to cause turbidity, an oxygen deficiency, and high mortality to the fish (i.e., the so-called "yellow water").

On the other hand, it appears that silica is a limiting factor in milkfish production and the application of zeolite (72.95% SiO₂) will help to keep the water clear and maintain the bottom "algal pastures" during the period that milkfish are cultured in ponds.³

The practice of flooding the milkfish and other marine culture ponds with seawater three times a year, allowing the water to evaporate, and then filling and leaving stagnant to preserve the accumulated nutrients is a very effective way to increase natural productivity of the culture ponds.

There is little information available on the composition of diets and

³ Lin (1968B) states: "A preliminary experiment carried out in 1966 indicates the possibility that silica may be required for the maintenance of bottom algal pasture throughout the culture period and to keep the water clear to allow a better chance for algae to grow. Because of the clearing effect, the plague of "yellow water" may be reduced to the minimum.

methods of supplemental feeding practiced in mainland China. Several references (e.g., Kenji 1962) note the use of supplemental feeding in the culture of marine species but the details are lacking. In Taiwan, milkfish have been found to grow faster on supplementary food than on the natural bottom algae. Furthermore the best growth was obtained from diets high in flaxseed and peanut cake, and not rice bran usually used by milkfish farmers (Lin 1968A).

Unfortunately there are no national production statistics for fisheries from mainland China during recent years. In 1957 the production from mariculture was reported as 430,000 MT (473,860 ST) and for 1959, 1,000,000 MT (1,102,000 ST) (Kenji 1962). There are also numerous references to the relatively slow growth of production from marine farms, certainly significantly less than the growth of production from the freshwater fish culture⁴; kelp and certain shellfish are the exceptions. Although impossible to confirm, a good estimate of mariculture production at present might be 1.5 million MT (1,653,000 ST), or possibly 2 million MT (2,204,000 ST) at the most. However, it should be kept in mind that much progress has been made by scientists and culturists at the several research laboratories and stations in developing an understanding of the marine species and the necessary technology for an expanded mariculture program. It is in this field of aquaculture that we can expect the greatest advance by China in the future.

SPECIAL ACKNOWLEDGMENTS

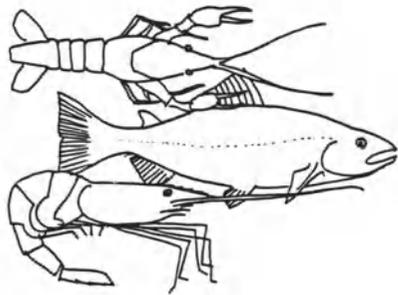
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⁴ The rapid advance in freshwater aquaculture during the first post-civil war years is attributed to the long history and tradition of freshwater fish culture, the natural association with agricultural cooperatives and communes, and the drive to fulfill the goals of the Water Conservation Programs of 1957–1959 and 1968–1969.

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Taiwan

FISH AND OTHER AQUATIC SPECIES

Bighead (<i>Aristichthys nobilis</i>)	Oysters
Carp	Perch
Catfish	Prawn
Clams	Sand shrimp (<i>Metapenaeus monoceros</i>)
Common carp (<i>Cyprinus carpio</i>)	Seaweeds
Crucian carp (<i>Carassius carassius</i>)	Shrimp
Eel	Silver carp (<i>Hypophthalmichthys molitrix</i>)
Freshwater clam	Tilapia (<i>Tilapia mossambica</i>)
Goldfish	Other brackish water fish
Grass carp (<i>Ctenopharyngodon idellus</i>)	Other freshwater fish
Grass shrimp (<i>Penaeus monodon</i>)	Other shellfish
Gray mullet (<i>Mugil cephalus</i>)	
Hard clam	
Japanese eel (<i>Anguilla japonicus</i>)	
Lobster	
Milkfish (<i>Chanos chanos</i>)	
Mullet	
Mullet roe	

Taiwan

Dr. Hsi-Huang Chen

Taiwan, with a group of over 70 small islands, lies between the East China and South China seas. The main island is subtropical and extends nearly 390 km (240 mi) north and south across the Tropic of Cancer. The maximum width is less than 150 km (about 90 mi).

Its total area is 35,980 km² (13,890 mi²), but about two-thirds is highly mountainous. It has a coastline of over 1600 km (994 mi). Along the eastern coast the deep waters abutting precipitous cliffs form a favorite highway for migratory fish from both the north and south. The gradually inclined shelf on the west abounds in marine resources and provides excellent grounds for the habitation and propagation of many species of fish.

Taiwan is roughly comparable in size to Belgium or the Netherlands, but with less arable land and more people. This small island supports a population of more than 16 million people, increasing at an annual rate of 1.8%. However, Taiwan's agricultural and fisheries production has increased rapidly enough to stay comfortably ahead of the domestic demand for food while at the same time steadily increasing exports of surplus commodities.

Fisheries production rose from a record catch of 119,520 MT (131,472 ST) in 1940 to 779,825 MT (857,808 ST) in 1975. This increase amounted to 552%. This rate of increase is second only to that of Peru.

Fisheries in Taiwan are classified, for statistical purposes, into four categories, on the traditional basis of type of fishing craft and gear used and the relative distance of fishing areas. These categories are deep-sea, inshore, coastal, and culture. According to 1975 statistics, the total catch of 779,825 MT was: (1) deep-sea, 41.9%; (2) inshore, 37.9%; (3) coastal, 3.8%; and (4) culture, 16.4%.

Fish culture ranked third in volume but first in value. Culturing, with 16.4% of production, accounted for 38.0% of value, deep-sea for 28.6% of value, inshore for 29.9%, and coastal for 3.5%. The value of cultured production in relation to volume indicates the culture of highly valued species (Table 25.1).

Cultured production in 1975 totaled 127,554 MT (140,565 ST), which was an increase of 11.4% over 1974. With respect to value, fish culture production totaled \$175,384,000 in 1975, an increase of 13.6% from 1974 (Table 25.2).

TABLE 25.1. FISHERIES PRODUCTION, TAIWAN, 1975

Category of Fisheries	Production (MT)	Production (ST)	Value (\$1000)	Quantity (%)	Value (%)
Deep-sea	326,707	360,031	131,664	41.9	28.6
Inshore	295,920	326,104	137,949	37.9	29.9
Coastal	29,644	32,668	15,917	3.8	3.5
Culture	127,554	140,505	175,384	16.4	38.0
Totals	779,825	859,367	460,914	100.0	100.0

Source: Anon. (1976).

In 1975 culturing included: (1) brackish water ponds, about 18,798 ha (46,431 acres), chiefly for milkfish but including some mullet and shrimp; (2) shallow seawaters for oysters and clams, about 13,480 ha (33,296 acres); (3) freshwater ponds, about 12,005 ha (29,652 acres), and pools and reservoirs about 9163 ha (22,633 acres), for raising carp, tilapia, eel, and mixed culture; (4) paddy fields in central and southern Taiwan for raising tilapia. These paddy fields covered about 115 ha (284 acres). Total water area devoted to culture in 1975 was 53,561 ha (132,296 acres) (Table 25.3).

The western coast of Taiwan, extending from Tanshui in the north to Tungkang in the south with a total length of 400 km (240 mi), is characterized by tidal lands having sandy bottoms exposed above water at low tide. This area is utilized by coastal villagers for culture of shellfish and seaweeds.

The brackish water ponds are constructed on the tidal lands for monoculture of milkfish, mullet, and shrimp. They represent an ecosystem which is basically different from that of freshwater ponds.

Shallow-water culture is usually conducted by coastal households on a part-time basis. Thus the average size of each unit is small. The average cultured area per household in 1972 was 0.78 ha (1.9 acres). In general, 80% of the shallow-water culturing units are less than 0.5 ha (1.25 acres) and are part-time enterprises. Those households with over 0.5 ha are either full-time enterprises or consider culturing a major sideline.

The freshwater ponds on the coastal plain are richer in minerals and are generally more productive than those on the higher levels in the interior. Many freshwater ponds are polluted by sewage from villages and cities. *Tilapia mossambica* constitutes the principal biological unit of the ecosystem in coastal plain ponds. In the same ponds silver carp, grass carp, goldfish, common carp, gray mullet, eel, and milkfish are also stocked.¹

The pools and reservoirs lie some distance from the coast at altitudes of 20 to 500 m (65 to 1620 ft) above sea level. They are chiefly for carp production. Also grown are silver carp, bighead, goldfish, grass carp, gray mullet, catfish, and perch.

¹Silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idellus*), common carp (*Cyprinus carpio*), gray mullet (*Mugil cephalus*), eel (*Anguilla japonicus*), milkfish (*Chanos chanos*), bighead (*Aristichthys nobilis*), and tilapia (*Tilapia mossambica*).

TABLE 25.2. FISH CATCH, CULTURED PRODUCTION, AND VALUES, TAIWAN

Year	(MT)	Totals		Cultured Fish Industry		Cultured Fish % of Total		
		(ST)	Value (\$1000)	(MT)	(ST)	Value (\$1000)	Quantity	Value
1941	85,336	94,040	1,241	12,338	13,596	148	14.46	11.89
1946	51,474	56,724	33,492	9,970	10,987	9,838	19.37	29.39
1951	104,180	114,806	11,650	24,966	27,513	3,489	23.96	29.95
1956	193,410	213,138	31,917	42,480	46,813	8,136	21.96	25.49
1961	312,439	344,318	66,957	57,354	63,204	18,535	18.36	27.68
1966	425,326	468,709	102,549	58,515	64,484	20,855	13.76	20.34
1971	650,188	716,507	221,495	77,789	85,723	46,448	11.96	20.97
1972	694,330	765,152	282,379	81,236	89,522	69,644	11.70	24.66
1973	758,484	835,849	377,475	107,489	118,453	108,550	14.17	28.76
1974	697,871	769,054	405,772	114,472	126,148	128,290	16.40	31.62
1975	779,825	859,367	460,914	127,554	140,565	175,384	16.36	38.05

Source: Anon. (1976).

TABLE 25.3. AREA¹ USED FOR FISH CULTURE BY TYPE OF CULTURE, TAIWAN

Year	Brackish Water Pond	Shallow Sea Culture	Fresh- water Pond	Paddy Field	Reservoirs and Others	Total
1956	14,178	5,704	4,938	7,328	7,400	39,547
1961	17,095	9,743	4,938	927	7,552	40,254
1966	15,587	9,822	5,336	123	7,261	38,129
1971	16,461	11,877	8,094	55	6,851	43,338
1972	16,744	12,943	10,275	26	7,180	47,167
1974	17,137	13,151	11,686	128	7,818	49,920
1975	18,798	13,480	12,005	115	9,163	53,561

Source: Anon. (1976).

¹Figures indicate hectares. To determine acres multiply by 2.47. For example, 115 ha is 284 acres.

The eel ponds lie either along the coastal plain or in the interior close to the hill area.

The ecosystem of individual ponds never remains the same. Because of this, fish production varies considerably from year to year and from pond to pond. For example, ponds or reservoirs on the high land in the interior may produce only 100 kg per ha per year (89 lb per acre) while those constructed on alluvial soil on the coastal plain may yield more than 500 kg per ha (445 lb per acre) annually without fertilization or supplementary feeding. A coastal pond under identical treatment could yield more than 2000 kg per ha per year (1781 lb per acre).

In 1975 the yield from fish culture amounted to 127,554 MT (140,565 ST) valued at \$175,384,000. Milk fish was predominant with production of 33,309 MT (36,707 ST) valued at \$33,778,000. Tilapia ranked second with 18,260 MT (20,123 ST) valued at \$6,262,600; then carp with 17,419 MT (19,196 ST) valued at \$10,633,952; and eel with 13,575 MT (14,960 ST) valued at \$83,753,315 (Table 25.4).

Also cultured were 13,850 MT (15,263 ST) of oysters, valued at \$20,843,501, and 12,481 MT (13,754 ST) of clams valued at \$7,267,639.

MILKFISH (*Chanos chanos*)

It is generally believed that the culture of milkfish in Taiwan dates back to the Ching Dynasty about 300 years ago. The Chinese fish farmers who migrated to Taiwan built dykes on the low land along the coast of the southern prefecture of Tainan and stocked these ponds with milkfish fry obtained from the littoral waters. About 1910 a fish culture station was established in Tainan, Taiwan, to conduct experiments in milkfish culture. At present milkfish farming is very important in the cultured fish industry. With the use of chemical fertilizers and pest control measures yields as high as 5700 kg per ha (5096 lb per acre) have been reported. Average yields are over 2000 kg per ha (1781 lb per acre).

Milkfish ponds are located in areas where: (1) the temperature is above 15°C (59°F) for eight months of the year; (2) there is little likelihood of

TABLE 25.4. VOLUMES¹ AND VALUES² OF FISH CULTURE PRODUCTION BY MAJOR SPECIES, TAIWAN, 1975

Species	Total		Brackish Water Pond		Freshwater Pond		Shallow Sea Culture		Paddy Field		Reservoirs and Others	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Carp	17,419	10,633	—	—	12,803	8,010	—	—	95	51	4521	2572
Tilapia	18,260	6,263	4,355	1,279	12,565	4,552	95	29	110	38	1044	365
Eel	13,575	83,754	17	95	13,516	83,400	—	—	1	2	41	257
Other fresh-water fish	3,466	2,323	8	4	2,784	1,960	—	—	60	41	614	318
Milkfish	33,309	33,778	33,164	33,631	145	147	—	—	—	—	—	—
Mullet	1,355	1,932	185	313	1,141	1,576	29	43	—	—	—	—
Other brackish water fish	1,346	207	1,189	182	38	7	115	18	—	—	4	0.3
Lobster, prawn, and shrimp	775	1,672	684	1,564	85	104	—	—	—	—	6	4
Oyster	13,850	20,844	3	4	—	—	13,847	20,839	—	—	—	—
Hard clam	12,481	7,268	1,570	836	—	—	10,911	6,432	—	—	—	—
Freshwater clam	1,375	577	—	—	604	305	—	—	—	—	771	252
Other shellfish	3,238	3,143	197	806	22	11	2,905	2,301	—	—	114	25
Total	120,449 ³	172,374 ³	41,372	38,714	43,794	100,072	27,902	29,662	266	132	7115	3793

Source: Anon. (1976).

¹Quantities given in metric tons. For short tons multiply by 1.1023.

²Quantities given in thousands of U.S. dollars, computed at the rate of 37.7 Taiwanese dollars to each U.S. dollar.

³Differs slightly in volume and value from data given in Tables 25.1 and 25.2.



Fig. 25.1. Harvesting cultured milkfish. Courtesy of Dr. Hsi-Huang Chen.

flooding; (3) the pond water is not likely to be seriously diluted during the rainy season; and (4) freshwater is available to adjust the pond water to a salinity of not over 50‰ during the dry season.

The main problem in milkfish farming in Taiwan is high mortality in the wintering ponds. The causes of high mortality are (1) low temperatures and (2) oxygen deficiency. To avoid chilling of the waters by the strong winter winds, milkfish farmers construct wintering ponds with narrow ditches between 1 and 2 m (39 and 78 in.) in depth and protected on the windward side by windbreaks. The milkfish are placed in the wintering ponds in October and held there until March, when they are transferred to the rearing ponds.

Harvesting begins at the end of May. About eight partial harvests of market-size fish are made before the middle of November. Then the rearing ponds are drained of water after netting and any fish left over are picked up.

The fish are packed in bamboo baskets, loaded onto trucks, and taken to the market. Crushed ice is spread on top of each basket to maintain quality. Milkfish are sold in the domestic market only. Farm prices in 1975 averaged \$1.01 per kg (\$0.46 per lb). Total production was 33,309 MT (36,707 ST) (Table 25.5).

TILAPIA (*Tilapia mossambica*)

Tilapia were first introduced to Taiwan from Singapore in 1974. They are raised in brackish and freshwater ponds as well as paddy fields. They have

become one of the most important cultured fish in Taiwan, ranking second in volume only to milkfish in 1975. They are, however, a low-valued fish. Farmer prices in 1975 were only \$0.34 per kg (\$0.15 per lb) (Table 25.5).

In Taiwan tilapia start to spawn at four months. The number of eggs from each spawning increases with the age and size of the fish, varying from 100 to over 1000. The number of spawnings by one fish in one year ranges between 6 and 11 in southern Taiwan. The interval between spawnings is generally 22 days. Optimum water temperatures for spawning range from 20° to 35°C (68° to 95°F).

One of the more interesting developments is the utilization of wastes for tilapia farming. For example, there are about 30 ha (74 acres) of fish ponds situated along drainage canals in Taiwan which use sewage water from the canals to supply nutrients and food for the fish. During the winter tilapia are moved into wintering ponds. At this time rearing ponds are thoroughly dried. Then the sewage water is let into the ponds and allowed to evaporate. After the pond bottoms are thoroughly dried the process is repeated. This process is done 3 to 4 times before the fish are stocked from wintering ponds in March. Generally, no supplementary feeds are given. Selective harvesting begins about 40 days after stocking and is continued at intervals of 10 to 15 days. The annual yield is 6500 to 7800 kg per ha (5789 to 6947 lb per acre).

Beginning in 1972 tilapia culture in combination with hogs or ducks became popular. Many farmers found rice farming to be unprofitable due to low prices and high labor costs. They converted their rice paddies into fish ponds and built pigsties or duck houses beside the ponds. The excretions of the hogs or ducks are diverted into the ponds, with or without fermentation, to serve as fertilizers and/or feeds. Since 1972 more than 5000 ha (12,350 acres) of paddy fields have been converted into fish ponds. It is estimated that 50 to 70 hogs or 2000 ducks can supply sufficient fertilizer and feed for fish in a 1 ha (2.47 acres) pond.

TABLE 25.5. VOLUMES AND VALUES OF FISH CULTURE PRODUCTION BY MAJOR SPECIES BY KILOGRAMS AND POUNDS, TAIWAN, 1975

Species	Quantity Harvested (1000s)		Value	
	(MT)	(ST)	(\$ per kg)	(\$ per lb)
Carp	17,419	19,196	0.61	0.28
Tilapia	18,260	20,122	0.34	0.15
Eel	13,575	14,961	6.17	2.80
Other freshwater fish	3,466	3,820	0.67	0.30
Milkfish	33,309	36,707	1.01	0.46
Mullet	1,355	1,493	1.42	0.65
Other brackish water fish	1,346	1,483	0.15	0.07
Lobster, prawn, shrimp	775	854	2.16	0.98
Oyster	13,850	15,263	1.50	0.68
Hard clam	12,481	13,754	0.58	0.26
Freshwater clam	1,375	1,515	0.41	0.19
Other shellfish	3,238	3,568	0.97	0.44
Total	120,449	132,736	—	—

Source: Computed from Table 25.4.

Fish farmers harvest tilapia of marketable size many times during a rearing season to avoid overcrowding and to obtain money for farm and household expenses. Tilapia are harvested and marketed nearly every day of the year. In some fish stalls in rural areas of southern Taiwan, only tilapia and mullet can be found in December and January.

Tilapia are usually sold fresh iced but live fish bring a better price.

JAPANESE EEL (*Anguilla japonicus*)

The climate of Taiwan is ideal for eel farming. However, the eel industry did not really grow until 1970, mainly due to the lack of demand. Since 1970 increased demand from Japan has resulted in higher prices for seed eel (elvers) and market-size eel. The total area used for eel farming increased from 60 ha (148 acres) in 1966 to about 830 ha (2050 acres) in January 1972. In 1976 it was in excess of 1600 ha (3952 acres). Although eel culturing in Taiwan has a short history, it appears still to offer great potential.

Eel ponds require plenty of freshwater and should be located in areas of good water supply, both quantitatively and qualitatively. The water should be free from pollution and have a pH between 6.5 and 8.0. Most eel ponds in Taiwan use underground water from deep wells but irrigation water is also used in some parts of northeastern Taiwan. Most eel-rearing ponds have concrete or brick walls and sandy bottoms, although some are mud ponds with steep earthen embankments. It is claimed that if the water quality is

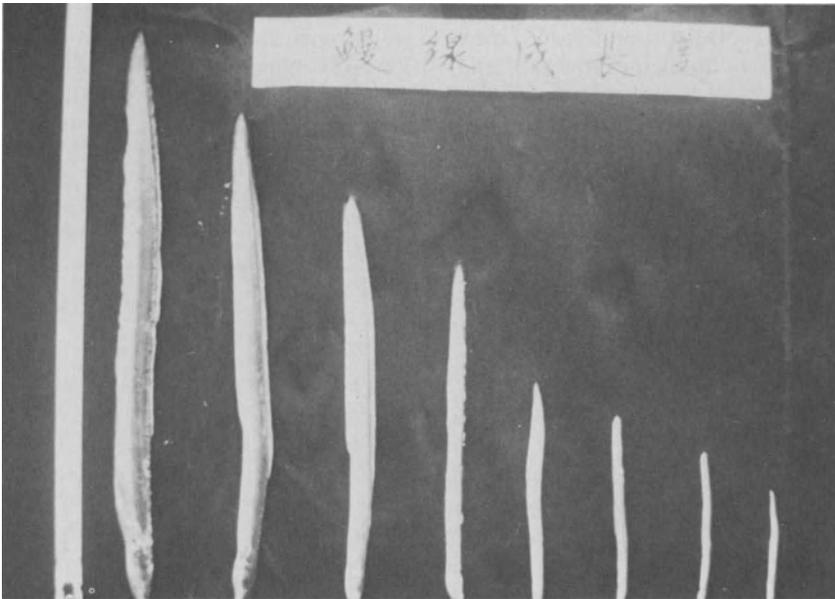


Fig. 25.2. Elvers (eel) at different stages. Courtesy of Dr. Hsi-Huang Chen.

good and the eels are well fed they will not try to escape, even from ordinary fish ponds with earthen banks.

From June to September, when some of the eels have reached marketable size, they are selectively harvested daily or every few days at feeding times. A net placed below the feeding platform is used.

Eels are sold either in the domestic market or exported to Japan. For transportation over short distances, the eels are first chilled in ice water to put them in a state of suspended animation and then put in bamboo baskets over which ice water trickles. For export to Japan, the previously chilled eels are put into a plastic bag with a small quantity of water. The bag is then filled with oxygen. Two such bags are encased in a strong carton for shipment by air.

The average farm price in 1975 was \$6.17 per kg (\$2.80 per lb). Total production was 13,575 MT or 14,960 ST (Table 25.6).

Exports increased from 950 MT (1047 ST) in 1970 to 7924 MT (8732 ST) in 1975. In 1970 foreign exchange earnings were \$3,325,000 while in 1975 they amounted to \$50,700,000 (Table 25.6). The export price in 1970 averaged \$3.50 per kg (\$1.59 per lb) and in 1975 averaged \$6.40 per kg (\$2.91 per lb). The domestic market in 1975 accounted for 42% of the market and the export market claimed 58%.

GRAY MULLET (*Mugil cephalus*)

Traditionally the dried roe of mullet is considered a gourmet food by Chinese people. Thus the gray mullet is one of the important commercial fish in Taiwan.

Mullet migrate southward in many schools for spawning. As they enter the Taiwan Strait they head toward the central part of the west coast of Taiwan and then proceed southward along the coastline. During the period of December to January mullets are captured and the roe are dried for local consumption and export to Japan.

For mullet culture the fingerlings are normally taken from estuaries along the west coast of Taiwan from December to March, for stocking in fresh and brackish water ponds. In the mid-to late 1970s the catch of fingerlings from natural waters was poor; thus a shortage of supply occurred.

In order to produce fingerlings by artificial propagation, Tungkang Marine Laboratory (also known as Tungkang Shrimp Culture Center) has carried out experiments for six years during the mullet spawning season. Significant success was achieved from 1969 to 1973. According to the last report from Tungkang, a total of 431 hatched larvae were obtained, measuring 3.28 cm (1.5 in.) and weighing 0.34 g on the forty-fifth day. They were about 1.5 times larger than the fingerlings normally collected from natural waters and were robust and strong. Some of them were stocked in fishponds and grew to 28.1 cm (11 in.) and 217.4 g (8 oz) by the two hundredth day.

In 1975 total mullet culture production was 1355 MT (1493 ST) (Table

TABLE 25.6. EEL EXPORTS FROM TAIWAN TO JAPAN

Year	Eel				Eel Fry					
	(MT)	(ST)	Total \$ (1000s)	(\$ per kg)	(\$ per lb)	(MT)	(ST)	Total \$ (1000s)	(\$ per kg)	(\$ per lb)
1970	950	1047	3,325	3.50	1.59	120	132	3475	290	132
1971	2300	2535	9,200	4.00	1.82	220	242	4300	195	87
1972	4500	4959	22,500	5.00	2.27	180	198	2500	139	63
1973	6750	7439	54,000	8.00	3.64	—	—	—	—	—
1974	6872	7573	42,269	6.15	2.80	—	—	—	—	—
1975	7924	8732	50,700	6.40	2.91	—	—	—	—	—

Source: Anon. (1976).

25.5) of which 1141 MT were raised in freshwater ponds. Generally speaking, mullet production is not important from a volume standpoint. However, its market prices are high both for the fish and roe. In 1975 the average farm price of fish body was \$1.42 per kg (\$0.65 per lb) while the market price of dried roe was more than \$44 per kg (\$20 per lb).

SHRIMP

It is not known when shrimp culture began in Taiwan. For more than 100 years, farmers have captured juvenile grass and sand shrimp (*Penaeus monodon* and *Metapenaeus monoceros*, respectively) from the coastal waters and stocked them in milkfish ponds, where they were given no special care and were harvested as an extra crop. It is only in recent years that shrimp culture has become intensified and appeared to offer economic potential.

In association with milkfish, the number of shrimp planted per hectare varies from 5000 to 8000 (2024 to 3239 per acre). They are stocked from February to early April. They grow to about 40 g each in 3 months and 2 crops can be raised per year. The survival rate is usually over 80%. No special feeds are fed. The shrimp live off the natural foods produced in the shrimp-milkfish ponds.

Taiwan has shrimp hatcheries for spawning, hatching, and rearing the larvae [see shrimp section, Chapter 23 (Japan) for details]. These hatcheries are located along the sea coast where clean seawater as well as freshwater can be found. Circular plastic tanks of 0.5 to 1.0 MT capacity and concrete tanks of 30 to 70 MT (33 to 71 ST) capacity are used. The number and size of tanks are determined by the scale of operation desired.

The major problem is to acquire spawners for seed production. Tungking Marine Laboratory (located in southern Taiwan) has been conducting research on this challenging problem and has been successful. A shrimp culture demonstration station has been built to provide young shrimp to growers on a large scale and to demonstrate the economic feasibility of production.

Harvesting marketable size shrimp is relatively easy. A net is placed at the sluice gate when water is being discharged at low tide. The shrimp attempt to escape by swimming with the current. After capture they are iced and shipped live to domestic markets by truck. In 1975 farm value was \$1,672,000 for the 775 MT (854 ST) of shrimp harvested. Market values are high, amounting to \$2.16 per kg, or \$0.98 per lb (Table 25.5).

CARP²

Polyculture is usually used for carp production. More than one species may be cultured in the same pond. Production is chiefly in freshwater ponds

²Silver (*Hypophthalmichthys molitrix*), grass (*Ctenopharyngodon idellus*), common (*Cyprinus carpio*), and crucian (*Carassius carassius*).



Fig. 25.3. Spawning carp. Courtesy of Dr. Hsi-Huang Chen.

or large reservoirs (Table 25.4). The carp subsist on natural foods found in the ponds and very little supplemental food is fed.

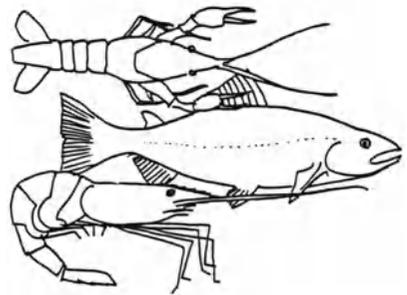
Total carp production in 1975 was 17,419 MT (19,196 ST). Hence carp production is very important from a volume standpoint. However, market prices are relatively low compared with other cultured species. In 1975 the average farm price was \$0.61 per kg, or less than \$0.28 per lb (Table 25.5).

OUTLOOK

It is expected that the cultured fish industry in Taiwan will continue to expand production. This will be due to results of research, which will increase the supply of seed fish, and to newer scientific methods of rearing and feeding. Nearly every species now raised should continue to increase in volume. This is particularly true for eel and shrimp.

REFERENCE

ANON. 1976. Taiwan Fisheries Yearbook. Taiwan Fisheries Bur., Provincial Govt. of Taiwan.



Israel

FISH SPECIES

Bighead carp

Catla

Chinese common carp

Common carp (*Cyprinus carpio*)

European common carp

Grass carp (*Ctenopharyngodon idellus*)

Gray mullets (*Mugil cephalus*,
M. capito)

Israeli mirror carp

Largemouth buffalo fish

Rainbow trout

Silver carp
(*Hypophthalmichthys molitrix*)

Tench

Tilapia [*Tilapia aurea*,
T. nilotica (African origin)]

Trout

Israel

Dr. G.W. Wohlfarth

The annual consumption of fish in Israel is about 10 kg (22 lb) per capita, about 4 kg (9 lb) of which is produced in ponds. The proportion of pond-raised fish in the total supply of animal protein is likely to increase in the future as a result of rising prices of meat and fowl and recent advances in fish farming. In 1975, 13,000 MT (14,326 ST) of fish were produced at 89 farms in a total pond area of about 4500 ha (11,100 acres). Two-thirds of this yield consisted of common carp, the rest being tilapia, silver carp, and gray mullets.

HISTORY

The first successful attempts at fish farming in Israel (then Palestine) were made by the Central European immigrants, Messrs. Schwartz and Sitzer, in ponds dug at Kurdaneh in the coastal marshes south of Acre (Hornell 1935). They introduced the common carp to this area from Central Europe. Yields attained were 2 or 3 times as high as those commonly attained in Central Europe, clearly a result of higher temperatures and a longer growing season. This encouraged the establishment of commercial fish farming in communal farms.

The first commercial ponds were constructed in 1938 in the Beisan Valley, a semi-arid region with a number of brackish water springs too saline for irrigation. Further developments of fish farming have been documented by Bertram (1946), Tal and Shelubski (1952), Reich (1952), Hofstede (1955), and Jones (1956). Since 1961 Sarig has published yearly reports entitled: "Fisheries and Fish Culture in Israel in [appropriate year]." These reports, published in "Bamidgeh, Bulletin of Fish culture in Israel," enable us to follow the yearly development of fish farming.

The total pond area increased from 10 ha (25 acres) in 1938 to 5100 ha (12,600 acres) in 1965. Since then it has decreased to 4500 ha (11,100 acres). Largely due to chronic water shortages, the construction of new ponds is stringently limited. The total yield of fish ponds increased from 14 MT in 1939 to 14,000 MT in 1973. This 1000-fold increase resulted from the larger pond area and the increase in average yield from 1 ton per ha in the early 1940s to 2 tons per ha between 1955 and 1967. Since 1969 the average yield has tended to increase again and now is close to 3 tons per ha. The data for

pond areas and yields are shown in Table 26.1. The ease with which it is possible to obtain such accurate data is due to the organization of fish farming in Israel. All fish are marketed through a central marketing board from which the annual total amounts of fish marketed may be obtained. Licenses are required for constructing ponds, so the exact pond area during each year is noted at the Ministry of Agriculture.

PONDS

Production ponds in Israel are relatively small and vary in area from 2 to 10 ha (5 to 25 acres). The small size is due to the high yields and the usual practice of harvesting the fish by draining the pond. The size of the pond is dictated by the amount of fish the farm can conveniently handle in one operation. Each farm also has a number of smaller ponds from 0.1 to 1 ha (0.25 to 2 acres) for spawning, nursing, storage, and various manipulations. The layout of two fairly typical farms is shown by Jones (1956). As a rule each pond has a separate water supply through an iron pipe and a separate water outlet to a drainage ditch via a concrete construction with sluice boards—the so-called monk. The early ponds were shallow with an average depth of 80 cm to 1 m (31 to 39 in.), but later deeper ponds were constructed

TABLE 26.1. DEVELOPMENT OF FISH FARMING IN ISRAEL

Year	Net Pond Area ¹ (ha)	Total Yield ² (MT)	Average Yield ³ (MT per ha)	Common Carp (%)	Tilapia (%)	Mulletts (%)	Silver Carp (%)
1939	15	14	0.93				
1941	120	128	1.07				
1943	560	689	1.23				
1945	993	1,260	1.26				
1947	1380	2,250	1.64				
1949	2100	3,700	1.76				
1951	2580	3,850	1.49				
1953	2950	4,650	1.58				
1955	3630	7,320	2.01	98.3	1.6	0.1	
1957	3640	7,530	2.07	98.6	0.5	0.9	
1959	3890	7,990	2.03	97.2	0.2	2.6	
1961	4520	8,870	1.96	96.2	2.6	1.1	
1963	4900	10,050	2.04	92.2	6.0	1.8	
1965	5100	10,180	2.00	94.3	3.3	2.4	
1967	4960	8,680	1.76	88.1	8.0	3.9	
1969	4780	10,260	2.15	81.8	11.6	6.6	
1971	4870	12,530	2.57	85.4	8.6	4.1	1.9
1973	4790	13,780	2.88	83.3	8.1	3.5	5.1
1974	4820	12,170	2.52	75.7	12.6	3.3	8.4
1975	4540	12,910	2.84	68.6	14.2	3.9	13.2

¹Net pond area includes operative production ponds, auxilliary ponds used for spawning, nursing, storage, etc., as well as any ponds not in use during a particular year due to pond repairs, etc.

²Total yield is in fact total amount marketed during a given year. This may not be identical with yield during that year if a surplus of fish was left from the previous year, or if a surplus of fish is left until the following year.

³Average yield is total yield divided by net pond area, and is lower than the yield of operative production ponds.

and some existing ponds deepened to average depths of 3 m (10 ft) for storing runoff water. All ponds are earthen, sometimes with stone reinforcement to prevent erosion by wave action. Some ponds have been constructed in marshy areas and on sand dunes while others have been constructed on good agricultural land.

Water is the main factor limiting the area devoted to fish farming. The decrease in pond area since 1965 is largely a result of water shortage. The amount of water supplied to each farm is strictly rationed, so that the alternative value of water is the real cost criterion. In many cases this is evaluated by comparison to cotton, i.e., the expected profit attainable by using a given amount of water for cotton. On this basis water is the main cost factor in fish farming, together with feed costs. Since water always has been in short supply, every effort is made to utilize sources of water not suitable for irrigation. This is the reason why the Beisan Valley with its brackish springs was the first area of fish farming. In the 1940s close to 60% of the fish pond area was in the Beisan Valley (Bertram 1946). The drop in this proportion to 30% in the 1970s, as fish culture spread to other regions¹, indicates the use of other sources of water. In some cases this is runoff water, trapped during the short rainy season in deep ponds and reservoirs. But in other cases fish culture is in direct competition with irrigated agriculture for its water supply.

PRODUCTION METHODS

Fish culture in Israel is geared mainly to supplying the market with live carp of about 600 g (21 oz) all year round. Schematic figures per hectare of production pond for carp are: 3000 fish growing at 5 g per day give a daily production of 15 kg. During a growing period of 250 days per year, this results in a yearly production of about 3.5 MT of carp per ha (3125 lb per acre). As a rule the carp reach market size in a period of 100 to 120 days, so that generally each pond produces two crops per year.

Typical production ponds are stocked, in addition to common carp, with 500 to 1500 tilapia and 500 to 1000 silver carp per ha, as well as varying numbers of gray mullet which produce about 1 ton per ha.

PROPAGATION

Carp are spawned in ponds in their natural spawning season in late spring, and often this is the only source of carp fry for the whole year. Since carp attain sexual maturity in one year in warm climates, the year-old fingerlings stocked into ponds in early spring often spawn "wild spawnings." The harm caused by these uncontrolled spawnings is two-fold—loss of

¹Proportion of the total pond area in different regions in 1975 was: Beisan and Jordan Valleys, 31%; Galilee, 28%; Coastal Plain, 17%; Zvulun Valley, 14%; Yizrael Valley, 10%.

control over the number of fish in the pond and loss of weight of the spawning fish. Wild spawning has been avoided by stocking immature fish, less than a year old, from either "early" or "late" spawnings. Early spawning is accomplished by spawning carp in very early spring, about two months before their natural season, in the water of warm springs, mainly in the Beisan Valley. Late spawning consists of spawning the carp out of season, in late summer with the aid of carp pituitary extracts.

Tilapia are also spawned "naturally" in ponds. As a rule they attain sexual maturity during their first year and spawn in the production ponds at the end of the summer. However, the main harm of wild tilapia spawnings comes from mature fish restocked into ponds in spring. Attempts to avoid this wild spawning by stocking only males has not been completely successful.

Silver carp are propagated by induced spawning, with the aid of carp pituitary extracts, at a number of fish hatcheries located at different fish farms.

FEEDING

The increased growth and yields of fish resulting from supplemental feeding were noticed in the very first observations of fish farming (Hornell 1935). The feeds used were lupine seed, maize, and cottonseed cake, largely depending on availability and price. For many years the standard practice of feeding consisted of feeding cereal grains once a day, six days a week. The amount of feed was calculated at 4 to 5% of the biomass of the fish or according to the conversion ratio. Feed conversion ratio improved considerably during the years from 6 to 7 in the early years to about 3 in the 1950s (Jones 1956) and to 2 to 2.5 in more recent years.

Feeding experiments starting in the 1960s showed that a more balanced diet (i.e., addition of protein to the grain feed) improved growth and yields (Hepher *et al.* 1971). As a result, high protein feed pellets containing 25% protein from fish meal and soy meal came into use. As a rule cereal grains, mainly sorghum, are fed at the beginning of the season when the fish biomass is low. With increasing biomass varying proportions of high protein pellets are added to the grain, until at the end of the season, at high biomasses of fish, feed pellets only are fed. The increase in yields per unit area starting in the late 1960s is presumably largely due to this improved feed. However, the rising costs of fish meal and soy meal require an examination of whether this level of protein in the feed is economical. Both 25 and 18% protein fish feeds are now commercially produced.

The feed was standardly applied to the ponds by tractor-driven feed blowers before the advent of fish feeders. The first to come into use in Israel, demand feeders, were found to increase growth, but often at the expense of a higher feed conversion ratio. More complex automatic feeders, now commonly used, enable a stricter control over the amount of feed and the rate of feeding. The use of these feeders appears to have improved yields. It is also

relatively easy to seine fish in the area around the feeder for intermittent cropping and spot checks.

FERTILIZING AND MANURING

The standard method of fertilizing fish ponds in Israel consists of bi-weekly applications of 50 kg (110 lb) ammonium sulfate and 50 kg of regular superphosphate per ha (2.47 acres). Potassium fertilizers are not used. Larger amounts and more frequent applications were found ineffective in increasing fish yields (Hepher 1963).

Variations in this method are:

- (1) Use of liquid ammonia, which is a cheaper nitrogen source but more complicated to apply.
- (2) Applying smaller amounts of nitrogen during the summer months when nitrogen-fixing blue-green algae supply some of the nitrogen needs.
- (3) Occasional heavy doses of ammonium sulfate to combat the ichthyotoxin-producing alga *Prymnesium parvum*.
- (4) Occasional heavy doses of regular superphosphate to combat lack of oxygen.

Chicken manure is often applied to the ponds at a rate of 0.5 m³ per ha (330 lb per acre). The early European practice of applying 3 to 5 m³ of cattle manure per ha (1 to 2 MT per acre) was tried at the beginning of fish culture in Israel but soon discontinued. The effect of this manuring on growth and yields of carp could not be demonstrated and shortage of oxygen sometimes occurred in the manured carp ponds. Lately, however, manuring has been coming into use in polyculture fish ponds, but in an entirely different method of application (see "Future Trends").

FISH STOCKED IN PRODUCTION PONDS

Originally the only fish stocked was the common carp. The idea of culturing supplemental fish in carp ponds has been considered almost from the inception of fish farming in Israel. Catla, grass carp, rainbow trout, tench, and largemouth buffalo fish were introduced years ago and attempts made to evaluate their performance. All these early attempts failed.

At present four main fish are grown in Israel: the common carp, tilapia, gray mullet, and silver carp. Two other fish, grass carp and bighead carp, have been spawned and some attempts are being made to evaluate them.

Common Carp (*Cyprinus carpio*)

The original introduction of common carp was from Yugoslavia. Subsequent further introductions were from Europe and the Far East. The so-called "Israeli mirror carp," sometimes mentioned in the literature, is by and large a European carp, though lately crossbreeds between European

and Chinese common carp have been evaluated (see "Genetic Improvement").

Frequently carp of two sizes are grown in production ponds: fish to be grown to market size, and fry for the next season. Nursing carp fry to fingerling size in production ponds requires a large weight difference between the two weight classes. Reich (1952) and Jones (1956) describe two such methods, i.e., stocking 2 to 5 g fry with 100 g fish or 10 g fry with 300 g fish. This "mixed nursing" method is thought to increase pond yields, obviates the need for special nursery ponds, and spreads the fry all over the pond area, so that a disaster in any one pond cannot kill off all the available fry.

Tilapia

The species mainly grown is *Tilapia aurea* of local origin. Problems besetting tilapia culture in Israel are similar to those in other parts of the world, i.e., high fecundity and sensitivity to cold. Originally young of the year were stocked into ponds in early summer and were marketed in the fall. This limited the supply of tilapia in the market to a short season. In order to increase the marketing period some of these fish are overwintered, the survivors manually sexed and only the males stocked into production ponds in spring. The females are discarded, when possible, to prevent spawning and because their growth is slower than that of males. Some attempts have been made to produce all male broods by crossing female *T. nilotica* of African origin with local *T. aurea* males, but at present this has only a limited commercial application.

T. aurea is regarded as a highly desirable species because its reported cold resistance is higher than that of other mouthbreeding tilapia and because of its wide spectrum of feeding. The total yield of pond-grown tilapia has been increasing from year to year and its proportion in the total yield reached 14% in 1975.

Gray Mullet

Gray mullet, of the species *Mugil cephalus* and *M. capito*, are the most highly priced of all fish grown in ponds in Israel. Their price is often twice that of common carp and close to that of trout. The main factor limiting mullet production is the supply of fry, seined from river estuaries since all attempts at artificial propagation of mullet in Israel have failed. This supply has been decreasing, apparently due to either overfishing or pollution or both. The proportion of mullets in the total yield increased to a maximum of 6.6% in 1969, but has decreased to between 3 and 4% since.

Silver Carp

Silver carp (*Hypophthalmichthys molitrix*) were introduced to Israel from Japan in 1965. Commercial production started in 1970 after preliminary

experiments had shown the great potential of this fish and its spawning problems were solved. Yields increased from 1.9 to 13% of the total production between 1971 and 1975. It has been estimated that yearly yields of up to 1 MT per ha (892 lb per acre) in polyculture do not detract from the yields of other fish, meaning that the 1975 yield could probably be doubled.

The silver carp is not a popular fish in Israel; it demands the lowest price of all pond fish and at present about half the yield is exported. However, excellent fish products have been prepared from silver carp in the form of fish sausage and smoked and canned fish.

Grass Carp

Grass carp (*Ctenopharyngodon idellus*) were introduced along with silver carp but their spread has been much slower. Observations to date indicate that even at low stocking rates they are capable of keeping the ponds clean of all higher plants, but they compete with common carp for supplemental feed. Small amounts of grass carp were marketed for the first time in 1976, less than 1–2 MT per year.

GENETIC IMPROVEMENT

Genetic improvement of the common carp has been under investigation since 1958. The results of these investigations show:

- (1) Mass selection of the largest individuals is apparently ineffective in improving growth of carp (Moav and Wohlfarth 1976). This was the traditional method of attempting genetic improvement in Europe, together with mass selection for a high-backed and "scarcely scaled mirror carp," and was transferred to Israel along with other European practices (Hofstede 1955).
- (2) Family selection, though more tedious than mass selection, appears to be more effective.
- (3) Crossbreeding between common carp with different origins was found to improve growth rate, viability, and disease resistance (Hines *et al.* 1974; Moav *et al.* 1975).
- (4) A particularly successful crossbreed was that between common carp of Chinese and European origins. Its growth rate was as good as that of the best commercial crossbreeds under conditions of supplemental feeding. In ponds whose only inputs were manures and fertilizers, these Chinese and European crossbreeds showed the best relative performance (Moav *et al.* 1975; Wohlfarth *et al.* 1975).

Crossbred common carp are standardly stocked in production ponds in Israel (Wohlfarth *et al.* 1965).

MARKETING

All fish are marketed through a central marketing board (Tnuva), the amount marketed daily and the farms supplying the fish being organized by

the Fish Breeders Association. The full market demands for fish are usually met, i.e., all four kinds of fish are marketed during the full calendar year, in spite of the fact that pond fish in Israel do not grow during winter (approximately four months from November to March). Common carp are live-hauled to the market, sold live to retailers, and again to customers. The price of common carp is government controlled. All other fish are marketed dead and cooled, and price fluctuates with supply and demand.

DISEASES AND PARASITES

The first "disease" to strike fish farming in Israel was the ichthyotoxin-producing alga *Prymnesium parvum*. Later it was found that blue-green algae of the genera *Microcystis* and *Anabaena* also release fish toxins into the water. These algae are now partially controlled by application of ammonium sulfate and copper sulfate. External parasites are a chronic nuisance due to their adverse effects on the fish and religious food laws, which forbid eating fish infested by external parasites. These parasites belong to the genera *Lernea*, *Argulus*, *Ichthyophthirius*, *Dactylogyrus*, *Gyrodactylus*, *Costia*, and others. Sarig (1971) has described the parasite fauna of pond fish in Israel, as well as control measures for these parasites. No serious bacterial or viral diseases of fish have been detected.

EQUIPMENT

From its inception efforts have been made to mechanize fish farming in Israel. This is the result of the concentration of fish farming in kibbutz farms, with their chronic labor shortage. Tractors are widely used for hauling nets and transport in the pond areas. Feeding has been described. Fish for market are raised from ponds to trucks with mechanical fish elevators. Intricate grading and sorting devices are in use, especially for harvesting fish from polyculture ponds. Carp are live-hauled to market in tanks with mechanical aeration. Lately intensive growing systems have been introduced, utilizing high stocking rates and mechanical aeration of the pond water.

EXTENSION SERVICE

Extension service of the Ministry of Agriculture provides an instructor in fish farming for each fish growing area. These instructors, who are fish farmers or former fish farmers, pay periodic visits to the farms in their areas and are members of the professional committees of the Fish Breeders Association. They also organize yearly courses of several weeks duration on fish farming and participate in occasional courses on fish diseases, etc.

RESEARCH

Research on many aspects of fish farming is carried out at the Fish and Aquaculture Research Station, Dor, which had its forerunner at Sdeh Nahum. Feeding, fertilizing and manuring, genetic improvement, polyculture, induced spawning, etc., are or have been under investigation. Lately integrated research plans have enabled the simultaneous investigation of several factors, e.g., manuring and breeding of common carp, and the interactions between these factors. The development of fish farming in Israel to its present level is a result of the contributions made by research as well as the initiative of the fish farmers. Due to the close contact between fish farmers and research personnel, the results of investigations at the research station are applied to practical farming in a short time.

FUTURE TRENDS

Since fish farming was established in Israel by immigrants from Europe, the European "feedlot" approach of fish farming was adopted. Feed inputs were always larger than fish yields on a calorie basis. Since the introduction of high protein feeds the protein yields of the ponds are smaller than the protein inputs. So long as the unit of input was much cheaper than the unit of yield, converting cheap feedstuffs into relatively expensive fish was economically feasible. Rising feed costs make this approach less and less profitable, unless cultured pond fish become a luxury food as in the USA. One possible future trend is the intensive culture of fish at high stocking rates, in monoculture on a protein-rich feed, and in running water or with mechanical aeration. In the long run this can only produce a product at a luxury price. Some intensification of fish farming of this type is already being practiced in Israel, but we do not believe that this will be economically viable in the future.

A different future trend is to adopt the Chinese method of balanced polyculture, where the inputs are largely agricultural by-products such as manures. The applicability of this Chinese type of fish farming to conditions in Israel has been demonstrated recently in a series of experimental ponds at the Dor Fishculture Research Station. Yields as high as 8 MT per ha per year (3.6 ST per acre) resulted from daily applications of liquid cow manure without any supplemental feed. The ponds were stocked with common carp, tilapia, silver carp, and grass carp. Moreover this practice of frequent manuring of polyculture ponds has already spread to commercial fish farming, an example of the rapid commercial application of experimental results. Preliminary reports of the fisheries extension people indicate increased yields or improved feed conversion ratios in many of these manured ponds.

A demonstration of what may be obtained by polyculture with supple-

TABLE 26.2. ABSOLUTE AND PROPORTIONAL YIELDS AT GAN SHMUEL

Fish	Average Yield (MT per ha)			Proportional Yield (%)		
	1973	1974	1975	1973	1974	1975
Common carp	2.74	3.52	3.70	66	60	51
Tilapia	0.69	0.99	1.42	17	17	20
Mulletts	0.26	0.25	0.40	6	4	6
Silver carp	0.43	1.06	1.66	10	18	23
Total	4.12	5.82	7.18			

mental feeding was given at Gan Shmuel, one of the best fish farms in Israel (Anon. 1976). This farm is beset by particularly difficult water problems, as shown by the fact that a majority of its ponds are deep ponds for storing runoff water and most of the shallow ponds are to be deepened, too. The results of 3 years of fish culture in 93 ha (230 acres) of ponds are shown in Table 26.2. During this period the feed conversion ratio decreased from 1.86 in 1974 to 1.73 in 1975. The table shows:

- (1) Yields rose from 4 MT per ha in 1973 to 7 MT per ha in 1975 (1.8 to 3.1 ST per acre).
- (2) The absolute yield of common carp increased from 2.7 MT per ha to 3.7 MT per ha (1.2 to 1.65 ST per acre), but its proportional yield decreased from 66 to 51%.
- (3) Both absolute and proportional yields of tilapia and silver carp increased, from 17 to 20% and from 10 to 23%, respectively.

It seems likely that the better yield and feed conversion result from the decreased proportion of common carp, that is, from a closer approximation of a balanced polyculture. Results similar to those at Gan Shmuel in 1975 have been attained for years in a number of 2 ha (5 acre) ponds at Dor.

SPECIAL ACKNOWLEDGMENTS

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Thailand

FISH AND OTHER AQUATIC SPECIES

- | | |
|--|--|
| <i>Artemia</i> spp. [brine shrimp] | Oyster (<i>Ostrea</i> spp.) |
| Banana shrimp (<i>Penaeus merguensis</i>) | Rock cockles (<i>Anadara granosa</i>) |
| Bighead carp (<i>Aristichthys nobilis</i>) | Rotifers |
| Catfish (<i>Pangasius sutchi</i>) | Sand shrimp (<i>Metapenaeus monoceros</i>) |
| Chinese carps | Sea bass (anadromous) (<i>Lates calcarifer</i>) |
| Clams | Sepat Siam (<i>Trichogaster pectoralis</i>) |
| Common carp (<i>Cyprinus carpio</i>) | Short-horned shrimp (<i>Metapenaeus brevicornis</i>) |
| Copepods | Shrimp |
| Daphnids | Silver carp (<i>Hypophthalmichthys molitrix</i>) |
| Fish eggs | Small shrimps |
| Giant freshwater prawns (<i>Macrobrachium rosenbergii</i>) | Snakeheads (<i>Ophicephalus striatus</i>) |
| Grass carp (<i>Ctenopharyngodon idellus</i>) | Squids |
| Green mussel (<i>Mytilus smaragdinus</i>) | Tawe (<i>Puntius gonionotus</i>) |
| Grey mullet (anadromous) (<i>Mugil</i> spp.) | Tiger prawn (<i>Penaeus monodon</i>) |
| Grouper (<i>Epinephelus tauvina</i>) | Walking catfish (<i>Clarias batrachus</i> , <i>C. macrocephalus</i>) |
| Invertebrates | Trash fish |
| Kissing gouramy (<i>Helostoma temmincki</i>) | Brackish water fish culture |
| Marbled goby (<i>Oxyeleotris marmoratus</i>) | Cage culture |
| Mussels | Freshwater pond fish culture |
| Nile tilapia (<i>Sarotherodon nilotica</i>) | Rice-field fish culture |

Thailand

Dr. Wiang Chuapoehek

HISTORY OF AQUACULTURE

Fish farming and husbandry, or aquaculture, in Thailand stems from the ancient practice of trapping fish. During the rainy season (May–August) the southwest monsoon wind dominates and brings about heavy rainfall so that flooding occurs in different parts of the country. Because of its topography, central Thailand is the most flooded area. When flooding occurs, fish from the headwaters follow the flood along the canals into the lower land rice fields. Fish that enter into small swamps in rice fields grow well and are caught for food consumption after the rice is harvested.

Equally interesting are the fish that follow the flood along canals and enter small ponds constructed and maintained by the farmers living along the banks of the canals. Those ponds, constructed for water purposes, are deeper than the adjacent canals and are connected with them by short and narrow passages through which fish enter into the ponds at the time when the water level is high. Attracted by high quantities of fish caught from these ponds when the water is drained out, the farmers have constructed numerous small ponds for the purpose of trapping fish during the flooding season, or even in some places where canals and streams are filled with water throughout the year. At intervals of about 2–4 months, the ponds are blocked and water is drained out and the fish are caught with simple hand nets. Operations of this kind may be regarded as a primitive type of fish culture.

The foregoing simple trapping operation was steadily improved and gradually developed from trapping-holding to trapping-holding-growing, and finally into complete husbandry practices when people learned how to collect or produce fry and fingerlings for stocking.

It is true that for a great many years people of Thailand used to release fish into the ponds of the temples all over the country, but such practices were mainly for religious purposes. Actual operations of culturing fish for the production of food started some 70 years ago. However, such culturing operations at that time were done only by a few people on a small scale, confined entirely around the Bangkok area. With establishment of the Department of Fisheries, Ministry of Agriculture and Cooperatives, in 1933, and the Faculty of Fisheries, Kasetsart University, in 1943, by the

Thai government, the extension and training program for fish farming management was established (Fig. 27.1). These developments strongly influenced both private and government fish culture in Thailand thereafter. It is only since about 1970 that fish culture practices have been expanded rapidly, mainly due to the increase in fish-protein demand derived from the rapidly increasing population.

At present, aquaculture is widespread in Thailand but not well developed, as indicated by low average annual production (Table 27.1) and underutilization of suitable areas (Table 27.2). The annual aquacultural product reported in 1976 was 197,584 MT (217, 342 ST). This tonnage is about 12% of the combined total catch and aquacultural yield of the entire country. Accounting for most of the aquacultural production are some 26,000 commercial aquaculturists whose pond surface areas range from less than 1 ha to some 40 ha (less than 2.5 acres to 16). The total water surface involved is about 70,000 ha (173,000 acres), a figure that is estimated at only 0.8% of the total potential area of the country.

AQUACULTURE PRACTICES AND TECHNIQUES

In general, the state of fish cultural practice remains largely the traditional one in which the average yield is low. The average fish farmer buys seed as small as fry, places them in rearing ponds, and may or may not add fertilizer or feed or practice disease prevention and control. He relies principally on the vagaries of nature plus whatever small adjustments experience has shown him he can make. His methods are inefficient; sound and proper means are needed for improving the efficiency of aquaculturists. These should come from refined experiments probably centering on nutritional requirements and optimal feeding regimes of the most commonly cultured species coupled with trophodynamic analyses of representative culturing environments.

Based on culturing facilities, practices of aquaculture found in Thailand today may be grouped into five categories: freshwater pond fish culture, rice-field fish culture, cage culture, brackish water fish culture, and shrimp farming.

Freshwater Pond Fish Culture

Of all the operations of fish farming in Thailand, pond fish culture receives the most attention. This kind of practice can be conducted under controlled conditions and yields high production if proper management is given. It is, therefore, extensively done in different parts of the country, mostly around the Bangkok area and the business center of the countryside's provinces in which good transportation and markets are available. Predictable values for fish production from pond culture are now available on such variables as food habits, feeding frequencies, stocking rate, stocking size, and species.



Fig. 27.1. Geographic distribution of government aquaculture activities, 1980.

TABLE 27.1. CAPTURE AND CULTURE PRODUCTION OF THAILAND, 1976

Source of Production	Production in Metric Tons ¹		Total
	Capture	Culture	
Marine	1,388,239	—	1,388,239
Brackish water	—	163,283	163,283
Inland	113,263	34,301	147,564
Total	1,501,502	197,584	1,699,086

Source: Anon. (1976).

¹1 MT is equal to 1.10 ST.

TABLE 27.2. EXISTING AND POTENTIAL AREA FOR AQUACULTURE IN THAILAND, 1976

Aquaculture	Area in Hectares ¹	
	Existing	Potential
Inland	58,924	4,520,000
Marine and estuarine	12,300	5,000,000
Total	71,224	9,520,000

Source: Anon. (1976).

¹1 ha is equal to 2.47 acres.

The names of the fish that have been most commonly propagated in freshwater ponds, along with their draft synopsis of aquacultural practices, are listed in Table 27.3. Among them, *Clarias batrachus*, *C. macrocephalus*, *Ophicephalus striatus*, *Pangasius sutchi*, *Ctenopharyngodon idellus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, and *Macrobrachium rosenbergii* have become the most popular in Thailand, mainly due to their rapid growth, good quality as table fish, and high marketing price.

Techniques presently employed under the type freshwater pond fish culture in Thailand include monoculture, polyculture, and fish culture integrated with agriculture or animal husbandry.

Monoculture. Monoculture involves the culture of a single species with or without the addition of fertilizers or feeds. Only a few applications of organic fertilizers without appropriate instructions have been conducted by the farmers in central and northeast Thailand to increase fish production. Fertilizers commonly used by local fish farmers are manures from cows, buffalo, pigs, and chickens. Inorganic fertilizers are not commonly used.

A typical example of controlled stocking monoculture with the addition of organic fertilizers is the culture of Nile tilapia, *Sarotherodon nilotica*. With a stocking density of 2 fish per m² (2 fish per 11 ft²) of pond surface area, production of 2500 kg per ha (2227 lb/acre), at least twice as many as fish as can be produced from naturally occurring organisms, is possible after four months of rearing by adding pig manure every day for five days a week at the rate of 75 kg per ha (67 lb/acre) per day.

Supplementary feeding is another means that can increase the production of fish culturing in ponds. At present, some commercial fish farmers use rice bran and broken rice to feed fish. Water spinach, duckweed, and other

TABLE 27.3. DRAFT SYNOPSIS OF AQUACULTURAL PRACTICE OF THE MOST COMMONLY CULTIVATED FISH¹ IN FRESHWATER PONDS, THAILAND²

Species (Common Name)	Stocking Density Fish/m ²	Growth to Marketable Size Size (g)	Time (Months)	Production kg/ha
<i>Clarias batrachus</i> (walking catfish)	± 150	± 175	± 4.5	± 25,000
<i>Clarias macrocephalus</i> (walking catfish)	± 50	± 175	± 5	± 10,000
<i>Ophicephalus striatus</i> (snakehead)	± 80	500–1200	± 7.5	± 28,000
<i>Pangasius sutchi</i> (catfish)	2+	1000–2000	6–12	± 20,000
<i>Puntius gonionotus</i> (tawe)	± 5	± 400	4–8	± 3125
<i>Trichogaster pectoralis</i> (sepat Siam)	± 5	± 200	10–12	± 1000
<i>Ctenopharyngodon idellus</i> (grass carp)	0.1	2000–2500	± 12	± 900
<i>Hypophthalmichthys molitrix</i> (silver carp)	0.05	2000–2500	± 12	± 450
<i>Aristichthys nobilis</i> (bighead carp)	0.01	2000–2500	± 12	± 150
<i>Sarotherodon nilotica</i> (Nile tilapia)	± 5	200–800	6–8	± 2500
<i>Macrobrachium rosenbergii</i> (giant freshwater prawn)	± 10	50–120	5–8	± 1250

¹The term "fish" also includes, for convenience, the giant freshwater prawn, *Macrobrachium rosenbergii*.

²Measurements are the best averages available and could differ significantly by varying environmental and management conditions.

aquatic weeds, soybean cake, peanut cake, fish meal, and fresh or frozen trash fish are also used.

Interesting among culturing fish in ponds is a feeding of walking catfish, *C. batrachus*, with a mixture of fresh ground trash fish (90%) plus rice bran (10%). This kind of feeding is done by commercial fish farmers whose farms are located near the Bangkok area where trash fish can easily be obtained. The average production is 60 to 90 MT per ha (2.67 to 40 ST/acre) when the fish were stocked at the rates of 100 to 180 fish per m² (10.76 ft²) of pond surface area.

Experiments also revealed that walking catfish could successfully and commercially be fed dry feeds prepared as sinking pellets. In a preliminary feeding test at the Kasetsart University Aquaculture Department extension ponds, walking catfish fry, averaging 0.4 g in body weight, stocked at 15 fish per m² (10.76 ft²) of water surface area showed an average net gain of more than 160 g in 5 months, with a feed conversion of 1.8 or 1 unit of gain per 1.8 units of feed. The ingredients and amounts of feed fed are given in Table 27.4, with the following feeding schemes:

Days After Stocking	Feeding Rate, % of Fish Body Weight
1–30	20
31–60	7
61–90	5
91–120	3
121–150	2

Giant Freshwater Prawns. More interesting is a culture of giant freshwater prawns, *Macrobrachium rosenbergii*, which spawn, under natural condition, in brackish water, and the fry migrate for long distances into inland waters where they grow to adult size. Most of the prawn seeds used for culturing are produced in prawn hatcheries (Fig. 27.2), but some are collected from their natural habitats. Apart from government experimental stations, several private prawn hatcheries are already in active operation.

TABLE 27.4. INGREDIENTS AND AMOUNTS TO MAKE A TON OF FEED FED TO WALKING CATFISH IN EARTHEN PONDS

Ingredient	Amount in kg	Percentage
Fish meal	200.0	20.00
Peanut meal	450.0	45.00
Rice bran	100.0	10.00
Ground corn	30.0	3.00
Ground duckweed	199.5	19.95
Dicalcium phosphate	10.0	1.00
Salt	7.5	0.75
Vitamin premix	2.0	0.20
Trace mineral premix	1.0	0.10

Source: Chuapoehuk and Pithisoong (1978).



Fig. 27.2. Government hatcheries of freshwater prawn, Bangpakong. Water quality laboratory in background.

In hatcheries, newly hatched larvae were usually fed *Artemia* spp. (brine shrimp) which are mostly imported and have become increasingly expensive and difficult to obtain. Locally available materials found to be useful as larval food include minute fish eggs, small pieces of animal material such as mussels, clams, squids, steamed egg custard, and minute live food such as rotifers, copepods, and daphnids.

The larvae become juvenile (6.8–7.5 mm) in about 45–55 days. Newly metamorphosed juveniles are usually allowed to remain in the larval tank for 1–2 weeks before transfer to juvenile tanks. Water in the juvenile tank is maintained at very low salinity. Materials suitable as food for juveniles are similar to those used as food for the larvae and are some kind of pellet forms of high protein fish feeds.

Most of the ponds (Fig. 27.3) used for prawn farming are converted from existing fishponds. They are earthen ponds, rectangular in shape, 1000 to 5000 m² (½ to 1¼ acres) in size, 1 to 1.5 m (39 to 59 in.) in depth, and provided with a water supply and drainage system.



Fig. 27.3. Grow-out ponds for giant freshwater prawns.

Juveniles of 2–4 weeks old are safe for stocking the grow-out ponds. A stocking rate of 5 juveniles per m² (10.76 ft²) of pond surface area is generally used.

In the present farming system, prawns depend largely upon the food produced in the pond. Supplemental feed are given only in moderate amounts. Materials used as food are trash fish or any inexpensive fish, small shrimps, mussels, squids, corn, peanut cake, soybean cake. Chicken feeds are sometimes utilized.

The juveniles attain marketable size (50–120 g) in about 5–8 months. There exists a wide range of production among the farms; a high average would be 1250 kg per ha (1113 lb per acre).

Polyculture. Polyculture is another system being practiced widely in controlled stocking ponds. This type of culture involves culturing together different species of fish with compatible food habits, or the culture of fish with prawns or other invertebrates, provided the fish is not a predator of the other cultured organisms.

Table 27.5 represents polyculture as practiced with the most commonly cultured fish in freshwaters of Thailand. A typical example is the combination culture of grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*). These three species of Chinese carps can be cultured in the same pond for they live in different water levels and their food habits vary. The grass carp is a plant feeder, the silver carp a plankton feeder, and the bighead carp a bottom

TABLE 27.5. POLYCULTURE AS PRACTICED WITH THE MOST COMMONLY CULTIVATED FRESHWATER SPECIES OF THAILAND

Species in Polyculture	<i>Clarias macrocephalus</i>	<i>Ophicephalus striatus</i>	<i>Puntius gonionotus</i>	<i>Ctenopharyngodon idellus</i>	<i>Hypophthalmichthys molitrix</i>	<i>Aristichthys nobilis</i>	<i>Cyprinus carpio</i>	<i>Sarotherodon nilotica</i>	<i>Macrobrachium rosenbergii</i>
<i>Clarias macrocephalus</i>									
<i>Ophicephalus striatus</i>	x	x							
<i>Pangasius sutchi</i>								x	
<i>Ctenopharyngodon idellus</i>			x		x	x	x		x
<i>Hypophthalmichthys molitrix</i>			x	x		x	x		
<i>Aristichthys nobilis</i>			x	x	x		x		
<i>Sarotherodon nilotica</i>			x						
<i>Macrobrachium rosenbergii</i>			x						
<i>Puntius gonionotus</i>				x	x	x			x



Fig. 27.4. A bamboo frame holding green plant materials for feeding grass carp.

feeder. The feeding system is very simple, that is, only grasses (Fig. 27.4) or plant materials are required to feed the grass carp. The feces from the grass carp then fertilize the water, thus resulting in the abundance of microorganisms which are consumed by both the silver carp and the bighead carp. Owing to the mentioned advantage, this combination is recommended to fish farmers for it can give considerably high profits to them if they clearly understand the other problems of their farm management.

Fish Culture Integrated with Agriculture or Animal Husbandry. This is another interesting operation being practiced in freshwater ponds mostly around the Bangkok area. This type of culture may involve: (1) vegetable gardening using aquatic vegetables such as water chestnuts and water spinach in the pond, (2) land vegetables grown on banks of the pond, and (3) fish culture integrated with chicken, pig, or duck farming (Fig. 27.5).

Droppings from pigs, chickens, and ducks become fertilizer for ponds, either directly or after being collected. Water weeds from the pond are used for feeding the pigs, the chickens, or the ducks. In addition to fish, the pigs, the chickens, the ducks, and eggs of the chickens or of the ducks may be harvested.

Fish species commonly cultured along with animal husbandry are Nile tilapia (*Sarotherodon nilotica*) and catfish (*Pangasius sutchi*). This type of culture is widespread in Thailand, but so far there have been no data available on production.

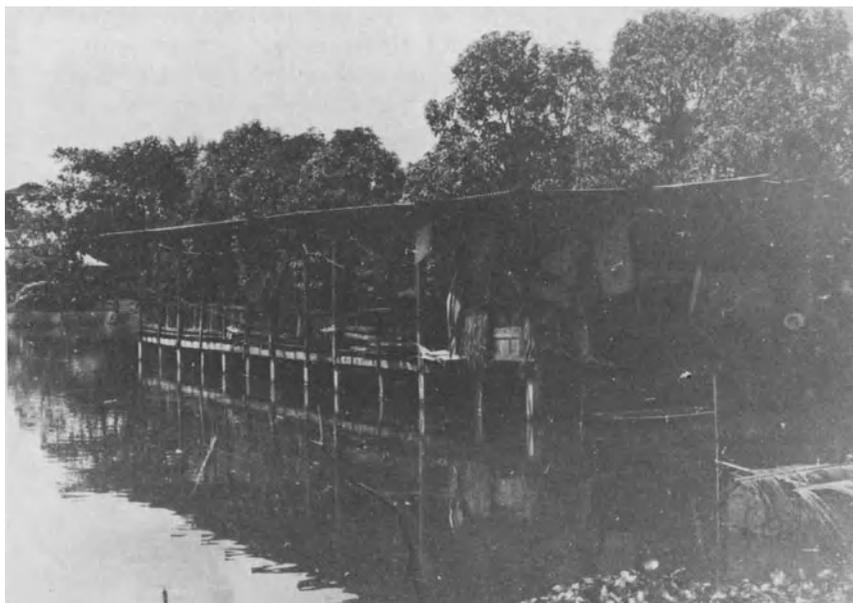


Fig. 27.5. Pig-raising house in *Tilapia* culturing pond.

Rice-field Fish Culture

It is known that raising fish in the rice field along with rice growing has been practiced for a long time in Thailand. Usually, fish farming has been known to bring additional income, protein feed, and to increase rice production as well. Rice-field fish culture is considered to be side work in some countries, but in Thailand, especially in the central part, the income from fish culture in the field is reportedly higher than or equal to the income from rice production itself.

The Agriculture and Cooperatives Ministry Fisheries Department of Thailand has considered fish culture in the rice field as an important matter for a long time, but the promotion of rice-field fish culture was started during World War II, and has been practiced throughout the central region since the war.

Even though the Department has put great effort into extension service, satisfactory results were obtained only in the central region and there is little activity in the northern region. The reason for little activity in that region is that rice-field soil there has a slightly higher percentage of sand instead of heavy clay as in the central region. Besides, topographically, most of the northern rice fields are not level. The other problem is frequent flooding which causes great damage to the farms.

Development of rice-field fish culture in the central region was initiated by the farmers who know how to culture and breed their fish. In a pond fish

culture operation, the farmers have to put great amounts of money into the construction of ponds. Consequently, there are few farmers willing to do this. Advised by the fisheries extension workers, the fish farmers released fish fry they had bred into prepared rice fields (Fig. 27.6) instead of into

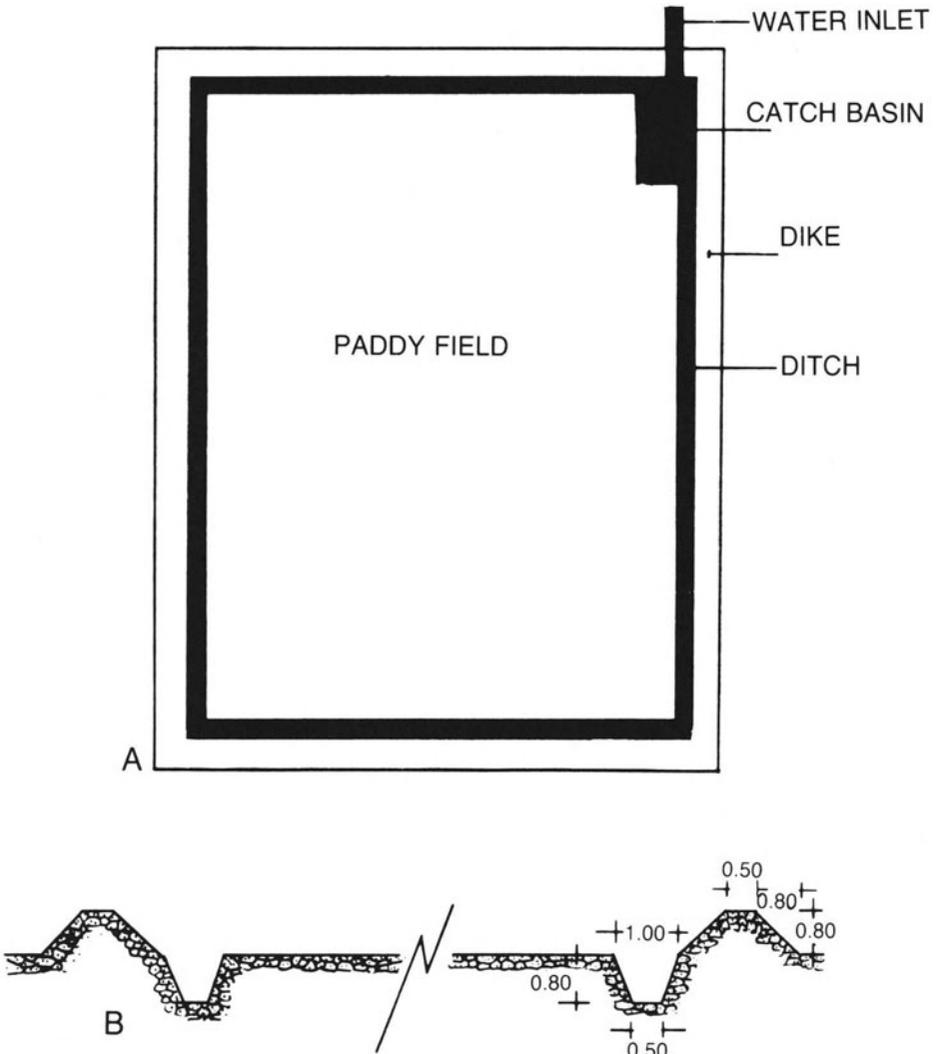


Fig. 27.6. Typical layout of fish-cum-rice field. A—Top view. B—Magnified scale of dike and ditch (m).

ponds. Attracted by satisfactory results, other farmers followed. Up to the present time, the fish culture operation in rice fields has expanded successfully throughout this region.

Methods of rice-field fish culture practiced in the central and northern region are slightly varied. However, there are two methods of rice-field fish culture, namely (1) fish culture along with rice, and (2) fish culture after the rice harvesting period. The first method is the most popular but the latter has started recently and there are still relatively few fish farmers using it. In the central region of Thailand both methods are being applied while only the first one is being practiced in the northern region.

The species of fish suitable for culture in the rice fields include common carp (*Cyprinus carpio*), Nile tilapia (*Sarotherodon nilotica*), sepat Siam (*Trichogaster pectoralis*), kissing gouramy (*Helostoma temmincki*), walking catfish (*Clarias batrachus*), and snakehead (*Ophicephalus striatus*). Most of the fish farmers prefer to raise a single species of fish in one rice field, but there are some who raise two or three species in the same field.

The average annual productions of fish and rice paddy per hectare of area for each method of culture reported by Pongsuwana in 1962 were as follows:

Central Region

Fish culture along with rice

One species fish culture

250–340 kg of common carp (223–303 lb/acre)

More than one species of fish culture

170 kg of common carp (151 lb/acre)

62 kg of sepat Siam and extraneous fish (55 lb/acre)

Fish culture after rice harvesting period

One species fish culture

137–330 kg of common carp (122–294 lb/acre)

More than one species of fish culture

1375 kg of sepat Siam (1225 lb/acre)

188 kg of walking catfish and snakehead (168 lb/acre)

The increase in yield of rice

810–1560 kg (721–1389 lb/acre)

Northern Region

One species fish culture

100–180 kg of common carp (89–161 lb/acre)

More than one species fish culture

30–170 kg of common carp (27–152 lb/acre)

6–105 kg of Nile tilapia (5–94 lb/acre)

The increase in yield of rice

76–760 kg (68–678 lb/acre)

Though the majority of fish farmers who culture fish in the rice field found it very beneficial for increasing the yield of rice, rice-field fish culture has still expanded slowly. The reason for this is that farmers lack appropriate loan funds for converting rice fields into fish-cum-rice field, bringing in a water supply, and for replenishing the field during the operation.

Cage Culture

Culturing fish in cages suspended at the surface waters of rivers, reservoirs, and lakes is being conducted in both the central and the north-eastern regions of Thailand. The species used are common carp (*Cyprinus carpio*), Nile tilapia (*Sarothernodon nilotica*), catfish (*Pangasius sutchi*), and marbled goby (*Oxyeleotris marmoratus*).

Fish feeds required for floating cage culture are different from those for pond culture. In the case of pond culture, the feed used does not need to be nutritionally complete as the fish obtain part of their diet from natural fish food organisms produced in the pond. In contrast, when fish are grown at high concentrations in cages, few natural foods are available and the feed used must be nutritionally complete.

Cage cultures are very useful in better utilization of reservoirs, lakes, and rivers. The production of fish from operations of this kind depends largely on the quality of fish feed and the stocking rate. In commercial production experiments in 1970 at Ubol Rajthani province, northeastern region of Thailand, common carp stocked at 70 fish per m³ (0.6 fish per ft³) of water volume and fed pelleted commercial chicken feed reached a total weight of 6 kg (13.2 lb) in 5 months. If a higher quality feed were available, higher production would be possible.

Another typical example of floating cage culture is the culture of marbled goby in the central region of Thailand. Typical bamboo cages (Fig. 27.7) 5 m long, 2 m wide, and 1.5 m deep (16 ft long, 6½ ft wide, and 4.75 ft deep) were partially submerged in rivers in the more remote riverside villages. Marbled goby fingerlings weighing 200 g each were stocked at 150 fish per cage and fed with a fresh ground trash fish at the rates of 3–5% of fish body weight per day for seven days a week. After six months of feeding, a total

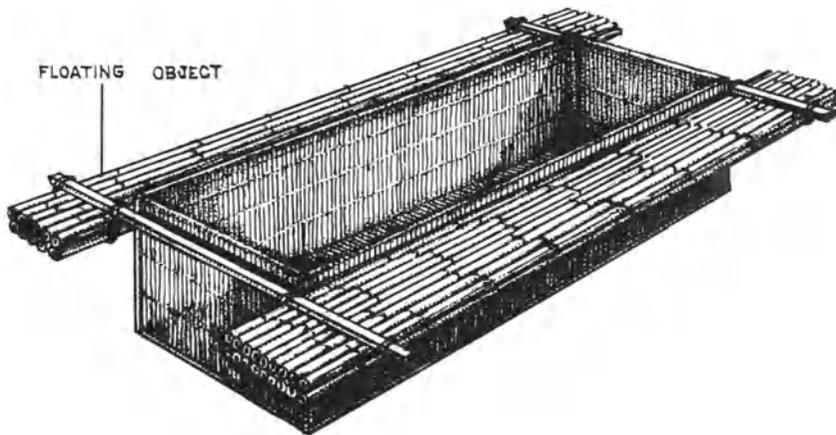


Fig. 27.7. Schematic structures of bamboo cages for culturing marbled goby.

production of 675 kg (1485 lb) was obtained. The following data (Chaingamuang 1979) presented the goby's production cost-benefit evaluation:

Cost		
cage and accessories	\$ 650	(U.S.)
fingerlings	1200	
feed	630	
chemicals and supplies	50	
Total	\$2530	
Returns		
675 kg @ \$7.25	\$4893.75	
Benefit	\$2363.75	

Brackish Water Fish Culture

Thailand has very large areas of mangrove swamps, most of which are suitable for fish culture purposes. Unfortunately, only a few brackish water aquaculture areas are in actual operation at present. Vast areas of such fertile tidal swamps are still not being utilized.

One of the very few fish ever cultured in brackish waters is the anadromous sea bass (*Lates calcarifer*). This fish is regarded as one of the best of all Thai estuarine fish. It is found along the entire coast of the Gulf of Thailand in brackish waters and may even ascend the rivers to where the water is entirely fresh.

Young sea bass are collected for culturing purposes from estuarine areas, especially at the river mouth of the Chao Phraya river. They are usually caught with traps and nets and are transported by small boats for culturing in areas near the mouths of rivers.

Sea bass may be cultured in ponds or in cages. To ensure good survival, young sea bass of 10–20 cm (4–8 in.) in total length are used for stocking. When sea bass are stocked in ponds, a stocking rate of 2500–5000 fish per ha (1011–2023 per acre) is generally used, and when stocked in cages, about 5 fish per m³ of water volume (approx. 5 fish per yd³).

Most of the ponds used for culturing sea bass are provided with strong dikes and gates to prevent flooding but allow the water to circulate freely. The ponds are earthen, rectangular in shape, at least 1600 m² in size (4/10 acre), and 1–2 m in depth (3–6½ ft).

In ponds, sea bass are generally fed a fresh chopped trash fish at the rate of 1.5 kg (3.7 lb) of feed per 100 fish. After six months of feeding, a production of 2500 kg per ha (2230 lb per acre) is possible, with a feed conversion of 7–10.

Cages generally used for stocking sea bass are made of nylon net. Their dimensions are usually 5 × 5 × 2.5 m (16.25 × 16.25 × 8.1 ft), although they vary considerably. The cages are set in great densities along the banks of mildly flowing waters.

Cage culture of sea bass relies entirely on heavy supplemental feeding of

fresh chopped trash fish. The best average production output of 400 kg of fish per 100 m² of cage (7.6 lb per ft²), with a feed conversion of 7–10, can be obtained in about one year of feeding.

Grey mullet (*Mugil* spp.) is another species of anadromous fish that has been encouraged for culture in brackish water ponds. Fry and fingerlings of this fish are found in the tidal streams and canals along the coast on both sides of the Gulf of Thailand.

Cage culture of grouper (*Epinephelus tauvina*) in brackish waters is underway but still at an early stage of development and is conducted on a pilot scale. Recent data (Dep. Fish. Minist. Agric. Cooperatives 1976) indicated that 300 grouper fingerlings, averaging 7.5 cm in total length, stocked in a nylon-net cage of 4 × 5 × 2 m, and fed fresh chopped trash fish or inexpensive shrimp attained their average weight of 500 g (30 cm in total length) in eight months, with a feed conversion ratio of 3.6.

Green mussel (*Mytilus smaragdinus*), rock cockles (*Anadara granosa*), and oyster (*Ostrea* spp.) farming are in operation in the estuarine areas along the muddy flats. Most of these farms are small and primitive.

Shrimp Farming

Brackish water shrimp farming is commonly done in the estuarine areas. Methods of this kind of farming are primitive and traditional. The ponds are mostly constructed in swampy areas near the mouth of the river, and have strong dikes and gates to prevent flooding but allow the tidal water to get into them freely. The estuarine water, which contains post-larvae and juvenile shrimps, is let into the ponds through the gates during high tide.

When the tide recedes, the gates are partially opened and water is allowed to flow out through a bamboo screen fixed in the gate to prevent the escape of the juveniles. This practice is repeated every high tide. The environment provided in these ponds is suitable for the natural growth of shrimp, and they feed on the naturally available plant and animal life. Some ponds are fertilized by farmers before the shrimps' spawning season. Shrimp fry are then stocked in such ponds and may reach marketable size within 3–4 months.

Harvesting is done in the periods of spring tide, when a special conical net is fixed to the mouth of the gate and water from the ponds is released through it with much force at low tide. The shrimp are caught at the cod-end of the net and are removed periodically. When total harvesting is done at the end of the culture season, shrimp are captured by various methods.

Among species harvested are tiger prawn (*Penaeus monodon*), banana shrimp (*P. merguensis*), sand shrimp (*Metapenaeus monoceros*), and short-horned shrimp (*M. brevicornis*).

Each culture pond occupies an area varying from 4 ha (10 acres) to more than 10 ha (50 acres). Annual production figures vary from 270 kg per ha to 330 kg (241 to 294 lb/acre).

The main disadvantages of this natural stocking system of shrimp cul-

ture result from the lack of control of the stocking process. Larval and young shrimp populations fluctuate unpredictably under natural conditions, and farmers cannot predict or regulate the kinds or number of shrimp entering the pond. The uncontrolled entry of predatory or competitive species with the young shrimp also keeps production down.

Modern techniques of shrimp hatcheries in Thailand have a history of less than two years, but are advancing rapidly. These hatcheries will soon be progressive to the point where post-larvae of desired species of shrimp can be mass-produced. Farmers will then be able to practice controlled stocking in the ponds, increasing shrimp production by at least 100%.

MARKETING SYSTEM

A great percentage of fish is sold fresh at the various local food markets. Catches from commercial fish farmers are transported by boats, trucks, or trains to other places. Hardy air breathers like snakeheads and catfish are sent alive in special tin containers filled partially with water. Various carps, sepat Siam, etc., are sent fresh in bamboo baskets or wooden cases lined with banana leaves and provided with crushed ice.

The New Wholesale Fish Market has been established in Bangkok by the government and has offered good services to all concerned. The market consists of fish agencies where all are given the right to occupy an office and a suitable space for auctioning in a big hall of the market. The main objectives of the market are to help fish farmers receive full value from their catch and to prevent frauds from occurring. The fish agencies are constantly inspected and checked by government fishery officers. However, such goals can be achieved only by fish farmers whose farms are close to the market and who can transport their catch to the wholesale market at their own expense.

Use of this fish market is prohibitive in cost to fish farmers who are in debt and whose farms are far away from the market. Since they cannot sell their catch directly to the wholesale market or to the consumers, their catches are disposed of through the hands of middlemen. The poor fish farmers, who have borrowed money from the middlemen for running their farms, are obliged to sell their products to their creditors. With such a marketing system, the fish farmers receive low prices. The prices are at the creditor's mercy, the creditor's bookkeeping might be false, and miscellaneous expenses are added and all charged to the fish farmers.

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Philippines

FISH AND OTHER AQUATIC SPECIES

Catfish (<i>Clarias</i> spp.)	Tiger prawns or “sugpo” (<i>Penaeus monodon</i>)
Common carp (<i>Cyprinus carpio</i>)	Tilapia (<i>Sarotherodon</i> sp., <i>Tilapia</i> spp.)
Crabs	<i>Tilapia mossambica</i>
<i>Elops</i> spp.	<i>Tilapia</i> (<i>Sarotherodon</i>) <i>mossambica</i>
Filamentous algae (“lumot”)	<i>Tilapia</i> (<i>Sarotherodon</i>) <i>nilotica</i>
Gobies	<i>Tilapia zilli</i>
Gourami	(Lizards)
Java tilapia	(Snails)
Microbenthic organisms (“lab-lab”)	(Snakes)
Milkfish (<i>Chanos chanos</i>)	
Native catfish or “hito” (<i>Clarias macrocephalus</i>)	
Penaeid shrimp	
Phytoplankton	
Shellfish	
Shrimp	
Siganids (rabbitfish) (<i>Siganus canaliculatus</i>)	
Snakehead or mudfish (<i>Ophicephalus striatus</i>)	
Thai catfish (<i>Clarias batrachus</i>)	

Philippines

*Margarita L. Hopkins
and Kevin D. Hopkins*

Milkfish culture in brackish water ponds dominates the Philippine aquaculture industry. It was introduced into the Philippines over 400 years ago by Malay emigrants. The fishpond industry was originally concentrated in the towns of Malabon and Navotas, 10 km (6 mi) north of Manila (Villaluz 1953). It is now scattered throughout the country with provinces of Iloilo, Bulacan, and Pangasinan having the largest concentrations of milkfish farms. Milkfish are also cultured in fishpens along the shorelines of Laguna de Bay, a 91,136 ha (225,000 acre) freshwater lake.

In recent years, the culture of species once considered to be pests or of only incidental interest in brackish water milkfish ponds has developed. These species include tiger prawns, crabs, Java tilapia, and some siganids. In freshwater, cultured species include tilapia, catfish, common carp, and snakehead or mudfish.

The Bureau of Fisheries and Aquatic Resources (BFAR) is the Philippine government agency which publishes fisheries production statistics. The statistics are derived from production estimates submitted by BFAR extension agents. Alternate estimates have been derived from the National Food and Agriculture Council (NFAC) food consumption surveys. The 1970–1975 BFAR fishpond production estimates (BFAR 1976) are approximately 35% lower than the NFAC estimates (Santos *et al.* 1976). BFAR fisheries statistics, compilations thereof, are used as the basis of the industry status.

The status of the Philippine fish culture industry in 1978–1979 is presented in Table 28.1. Approximately 73% of the production was milkfish, 13% was tilapia, 7% shrimp, 6% crabs, and about 0.6% carp (Juliano and Yutuc 1977). The official estimate of total industry investment is \$250 million based on an average development cost of \$1350/ha (547/acre). However, current average development costs of freshwater fishponds now exceed \$6700/ha (\$2713/acre) (Hopkins *et al.* 1980). The aquaculture industry, including shellfish and seaweed culture, employs 190,000 people who support a population of 1 million Filipinos. In 1978, 2975 MT of frozen shrimp, 13,574 MT of seaweed, and 152.2 MT of milkfish valued at \$56 million were exported (FIDC 1980).

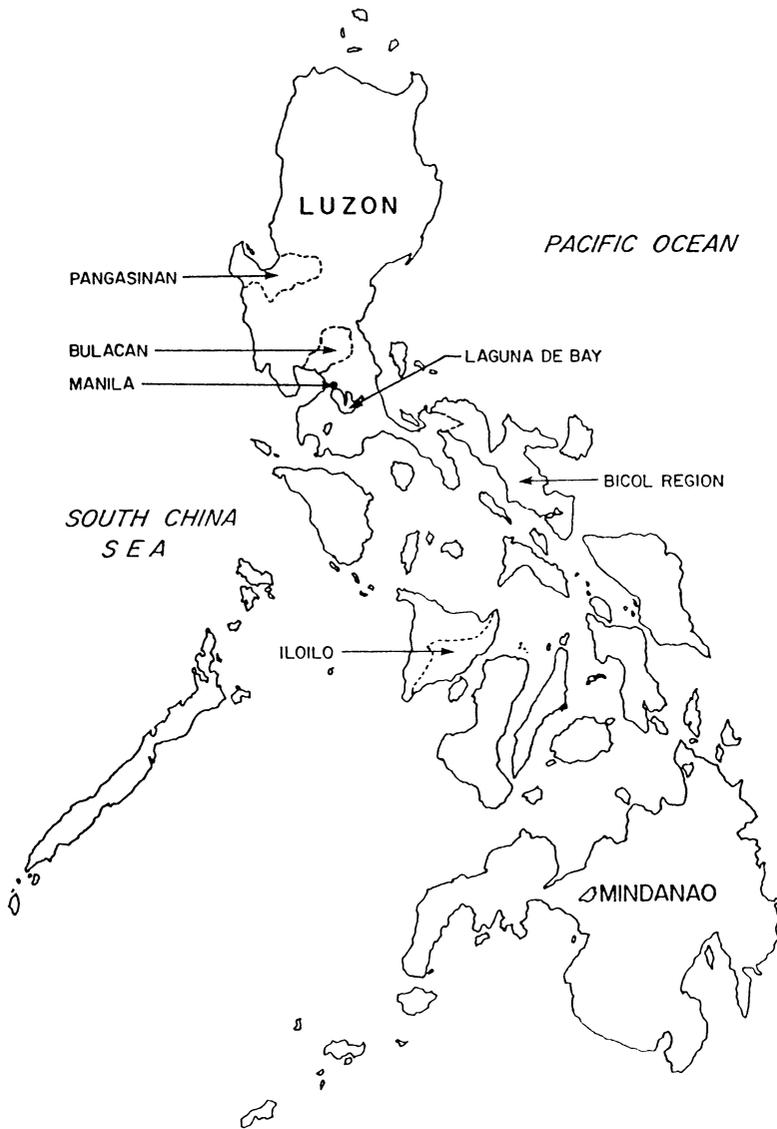


Fig. 28.1. Map of the Philippines.

TABLE 28.1. STATUS OF PHILIPPINE AQUACULTURE INDUSTRY IN 1978–1979

Sector	Area (ha)	Production (MT)	Value \$ × 1000
Brackish water ponds	176,000	112,640	111,275
Freshwater ponds	6,000	3,000	2,550
Fishpens	4,400	30,800	30,430
Total	186,400	146,440	144,255

Source: FIDC (1980).

Each ha is equivalent to 2.47 acres and each U.S. customary short ton is 1.10 MT.

MILKFISH (*Chanos chanos*)

Traditional Philippine milkfish farming uses extensive culture methods which rely on the brackish water ponds' natural productivity. Few or no supplementary inputs such as fertilizers are used (Chong 1980). Yields tend to be low, only 50–300 kg/ha/year (45–260 lb/acre/year). The traditional methods still predominate in much of the country.

Intensive systems, which utilize supplementary inputs, yield over 1000 kg/ha/year (900 lb/acre/year) and are operated by the more progressive fish farmers. The widespread use of fertilizers which started in the 1950s (Lujauco 1979), in addition to the introduction of fish culture innovations from neighboring countries, particularly Taiwan, has raised the national average production to 640 kg/ha/year (570 lb/acre/year).

Brackish water fish farms vary in size from 200 m² to 700 ha (1/20–1729 acres) with an average farm size of 13 ha (32 acres). The farms are usually constructed with manual labor. Pond depth is determined by the tidal characteristics and whether shallow- or deepwater culture methods are to be used. The perimeter or main dike must be higher than the highest tide and is larger than the secondary dikes which subdivide the farm. A typical farm has three major types of ponds (Fig. 28.2). The rearing ponds occupy 83 to 89% of the farm, 10% is used for transition ponds, and 2 to 7% is nursery ponds. In addition, large farms normally have catching ponds although the supply canals are often used for this purpose (Librero *et al.* 1977).

Water control structures are usually sluice gates. The main gates control the entry and exit of tidal water. The size and number of main gates are determined by the farm size. Main gates are usually constructed of reinforced concrete hollow block. Secondary gates, usually made of treated woods, are used to control water movement inside the farm.

The shallow-water culture method, commonly called the "lab-lab" method, is based on growing dense mats of filamentous algae ("lumot") and microbenthic organisms ("lab-lab") in ponds 30–50 cm deep (12–20 in). This method can be either extensive or intensive depending on whether or not the farmer uses supplementary inputs.

The deepwater or plankton method was first promoted in the early 1970s.

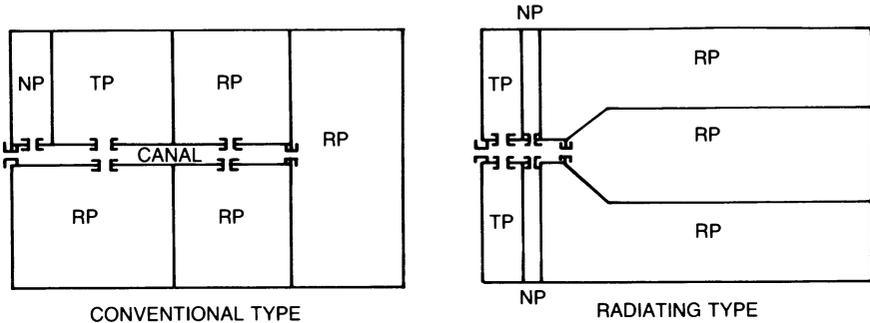


Fig. 28.2. Examples of Philippine brackish water milkfish pond designs. NP—Nursery pond. TP—Transition pond. RP—Rearing pond.][—Gate. Courtesy of Dr. Catalino de la Cruz.

Ponds are 1.0–1.5 m deep (39–58 in.) and phytoplankton growth is encouraged with fertilization. Both the deepwater and shallow-water methods can produce high yields.

Extensive culture systems require little management. Water is allowed to enter at high tide, the gates are closed, and fry/fingerlings are stocked. Stocking levels tend to be very low, sometimes relying only on fish that enter with the tide, and are often contingent upon the availability of operating funds. There are two culture periods per year each lasting 4–5 months. During the driest time of the year, about two months, milkfish are usually not cultured because the salinity becomes too high in the ponds. The dry season varies throughout the country.

Intensively managed ponds are prepared before stocking by eliminating pests, liming, and fertilization. Fishpond pests include fish such as *Tilapia mossambica*, gobies, and *Elops* spp., lizards, snakes, crabs, and snails. Control measures include manual removal, use of pesticides, and drying of the pond bottom.

Inorganic and/or organic fertilizers are used to enhance the growth of fish food. A majority of milkfish farmers prefer inorganic fertilizers, particularly ammonium phosphate and urea. Average inorganic fertilizer rates vary from as few as two applications of 37 kg/ha/year (33 lb/acre/year) of nitrogen to as many as seven applications of 40 kg/ha/year (36 lb/acre/year) of phosphorus to somewhere between these two extremes. (Librero *et al.* 1977). Research has shown that phosphorus is more limited than nitrogen and that potassium is not limited in brackish water ponds. Fertilization practices do not reflect these findings. The “uncontrolled” usage of fertilizer may be caused by a lack of technical information on the part of the farmers or by the farmer’s using whatever fertilizer is available.

Chicken manure is the most commonly used organic fertilizer. Other organic fertilizers used are hog manure, guano, rice bran, night soil, and mud press (refuse from sugar molasses). Organic fertilization rates are highly variable. The average rate for chicken manure is 1500 kg/ha/year (1336 lb/acre/year).

In addition to fertilization, many fishpond operators also add lime to their ponds. This is often necessary, particularly in ponds on acid-sulfate soils, in order to raise the soil pH and increase the buffering capacity of the water.

Fry or fingerlings are stocked when the farmer decides that there is enough natural food present. Prior to stocking, the fish are acclimatized to reduce stress from temperature and salinity changes. Fish are stocked in the early morning or late afternoon. Fry are collected from the wild, so stocking usually occurs during the fry-collecting seasons. Many farmers do not follow any readily apparent rules on the number of fry to stock although 10,000 fry/ha (4050/acre) seems to be the maximum. The availability of fry and operating capital seem to be the factors controlling stocking rate. The more progressive farmers consider carrying capacity of the ponds, type and amount of fish food raised, and size desired at harvest when determining stocking rates.

Typically, fry are raised in nursery ponds until fingerling size, about 10 cm (4 in.) total length, and are transferred to transition ponds where they are grown to 15–20 cm (6–8 in.). The fish are then transferred to the rearing ponds for culture to market size (100 to 250 g or ¼ to ½ lb). Most intensively managed milkfish farms have two culture periods per year but some are able to grow three crops per year. Milkfish are sometimes cultured for longer periods in order to produce export size (500–1000 g or 1–2 lb) fish.

The most common harvesting method is draining the pond. Other harvesting methods include seining, gill netting, using fish corrals, and the "pasubang" method. In the "pasubang" method, the pond is partially drained, and at the next tide, water is allowed to enter the pond. The milkfish swim against the current and congregate at the gate where they are netted out.

The milkfish industry is dependent upon seasonal supply of fry from the sea. The main season is from March to mid-August. A second season, October and November, occurs in some areas. Fry are collected along shallow sandy coasts, tidal creeks, and the mouths of rivers using various types of collecting gear including set bamboo and net traps and seining nets. Fry are sorted on the beach and stored in widemouth earthen jars. They are transported to the fishponds in oxygenated plastic bags inside woven "pandan" (similar to palm leaves) bags.

The adequacy of the fry supply is a matter of some debate. Several Philippine and international organizations are exerting considerable efforts to induce and control the spawning of milkfish, and the Philippine

government has imposed numerous trade restrictions on the export of milkfish, all in the name of alleviating a fry shortage. However, Smith *et al.* (1978) examined the fry industry in detail and concluded that adequate fry supplies are available.

The economics of milkfish culture in brackish-water ponds are highly dependent on whether extensive or intensive culture systems are used. Tables 28.2 and 28.3 present examples (not average) of costs and returns from extensively and intensively managed fish farms, respectively. Why do farmers still manage their milkfish ponds extensively when intensively managed ponds are much more profitable? Chong (1980) listed several reasons, including lack of knowledge, lack of capital, unawareness of credit availability, and high cost/unavailability of inputs in many areas. The Philippine government is trying to alleviate many of these problems.

The marketing procedure for most milkfish is relatively simple. After harvest, the fish are sorted, sized, and packed for transport. The fish are usually packed in ice when transported to places requiring more than one day travel time. Transport is by truck, water, and air. Figure 28.3 shows the marketing channels and disposition of milkfish in Luzon.

Milkfish pen culture in Laguna de Bay is based on technology developed by BFAR and the Laguna Lake Development Authority during the late 1960s. Laguna de Bay is shallow and is highly eutrophic due to the agricultural runoff and wastes it receives from surrounding towns.

Fishpens are usually made of bamboo and wooden posts to which synthetic nets are attached. A few are of bamboo and chicken wire or bamboo screens alone. Most large pens have double walls of netting to reduce the possibility of escape. Pen shapes vary from circular to rectangular. Although a circular pen is the least expensive to construct, a square shape is preferred because of the area lost between adjacent circular pens. A very

TABLE 28.2. COSTS AND RETURN OF AN EXTENSIVELY MANAGED BRACKISH WATER MILKFISH FARM IN PANGASINAN, PHILIPPINES, 1978
U.S. \$/ha/year and \$/acre/year.

	Per ha (\$)	Per Acre (\$)
Operating costs		
fingerlings (267 pieces/ha or 108/acre)	16.67	6.75
labor	4.64	1.88
maintenance and repair	27.84	11.27
marketing cost	0.24	0.10
Fixed cost		
depreciation	13.00	5.26
Total costs	62.39	25.26
Returns		
milkfish (33 kg/ha or 30 lb/acre)	33.40	13.52
Net return	(28.99)	(11.74)

Source: Chong (1980).

TABLE 28.3. COSTS AND RETURNS OF AN INTENSIVELY MANAGED BRACKISH WATER MILKFISH FARM IN PANGASINAN, PHILIPPINES, 1978
 U.S. \$/ha/year and \$/acre/year.

	Per ha (\$)	Per Acre (\$)
Operating costs		
fingerlings/fry (6364 pieces/ha or 2577/acre)	79.55	32.21
fertilizers (109 kg manure/ha or 97 lb/acre) (50 kg 16-20-0 or 45 lb/acre)	13.79	5.58
algae	4.55	1.84
pesticides	5.13	2.08
labor	61.26	24.80
marketing cost	86.17	34.89
Fixed costs		
depreciation	4.51	1.83
lease fees and imputed rent	57.47	23.27
taxes	9.47	3.83
Total costs	321.90	130.32
Returns		
milkfish (1365 kg/ha or 1216 lb/acre)	1609.86	651.77
shrimp ¹ (27 kg/ha or 24 lb/acre)	85.54	34.63
Total returns	1695.40	686.40
Net returns	1373.50	556.08

Source: Chong (1980).

¹ Shrimp fry entered with the tide.

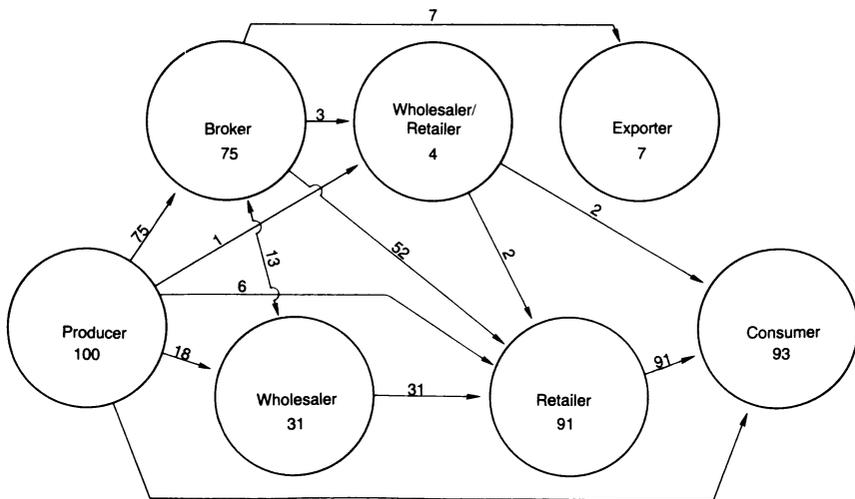


Fig. 28.3. Marketing channels for milkfish, Luzon, 1980. From Guerrero and Darrah (1975).

detailed description of fishpen construction is presented in Delmendo and Gedney (1974).

Fishpens range from $\frac{1}{6}$ ha to over 100 ha (0.4 to over 250 acres) with an average size of 6.5 ha (16 acres). Fishpens below 5 ha (12.4 acres) are managed as a single compartment. Otherwise, they are subdivided into rearing compartments. Temporary nursery pens are located inside the rearing compartment. The area devoted to nursery pens depends on the number of fish held at one time. A suggested nominal size nursery pen is 400 m² ($\frac{1}{10}$ acre) which can hold 50,000 fingerlings. Fry/fingerlings are delivered to the pen by using motorized boats filled with water. The boat can accommodate 40,000–50,000 fingerlings (5 cm or 2 in. or less). When a motorized boat is not available, plastic bags with water and oxygen are used. Acclimatization of at least 5 hr is necessary prior to release into the nursery pen.

Prior to stocking, the pen is idled to allow complete decomposition of excess food and other organic matter left from the previous production cycle. Pens should be idled at least one month per year. Pens are prepared for stocking by cleaning and checking for holes in the nets, replacement of deteriorated poles and nets, harrowing the bottom mud until it is softened, removal of floating debris, and eliminating predators by seining, hand, or electric shock.

Harrowing is done with the native harrow used for cultivating rice fields. A long handle is fitted on the harrow and placed in front of a small motorboat. It is held by a man who regulates the depth that the harrow sinks into the mud as the boat pushes it forward (Mane 1975).

When the fingerlings reach a size larger than the net opening and if natural food is sufficient, they are released into the rearing pens. If natural food is lacking, the fingerlings will be allowed to remain in the nursery pen and fed supplementary feeds until the natural food supply is sufficient. Major stocking is done in May. The average stocking rate is 36,000 fingerlings/ha (14,575/acre). The rearing period is six months from stocking to harvest. During the entire rearing process, constant surveillance is required. Pens have to be checked above and below water for holes in the nets and defective poles, and floating debris and water hyacinths that collect along the pens must be removed. Although fertilization in Laguna de Bay fishpens is discouraged due to its potentially deleterious effects on water quality, some operators add chicken manure. Most pens rely on natural productivity, although some operators of larger pens add supplementary feeds such as bread crumbs, rice bran, broken ice cream cones, fish meal, algae, and *Leacaena leucocephala* and *Ipomoea reptans* leaves (Nicolas *et al.* 1976).

Fish are harvested by seining, gill netting, or a combination of both. Factors determining time of harvest are size of the fish desired, market demand, and weather conditions. Laguna de Bay fishpens are susceptible to typhoon damage so notice of an approaching typhoon can trigger harvesting.

Pen culture of milkfish is extremely sensitive to economics of scale. For example, in 1975, a 1600 m² (0.4 acre) pen cost approximately \$1150 to build (\$7120/ha, \$2883/acre) while a 5 ha (12.5 acre) pen cost only \$10,100 or \$2020/ha (\$818/acre) to build (Felix 1975). The average receipts for a Laguna de Bay milkfish pen are shown in Table 28.4.

Extensive typhoon damage of pens occurs every year or two. The loss to society is not complete, however, because the fishermen catch much of the escaped fish. Other problems are susceptibility to theft, off-flavor, and occasional die-offs when plankton blooms become too dense in parts of the lake.

TILAPIA (*Sarotherodon* and *Tilapia* spp.)

Tilapia are cultured primarily as a secondary crop in brackish water fishponds. Tilapia production was approximately 19,037 MT (20,940 ST) in 1978 of which approximately 2100 MT (2310 ST) came from freshwater ponds and pens and 16,937 MT (18,630 ST) from brackish water ponds. *Tilapia (Sarotherodon) mossambica* is the predominant species, although it is now being supplanted by *Tilapia (Sarotherodon) nilotica* in freshwater areas. Some *T. zilli* are also grown.

In brackish water ponds, tilapia are essentially unmanaged. Wild fish enter the pond, grow, and are harvested along with the milkfish.

Most freshwater ponds are located in Luzon. One-third of all farms are less than 500 m² (0.12 acre) and only 29% are larger than 1 ha (2.47 acres). Approximately 40% of the farms use a monoculture system while the

TABLE 28.4. AVERAGE RECEIPTS AND EXPENDITURES FOR MILKFISH PENS IN LAGUNA DE BAY DURING JANUARY 1974–MARCH 1975

Item	per Farm (U.S. \$)	per ha (U.S. \$)	per Acre (U.S. \$)
Receipts			
cash	17,459	2682	1086
non-cash	151	23	9
total	17,610	2705	1094
Expenditures			
fingerlings	8,549	1313	532
feeds	312	48	19
hired labor	1,691	260	105
commissions	292	45	18
ice	82	13	5
equipment	913	140	57
transportation	319	49	20
others (including non-cash)	1,103	169	68
total	13,261	2037	825
Net returns	4,349	668	269

Source: Nicolas *et al.* (1976).

remainder add carp, milkfish, and other species singly and in various combinations (Tidon and Librero 1978).

Pond preparation includes pond cleaning, leveling, pest eradication, and fertilization. Pest eradication, primarily of the snakehead or mudfish (*Ophicephalus striatus*) is usually by "catch and kill." Only 40% of the farms use fertilizer. Two-thirds of the farmers use supplementary feeds such as rice bran.

Fish seed is collected from the wild or obtained from BFAR and commercial sources. The wild tilapia are primarily *T. mossambica* while commercial sources are trying to sell primarily *T. nilotica*. About one-half of the farmers now produce their own fingerlings, but the other half still rely on outside sources.

Market size is the major factor determining the time of harvest. Market size is defined as 50 g (about 2 oz) or larger. Although smaller fish are eaten, larger fish, 150–250 g (5–9 oz), are usually preferred. Selective harvest is most common with gill nets being the favorite gear. The average yield from a monoculture farm is 418 kg/ha/year (372 lb/acre/year). The tilapia yield in tilapia-carp ponds averaged 404 kg/ha/year (360 lb/acre/year), but the average production drops when milkfish and other species such as catfish are added to the pond. Whether this decrease is caused by competition and predation in the polyculture systems or by a tendency of the monoculture operations to be more intensively managed is not readily apparent.

One-third of the freshwater farms produce tilapia for home consumption but most of the output from monoculture farms is sold. The fish are sold primarily to local consumers on a cash basis. Only 18% of the farmers sell on a wholesale basis.

SHRIMP

Most cultured shrimp are a secondary crop from brackish water milkfish ponds. Although a large volume of literature exists on Philippine shrimp culture research and recommended culture techniques, the number and characteristics of shrimp culture operations are not presently known. Cultured shrimp production in 1978 was approximately 10,000 MT (11,000 ST). There are several species of penaeid shrimp cultured in the Philippines but *Penaeus monodon* (tiger prawn or "sugpo" locally) receives more attention because of its large size and export market potential.

Traditionally, juveniles and fry are collected from estuaries and are stocked into milkfish ponds. Stocking rates are reported to be 5000 to 10,000 fry/ha (2024 to 4048/acre), but there are farmers who rely on what enters with the tide. The completed reliance on the natural supply of prawn fry may change with the recent establishment of private shrimp hatcheries (Anon. 1980). Tiger prawns grow to market size (15–30 pcs/kg, 7–14/lb) in 5 to 7 months with "lumot" and "lab-lab" as food (Lopez 1975).

Intensive culture of shrimp is practiced by a limited number of farmers, primarily in areas served by the Southeast Asian Fishery Development Center's Cooperator's Program. This program disseminates information on shrimp culture and provides technical assistance to the cooperating farmers. The farmers are concentrated near Iloilo. The culture methods are very similar to methods used by progressive milkfish farmers. Platon (1979) presents a detailed description of the methods.

OTHER CULTURED SPECIES

The common carp, *Cyprinus carpio*, is a minor culture species with an estimated 1978 production of 879 MT (967 ST). Carp is cultured alone and in combination with tilapia. Average carp yield, when cultured with tilapia, is 322 kg/ha/year (287 lb/acre/year). Carp is well accepted in the Bicol region (southern Luzon) but is not particularly relished in most other parts of the country. The limited market for carp in addition to problems with fingerling supplies resulted in the slow development of carp culture.

Catfish, *Clarias* spp., are cultured on a very small scale in central and northern Luzon. The native catfish or "hito," *Clarias macrocephalus*, is preferred by consumers over the Thai catfish, *C. batrachus*, because of its taste. A majority of the catfish farmers use a polyculture system with various combinations of snakehead, tilapia, carp, and gourami. Fingerlings are collected from the wild or from wild spawning in fishponds. Stocking rate is around 500 fingerlings/ha/year (2024/acre/year). The fish are grown for at least 8 months before they can be harvested. Selective harvest is commonly practiced using seines, fill nets, or cast nets. Average yield of catfish is 320 kg/ha/year (285 lb/acre/year) for monoculture systems. Fertilized ponds yield approximately three times as much as unfertilized ponds (Ramos and Lapie 1979). Problems with catfish culture are lack of dependable fry and feed supplies.

The snakehead or mudfish, *Ophicephalus striatus*, is a predator which is cultured on a very small scale in Luzon. Mudfish farming is a part-time venture. The average farmer spends only one-twelfth of his time on mudfish culture. A majority of the mudfish farmers use polyculture systems with carp, tilapia, gourami, and catfish. Fingerlings are collected from natural waters, irrigation canals, or from wild spawns in fishponds. Approximately half of the operators add supplementary feeds such as rice bran, bread crumbs, starter mash, ants, and *Ipomoea* leaves. The efficiency of these feeds for mudfish has never been determined but it is expected that the other fish derive most of the benefits from the feed. Mudfish are harvested after about six months at an average weight of 250–500 g (½–1 lb). Selective harvest of larger fish is done by a majority of the farmers. Most of the harvested fish are sold on a retail basis (Fabro and Librero 1979).

Siganids (rabbitfish), particularly *Siganus canaliculatus*, are cultured on

a very limited scale in the province of Pangasinan on the island of Luzon. They are cultured singly or in combination with milkfish or shrimp, particularly in those ponds in which the salinity becomes very high during dry season. Fry are collected from the wild. The fish are grown for at least three months after which they are harvested. Usually farmers harvest siganids twice a year (Masajo and Librero 1976).

POTENTIALS AND PROSPECTS

The potentials for aquaculture development are numerous but the prospects are not so clear. There are an estimated 140,000 ha (346,000 acres) of mangrove swamps which can be converted into brackish water fishponds and 500,000 ha (1,235,000 acres) of freshwater areas which could be used for ponds, pens, and cages (Asian Inst. Aquaculture 1978). However, the conversion of mangroves into fishponds may upset the ecological balance on which the fish and shrimp that make up the capture fishery rely. The Proceedings of the International Workshop on Mangrove and Estuarine Area Development for the Indo-Pacific Region (PCARR 1978) addresses this problem in some detail, including methods of minimizing the effects of converting mangroves into fishponds. It is expected that much of the 0.5 million ha (1,235,000 acres) of freshwater areas will prove to be uneconomical to develop for aquaculture.

The widespread use of intensive culture methods in existing brackish water fishponds could greatly increase fish production; but that would require large-scale financing programs which might be beyond the capability of the existing capital structure.

However, the future is not bleak. Large quantities of fish are now cultured and this should continue. As long as there is a very high-priced market for shrimp, that sector of the aquaculture industry is expected to increase in importance. Integrated agriculture-aquaculture systems, particularly rice-fish, are also expected to do well. There are an estimated 420,000 ha (1,037,000 acres) of rice field suitable for rice-fish culture (PCARR 1979). The BFAR with assistance from the U.S. Agency for International Development and several Philippine agencies has started a large-scale rice-fish extension program. The aquaculture research establishment in the Philippines is extensive. New and more efficient technologies are expected to be developed in the next few years.

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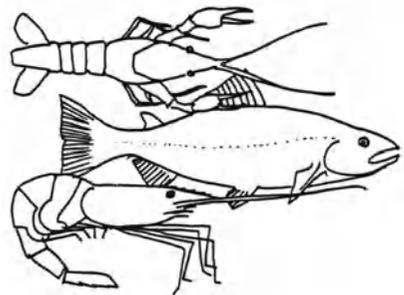
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Indonesia

FISH AND OTHER AQUATIC SPECIES

Bighead carp (*Aristichthys nobilis*)

Catfish (*Clarias* sp.)

Chinese carps

Common carp (*Cyprinus carpio*)

Freshwater shrimp (*Macrobrachium* sp.)

Giant gourami (*Osphronemus goramy*)

Goldfish (*Carassius* sp.)

Grass carp (*Ctenopharyngodon idellus*)

Kissing gourami (*Helostoma temmincki*)

Milkfish (*Chanos chanos*)

Mud carp (*Cirrhinus molitorella*)

Nilem (*Osteochilus hasselti*)

Penaeid shrimp

Sepat Siam (*Trichogaster pectoralis*)

Shrimp (*Penaeus indicus*, *P. merguensis*, *P. monodon*, *P. semisulcatus*, *Metapenaeus* sp.)

Silver carp (*Hypophthalmichthys molitrix*)

Snakehead (*Ophicephalus striatus*)

Tawes carp (*Puntius gonionotus*)

Tilapias (*Tilapia nilotica*, *T. mossambica*)

Tuna

Brackish water shrimp

Marine shrimp

Freshwater capture

Marine capture

Brackish water aquaculture

Freshwater aquaculture

[Red alga (seaweed) (*Eucheuma*)]

Indonesia

Michael C. Cremer

Indonesia is an archipelagic nation composed of approximately 13,600 equatorial islands. It extends nearly 5000 km (3100 mi) on an east-west axis, from eastern Irian Jaya (New Guinea) to the northern tip of Sumatra. Java, the most densely populated of an estimated 1000 inhabited islands, sustains about 63% of Indonesia's 140 million people on 7% of the nation's land area.

Fish is the primary source of animal protein in Indonesia. Per capita consumption of fish is estimated at 10.2 kg/year (22 lb). Consumption rates vary regionally, with estimates for major island groups of: Sumatra, 15.9 kg/year; Java, 5.5 kg/year; Kalimantan (Borneo), 33.2 kg/year; Maluku (Moluccas) and Irian Jaya (New Guinea), 30.6 kg/year (Ilyas and Djajadiredja 1976). The majority of fish consumed are supplied by the marine and freshwater capture fisheries. In 1976, approximately 73% of the estimated 1,483,000 MT (1,631,000 ST) of total fisheries production was of marine origin (Ilyas and Djajadiredja 1976). The remainder was obtained from the freshwater capture industry and from brackish water and freshwater aquaculture. Aquacultural production, estimated at 175,000 MT (193,000 ST) in 1976, contributes nearly 12% of total fish production (Ilyas and Djajadiredja 1977). Most fish products are marketed either fresh or salted and dried. Cold storage and freezing are reserved almost exclusively for high value export products such as shrimp and tuna.

Fish culture is practiced in freshwater and brackish water systems throughout Indonesia. In 1971 an estimated 290,400 ha (699,000 acres) were committed to fish culture (Brown 1977). Approximately 63% of this area (184,000 ha) was in brackish water pond production, with the remainder (106,400 ha) divided approximately 2:1 between paddy and freshwater pond production, respectively. More recent estimates of production areas are unavailable; however, both brackish water and freshwater production areas have expanded since 1971.

Brackish water culture areas are located predominantly along the north coasts of Java, Sulawesi (Celebes), and Sumatra. Limited brackish water culture is also conducted on Kalimantan and several of the smaller eastern islands. Freshwater fish culture is centered in Java, although many species are cultured in limited quantities on nearly all of the populated Indonesian

islands. Paddy culture (rice-cum-fish) is widespread throughout Indonesia, but has declined in recent years due to increased use of pesticides toxic to fish.

FRESHWATER AQUACULTURE

Numerous species of native and introduced freshwater fish and shrimp are cultured throughout the Indonesian islands. Primary culture species are the common carp *Cyprinus carpio* and the tawes carp *Puntius gonionotus*. Secondary culture species include the tilapias *Tilapia nilotica* and *T. mossambica*, nilem *Osteochilus hasselti*, snakehead *Ophicephalus striatus*, sepat Siam *Trichogaster pectoralis*, giant gourami *Osphronemus goramy*, kissing gourami *Helostoma temmincki*, silver carp *Hypophthalmichthys molitrix*, bighead carp *Aristichthys nobilis*, grass carp *Ctenonpharyngodon idellus*, mud carp *Cirrhinus molitorella*, catfish *Clarias* sp., goldfish *Carassius* sp., and freshwater shrimp *Macrobrachium* sp. These species are cultured in both mono- and polyculture systems under varying conditions.

Carp

The common carp is the most commercially important freshwater species cultured. Production techniques have largely been developed in Java, the historical center of agricultural and industrial development in Indonesia.



Fig. 29.1. Common carp are harvested from wooden cage submerged in an irrigation canal, West Java.

Numerous culture systems are used, including culture in paddies, ponds, cages, and raceways. In the traditional rice paddy and cage culture systems, fish nutrition is provided by the natural environment and no supplemental feed is given. In paddy culture, both rice-*cum*-fish culture and fish culture between rice plantings are practiced. Cage culture is generally conducted in irrigation/sewage canals. In raceway and pond culture systems, intensive feeding with high-protein pelleted feeds and/or agricultural by-products is generally incorporated. Combinations of the preceding systems are also common.

A system has developed in West Java in which carp are spawned and the fry grown to fingerling size at one site, then sold to farmers who grow the fish to 50–100 g (2–4 oz) in rice-*cum*-fish culture and then to 200 g (7 oz) in small ponds, after which the fish are sold to other producers who grow them to market size (0.5–1.0 kg/fish; 1–2.2 lb) in bamboo cages in sewage canals. In this West Java area the high market value of the carp (approximately Rp. 2000/kg; \$3.21/kg) has been the basis for the establishment of a large restaurant business. The carp are purchased directly from the producers and held in ponds at the restaurants prior to cooking.

Backyard Fishponds

West Java is also well known for its backyard fishpond systems in which ponds are located adjacent to family dwellings. Carps, tilapias, and gouramis are cultured, both for family consumption and for barter. Fish for sale or trade are harvested individually or in small lots as currency or trade goods are needed by the family. The fish are retailed on the premises or in local markets. Fingerlings are purchased to replace harvested fish. Markets designed specifically for selling and trading live fish of all sizes have developed which are unique to the Javanese fish culture industry.

Integrated Aquaculture Systems

A variety of integrated aquaculture systems is also used to culture fish. Common carp, tawes carp, nilem, *T. nilotica*, and *T. mossambica* are used in plant-*cum*-fish culture. In addition to rice, shallow-water paddies are planted with kankung (water spinach *Ipomoea reptans*), genjer (*Limnocharis flava*), or mendong (*Fimbristylis globosa*) and stocked with one or more of the preceding fish species. Periodic, partial harvesting of the plant material is customary, as are small applications of inorganic fertilizers after each harvest to stimulate new plant growth. The kankung and genjer are sold in local vegetable markets; mendong is pressed and dried and used to weave mats, bags, hats, and other products. Fish in the paddies are partially harvested as needed or completely harvested after 2–6 months. Other integrated systems use human wastes and the manures from cows, chickens, ducks, and other farm animals to enrich pond waters. The wastes are

either washed into the ponds from adjacent latrines and animal pens, or drop from pens and latrines built directly over ponds.

Economic returns to family labor and capital vary considerably for the integrated plant-cum-fish systems. In West Java, where production paddies are rented by farmers, net income ranges from approximately Rp. 210,000/ha/year (\$336) for rice-cum-fish culture to Rp. 790,000/ha/year (\$1264) for mendong-cum-fish culture (Djajadiredja 1980). Fish production in these systems is about 150–300 kg/ha/year (130–260 lb/acre), depending on the culture system and the level of technology used by the farmer.

Other Fish Species

Culture of other fish species is regionally scattered, with most culture being conducted in the provinces of Java and in Bali and South Sulawesi. The tawes carp, giant gourami, sepat Siam, nilem, catfish, goldfish, and tilapias are cultured in ponds. All but the goldfish are sold for food consumption. A fingerling production industry exists in some areas to produce tawes carp for stocking farmer ponds and paddies. Government hatcheries also produce tawes carp fingerlings for stocking in municipal waters. Although numerous Chinese carps, including silver, bighead, grass, and mud carps, have been introduced into Indonesia by the government, few have been released to the public sector. All but the silver carp are classified as experimental. The silver carp has been released to private farmers, but initial farmer acceptance has been poor, due to fish boniness and difficulties with harvesting and marketing.

Marketing

Pond-produced fish are normally sold fresh in local markets. Prices vary considerably by region and are generally influenced by the prices and availability of commercially caught marine and freshwater fish. In parts of West Java, for example, *T. mossambica* sells for Rp. 300/kg (\$0.22/lb), while in Aceh (northern Sumatra) the market price is only Rp. 75/kg (\$0.05/lb). The availability of marine fish is much greater in Aceh than in West Java.

Swamps and Lakes

In the provinces of South and East Kalimantan, the snakehead is cultured in floating cages in freshwater swamp and lake areas. These two provinces jointly have approximately 690,000 ha (1,663,000 acres) of swamp and lake area that support a large commercial fishery. This fishery provides much of the salted and dried fish for the Java market. In the snakehead culture, fingerlings are captured in the swamp and lakes and stocked into floating cages 2–3 m³ (22–33 ft³) in size. The fish are fed the entrails of other commercially caught fish that are eviscerated for salting and drying. Approximately six months after stocking, the snakehead are sold in local

markets on the perimeters of the swamp and lakes. The sale of cage-reared snakeheads supplements the income of canoe fishermen, many of whom live in floating houses in the swamp interior.

BRACKISH WATER AQUACULTURE

Brackish water fish culture has been practiced traditionally for centuries in Indonesia, particularly on Java. It was initiated at least 600 years ago as a mangrove swamp fishery using traps. Gradually the mangrove was removed, dikes were constructed, water control structures were installed, and, finally, the custom was established of stocking the ponds with milkfish *Chanos chanos* and shrimp juveniles caught along coastal beaches and estuaries.

Milkfish

The culture of milkfish in brackish water ponds (tambak) is now the largest fish culture industry in Indonesia. More than 180,000 ha of tambak are owned and operated largely as family businesses. Average farm family holdings are 2–2.5 ha. The industry has three major components: fry capture and distribution, pond culture, and marketing.

Milkfish fry are collected in coastal and estuarine waters when the normally pelagic adult fish come inshore to spawn. Fry are collected by pushing triangular, fine-mesh nets through shallow water areas. The fry are purchased from local collectors by brokers who then distribute the fry regionally and interinsularly to fish farmers and other brokers. Farmers stock the fry in fertilized nursery ponds of approximately 100 m² to acclimatize them and initiate growth. Fry at this time are transparent and about 2 cm long. Supplemental feeding with strained egg yolk, powdered milk, or ground agricultural by-products is often given to strengthen the fry and increase survival.

Fry are reared to fingerling size (10–20 g) in fertilized ponds in about 3 months. A portion of the fingerlings are then stocked into production ponds for grow-out to market size (200–500 g). The remainder of the fingerlings are stunted in holding ponds for stocking and grow-out in successive culture periods in production ponds. This is necessary because of the seasonality of fry availability.

Production ponds are constructed in tidal areas by digging a peripheral canal around the perimeter of the designated pond area and using the excavated soil to construct dikes. Wooden or concrete sluice gates with flashboard closures allow filling and draining of the ponds via tidal action. Water depth in the interior peripheral canal is maintained at a depth of about 1 m, allowing a 30–40 cm water depth over the majority of the pond. Production ponds range in size from about 0.25 to 5 ha, with an average area of approximately 1 ha.

Production rates vary with stocking density, level of management, and

number of culture periods per year. Average milkfish production is 400–500 kg/ha/year. More sophisticated management techniques achieve productions of 1000–1800 kg/ha/year. The latter use stocking densities of 1500–2000 fish/ha for 3 consecutive culture periods of 3 months. Returns to management and capital for the more intensive milkfish culture practices (1200 kg/ha/year) are approximately Rp. 190,000/ha/year (\$458—1978 exchange rate) (Table 29.1).

Marketing systems for milkfish are complex, with a large number of buyers and traders between farmer and retail outlets. Marketing is predominantly localized. Some regional marketing occurs when transportation linkages can operate economically. In Java, where road infrastructure is well developed, surplus production from East Java is shipped to the national capital, Jakarta, located in West Java. Milkfish sales are often seasonal, declining from October to March when increased marine fish landings depress market prices.

Penaeid Shrimp

Penaeid shrimp have traditionally been cultured with milkfish in brackish water ponds as secondary species. More recently shrimp culture has increased in importance with increasing export value and market stabilization. Shrimp is the leading fishery export product in Indonesia, both in quantity and value. In 1976 total export was 31,279 MT valued at \$116,235,000 (Ilyas and Djajadiredja 1979). Although shrimp exports were predominately marine-captured, cultured shrimp are gaining as a percentage of total exports. In 1974 the Indonesia government estimated brackish

TABLE 29.1. PRODUCTION COSTS AND RETURNS FOR A 1.0 HA MILKFISH PRODUCTION POND¹

Item	Unit	Cost/Unit (Rp.)	Unit/ha/Year	Total (Rp.)
Fixed costs				
depreciation	ha	36,000	1	36,000
Variable costs				
milkfish fry	each	6	5000	25,000
organic fertilizer	kg	7	3000	21,000
inorganic fertilizer	kg	70	300	21,000
brestan	kg	10,000	1	10,000
derris root	kg	1,000	12	12,000
harvest labor	man-day	400	32	12,800
maintenance labor	man-day	400	120	48,000
				149,800
Interest on operating capital excluding labor (15% per annum)				13,350
Total costs				199,150
Gross returns				
milkfish sales	kg	300	1200	360,000
Net returns				160,850
Returns to family labor				28,800
Cash income				189,650

¹Source: Data from Cremer (1978).



Fig. 29.2. Milkfish, the principal brackish water cultured species in Indonesia, are harvested and packed in rattan baskets for transport to market, Sumatra.

water shrimp production potential at 63% of marine shrimp production potential (Anon. 1974).

Farmers collect shrimp juveniles from natural waters by opening pond gates at high tide for several consecutive nights. Shrimp enter with incoming water. Shrimp are then either left to grow in the ponds or the ponds are drained and the shrimp collected for stocking in separate production ponds. Production ponds are stocked with shrimp juveniles at rates from 1000 to 20,000 shrimp/ha.

Major shrimp culture species are *Penaeus indicus*, *P. merguensis*, *P. monodon*, *P. semisulcatus*, and *Metapenaeus* sp. Production techniques are similar to those for milkfish in which fertilization, pest control, and water management methods are practiced. No supplemental feeds are given. Culture periods range from 2 to 6 months. Productions average 200–400 kg/ha/year, and range as high at 800 kg/ha/year. Shrimp production is seasonal, depending on the availability of juveniles. Economic returns are often high even on low productions, as farmers receive up to \$8/kg for large, export-quality shrimp. Large mortalities and size variation are common in production ponds as management techniques are presently not well developed.

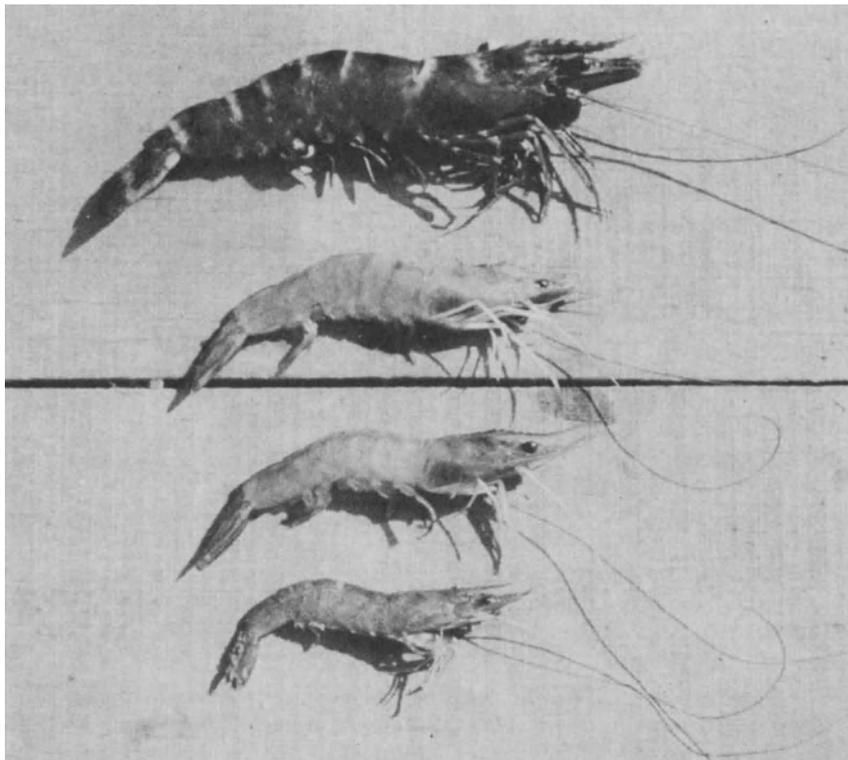


Fig. 29.3. Four species of penaeid shrimp used in monoculture, traditionally cultured in brackish water ponds in Indonesia.

MARINE AQUACULTURE

The culture of *Eucheuma* seaweed is the only mariculture activity in Indonesia known to the author. The red alga is cultured for its valuable extract, carrageenan, which is used as an emulsifying and stabilizing agent in food, cosmetic, and chemical industries. *Eucheuma* farming is relatively new in Indonesia, having been started in the late 1970s to increase rural family income and to help alleviate depletion of natural seaweed beds.

The eastern islands are the main *Eucheuma* producing areas of Indonesia. The seaweed is cultured in shallow, protected reef areas. The most common culture technique is the monoline method, in which nylon line is strung between wooden stakes at a depth of approximately 15 cm below the lowest tide level. Lines are spaced at 50 cm intervals. Small pieces of *Eucheuma* are tied at 10–20 cm intervals along the nylon line. The seaweed

grows down and out and is harvested in approximately 2 months. The strongest appearing plants are retained and are split and retied for another crop. The harvested seaweed is sun-dried and sold in bulk form. FOB price at Ujung Pandang, South Sulawesi, was \$620/MT (dry weight) in 1979 (Hollenbeck *et al.* 1979).

Family production plots are generally less than 0.5 ha in size. Estimated returns for an established 0.50 ha family unit are approximately \$3050 per annum (Hollenbeck *et al.* 1979).

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Papua New Guinea

FISH AND OTHER AQUATIC SPECIES

Brown trout (*Salmo trutta*)

Freshwater crayfish

Cherax (Parastacidae) (10 spp.)

Rainbow trout (*Salmo
gairdneri*)

Salmonoids

Papua New Guinea

J.L. MacLean

RAINBOW TROUT (*Salmo gairdneri*) AND BROWN TROUT (*Salmo trutta*)

The highlands of Papua New Guinea have been supporting trout populations since their first recorded introduction in 1949. Regular stockings began in 1971 with the establishment of a government hatchery. Eyed-eggs for the hatchery are imported from Australian trout farms. Both rainbow and brown trout have become established in several small rivers above 1200 m (4000 ft) altitude.

The successful acclimatization in stocking led to the commencement of the country's first and only private culturing farm. This is the Kotuni trout farm near Goroka which was established in 1973. This farm imports eyed rainbow trout eggs from several private disease-free hatcheries in Australia. The eggs are hatched at the farm.

The hatchery, circular, and rectangular ponds are gravity fed by pipes and channels which convey 6400 liters (1500 gal.) of water per minute. Fry and fingerlings are fed on standard fish pellet food which is imported. An equivalent product may be produced locally in the near future.

Marketing began in 1975 when 9 MT (10 ST) of dressed trout were produced from 446 m² (4800 ft²). In 1976 production was anticipated to be 10 MT (11 ST) from 566 m² (6090 ft²). The capacity of the farm is estimated to be about 15 MT (16.5 ST). This volume is seen as sufficient to fill the total demand in Papua New Guinea. In addition to this volume of food fish, some fingerlings are also sold for river stocking. While the present capacity of the farm is 15 MT, there is ample cold water in the district for a projected expansion to 100 MT (110 ST) if export markets can be commercially exported.

A number of problems are associated with the venture. The most difficult are the logistics of marketing and distribution of the product to a widely scattered population. On the technical side, the major problem is water temperature. On a sunny day the temperature of the water reaching the farm climbs from an overnight low of around 8°C (46°F) to 18°C (64°F). This plays havoc with fish feeding and affects feed conversion rates. Growing time of the fish is 18 months.

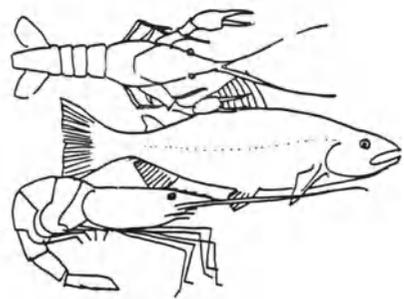
So far the wild and farmed stocks of trout in Papua New Guinea are

disease-free. Legislation is in hand to ban import of salmonoids from countries known to have disease problems.

There are no other aquaculture projects in the country at present. Growing international trade in small freshwater crayfish is creating interest, however. Ten species of *Cherax* (Parastacidae), some of which are suitable for export, inhabit a wide range of habitats throughout Papua New Guinea, and there are large tracts of land ideal for extensive farming.

SPECIAL ACKNOWLEDGMENTS

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Australia

FISH AND OTHER AQUATIC SPECIES

Brown trout (*Salmo trutta*)

Catfish (an eel-tailed fish)
(*Tandanus tandanus*)

European kraftor

Freshwater crayfish

Freshwater crustaceans

Golden perch (*Plectroplites
ambiguus*)

Marron (freshwater crayfish)
(*Cherax tenuimanus*)

Murray cod (*Maccullochella
macquariensis*)

Native freshwater fish

Oysters

Rainbow trout
(*Salmo gairdneri*)

Rock oysters

Salmonoids

Saratoga (*Scleropages
leichardti*)

Shrimp (*Macrobrachium
rosenbergii*)

Silver perch (*Bidyanus
bidyanus*)

Sleepy cod (*Oxyeleotris
lineolatus*)

Trout

Yabbies (*Cherax destructor*)

Australia

J.L. MacLean

The Australian aquaculture scene is dominated by oyster producers—10,000 MT of Sydney rock oysters are produced annually in New South Wales. The year 1960 can be taken as the starting point of finfish aquaculture. A small trout farm began then as well as a research station to study reproduction in native fish. Commercial-scale trout production commenced in the mid-1960s while native fish are still not reared to market size commercially. The 1970s saw research begin on several freshwater crustaceans with plenty of promise, but as yet there are no signs of a farmed crayfish industry.

Australia is the driest continent. The few native freshwater fish the early settlers found in the rivers were not very appealing and trout for stream stocking began to be imported as early as 1864, feeding highland streams and now supporting a vigorous sport fishery.

RAINBOW TROUT (*Salmo gairdneri*)

Rainbow trout were the first finfish species used for farming in Australia. A small farm in Victoria produced small quantities of table trout in 1960. The first commercial-scale development began in 1964 in Tasmania. Rainbow trout production commenced there in 1965 on a site containing 4 ha (10 acres) of ponds and earthen raceways. Production costs seemed likely to outweigh the price of imported trout until 1970, when a tariff board inquiry found the embryonic industry worthy of protection and placed a tariff on trout imports. By 1971 there were five trout farms in operation. The future of the industry was further enhanced by a ban placed on the importation of all fresh and frozen salmonoids in 1975. The reason was valid enough. Australia had found itself still free of the highly infectious diseases which were currently devastating trout farms in some parts of the world. Quarantine and fisheries authorities in Australia wish to preserve this happy situation.

There are now 12 trout farms in Australia spread through southern New South Wales, Victoria, South Australia, and Tasmania. Total production of dressed trout from these farms for the year ending June 30, 1976, was 177 MT (195 ST), almost all of it being rainbow trout from 3 farms totaling 6.2

ha (15 acres) in pond and raceway surface area. The remainder of farms supply fingerlings to local farmers, and there are a few “fish-out” operations where anglers pay to catch the trout from farm ponds.

Most of the farms produce eggs and/or fingerlings for sale to other farms, acclimatization societies, and for export. The total quantities are unknown, but a minimum estimate of private hatchery production is 100,000 fingerlings and 20 million eggs per year. In addition government hatcheries supply various farms, rivers, and impoundments with both brown (*Salmo trutta*) and rainbow trout.

Current producers anticipate increasing their production of table trout to a total of 482 MT (531 ST) of dressed fish from their present pondage area of 6.5 ha (16 acres). Only cultured trout can be sold. Wild trout are reserved for amateur anglers.

The problems faced by trout farmers in Australia are mainly of a “teething” nature—the lack of expertise in trout husbandry and local feed formulations. Australian banks are still skeptical of aquaculture. Demand far exceeds supply as yet but farmers see a need for consumer education to maintain sales. On the other hand, much of the land suitable for trout farming is in national parks and the remainder, in which developments such as fish farming are permitted, is at a premium. In Tasmania at least, intermittent closing down of hydroelectric stations prevents use of the majority of waterways.

NATIVE FISH

In contrast to the mystique of introduced trout, native freshwater Australia fish have dubious reputations as far as edible qualities are concerned. Limited in their distribution to muddy inland river systems, they have not found ready acceptance by Australians. These species in order of preference are Murray cod (*Maccullochella macquariensis*), golden perch (*Plectroplites ambiguus*), silver perch (*Bidyanus bidyanus*), and catfish (*Taridanus taudanus*).

Of these fish only the catfish, not related to the American farmed species but an eel-tailed fish, will breed in enclosed waters. Lake (1967), at the New South Wales Inland Fisheries Research Station, Narrandera discovered the environmental trigger that induces the other species to spawn—the spring flooding of rivers—and reproduced this phenomenon with miniature floodplains around tiny spawning ponds at the research station.

That station, which began in 1960, produces fry and fingerlings for farm dams in addition to its research functions. There are 37 ponds totaling 4 ha (10 acres) used for fingerling production.

The floodplain spawning technique was adopted by a private hatchery and farm in New South Wales in 1969. The farm currently produces Murray cod and golden perch fingerlings. Some 30 ha (74 acres) of grow-out ponds are being prepared for production of table fish.

A second New South Wales hatchery began using the floodplain spawn-



Fig. 31.1. Spawning pond for two pairs of "native" fish. Spawning induced by flooding adjacent area. Courtesy of J.L. MacLean.

ing technique in 1971 and now produces golden perch by this method. Catfish, requiring no floodplain, are also produced.

Spawning of native fish occurs in October and November, and fingerlings can be sold about three months later.

Total production from government and private hatcheries for the year

ending June 30, 1976, was 10,000 Murray cod, 39,000 golden perch, 45,000 silver perch, and 11,500 catfish. Total pond area is 9 ha (22 acres).

The private hatcheries envisage increasing production in the near future to some 50,000 Murray cod, 91,000 golden perch, and 6000 catfish from ponds which will then total 10.4 ha (26 acres).

Farmers of native fish face many problems. The floodplain technique is not fully understood and there have been cases where failures have occurred. Both government and private hatcheries are using hormone injections on an experimental basis, which may enable fingerling production to become regularized. However, the critical point is the search for adequate live food, which is required in the early stages, particularly by newly emerged fry. This is proving to be the main obstacle to production of sufficient quantities of fingerlings for subsequent commercial-scale farming.

A private hatchery in Queensland has also been producing for some years limited quantities of fingerlings of catfish, golden perch, Murray cod, sleepy cod (*Oxyeleotris lineolatus*), and saratoga (*Scleropages leichardti*), the last two being indigenous to northern Australia.

The native fish industry is in its infancy. Hatchery operators could sell many times their present production of fingerlings alone. That demand plus the prospects of growing fish to marketable size assures the industry of a viable future.

CRAYFISH

There are in Australia the largest freshwater crayfish species in the world. They are carefully guarded. Live specimens are prohibited from export, and one, the marron (*Cherax tenuimanus*) from south Western Australia has been the subject of experimental aquaculture for several years under a Commonwealth government grant. There is only an amateur fishery for marron, so limited are natural stocks.

The main interest has been in yabbies (*Cherax destructor*), small freshwater crayfish about the size of the prized European kraftor and consequently exported to Europe both live and processed. Trade is promising enough to warrant research into their aquaculture by the South Australian government, under a Commonwealth government grant commencing 1976. That state is the largest producer with about 300 MT (330 ST) per year. There are also farming enterprises in Victoria and New South Wales but these are not yet commercial. The resource is widespread and still abundant, facts which have discouraged concentrated efforts on yabbie aquaculture to date.

Macrobrachium rosenbergii inhabits northern rivers of Australia. A private hatchery has begun producing juveniles but none have yet been reared to market size. Depending on funding, it seems only a matter of time before these shrimp are marketed in Australia.

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Outlook

FISH AND OTHER AQUATIC SPECIES

Clams

Cockles

Finfish

Mollusks

Mussels

Oysters

Prawns

Scallops

Shrimps

Outlook

In spite of a worldwide expansion in fish farming, only limited progress has been made in the compilation of statistical data to indicate trends and the rate of growth. The lack of specialized enumerators, the unwillingness or inability of producers to provide detailed information, the widely scattered location of production units and areas, and the lack of interest and unwillingness to finance the collection of usable data by some countries have all contributed to this scarcity.

In 1970 a partial estimate, made on the basis of data gathered from 36 countries, indicated total fish production through aquaculture of 2.6 million MT (2.9 million ST) (Pillay 1972). A more comprehensive but still rough estimate for 1975 indicated nearly 4.0 million MT (4.4 million ST) of finfish production, 16,000 MT (17,632 ST) of shrimps and prawns, 608,000 MT (670,016 ST) of oysters, 239,000 MT (236,378 ST) of mussels, 39,000 MT (42,978 ST) of clams, 63,000 MT (69,426 ST) of scallops, 30,000 MT (33,060 ST) of cockles and other mollusks, and 1,055,000 MT (1,162,610 ST) of seaweeds. The total was over 6 million MT (6.6 million ST) (Pillay 1976). The largest producer was the People's Republic of China with 2,200,000 MT (2,420,000 ST) of finfish. This volume is undoubtedly a rough and perhaps low estimate. Similar estimates by China watchers whom the author contacted ranged up to 3 million MT (3.3 million ST). If it is reasonable to assume that these two estimates are the minimum and maximum, then finfish culture ranged between 4 and 5 million MT (4.4 and 5.5 million ST) in 1975. This would indicate a world increase of 80 to 127% in five years. These increases occurred largely through application of technology which existed in 1970 and by the intensification of production per unit of area engaged in fish farming.

Pillay (1976) projected a doubling of output for the decade between 1975 and 1985, and a five-fold increase by the year 2000 if the rate of increase is maintained. The author believes that a doubling of output to the area of 9 million MT (9.9 million ST) is possible by 1985. This can be accomplished through application of present-day technology which involves more efficient use of each unit of water through greater concentrations of numbers of fish, polyculture, more area devoted to culture, feeding efficiency, and breeding. However, the author does not believe that production will in-

crease by five-fold to 20 to 25 million MT (22 to 27.5 million ST) by the year 2000. This belief is based on the assumption that the rate of increase will not be sustained. In every industry initial gains are large, but as the industry increases in size and output the percentage rate of increase declines. Thus the author predicts that output will increase only 3 to 3.5 times the 1975 level by the year 2000. This would put output at a 12 to 18 million MT (13.2 to 19.8 million ST) level. To achieve even this lower level will require a greater proportion of the world's supply of fish meal to be directed to fish feeds, or the development of substitutes. The ability of the fish farming industry to use a greater share of the available supply of fish meal would indicate that fish feed conversions must improve or the price of cultured fish increase relative to other competing animal uses such as the poultry industry. There are no existing data that indicate that fish is preferred to other meats by many people. The major determinant of how fast the volume of production of cultured fish will increase lies with forage fish which can be produced in fertilized waters and rely on natural foods. To a large extent, this type and volume of production will depend upon the use of more water area in those parts of the world where fish culture is not commonly practiced today. Hence if the African, Central and South American countries intensify production, then a rate of increase of 3 to 3.5 times the 1975 world level can be achieved by 2000.

Individual segments of the aquaculture industry may have phenomenal growth during the next 20 years. For example, some countries may turn to the production of one or more highly valued species for export to developed countries. This is particularly true for shrimp and prawns wherein the developing country may wish to increase the availability of foreign exchange earnings.

The ability of any one country to increase production significantly is related not only to marketing and price structures but also to political and legal considerations. For example, in the United States most public waters are presently part of the public domain. Fish farmers, however, because of the nature of investment and the length of commitment, must have long-term rights to a water area. How this and similar situations are resolved will affect the aquaculture industry.

The types and amounts of development assistance by governments to fish farmers will also have considerable significance on the rate of development and the volume of production in any given time period. The ability to finance development, the repayment provisions, and governmental infrastructure such as research applied to local conditions, extension service efforts, roads, and a host of other factors will affect aquaculture.

The author is confident that most of the restrictions will be removed as the need for more fish production increases. There is little or no disagreement on whether fish farming will increase, but only on the rate of increase in any given time period.

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Appendix

TABLE A.1. CONVERSION FACTORS

Metric and U.S. Customary Systems		
10 millimeters (mm)	=	1 centimeter (cm)
1 centimeter (cm)	=	0.3937 inches (in.)
1 meter (m)	=	39.37 inches (in.)
1 kilometer (km)	=	0.62137 mile (mi)
1 square meter (m ²)	=	10.76 square feet (ft ²)
10,000 square meters (m ²)	=	1 hectare (ha)
1 hectare (ha)	=	2.471 acres
1 acre	=	4047 square meters (m ²)
1 liter	=	1.0567 liquid quarts (liq qt)
1 quart (qt)	=	0.25 gallon (gal.)
28.4 grams (g)	=	1 ounce (oz)
16 ounces (oz)	=	1 pound (lb)
454 grams (g)	=	1 pound (lb)
1 kilogram (kg)	=	2.20 pounds (lb)
1 metric ton (MT)	=	2204.6 pounds (lb)
1 short ton (ST)	=	2000 pounds (lb)
1 short ton (ST)	=	0.907 metric tons (MT)

TABLE A.2. CURRENCY CONVERSIONS

Norway	\$1 U.S.	=	5.44 kroner
Denmark	\$1 U.S.	=	5.94 kroner
West Germany	\$1 U.S.	=	2.57 deutsche marks
Netherlands	\$1 U.S.	=	2.64 gulden
Belgium	\$1 U.S.	=	39.43 francs
Switzerland	\$1 U.S.	=	2.66 francs
Italy	\$1 U.S.	=	667.0 lire
France	\$1 U.S.	=	4.36 francs
United Kingdom	\$1 U.S.	=	0.47 pound
Ireland	\$1 U.S.	=	0.47 pound
Republic of (South) Korea	\$1 U.S.	=	500 won
Japan	\$1 U.S.	=	250.0 yen
Taiwan	\$1 U.S.	=	37.7 yuan
Philippines	\$1 U.S.	=	7.3 pesos
Hungary	\$1 U.S.	=	23.2 forints
USSR	\$1 U.S.	=	3.45 rubles

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