# Fisheries and Aquaculture in the People's Republic of China

IDRC-115e

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Pritchard, G.I.
IDRC-115e
Fisheries and aquaculture in the People's Republic of China. Ottawa, Ont., IDRC, 1980. 32 p. : ill.

/IDRC publication/, /fish culture/, /fishery research/, /China/ — /science/, /fishery industry/, /inland fishing/, /marine fishing/, /freshwater fish/, /evaluation/, /trends/, bibliography.

UDC: 639.3(510) ISBN: 0-88936-189-4

Microfiche edition available

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# Contents

# Foreword

The fisheries success of the People's Republic of China well illustrates the guiding principle that should be applied to the structuring of fisheries in developing countries. Fisheries within the PRC are based on *past* historical traditions, have helped China build toward its *present* state of food production sufficiency, and have helped to chart the *future* patterns of animal protein requirements. This has been achieved with low capitalization and labour-intensive systems, both of which are of prime socioeconomic importance in most developing countries. Twenty-five centuries of tradition and a quarter century of total self-reliance were focused on the maximization of indigenous fish resources. The results of these efforts have made China one of the top fish-producing nations in the world and the leading nation in aquaculture production with more than 50% of the world's finfish production.

It is therefore timely that this assessment should be made of the current activities, priorities, achievements, and perspectives of the Chinese. There has been a remarkable worldwide application of their polyculture techniques using six major Chinese carps. They are now using additional species such as *Megalobrama amblycephala*. The concentration on the study of their indigenous species has yielded high dividends for their own benefit, and the polyculture system has been adopted by many other countries who have now introduced and used the Chinese carp species together with their own fish.

It is to be hoped that many lessons in natural recycling will be learned from Chinese fisheries and that the ecological balance that has been harmoniously achieved by the use of fish, vegetable growing, and animal husbandry will be seen as an efficient multiple usage of water resources. With low investments and maximum utilization of land and water, the Chinese have developed fish production systems that are less dependent than capture fisheries on the inflationary costs associated with automated boats, engines, electronic technology, and spiraling fuel costs.

Because aquaculture involves low-cost technology and is applicable to poorer rural communities, the fisheries program of the International Development Research Centre (IDRC) has a large segment of projects in this field. More than eight research projects supported by IDRC are concerned with the use of carps in aquaculture, reflecting the significance of these species to developing countries. Accordingly, IDRC has arranged for the translation and distribution of two important publications of the People's Republic of China on the breeding and culture of Chinese carps.

Dr Pritchard visited the People's Republic of China in 1974 as a member of one of the first scientific and technical missions on fisheries to that country in more than 2 decades and has maintained an avid interest in their fisheries and aquaculture development. This publication presents a scholarly analysis of the open literature and a reexamination of his observations of Chinese fisheries practices.

IDRC hopes that by making this perceptive appraisal of fisheries in China available to a wide readership it will stimulate greater interest in the applied research results of Chinese fisheries among fisheries researchers of developing countries. This survey also highlights data from an important list of references, which may otherwise be unavailable to readers.

The increasing need for protein for burgeoning populations in developing communities clearly requires us to mobilize the water resources of this planet responsibly as if life depended on it because, in the final analysis, all life does. Wherever there is water there can be fish!

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# Introduction

The coastal and inland fisheries of the People's Republic of China are among the most productive in the world, providing diversity in human diets and food of high nutritional quality that is much in demand. As yields of fisheries on a global scale tripled in the 25 years before peaking in the early 1970s, China rightfully claimed to have kept pace with countries much more dependent upon science and technology. Harvests today put China among the top four fishing nations in the world. The manner in which this status was attained differs from all others.

Unable to compete in distant ocean fisheries, but faced with a need to provide food, China turned to husbandry and intensive use of resources within its national control. Emphasis was placed on freshwater fish culture, which had both a long tradition and a large body of know-how. China was therefore little affected by the economic fishing zones now being established in many parts of the world and the associated curbs on the plunder of wild marine resources. Other countries so affected are now being forced to move toward intensive forms of fish production and therefore look with much interest to experiences within China.

The Government of China also has become more receptive to modern fishing methodologies, extending its own coastal fishing zones and opening international exchanges in science and technology. Problems in such areas as detection and harvesting of fish that move freely in the upper strata of the sea are acknowledged, and solutions are being sought. Benefits are foreseen from introducing international science into the traditional Chinese fisheries.

It is therefore most timely to examine the fisheries and their supporting science in relation to the national goals and priorities of the People's Republic of China, to review the perceptions of fisheries science until 1970 and the trends since, and to provide a general assessment of the fisheries and the future outlook.

# The Fishing Industry and its Resource Base

Freshwater and marine fisheries are both important protein sources for the People's Republic of China. Elaborate systems of dams, flood controls, reservoirs, canals, and irrigation trenches provide the key to successful food production in China, and inland fish culture is but one phase of both an intensive and an integrated land-use system. Thirty percent of the approximately 6 880 000 tonnes of fisheries production (FAO 1977a) comes from inland fisheries (exclusive of subsistence food fisheries in natural waters for which there is no assessment), making China the largest cultured-fish producer in the world.

The freshwater fisheries are located throughout much of the People's Republic of China's 20 million hectares (ha) of freshwater rivers, reservoirs, lakes, and ponds. About half of that area is suitable for fish culture, and in keeping with the Chinese principles of multiple, intensive use of all natural resources, virtually all suitable waters are stocked with fish and managed to some degree (Ryther 1979). Production, however, is concentrated in areas of the big lakes and river systems, the Yangtze basin being the largest followed by the Pearl basin. There are about 20 species of freshwater fish of economic importance in the country, with emphasis being placed on the four native Chinese carps that constitute the so-called Kia-yu or household fish. These fish, cultured in family ponds in China for generations, are the silver carp (*Hypophthalmichthys molitrix*), a phytoplankton feeder; the bighead (*Aristichthys nobilis*), a zooplankton feeder; the grass carp (*Ctenopharyngodon idella*), which feeds on grasses and other aquatic plants; and the black carp (*Mylopharyngodon piceus*), which feeds on molluscs and snails. These household fish may be cultured together with several varieties of the common carp, bream, dace, tilapia, or other nonpredator fishes.

The marine fisheries are located along the 14 000 km of coastline, where there are good harbours. The present fishing capability is limited to an area within 320 km from shore as China has never had a distant high-seas fishery. Within this coastal area of China lies one of the largest and most productive fishing shelves in the world, extending from the Bohai Sea in the North, through the Yellow Sea and East China Sea, and into the South China Sea. The shelf has a great variety of fish, urchins, and prawns. More than 80 species are of commercial importance including herring, mackerel, sardines, hair-tail, yellow croaker, butterfish, sharks, eels, flounder, prawns, sea cucumbers, oysters, jellyfish, and seaweeds.

The fishing industry of China is a traditional source of employment. More than one million families are engaged in collective fishing enter-

*Chinese carp called Kia-yu or household fish form the basis for much of the freshwater fish culture in China.*

prises, which alone account for 80% of production; the remainder comes from the state-owned fishing corporations. These corporations are owned by provinces, municipalities, cities, counties, and regions, and differ greatly in size and function. The largest are at Luda also called Dairen (Dalian) in Liaoning Province in the north, at Yantai on the Shantung (Shandong) Peninsula, at Tsingtao (Qingdao) in Shantung Province, and in Shanghai. Numerous smaller state corporations are distributed throughout the length of the country. They include the South China Sea State Fishing Corporation on Hainan Island, the State Fishing Corporation on the Raychow Peninsula in West Kwangtung (Guangdong) Province, the State Fishing Corporation at Foochow (Fuzhou) in Fukien (Fujian) Province, the Corporation at Wenzhow in Chekiang (Zhejiang) Province, and various others.

Virtually all vessels and gear used in this fishing industry are manufactured domestically although some designs are copied from abroad.

Domestic markets quickly absorb much of the production of finfish, shellfish, and marine plants although some high-priced products are processed and set aside for export. Live fish sold to Hong Kong constitutes a substantive portion, second only to shrimp, of the U.S.$100 million fish exports from the People's Republic of China (Environment Canada 1976).

# The Fisheries Sciences in Relation to Goals and Priorities

Central responsibility for fisheries matters in China fell under the Ministry of Agriculture and Forestry until June 1979, when a separate General Administration of Aquatic Products directly responsible to the State Council (FAO/UNDP 1979) was established. Thus, objectives and priorities have been frequently entwined with those of food production. Fisheries was identified as one of 108 items selected as key projects in the nationwide endeavour for scientific and technological research at the National Science Conference in March 1978. Fang Yi (1978), Minister in charge of the State Scientific and Technological Commission, called for a comprehensive survey of resources in fisheries, for study of the rational exploitation and utilization of the resources with the protection of the ecological systems, and for study of the rational arrangement of these undertakings to provide a scientific basis for the all-round development of food production.

Specifically, Fang Yi called for increasing water-life production, for fish breeding, and for marine fishing and processing to contribute to improving the ingredients of the people's diet. He promised the establishment of up-to-date centres for experimental fishing and coordinated efforts to tackle key scientific problems. Emphasis was also to be placed on basic theory and sciences of food production and on laying a solid foundation for constant innovation in techniques for expansion of production. These statements, offered in the spirit of the "Four Modernizations" campaign, which is China's effort to modernize agriculture, industry, national defence, and science and technology by the end of this century (Culliton 1979a), may well set the tone for China's development in the decades ahead.

To appreciate the impact of the Fang Yi statement on fisheries sciences, it is necessary to look at what has gone before. But first, one should also note the contributions of fisheries to international goals and priorities. Information on the successful technology for the multispecies culture of native Chinese carp is actively sought by many developing nations, and special programs of technology transfers, training, and scientific exchanges have been proposed (Tapiador et al. 1977; Culliton 1979b). Also, the conduct of marine fishing operations in coastal and offshore waters of China provides a means for exercising sovereignty over geographic areas of potential dispute (Choon-Ho Park 1974; Kenji Asakawa 1962).

# Perceptions of Fisheries Science to 1970

The silk line and tapered bamboo rod in all likelihood were the first examples of Chinese fishing technology to be transferred and adapted throughout the world, but even these items were probably predated by nets and other fishing implements. Considerable literature on fishing was produced in ancient China, but most of this is inaccessible to those unversed in the language. Earliest distinct mention of fishing was 1122 BC, so centuries were necessary for the evolution of the fish catching and hatching techniques that have long held fascination to the Western World. Fishing laws with respect to closure and the willful destruction of fish were extremely strict and had existed from time immemorial. To the Chinese, in all probability, belongs the credit of having invented pisciculture, or the art of breeding and rearing fish artificially. Even though this is not quite certain, they were undoubtedly among the first in the field. These facts and other fascinating stories about Chinese fishing can be found in William Radcliff's book (1926) *Fishing from Earliest Times*.

Two significant events, which preceded publication of this work, opened Chinese fisheries to Western view. First, there was the publication in Paris of the work entitled *La Pisciculture et la Pêche en Chine* by Pierre Dabry de Thiersant (1882), an expert sent out by the French Government to report fully on fishing in China. Second, was the holding in London of the International Fisheries Exhibition of 1883 for which China mounted a comprehensive exhibit both illustrating and documenting fisheries that had been set apart for hundreds of years (Whymper 1883; Campbell 1883).

The years that followed these disclosures had few significant changes to report (Yen Wei-Ching W. 1908), and little attention was paid to the Chinese fisheries until after 1945 when Westerners again became aware of the importance of Far Eastern fish culture. Developments that occurred within the industry are probably best examined in comparison with those elsewhere, as was ably done by Drews (1951) using Japan as the contrast. Drews became convinced that the exploitation of aquatic resources had been subjected to the cultural controls of human attitudes, and that the supporting science too had fallen under a similar influence of cultural values with a loss of objectivity. He set out systematically to compare the cultivation of food fish in China with that in Japan, and his results showed several sharp contrasts.

The first was a matter of antiquity, Chinese fish culture being much older than that of Japan. Pisciculture, a term used synonymously with fish culture and aquaculture, was truly important in China at an early time but remained unimportant in Japan until quite modern times. Also, pisciculture was an almost wholly autochthonous development in China, whereas it undoubtedly entered Japan from the adjacent continent in a relatively perfected state. Not only was fish culture native to China but, more important in this context, it remained so. In contrast, Japan borrowed diligently and in many cases improved on what was borrowed. In time, the cultural force that was followed changed from the East to the West, and the Japanese continued with a genius for synthesis, to borrow, to assimilate, and to change the new patterns as they had the old.

Turning to the contemporary patterns of fish culture in the two countries, Drews found additional contrasts that were readily observable. One was the striking difference of species reared. The Chinese relied almost exclusively upon the carp family that prefer warm and turbid freshwater, although they also reared mullet. In Japan, several non-cyprinid fish were reared, including eel, trout, salmon, and smelt, all of which are anadromous and prefer clear waters that are cool or cold. The kinds of fish reared also differ in respect to size and to the importance of nonnative species. Although pond fish are usually immature and small when marketed, it is significant that all fish reared in China will reach medium to large sizes if permitted to do so. This contrasts with the number of really small fish reared in Japanese ponds. Again, all the species of fish reared in China are native in origin whereas in Japan species foreign to the islands have come to play some part in aquaculture. Further, in Japan, public health is protected by official limitation of the use of raw "night soil" in ponds used for rearing food fish. There is no similar Chinese prohibition of the use of this source of fertilizer.

Shao-Wen Ling (1977) presents the picture from another viewpoint. The traditional systems of aquaculture were practiced in China by the common man without help from the government for years. It was only at the beginning of the 20th century that the government felt that new

*New concepts and ideas have been applied to the traditional systems of aquaculture.*

concepts and ideas should be applied to the field. At that time modern sciences had already been introduced into China, and young students and scholars were sent abroad to study biology. Nobody was trained specifically in fisheries, but some of the young biologists took an interest in it and became fisheries biologists and fish culturists. In those days most of the biology teachers in China were trained in foreign countries and were taught using foreign textbooks and foreign organisms as examples. In the early 1920s a group of progressive young biologists began to study Chinese animals and plants and write biology textbooks in Chinese. Although these efforts were devoted mainly to natural studies, fisheries as a subject was beginning to receive attention, and some of the young scientists tried to interpret the traditional aquaculture operations on a scientific basis. Many of the old fish masters were illiterate, but they possessed invaluable practical experience and skill. By observing weather conditions, the colour of pond water, or the movement and behaviour of fish, they could determine reasonably accurately the water quality of the pond and the health of the fish. They could detect important deviations from the norm, and knew how to correct or prevent such undesirable happenings without the aid of expensive equipment. Asian scientists gradually began to apply their knowledge of biological and physical principles to the practices of the old masters. It was at this time that fish polyculture became known to the world.

Before World War II, most scientific fisheries work involved the survey and interpretation of existing practices. With the realization of the potential of aquaculture to produce cheap protein food, efforts began to pour into fish culture, and experiments were initiated to improve and refine existing practices. It was not until the early 1950s that serious efforts were made to produce select "seed," or stocking material. Traditionally, "fry seed" of the major carps was collected from natural habitats. In 1955 the technique of using hormones (e.g., human chorionic gonadotropin and fish pituitary gland extract) to induce spawning provided a major breakthrough. Many fish that could not be spawned previously could now be induced to reproduce in simple hatcheries under controlled conditions so that successful mass production of select fish seed of many of the important cultivable species resulted.

Today, Chinese fish culture remains indigenous and extremely practical. Success is assured through controlled water supply and timely drainage. One of the major contributing factors is the availability of electric power in every rural area (Tapiador et al. 1977).

The predilection for fish culture in inland waters tended to discourage Chinese investments in marine fishing and in particular deep-sea fishing. Solecki (1966) reviewed this pattern of development and concluded that present-day Chinese economists are quite right in stating that in 1949 when the People's Republic of China was formed, the fishing industry was far behind the more industrialized fishing nations. The underutilized resources then offered the centralized government opportunities for development, and the fishing industries underwent sweeping organizational changes as in other branches of the economy. Mechanization of the fleet followed within the next 2 decades with the construction of more than 1000 vessels to harvest coastal waters up to 320 km, a considerable extension of fishing capability as traditional junks were limited to 16–19 km.

# Current Approaches to Scientific Research and its Transfer

The fisheries sciences in China appear to have followed three often expressed themes of "letting a hundred flowers bloom and a hundred schools of thought contend," of "making the past serve the present and things foreign serve China," and of "weeding through the old to bring forth the new." Also, there is little doubt that the so-called open-door policy of research and teaching has been practiced widely (Anon. 1974a, 1975a; Gu San du 1975; Tapiador et al. 1977). Leaders, researchers, and workers together identify problems and solutions, and the foremost goal is to serve production. The research institutes adopted a basic pattern by which researchers go into the production field to learn from fishery workers and fishermen, while assisting them in production and in practical research, although recent evidence suggests that such emphasis is on the decline.

Production units themselves also developed research programs and participated in the technology exchanges. For example, a network system of collecting all problems of production, views, and experiences was organized by the Fisheries Research Institute in Shanghai. After collecting the problems, a Science Exchange Group meets once a year to discuss possible solutions. Similar exchanges were no doubt widespread, but much of the applied research remains evasive to outsiders as it may not reach the scientific literature. When it does, the work is seldom credited to particular individuals, and cooperative affiliations are common.

Judging from the English Abstracts from these reports as compiled by the U.S. Joint Publications Research Service, one may conclude that the comments made by Gould (1961) still apply to some degree. Contributions by Chinese scientists to zoological knowledge have to a large extent been restricted to descriptive and observation reports. Experimental zoology is still in its infancy, although its needs would now appear to be recognized (Teng Hsiao-ping 1978). A review of the scientific literature relative to fisheries originating from China within recent years indicates a shift more and more to systematic and controlled experimentation. These trends will be apparent in examples from specific study areas related to fisheries sciences that follow later in this book.

Diversification of domestic resources is also encouraged by museums of the classical stance at the Peking (Beijing) Institute of Zoology, the Shanghai Institute of Fisheries, and the Tsingtao Institute of Oceanography. All have extensive collections of local flora and fauna including fish and marine plants. These collections are well attended with the result that the taxonomy of China's aquatic biology is probably as well understood and documented as that of any country of the world.

*Old and new vessels seen in the busy harbour of Shanghai.*

If necessary, other approaches to problem solving are also used. The design changes embodied in the transition to steel vessels is of particular interest. The Chinese apparently imported foreign vessels and then copied and continually modified them. The original design for some classes of vessel, notably the 44-m stern trawler and the light purse seiner, appeared to have come from some common source; the older vessels of these classes seen in Shanghai and Dairen were virtually identical. The newer units in each port have minor but distinctive differences, indicating the presence of both a control planning and a design authority, as well as a semiautonomous regional group. The design of the 600-hp, Canton-built trawlers was however distinctively different from that of the trawler of similar power and class from Shanghai and Dairen, suggesting a higher degree of design autonomy in the Canton yard. Furthermore, the 400-hp diesel engines manufactured in Dairen have been completely different from those of the same power made in Shanghai (Environment Canada 1976).

Educational approaches to train research workers in fisheries now differ from those described by Balderon and FitzGerald (1973) for the other sciences. Educational and research conditions have improved since 1977. Previously, students were frequently not selected on aptitudes for science and technology, but as of 1977 they must pass exams to be accepted into universities. Courses are now 4 years duration. Curricula in ichthyology contain basic courses in chemistry, genetics, microbiology, physiology, embryology, and a foreign language. Educational centres giving instruction in aquatic biology and fisheries are extremely numerous, and it is common to find such centres in close proximity to the research institutes.

Solecki (1966) reported that there were 12 institutes devoted to aquatic and marine research, and three laboratories working under the Chinese Academy of Science. The basic networks of fisheries research stations outlined by Swannack-Nunn (1976) are still active, although some have been restructured from time to time, and from these there is a limited but continuous flow of reports. Of these institutes, six are considered by the Chinese to be the most important centres for research on fisheries; they are: the Yellow Sea Fisheries Research Institute (Tsingtao), the East China Sea Fisheries Research Institute (Shanghai), the South China Sea Fisheries Research Institute (Canton), the Yangtze River Freshwater Biology Research Institute (Hupeh Province), the Institute for Fisheries Mechanization Research (Shanghai), and the Institute of Hydrobiology at Wuhan, previously called the Hupeh Provincial Hydrobiology Laboratory.

A more in-depth look at current research approaches follows as selected research reports are examined.

# Present Status of Freshwater Research

## Freshwater Biology

In contrast to the marine areas, scientific evidence relating to freshwater biology is abundant, and at the forefront of this work has been the Institute of Hydrobiology at Wuhan in Hupeh Province (FAO/UNDP 1979). Interest in freshwater biology stems from the necessity to recycle organic wastes (FAO 1977b), but equally relevant is the need to use the vast inland reservoirs and waterways for effective food production. Visitors to China continue to be fascinated by the extensive carp polyculture systems in use there.

The scope to which investigations related to fish polyculture are carried out is shown in a press release (Anon. 1977a) from Wuhan that states that in recent years more than 100 experimental stations have been set up in 18 provinces, municipalities, or autonomous regions on breeding of new fish varieties, domesticating wild fish for economic use, prevention and treatment of fish diseases, and nitrogen fixing of blue algae. Based on field scientific work and laboratory classifying studies, they compiled or revised many texts. Those published include *Monograph on Chinese Carp Family (Cyprinidae)*, *Fish of the Yangtze River*, and *Study of Cultivation and Biology of Fishes in Chinese Freshwater* (Anon. 1973a), all of which have yet to be translated to English. These works provide data on exploiting the rich aquatic resources of the country, on studying Chinese zoogeography, and on the development of fish culture in China. The work conducted is both varied and of high quality, as the following examples illustrate.

Chen Hung-ta and Ho Chu-hua (1975) presented the results of investigations carried out from 1962–64 on the aquatic macrophytes (83 species) of Tung-hu Lake, Wuchang. Data on biomass, based on sampling along 21 transects (involving 3 zones, 17 plant-associations, and 224 sampling positions), were also compared with that for the macrophytic biomass of 6 shallow lakes of the Middle and the Lower Yangtze Basin. The monthly changes in biomass of two transects were followed throughout the year and the biomass conditions for zones of different depth-ranges analyzed. The lake, 28.5 $km^2$ in area, had a peak average biomass of 322 $kcal/m^2$ in August. Annual production of aquatic vegetation in the whole lake amounted to $9 \times 10^9$ kcal (30 440 tonnes) in terms of calorific value. *Potamogeton maackianus* ranked first in biomass production (38.2% of the total wet weight or 52.5% of the total air-dried weight) and was followed by *Najas major*, *Myriophyllum spicatum*, *Hydrilla verticillata*, and *Ceratophyllum demersum* in turn. In the total lake biosphere, annual primary production derived from aquatic macrophytes and phytoplankton together amounted to $25 \times 10^9$ kcal, of which the aquatic macrophytes contributed

36%. To show the relevance of this work, the authors discussed the rational utilization of this resource in special regard to pisciculture, and the following formula was proposed for calculating the stocking density of the phytophagous fish (e.g., grass carp):

$$X = \frac{B \cdot P}{K \cdot W \cdot S}, \text{ in which}$$

X = the number of fingerlings of phytophagous fish to be stocked per mou (1 mou = 1/15 ha),
B = maximum average biomass (attained during August–October) of the macrophytes suitable for fish consumption (in chin per mou) (1 chin = 500 grams[g]),
P = percentage of the macrophytic biomass intended to be consumed by the fish,
K = gross feed-coefficient of the phytophagous fish during the entire growing season (in chin),
W = expected average increase in weight per fish (in chin), and
S = percentage of the number of survivors (to the end of the growing season) to the number of fingerlings stocked.

Chen Chi-yu et al. (1975) reported on ecological distribution and population densities of molluscs in the same lake by analyzing the data of mollusca from quantitative samples taken by a 1/7 $m^2$ hand-grab from 101 sampling positions randomly distributed in the lake during March–April and October–November 1963. The most abundant forms of Mollusca were the gastropods, among which *Alocinma longicornis*, *Parafossarulus striatulus*, and *Bellamya aeruginosa* were predominant. They represented 79% of total molluscan biomass in spring and 91% in autumn.

Research emphasis is placed most often on native species, as illustrated in the work of Wu Ching-chiang (1975). The long-snout catfish, *Leiocassis longirostris*, has long been a valuable commercial fish in the Yangtze Valley; yet practically no information on its biological features had been reported in the literature. Age-composition, growth, spawning, feeding, and the problem of maximum sustained yield of this fish were thus investigated for the first time.

Similarly, Ko Hung-wen (1975) investigated the herbivorous bream or "Wuhan" fish (*Megalobrama amblycephala*), which occurs wild in certain large- and medium-size lakes of the mid-lower Yangtze Basin and was not found elsewhere. Since its recognition in 1955 as a new species distinct from *Megalobrama terminalis*, to which it bears a superficial resemblance, it has been subjected to general biological studies as well as pond-culture experimentation. It has now been successfully cultivated in 21 provinces (Anon. 1974b). Observations made in the hatcheries indicated that this bream is much more resistant to bacterial diseases than the well-known grass carp. The grass carp is highly esteemed by fish culturists because of its large size, rapid growth, taste, and herbivorous food habit, but it is highly susceptible to bacterial infections.

Experimental introduction of the Wuhan fish at a Hupeh fish farm was reported by Chen Chu-hsing (1975). First introduced into the Hua-Ma

Lake in 1960, survival rate of its fry was extremely low although they spawned regularly. Renewed efforts to improve yields were made through mass release of fingerlings (8–11 centimetres [cm] in total length) into the lake yearly after 1972, with the result that its annual catch rapidly rose and reached a record peak of 20 t in 1974, comprising 5% of the gross yield of all fish. Growth rates of this fish in the lake and methods of induced spawning and of hatchery management were described, and plans for further production increases were discussed.

Other topics under investigation include selection of high-temperature strains of green algae (Hsia I-cheng et al. 1975) and the extraction and quantification of alpha-tocopherol in freshwater algae (Anon. 1975c). Investigations are sometimes even directed toward uses other than food to provide a comprehensive use of the water resource. Reports such as that of Men Mo-hsi and Yao Shin-yan (1974) from Jiangsu Province dwell on the feeding and management of river oysters for the culturing of pearls in the ponds, brooks, lakes, and reservoirs where fishes are also bred. Cage culture was found most suitable in large waters, whereas culture by suspension was suitable in smaller ponds.

## Genetics and Selective Breeding

Genetics and selective breeding are an important instrument in expanding freshwater fish culture to all parts of China, as well as in improving production levels in ponds near the urban centres. Although probably not widespread, there is some awareness of basic quantitative genetic principles or practices, and examination of the scientific literature certainly suggests the availability of some excellent expertise with a strong commitment to genetic improvement of fish. Anon. (1975d) reports that basic research on fish breeding has just begun and claims it to be neither profound nor sufficiently broad. Since the First Conference on Selective Breeding of Fresh Water Fish and Basic Theoretical Research was held in 1972, considerable progress has been made in various provinces. Surveys of local varieties show that species of other provinces have frequently been introduced and that more than 30 species of fish have been brought from foreign countries, especially Africa. A total of 60 new hybrid groupings are under investigation, and the effect of radiation dosages on the development and heredity of different species of fish is being assessed. Basic cytology and reproductive physiology studies have also been launched.

The Institute of Hydrobiology, best known for its "Wuhan" fish, has other recent investigations. Anon. (1975e) reported on three varieties of carp chosen as parental stocks for cross breedings: mirror carp of the scatter-scaled type (MCS), fully scaled red carp (RC), and the longmouth mirror carp (LMC). Hybrid offspring ($F_1$) were reared in coexistence with the inbred offspring at the same stocking rate and in the same pond. By the end of the first growing season the average individual weight of the offspring of MCS males × RC females was 50–60% heavier than the inbred RC, and that of MCS males × LMC females was 57% heavier than the inbred LMC; meanwhile the survival rate of both hybrids was as high as

*Genetics and selective breeding are an important instrument in expanding freshwater fish culture to all parts of China.*

the inbred ones. The experiment showed both the scattered scale covering and the red coloration to be recessive characters. The second generation ($F_2$) derived from the self-cross of the hybrid ($F_1$) of MCS males × RC females theoretically should have 8 genotypes and 4 phenotypes. The occurrence of the 4 phenotypes has been confirmed, among which the red mirror carp (scatter-scaled, red coloration) has been a new recombination distinct from the $F_1$ hybrid and from either parent in external appearance. The scale pattern and the body coloration of the red mirror carp seem to be the result of homozygosis of the two recessive genes. Growth trials showed that the red mirror carp has a growth rate superior to MCS or RC. This was to be expected, and if it should be relatively stable in inheritance, it could emerge as a new, economic variety of carp.

Another report from the same institute (Anon. 1976b) concerned the mortality of grass carp during the fingerling stage, which runs to about 60%. A hybridization experiment started in 1966 showed that hybrids of grass carp female × round-head bream (*Megalobrama amblycephala*) males are highly disease resistant and have the advantage of being both herbivorous and fast growing. However, summer spawned fingerlings have a very low survival rate and the sex glands of adults do not develop. To address these problems, a study was undertaken to induce triploidy and tetraploidy in these hybrids; an identical experiment was conducted with grass carp as well. With low-temperature induction of the hybrids, triploidy appeared in all age groups. In the large-size group, the triploidy rate was 57%, with 14% tetraploidy as well. Under colchicine induction (20 minutes of treatment in solutions of 500 and 100 ppm) triploidy and tetraploidy also appeared in rates varying from 2% to 5%.

Studies at the Yangtze River Fisheries Research Institute (Anon. 1975f) reported the backcrossing of bighead females with the males from the cross of bighead females with silver carp males and included descriptions of fertilization, embryology, morphology, food habits, and growth tests carried out on these hybrids from 1968 to 1972. The Szechwan University group (Anon. 1976c) reported a study on the phylogenetic relationship between common carp, grass carp, and bighead. Also, Yin Yuan-hung et al. (1974) of Shansi University reported on an artificial hybridization of Pien (*Parabramis pekinensis*) and Fang (*Megalobrama terminalis*), two other species of cultivated fish in China.

## Reproductive Physiology

The spawning of fish cultivated in China has presented many problems throughout the years, with the result that success was achieved only in certain areas with favourable environments and at restricted times during the year. Some of the most significant basic scientific work on fisheries to come recently from China relates to solution of this problem. The manner of its reporting is of interest.

First, results of a workshop on the application of "luteinizing hormone released hormone" (LH-RH) to the induction of pisciculture spawning in November 1975 at Hunan Hengyang were reported (Anon. 1976d). The participants — more than 130 representatives from 27 provinces, municipalities, and autonomous regions — reviewed application of ovulating agents and stressed the importance of further research on their action and mechanism.

The scientific group called the "Cooperative Team for Hormonal Application in Pisciculture" was apparently behind this initiative, having conducted their experimentation in the spring of 1975. Later (Anon. 1977b), they reported in the scientific literature a new synthetic analogue of the nonapeptide LH-RH found to be highly effective in the induction of spawning of farm fishes (the grass carp, the silver carp, the spotted silver carp, and the black carp). Its biological activity was many times that of the synthetic decapeptide or natural releasing hormone. Of a total 500 mature fishes treated with the nonapeptide alone or in combination with a minimum amount of fish pituitary, 396 spawned with an overall spawning rate of 78%. This is probably the most effective ovulating agent or hormone now available for fishes, and this finding was considered of paramount importance in pisciculture for large-scale production of fry.

The report proceeded to provide recommended dosages for the following farm fishes: grass carp, 1.10 μg/kg body weight (b.w.); silver carp, 3 μg or more/kg b.w. in divided doses; spotted silver carp, 1.4 μg or more/kg b.w.; the black carp, 10 μg/kg b.w. The efficacy of the peptide could be improved in the black carp by a concurrent administration of 0.5–2 mg of the pituitary gland.

It was apparent that the fisheries biologists had no hesitancy to go outside their own disciplines when specialized expertise was needed. Also in 1977 the Peptide Hormone Group, Shanghai Institute of Biochemistry, Academia Sinica, and the Isotope Laboratory, Hwa Tong Hospital, Shanghai, combined their talents and published a paper (Anon. 1977c) entitled "A Procedure for the Radioimmunoassay of LRH in the Hypothalamus of the Carp."

The following year, two further papers were published jointly by the Institute of Zoology in Peking and the Yangtze Institute of Fisheries (Anon. 1978a,b) that related to the spawning in grass carp. Histochemical studies showed that in teleosts, as in mammalian species, the functional changes of the pituitary and the ovary were directly and indirectly under the control of the hypothalamic releasing hormone. The medium lobe of the grass carp's pituitary has only one type of gonadotroph, which contains two kinds of granules differing in size and staining reaction. The gonadotrophs showed extensive activity of hormone synthesis and release following the LH-RH treatment. This was evidenced by the progressive decrease in number of small granules, the increase in number and size of the huge heterogeneous granules, and the appearance of cytoplasmic vacuolation. The small granules are likely to be the LH secreting granules and the huge granules, the follicle-stimulating hormone (FSH) secreting granules. Owing to the rapid elevation of pituitary LH, the ovary is activated. This is demonstrated by the increased enzyme activities in the follicular cells of the ovary after hormonal treatment. The result suggested that the steroid hormone plays an important role in the regulation of the gonadotropin action.

Following the histochemical study, an ultrastructural investigation was also carried out to reveal more details about the effect of LH-RH on subcellular structure of the teleost gonadotrophs. It was found that there

*Brood fish maintained in a central Chinese hatchery that supplies fry and fingerlings to northern provinces.*

is only one type of gonadotroph existing in the grass carp's hypophysis responding to LH-RH treatment and likely to be the target cells of the hypothalamic hormone. In the untreated control fish, three types of secreting granules could be differentiated in the gonadotroph; namely, the small granules, the globular granules, and the huge heterogeneous granules. In the experimental groups, the following changes were observed 2 or 6 hours after hormonal injection: (1) a fusion of the gonadotrophs; (2) an enlargement of the endoplasmic reticulum cisternae; and (3) a decrease in number of both the small and the globular granules. On the other hand, the huge granules continue to increase in size, owing probably to the aggregation of the individual granules. After spawning, gonadotrophs are loaded with endoplasmic reticulum cisternae. The small granules become sparse, but the number of huge heterogeneous granules keeps increasing.

The experiments also showed that mammalian LH-RH is capable of inducing the synthesis and release of gonadotropins. The small granules are likely to be the LH secreting granules, but the huge ones are most probably the FSH secreting granules, the persistence of which after spawning may indicate the continuation of hormone synthesis that is necessary for the maturation of the next generation oocytes in preparation for another spawning in the same breeding season. This result is in agreement with the finding that repeated spawning is possible for the grass carp in the southern part of China.

## Health and Nutrition

Although the hormone studies reveal that the Chinese have a capability to work at the biochemical level with sophistication when they wish to do so, an equivalent effort on the subjects of fish health and nutrition has yet to appear. Mortality problems are referred to frequently, and numerous reports on specific disease problems appear in the literature (Anon. 1974c, 1975g, 1976e). Emphasis is placed on prevention (Anon. 1974d) and on simple treatments. Adequate laboratory procedures for diagnosis of communicable fish diseases appear to be lacking, particularly for virology and to a lesser extent bacteriology, and there appears little if any systematic testing of treatment procedures against known disease organisms with the possible exception of certain parasites. Nutrition research also tends to be confined to empirical studies on feeding habits, age, and growth.

Nevertheless, fish health must ultimately be judged from the pond production practices, and by most measures these are successful, as the productivity of Chinese fish culture is high. Tapiador et al. (1977) reports that the following figures are used in national planning for the production of fish ponds: North of the Great Wall — 1500 kg/ha; North of the Yangtze River — 3000 kg/ha; and South of the Yangtze River — 3750 kg/ha.

A report (Anon. 1975h) from the Hatchery of Hsing-ning County in Guangdong (Kuangtung) Province illustrates yields upward of 15 tonnes of fish per ha. It was reported that in 1971, a fish culture high-yield experiment began in a pond with 4 mou of water surface and an average depth of 1.8 m. In January, the minimum water temperature was 8–9 °C;

*Outdoor hatchery for carp located in Southern China.*

in July the maximum was 37-38 °C. The pH was 6.8-8.5. In 3 consecutive years, the yield was more than 2000 chin per mou per year (1 chin = 500 g; 1 mou = 1/15 ha). Fingerlings of 16 different species had been raised in that pond, and pig manure, grass, black algae, and green vegetables were used as feed. Before this experiment, the farm had experienced a high death rate toward the end of summer due to fish diseases. Such was not the case in the experimental pond. Inclusion of an African species of *Tilapia mossambica* was credited with reducing the incidence of fish diseases. Mud, organic fragments, planktons, and aquatic insects are eaten by this species, thus indirectly improving the quality of the water. However, this is not a typical high-yield experiment as the pond was very small. Best high-yield results are normally obtained with polyculture.

The success of a Chinese fish pond is dependent upon its size and manageability. Ponds are tended carefully as are the plants and vegetables grown on their banks whose leaves are often fed to the fish. Ponds are almost always isolated from the rice paddies in China where pesticides might be applied. Moreover, as in other forms of livestock grazing throughout the world, special attention is paid to stocking rates, to tillage, and to organic fertilization. Ponds in China are small enough to be drained regularly, a practice greatly enhanced by extensive use of rural electrification. When unsatisfactory algal blooms develop, ponds are promptly drained, dried, sometimes limed, and allowed to stay fallow for several weeks. Therein lies the prime instrument of disease control, also of obtaining the preferred blue-green algae species that give optimal nutrition.

Product quality and public health aspects of fisheries products tend to be of concern to people other than the producers. Diseases that affect fish seldom affect people, but widespread use of "night soil" poses human hazards only coped with through rigid cultural patterns. Fish in China is not eaten raw, vegetables grown on the wastes recycled from the ponds are invariably cooked, and water used for human intake is always boiled and usually consumed as tea.

# Present Status of Marine Research

## Population Assessments

The results of research on the marine fisheries are somewhat more elusive than those related to freshwater, probably in part because of defence considerations. The research literature illustrating the population assessment studies now being conducted on the marine resources is particularly sparse.

The Canadian Delegation (Environment Canada 1976) reported that the Chinese are aware that some stocks are endangered from overfishing and have established systems of monitoring commercially important stocks. A combination of closed seasons, restricted areas, and mesh-size regulations to protect and manage marine fish stocks is in use, and coastal areas are patrolled regularly so that these regulations are enforced. Fishery research institutes exist in all coastal provinces and in Shanghai and Tientsin (Tianjin); staff at these institutes conduct surveys and examine catch statistics as a basis for planning and regulating the fisheries. However, the Chinese approach to development seems to be based on a philosophy of expansion assuming that total marine resources are not fully utilized. Whether, in fact, this premise is based on hard scientific information is conjectural.

Another possible explanation for the lack of scientific documentation in this area is the difficulty in sampling pelagic fishes. Species on the surface and in the upper strata have more acute vision and are harder to capture, so the Chinese are more accustomed to harvesting the deep strata fish, and a sampling of commercial catches reflects this practice. Yu Ying (1973) alludes to these problems in his paper on lamp light seining, reporting studies on why fish are attracted to light and how to lure and concentrate them for capture.

These problems are in keeping with the observations of the Canadian Mission who noted that the lack of refined electronic equipment for fish finding probably accounts in part for lower productivity per unit than would be expected in North American fishing operations. Diesel engines, hydraulic equipment, electronic equipment, and engines for the fleet were all manufactured in China. With the exception of sonar equipment, which is lacking, all appear satisfactory for their purpose.

## Oceanography

All marine research in China including oceanography is aimed at an increase in the yield of nutrients from the sea. Öström (1977) of the

Swedish National Board of Fisheries who visited China to report on oceanographic research with emphasis on the physical and chemical aspects emphasizes this point, together with a growing awareness of the hazards in pollution of the marine environment. Research institutes are growing, new vessels are being built, field stations are established, and new problem areas are being investigated in response to the increased awareness of the potential richness of the sea. A review of the full scope of this marine research is beyond the purview of this paper.

## Marine Cultures

Pollution of inshore coastal areas is no doubt a serious constraint to Chinese mariculture. Nevertheless, recent expansion of seaweed culture throughout the coastline of China has caused particular attention to be placed on new species of marine plants.

Fang Tsung-hsi (1973) of the Shantung College of Oceanography reported an investigation on the variability of *Laminaria* under different kinds of environment. When photoperiod was increased to 19–24 hours, some female gametophytes developed into multicellular silk-like bodies. At 20 °C, most of the gametophytes stopped development, could not produce egg cells, and eventually died after a month. The few that withstood this water temperature and survived produced eggs when temperatures were lowered. A new variety was developed through generations of selection.

Research on seaweed cultivation at the Institute of Marine Fisheries in Tsingtao has been extensive (Anon. 1976a). Through intensive inbreeding, selection, and X-ray treatment, two new varieties of *Laminaria* with high production and high iodine content were successfully bred. The original materials were obtained from the natural population with a high level of hybridity. One of the new varieties has been subjected to inbreeding and selection for 15 generations (1959–74) and, compared with the local natural varieties, is characterized by higher iodine content as well as more rapid growth of the leaf at raised temperatures and, hence, a longer leaf and higher production. The other variety, which has undergone five generations of inbreeding, selection, and X-ray treatment, has the same advantages over the local varieties as well as having a lower water content.

Tseng C.K. and Chang T.A. (1978) also reported two new *Porphyra*, now described and on deposit at the herbarium of the Institute of Oceanography in Tsingtao.

Shen Chi-cheng (1974) of the Fish Culture Station in Shanghai summarized their experiences on the artificial collections of clam larvae. The temperature and aeration for spawning females under natural conditions have been duplicated in laboratory holding tanks, and by the use of adults at the proper maturity, many larvae were collected. The females, if they underwent a second spawning, could be used again. However, each adult could only bear 100–200 larvae, but this was not thought to indicate a future limitation to the large-scale cultivation of edible clams.

Wu Geng-jung and Hsu Peng-fei (1974) reported success with cultivation of prawn larvae using a combination of outdoor and indoor

*Agriculture and fisheries are closely integrated on the coastal zone of the Po Sea (Bohai).*

techniques. The low-temperature mortality of eggs had been greatly reduced; of 5 million eggs fertilized, some 30 000 hatched and 6000 developed to the stage 14 larval form. Anon. (1975b) also reported success in the cultivation of sea cucumbers, abalones, and scallops in Shantung communes. After many failures, they succeeded in 1973 in hatching 170 000 sea cucumbers, 2200 scallops, and 300 abalones, thus widening the possibilities for cultivating marine organisms.

Efforts, however, are not fully confined to species that are traditional delicacies in China. Teng Sheng (1974) of the Tsingtao Marine Produce Museum reported preliminary successes in artificially feeding seals and promoting their reproduction.

Neither have researchers stayed away from problems traditionally viewed as difficult. For example, Lin Hao-ren and Lin Ting (1975) of the Biology Department at Chung-shen University reported progress in the artificial propagation of eels. In China, the eel program began in 1972, and eggs were successfully hatched in May 1974. Benefits, no doubt, were derived from similar work in both France and Japan, but the technique is still a long way from being applied in production practices.

# Assessment and Future Outlook

An appreciation of the ethics of self-sufficiency; of a working symbiosis between people and environments where preservation of biological diversity is a prerequisite to keeping options open for future generations; and of the need to focus societal efforts first and foremost on meeting the basic real needs of people, e.g., ensuring adequate food, safe water, clothing, and shelter for all, is essential to the understanding of the fisheries sector in the People's Republic of China.

Information on scientific efforts on fisheries is somewhat obscure, and what may appear on the surface to be a debasement of research and the scientific community can be misleading. Innovation has played a key role as an instrument of development as well as of politics, but often only can be identified by close examination of the production processes.

Against these values and the new policy of modernization, which encourages the development of experimental approaches to science, the outlook for fisheries is for continuing change and fascination to other parts of the world.

China has a rich resource base for its fisheries, use of which is utilitarian and built upon ecological imperatives. Resource use is closely integrated into the cultural patterns, many of which are of long historical significance and which have changed little in the passing years. Moreover, the development of fisheries in China has followed largely an indigenous route, although some technologies have been borrowed and modified to satisfy local needs. On the basis that diverse systems are the most stable ones, a rich variety of approaches has been not only encouraged but also considered as an integral part of development planning.

The time frame for change is not necessarily a short-term one. Goals tend to be long-term and not rigidly fixed. Time will be needed to train research specialists, and although the research institutes and educational systems are in place, many have had their roles de-emphasized in favour of other priorities. The research disciplines needed to support the fisheries sciences are numerous, and some gaps (e.g., virology, sonar electronics, etc.) need to be filled. The science and expertise of these disciplines are readily transferable, thus gaps could readily be overcome once the need is perceived and there is a will to do so.

The outlook is good for basic science of interest to the fisheries and aquaculture sectors in China. The pronounced utility of present research, if coupled with the broad base of science and technology provided from research in the Western world, offers a formula for effective scientific research in the years ahead. The Chinese appear to have avoided the pitfalls associated with routine monitoring of resources and the environment in the name of science but have turned their attention to obtaining an understanding as to how basic systems work, whether they be biological, mechanical, or social.

China, probably more than any other country, now appears to have realized that most scientific and technical efforts applied to food problems are still directed to technical modifications of relatively primitive agriculture and fisheries systems, many of which are highly inefficient in terms of resource use and dependent upon high-cost energy inputs. Benefits are foreseen from assessing the potential that lies in improved conversion processes for delivering nutritional energy from natural resources to people. In contrast to most others, they can justifiably claim to have already begun assessing and preparing inventories of the natural material and scientific knowledge available for making a concerted attack on this most basic of human problems, the lack of adequate nutrition. In the decades ahead, on problems of city food production, of nutrient yields in finite areas and from limited natural resources, and of waste recycling to maintain environmental quality, China is likely to be at the forefront. In all of these subjects, aquatic biology will play an integral role.

# Acknowledgments

Special thanks are expressed to Dr Leo Orleans of the Committee on Scholarly Communication with the People's Republic of China, National Academy of Sciences, Washington, for encouragement in the preparation of this study, also for the provision of English summaries of Chinese publications. Comments on the manuscript provided by T.G. Carey, W.H.L. Allsopp, and Lin Hao-ren were much appreciated.

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**Credits:**
*Technical Editing: K. Kealey-Vallière*
*Photos: p. 11 A.G. Woodland, all others by author*