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# AQUACULTURE: THE TAIWANESE EXPERIENCE

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**I-Chiu Liao** (1991) Aquaculture: The Taiwanese experience. *Bull. Inst. Zool., Academia Sinica, Monograph* **16**: 1–36. Aquaculture in Taiwan has a history of over 300 years. The species under culture include finfish, reptiles, amphibians, crustaceans, echinoderms, molluscs, and seaweeds. There are 70 current and 35 candidate commercial culture species. As a result of the impressive output in some of its species, Taiwan has gained distinction in the aquaculture world. Three major qualities characterize the Taiwanese experience in aquaculture. First is flexibility. The setback of one species is not a deterrent to the success of other species. Second is capability. People in the industry are capable of bringing it to greater heights. Third is potentiality. With a favorable climate and a wide variety of species under culture, the possibilities for growth and expansion are high.

Taiwan's rise to prominence in aquaculture was brought about by the fast and steady growth of production in the last three decades. In the 1960s, several research breakthroughs established a solid foundation for the artificial propagation techniques of freshwater finfish, prawn, and marine finfish species. In the 1970s, significant progress was attained with the commercial availability of formulated feeds paving the way for the development of an intensive culture system. In the 1980s, Taiwan's share of aquaculture products in the international market increased not only in quantity but also in the kinds being offered. The increase brought more interest and confidence among aquafarmers and entrepreneurs and at the same time, contributed to the foreign exchange earnings of the country. The last three decades thus saw a boom in the aquaculture industry in Taiwan. The late 1980s, however, brought about an unexpected ebb in the industry.

This paper cautiously and closely analyzes the state of aquaculture in Taiwan with the purpose of sharing with the rest of the world the Taiwanese experience in aquaculture and on how policy-makers, scientists and aquafarmers can respond to current developments.

**Key words**: Aquaculture, Taiwanese Experience, Prospects.

*Give a man a fish and you feed him for a day.*
*Teach him how to fish and you feed him for a lifetime.*

This old Chinese proverb is not only relevant to the Taiwanese experience in aquaculture but also to the Taiwanese perspective of the role of aquaculture. Taiwan, a mountainous island surrounded by sea, is located between Japan and the Philippines, on a line running from the northeast to southwest. It is crossed about its mid-length by the Tropic of Cancer. Total land area is about 36,000 $km^2$, and population is over 20 million. There is a big difference between the climates of the northern and southern parts of Taiwan. In the north, it is temperate, where temperatures can go down below 10°C in the winter. In the south, it is subtropical, where temperature rarely drops below 17°C. This makes the south more suitable for culturing warm water fishes. In the west, the coasts are shallow and sandy; in the east, the coasts are mostly rocky and steep. Thus, most aquacultural activities are concentrated in the western parts of Taiwan (Fig. 1).

Aquaculture plays a very important rôle as a food industry in Taiwan, where the per capita consumption of aquatic products is about 50 kg. Aquatic products, or fishes in particular, are important and healthful sources of animal protein. Since capture fisheries production is likely to level off, fluctuate or even drop due to the establishment of the exclusive economic zones, aquaculture is being pushed as one possible way of filling the increasing need for seafood. Aquaculture also makes effective use of idle, marginal lands. It exists primarily to meet the domestic demand for aquatic

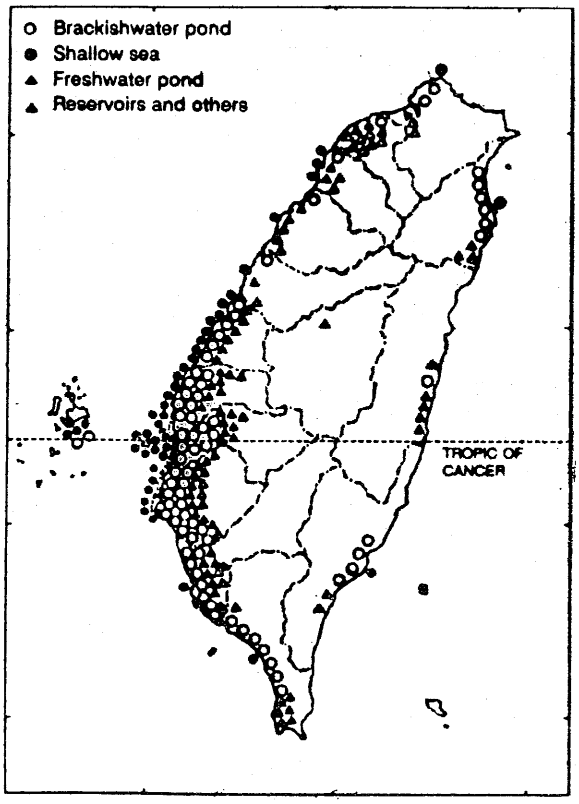


Fig. 1. Areas devoted to aquaculture in Taiwan.

food, although some of the species cultured are exported. Aquaculture also offers many job opportunities, providing better income and livelihood especially for aquafarmers with small, family-based operations. The expansion of aquaculture has likewise spurred the development of related and support industries such as the feed industry. It is expected also to play a big role in the restocking of nearly exhausted aquatic resources.

The Taiwanese experience in aquaculture has been used as a model by many countries, particularly by Southeast Asian countries. It shall be examined for its successes as well as its failures as an exampe of the attendant problems of too rapid a development that could await existing or potential aquacultural nations. A basic understanding of the Taiwanese experience in aquaculture shall be given by presenting a brief history of this experience and explaining the concepts and values behind many of the practices.

## HISTORICAL OVERVIEW

Aquaculture in Taiwan had its beginnings over 300 years ago, and since then, it has gone through spectacular, as well as difficult, developments. These developments have been the subject of some studies and have been divided into several stages either in socioeconomical, technological, or historical terms. In Liao (1992), the divisions were based mostly on technological terms. In the present paper, the development of aquaculture in Taiwan is divided into four distinct stages, based on historical as well as socioeconomical terms (Fig. 2).

### Traditional stage (1661-1962)

Aquaculture, particularly fish culture, was already practiced in Taiwan during the reign of Cheng Cheng-Kung whose name under the Ming Dynasty banner was Kuo Hsing-Yeh, otherwise known to the West as Koxinga. Koxinga's reign which started in 1661 was brief but influential. Having driven out the Dutch (who occupied Taiwan from 1624 to 1661), Koxinga set up his court and government near Tainan, in southwestern Taiwan, where a milkfish, *Chanos chanos*, farm was built and named in his honor. The milkfish became the most popular fish species cultured with most of the farms built in the Annan District of Tainan (Lin, 1968).

In 1684, the Manchus succeeded finally in imposing sovereignty over the island. Taiwan thus officially

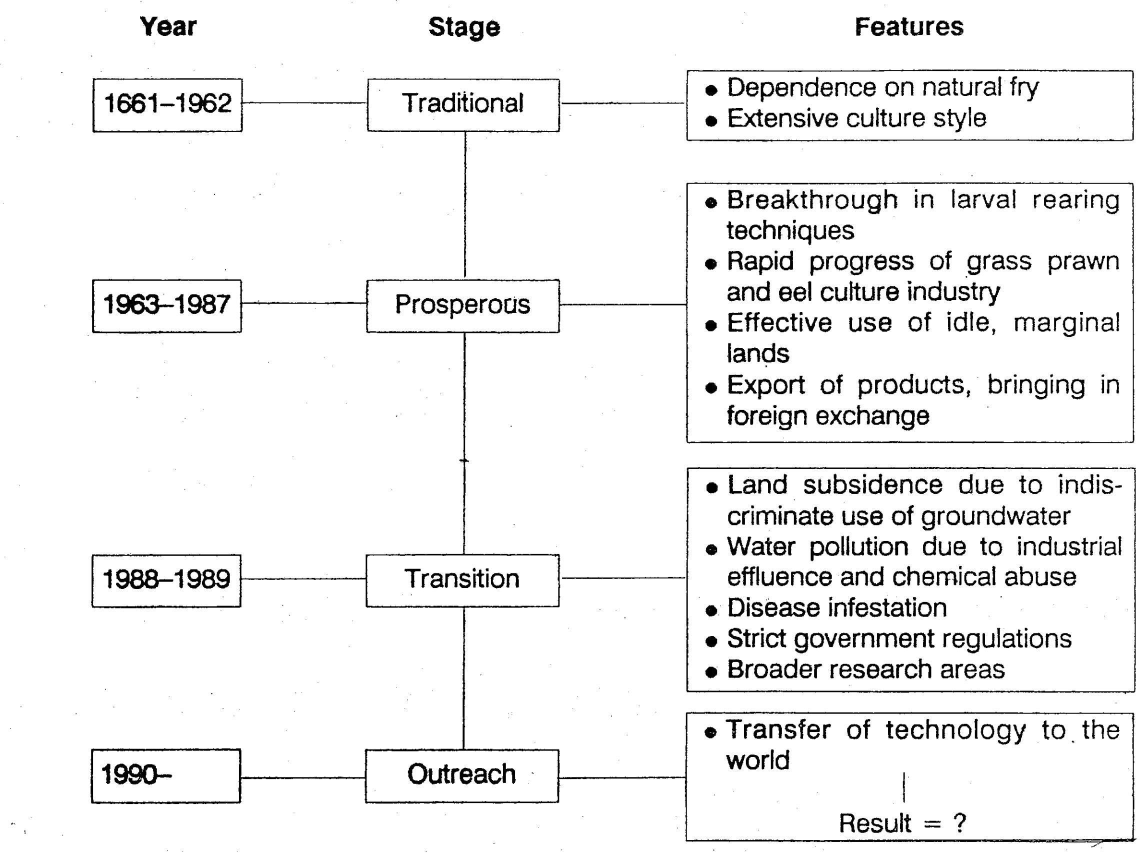


Fig. 2. Evolution of the aquaculture industry in Taiwan.

became an integral part of the Chinese empire as the Ching court of the Manchus. The court governed Taiwan until 1895 when it ceded Taiwan under the Treaty of Shimonoseki to Japan as a result of the Sino-Japanese War.

Among many things, the Taiwan Viceroy Office of the Japanese government established two fisheries research stations in Taiwan, one in Hsinchû in 1913 for freshwater species and another in Tainan in 1918 for marine species. Later, in 1929, these stations were merged with two other units to form the Taiwan Fisheries Research Station. With the establishment of the station, aquaculture in Taiwan advanced. The station became the Taiwan Fisheries Research Institute in 1945, and in 1949 it was placed under the Department of Agriculture and Forestry of the Taiwan provincial government which is still the present set-up.

Production during this stage, however, was low and slow. In 1945, for example, production was only 5,242 tons (Fig. 3). This gradually

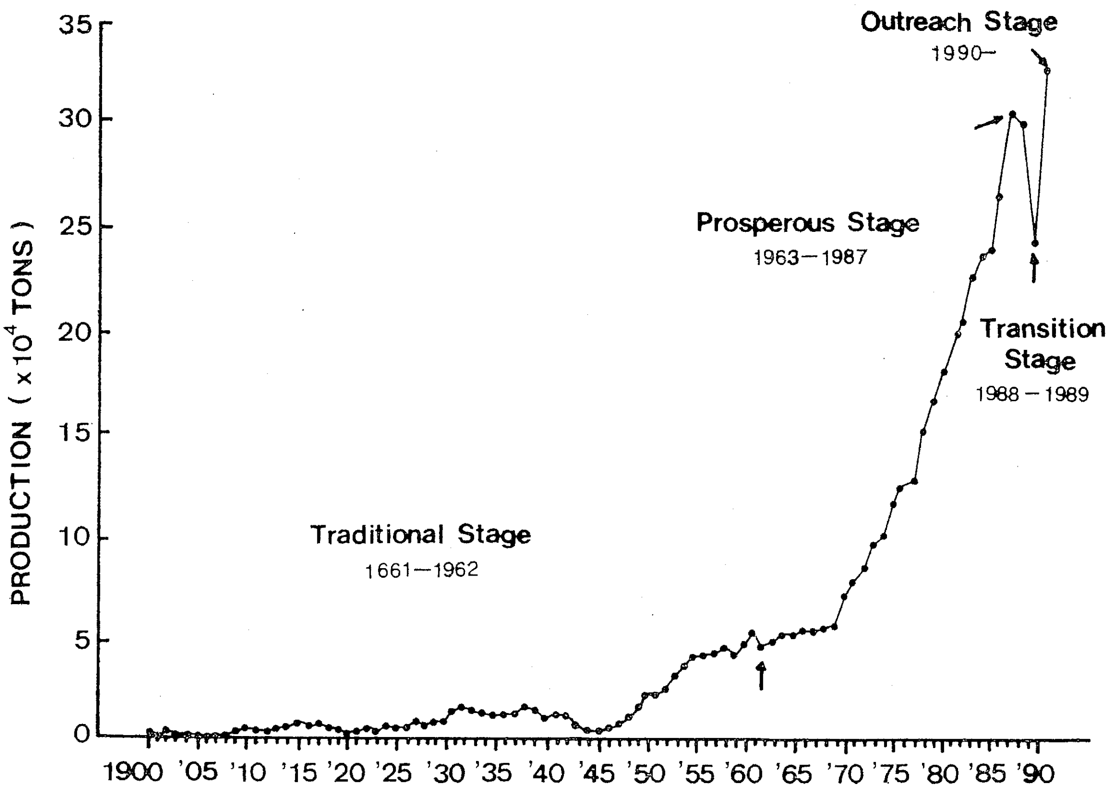


Fig. 3. Annual aquaculture production in Taiwan, 1900-1990.

increased, peaking at 57,354 tons in 1961. Although it was still not high, the growth nevertheless was maintained at 3.3%.

This stage was characterized by the reliance on natural fry for stocking materials and the use of extensive culture systems.

**Prosperous stage (1963-1987)**

The rise of Taiwan to prominence in aquaculture was brought about by the fast and steady growth of production from the early 1960s to the late 1980s. The rise was largely due to several revolutionary breakthroughs in research during the 1960s, considered as the turning point in Taiwan's aquaculture history. In 1963, the establishment of the techniques for artificial propagation of Chinese carps (grass carp, *Ctenopharyngodon idellus;* and silver carp, *Hypophthalmichthys molitrix*) (Tang *et al.*, 1964) set a precedent for freshwater finfish fry production. The successful completion of the experiments on the larval rearing of grass prawn, *Penaeus monodon,* in 1968 (Liao *et al.*, 1969*a*) provided a good basis for the culture of other prawn species. The culmination of the research studies on the artificial propagation of grey mullet, *Mugil cephalus*, in 1969 (Liao *et al.*, 1969b; Liao *et al.*, 1973) established a solid foundation for the artificial propagation techniques of marine finfish species.

In 1968, scientists transferred the techniques of prawn larval rearing to the industry, and the first private hatchery was established. Soon, several hatcheries were established all over Taiwan, particularly along the southwest parts. After this initial success, other breakthroughs further contributed to the growth of the grass prawn culture industry. In 1977, formulated prawn feeds were developed and put on the market thus paving the way for the development of the culture of prawns on a commercial scale. After that, production continued to increase year after year. Production reached its peak in 1987, when Taiwan became the world's top producer of one single species, that is, of cultured grass prawn, with a record volume of 95,000 tons (Liao, 1989a).

After 1970, because of these earlier successes, the development of tilapia (*Oreochromis* spp. and *Tilapia* spp.) culture also quickened. During this stage, genetic research was used in tilapia culture resulting in monosex fish and better strains of red tilapias, the species favored by consumers. By 1986, a record production of 100,000 tons was reached (Liao and Shyu, 1992).

Japanese eel, *Anguilla japonica*, culture also prospered when production reached over 40,000 tons in 1985. Eel culture gained much attention because of its relatively good return on investment.

Taiwan was also experiencing an economic boom during this period with a large portion of the population enjoying a higher standard of living. People were asking not only for an ample supply of fish, but also for better quality fishes, that is, better tasting notwithstanding the high price. To meet these demands, more species, particularly the high priced ones, were cultured. Average production growth rate was 8.7% with the highest in 1973, at 32.2%.

In the 1980s, Taiwan's share of aquaculture products in the international market increased not only in quantity but also in the kinds being offered. The increase brought more interest and confidence among aquafarmers and entrepreneurs and at the same time, contributed to the foreign exchange earnings of the country.

**Transition stage (1988-1989)**

In spite of the successes, Taiwan encountered several difficulties and problems which may be attributed to its rapid rise to aquaculture prominence. Several of these problems were directly linked to the culture of a particular species. For example, the culture systems used for grass prawn and Japanese eel, the species with which Taiwan has staked its claim to aquaculture history, have caused a serious problem with the water table, resulting in a partial settling of land and salination of groundwater in the vicinity of the aquacultural areas (Liao, 1990a). This arose from the uncontrolled use of freshwater drawn indiscriminately from the underground water table and landward piping or seawater seepage to replace the exhausted fresh groundwater.

Another prominent problem of more recent origin was disease infestation, particularly MBV (monodon baculovirus) infestation. Although there were several pathogenic explanations to the infestations, the injudicious use of some culture techniques were found to actually facilitate the spread of such diseases. Another related problem was water pollution due to the indiscriminate use of chemicals to prevent disease outbreaks (Liao, 1989a).

Certain warnings must be considered with the onset of more intensive aquaculture such as the impact of aquaculture on the environment and possible subsequent impact on the industry. Land subsidence and disease are manifestations of this impact. Although aquaculture in Taiwan during this stage suffered several setbacks, prospects were still very high.

**Outreach stage (1990- )**

Taiwan has gone a long way in its aquaculture efforts. It is now at a point where it is capable of sharing its findings and technology with other countries. Realizing that aquaculture has the potential of bringing about higher economic benefits in the development of lesser developed countries (LDCs), Taiwan is embarking on an active, intentional transfer of its experience in aquaculture.

An example of this outreach is the cooperative project between the Taiwan Fisheries Research Institute through one of its branches, the Tungkang Marine Laboratory (TML), and the Hawaii-based Oceanic Institute (OI) to conduct a four-year program in aquaculture technology transfer to LDCs. This recently-established program is being carried out under the support of the International Economic Cooperation Development Fund (IECDF) of the Republic of China and the US Agency for International Development (USAID). Another example is the Shrimp Village of Taiwan established in Hardingen, Texas, U.S.A. Other outreach venues include technical assistance in the form of technical training in Taiwan or in the LDCs itself or in the form of facilities and equipment.

It is a challenging time for Taiwan because the attention of the whole aquacultural world is still focused on her. What the future will bring for Taiwan remains to be seen.

## SPECIES CULTURED

The species under culture in Taiwan include finfishes, reptiles, amphibians, crustaceans, echinoderms, molluscs, and seaweeds. There are 70 current (Table 1) and 35 candidate (Table 2) commercial culture species. Out of the 70 current culture species, 45 are finfishes, 4 reptiles, 2 amphibians, 7 crustaceans, 8 molluscs, and 4 seaweeds. On the other hand, of the 35 candidate species, 19 are finfishes, 5 crustaceans, 2 echinoderms, 3 molluscs, and 6 seaweeds.

The species described below are just a few of those that the Taiwanese have found worth culturing and represent the diversity of the species under culture.

### Milkfish

The milkfish culture industry has grown profusely in Taiwan since its first known beginnings during Koxinga's reign (Fig. 4). Total culture area until 1960 was already 16,000 ha and the culture style used was extensive (Lin, 1968). Milkfish provided the main source of protein of the Taiwanese then.

Up to 1979, the traditional or shallow water pond culture system, which was based on practical knowledge obtained through centuries of experience by Taiwanese aquafarmers, was used (Lin, 1968; Liao, 1985). In this method, milkfish farmers thoroughly sun-dry the pond bottom until the soil cracks during winter, when the water temperatures are too low for the growth of the fish. The pond is filled with seawater to a depth of 5-20 cm, and sun-dried again. This procedure is repeated two to three times to

Table 1
Current commercial culture species in Taiwan

| Scientific name | Common name |
|---|---|
| Finfishes | |
| *Acanthopagrus latus* | Black sea bream |
| *A. berda* | Yellowfin sea bream |
| *A. schlegeli* | Black porgy |
| *Anguilla japonica* | Japanese eel |
| *Aristichthys nobilis* | Bighead carp or black silver carp |
| *Boleophthalmus pectinirostris* | Mudskipper |
| *Carassius auratus* | Crucian carp |
| *Channa maculata* | Snakehead |
| *Chanos chanos* | Milkfish |
| *Cirrhina molitorella* | Mud carp |
| *Clarias fuscus* | Walking catfish or white-spotted freshwater catfish |
| *Ctenopharyngodon idellus* | Grass carp |
| *Culter erythropterus* | White fish |
| *Cyprinus carpio* | Common carp |
| *Epinephelus akaara* | Red grouper |
| *E. fario* | Black-saddled grouper |
| *E. malabaricus* | Malabar rockcod |
| *E. tauvina* | Estuary grouper or bullnose bass |
| *Hypophthalmichthys molitrix* | Silver carp |
| *Lates calcarifer* | Giant perch |
| *Lateolabrax japonicus* | Japanese sea bass |
| *Lethrinus nebulosus* | Blue emperor |
| *Lutjanus argentimaculatus* | Gray snapper or creek red bream |
| *Megalobrama amblycephala* | Wuchang fish |
| *Micropterus salmoides* | Largemouth bass |
| *Misgurnus anguillicaudatus* | Pond loach |
| *Monopterus albus* | Rice eel |
| *Mugil cephalus* | Grey mullet |
| *Oreochromis aureus* | Blue tilapia |
| *O. mossambicus* | Mozambique tilapia |
| *O. mossambicus* × *O. niloticus* | (Hybrid) |
| *O. niloticus* | Nile tilapia |
| *O. niloticus* × *O. aureus* | (Hybrid) |
| *Pagrus major* | Red sea bream |
| *Pangasius sutchi* | Thailand catfish |
| *Parasilurus asotus* | Chinese catfish or mudfish |
| *Plecoglossus leopardus* | Blue-spotted grouper |
| *Salmo gairdneri* | Rainbow trout |
| *Siganus fuscescens* | Dusky spinefoot |

Table 1
Current commercial culture species in Taiwan (continued)

| Scientific name | Common name |
|---|---|
| *S. oramin* | Net-pattern rabbitfish or pearl-spotted spinefoot |
| *Siniperca chuatsi* | Freshwater grouper |
| *Sparus sarba* | Goldlined sea bream or natal stumpnose |
| *Takifugu rubripes* | Tiger puffer |
| *Tilapia zillii* | Red belly tilapia |
| *Trachinotus blochii* | Snubnose pompano or yellow-wax pomfrat |
| Reptiles | |
| *Alligator mississippiensis* | Alligator |
| *Crocodilus siamensis* | Crocodile |
| *Tomistoma schlegeli* | Caimans |
| *Trionyx sinensis* | Soft-shelled turtle |
| Amphibians | |
| *Rana catesbeiana* | Bullfrog |
| *R. tigrina pantherina* | Tiger frog |
| Crustaceans | |
| *Macrobrachium rosenbergii* | Giant freshwater prawn |
| *Metapenaeus ensis* | Sand shrimp |
| *Penaeus chinensis* | Fleshy prawn |
| *P. japonicus* | Kuruma prawn |
| *P. monodon* | Grass prawn |
| *P. penicillatus* | Redtail prawn |
| *Scylla serrata* | Mud crab |
| Molluscs | |
| *Ampullarius insularum* | Apple snail |
| *Anadara granosa* | Blood clam |
| *Corbicula fluminalis* | Freshwater clam |
| *Crassostrea gigas* | Japanese oyster |
| *Haliotis diversicolor aquatilis* | Small abalone |
| *Meretrix lusoria* | Hard clam |
| *Sinovacula constricta* | Constricted tagelus |
| *Soletellina diphos* | Purple clam |
| Seaweeds | |
| *Gracilaria* spp. | Gracilaria |
| *Porphyra dentata* or *P. tenera* | Laver or nori |
| *Undaria pinnatifida* | Wakame |

Table 2
Candidate commercial culture species in Taiwan

| Scientific name | Common name |
|---|---|
| Finfishes | |
| *Acanthogobius flavimanus* | Genuine goby |
| *Caranx* spp. | Pompano |
| *Cromileptes altivelis* | Barramundie cod |
| *Evynnis cardinalis* | Golden-skinned pargo or cardinal sea bream |
| *Glossogobius giuris* | Flathead goby |
| *Kyphosus lembus* | Lembus rudderfish |
| *Lutjanus russelli* | Russell's snapper or fingermark bream |
| *Plectorhynchus cinctus* | Yellow spotted grunt |
| *Polynemus plebius* | Striped threadfin |
| *Psettodes erumei* | Big-mouthed flounder |
| *Scatophagus argus* | Common spade fish or spotted butter fish |
| *Sciaenops ocellatus* | Red drum |
| *Seriola dumerili* | Greater yellowtail or allied kingfish |
| *Siganus guttatus* | Golden spinefoot |
| *S. vermiculatus* | Reticulated rabbitfish or vermiculated spinefoot |
| *Sillago sihama* | Sand borer |
| *Terapon jarbua* | Three-striped tigerfish |
| *Oreochromis hornorum* | — |
| *Varicorhinus barbatulus* | Kooye |
| Crustaceans | |
| *Penaeus semisulcatus* | Bear prawn |
| *P. stylirostris* | Blue shrimp |
| *P. vannamei* | Whiteleg shrimp |
| *Panulirus ornatus* or *P. homarus* | Spiny lobster |
| Echinoderms | |
| *Thelonota ananas* | Sea cucumber |
| *Tripneustes gratilla* | Sea urchin |
| Molluscs | |
| *Babylonia formosae* | Sea snail |
| *Mytilus smaragdinus* | Green mussel |
| *Tapes japonica* | Short-necked clam |
| Seaweeds | |
| *Caulerpa* spp. | Marine grape |
| *Eucheuma* spp. | Eucheuma |
| *Halymenia* or *Grateloupia* spp. | Red algae |
| *Gelidium* spp. | Gelidium |
| *Monostroma* spp. | Green algae |

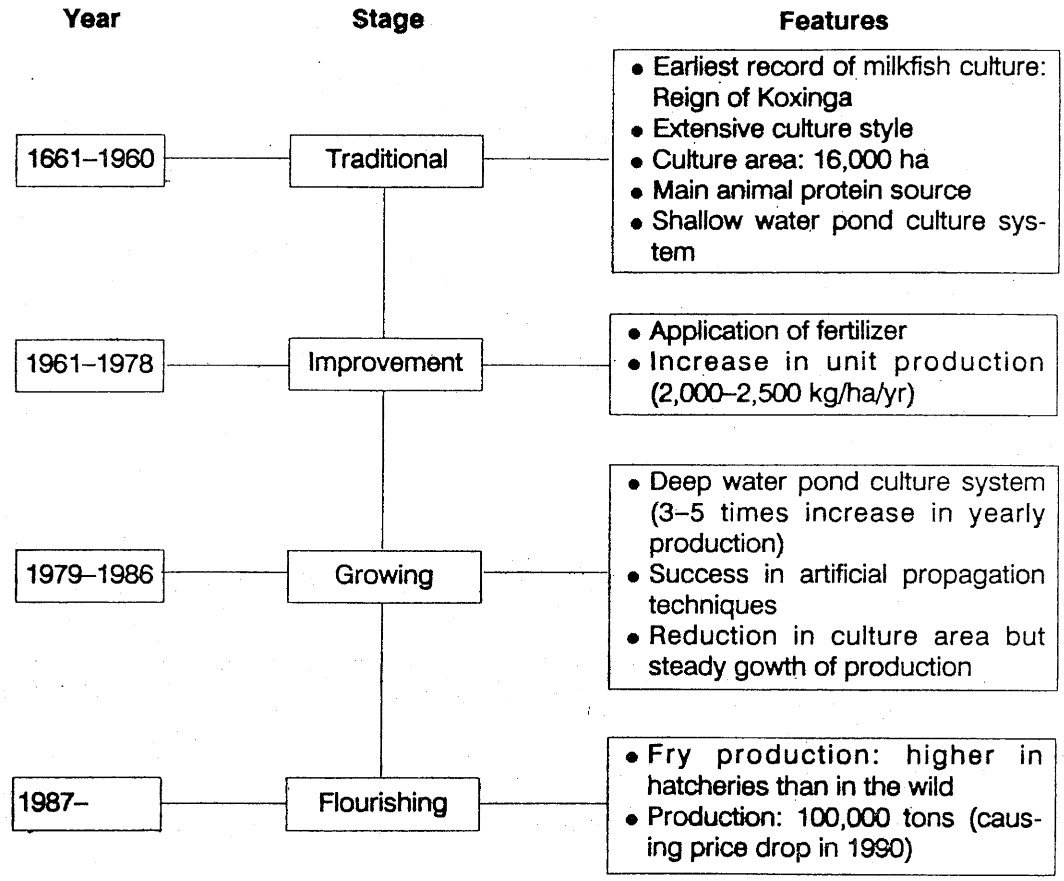


Fig. 4. Development of the milkfish culture industry in Taiwan.

achieve the sterilization by high content of salt accumulation in the bottom soil. At the same time, organic fertilizers like animal manure or rice bran are applied to the pond bottom before seawater is introduced into the pond to stimulate the growth of benthic algae, which is the main food of the fish.

During the fish culture period, pond water is generally kept at a depth of 30-40 cm to allow enough sunlight to enhance the growth of benthic algae. This is a satisfactory culture method in the sense that it uses a balanced ecosystem (Lin, 1968; Liao, 1985). It is also feed- and energy-saving as only a small amount of supplementary feeds is needed to get a yield of 2,000-2,500 kg/ha/yr. Yield is relatively low in this culture method and it is therefore more suitable for tropical countries where a vast land area is available and the population is low, which unfortunately is not the case in Taiwan anymore.

As a response to the pressing

factors affecting the milkfish culture industry, the deep water pond culture system was devised. In this culture system, the depth of ponds are increased to 2-3 m. Formulated feeds must be provided using automatic feeders and the insufficient supply of dissolved oxygen is remedied by using aeration devices such as paddlewheel aerators. To increase unit production, stocking density is increased three- to five-fold. Under this system of culture, two crops and an annual yield of 12,000 kg/ha or higher can be achieved (Liao, 1985).

A success in the artificial propagation of milkfish larvae to fry stage was first recorded in 1978 (Liao *et al.*, 1979). This achievement revealed mysteries in the early developmental stages of the milkfish. In Taiwan, the first successful induced spawning occurred in 1979 (Tseng and Hsiao, 1979; Hsiao and Tseng, 1979), while the second one was in 1982 (Lin, 1982). On the other hand, progress on spontaneous spawning was made in 1983 (Lin, 1984). The breakthrough of spontaneous spawning attained in 1983 has increased and ensured a source of fry in Taiwan. From 1987, milkfish fry production from hatcheries was higher than that from the wild (Liao, 1990b). The completion of the life cycle of milkfish in the ponds has provided more impetus to the industry.

The development of a more efficient culture system has resulted in higher productivity for milkfish. Although its culture area has declined by about 53% from 16,000 ha in 1985 to only 7,500 ha in 1988, production has remained stable. The volume has increased by about 24% from 32,000 tons in 1985 to 39,853 tons in 1988 (Taiwan Fisheries Bureau, various years).

The sudden increase in total production of 100,000 tons in 1990 has resulted in overproduction, and has caused a drop in the price of milkfish. Some aquafarmers have thus resorted to the culture of other high-valued species.

**Prawn**

Prawn culture in Taiwan has a history of many centuries, too. Although commercial production started only in recent years, the industry has been expanding steadily in the last two decades (Fig. 5). The industry is a large, well-organized industry, and is now recognized as one of the most advanced in the world. In 1987, total exportation reached 42,600 tons, for one cultured species alone (Liao, 1990a).

The grass prawn is the prime

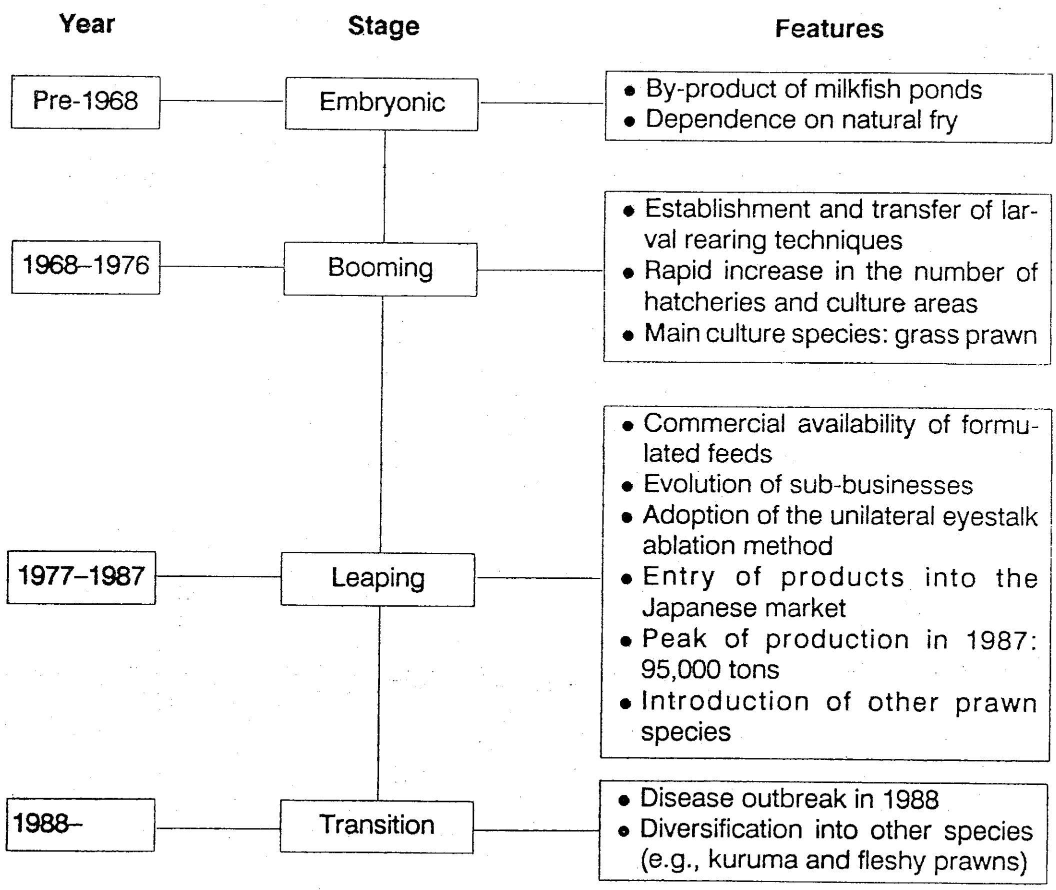


Fig. 5. Development of the prawn culture industry in Taiwan.

indigenous species cultured in Taiwan. At the onset of the prawn culture in Taiwan, grass prawn was traditionally polycultured with milkfish, and merely as a by-product. Under this system, only a few hundred kilograms of prawn per hectare were harvested. However, this situation began to change after the successful development of the techniques for larval rearing of grass prawn in 1968 (Liao *et al.*, 1969a). In that same year, scientists transferred the techniques to the industry, and the first private hatchery was established. Succeeding milestones further contributed to the rapid growth of the grass prawn culture industry. After formulated feeds were developed in 1977 and put on the market (Liao, 1989a), productivity continued rising year after year. In 1981, Japan began to respond favorably to Taiwan's efforts in penetrating its grass prawn market. From 1981 to 1987, production volumes rose steeply. Production reached its peak in 1987, when

Taiwan became the world's top producer of cultured prawn with a record volume of 95,000 tons (Liao, 1989a). Exports to Japan reached a record 35,600 tons, which is about 51% of Japan's total imports of grass prawn for that year (Liao, 1989a). However, this was interrupted by a drastic drop in 1988, when production volume plunged by 70%, and exports by 80% (Liao, 1990a), only from the previous year.

Grass prawn culture became most popular because of the many favorable characteristics it possesses, thus making it an ideal culture species. One is that grass prawn exhibits a high growth rate. A comparison of six penaeid prawns that were cultured at TML showed that grass prawn grows much faster than the other prawns (Liao and Chao, 1983). It takes only 14 weeks to reach a marketable size with an average body weight of 30 g, and 19 weeks to reach 44 g. Another remarkable feature is that the prawn is eurythermal and euryhaline. Furthermore, it is omnivorous rather than carnivorous. It thus requires a low protein feed content at about 35-45% (Liao and Liu, 1989), and hence, lower production costs. Another advantage is that it requires relatively simple culture facilities. Ponds using such materials for the bottom as clay are adequate for its growout. This generates savings on investment costs specially on the initial budget for pond construction and maintenance. Being hardy, the high survival rate (70-80%) of grass prawn under culture results in remarkable revenue (Liao, 1977). The production cost of this species, with a survival rate of 95%, is only half that of similar species with a survival rate of 50% (Liao and Chao, 1983).

Since the start of the commercial production of suitable formulated prawn feeds in 1977, hatcheries have been proliferating in Taiwan. In 1977, there were only about 150 private commercial hatcheries operating on a large scale. By 1986, there were more than 2,000 hatcheries. These hatcheries have now evolved into an efficiently organized subbusiness within the prawn culture industry (Liao and Murai, 1985) (Fig. 6).

Traditionally, ponds for polyculture generally measured 1-3 ha in area and 30-40 cm in depth (Liao, 1989a), with earthen dikes and sand or clay bottoms. Water exchange relied on the natural tidal fluctuation. In the 1970s, growout ponds especially designed for prawn were constructed. Biologists along with aquacultural engineers took into account the water

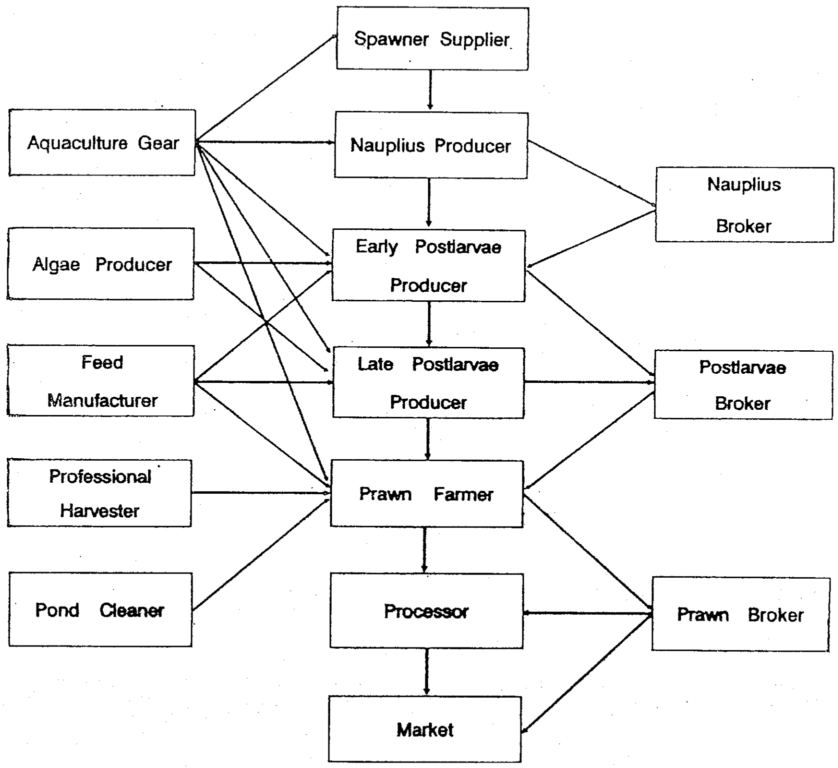


Fig. 6. Specialized sub-businesses in the prawn culture industry of Taiwan.

distribution systems and aeration equipment, thus better designs were created (Liao, 1986).

In 1988, an unexpected event struck the industry. Disease infestation resulted in mass mortality which significantly pushed down the production of grass prawn, but not the dauntless and persevering spirits of aquaculture scientists and prawn farmers (Liao, 1989a, 1989b).

In dealing with the crisis that confronted grass prawn, scientists recognized the need to diversify the choice of culture species. The search for alternative species has actually started many years ago, but this has been accelerated due to the crisis. Considerable success has been achieved from this effort, as some of these species are now commercially cultured on a large scale. Among these species are the kuruma prawn, *Penaeus japonicus*; redtail prawn, *P. penicillatus*; sand shrimp, *Metapenaeus ensis*; and giant freshwater prawn, *Macrobrachium rosenbergii*. Of these, the kuruma prawn looks very promising.

The kuruma prawn is the first prawn in the world to be successfully propagated under controlled conditions (Hudinaga, 1942). In Taiwan, the culture history of this prawn is quite short. Its wild fry were mixed with that of grass prawn and cultured in milkfish ponds. But since unsuitable pond conditions were not favorable for their growth, they were seldom harvested (Liao and Huang, 1973; Liao, 1988a). It was only in the mid-70s that the culture of this prawn started as a crop in winter, when temperature is too low for the culture of grass prawn. Subsequently, a better understanding of its ecology had established a moderately successful kuruma prawn culture industry in Taiwan.

In 1981, production of kuruma prawn started picking up and reached the 100-ton level. Although production was still relatively low, the high price that it commanded at the Japanese market made it favorable for culture. By 1986, Taiwan had exported 196 tons to Japan (Table 3). Production increased to 1,330 in 1987 and to 3,747 tons in 1988, ranking second to grass prawn among the marine prawns in that year. In 1990, production reached the 10,000-ton mark. Of these, 2,710 tons were exported to Japan, which is more than Japan's total kuruma prawn production.

The kuruma prawn is ideal for culture because it can withstand low temperatures and is easily transported live for a period of about 30 h if packed in chilled dry sawdust in an insulated styrofoam container. Its colorful appearance, delicious taste, and the possibility of being sold live helped maintain its higher market price. In addition, the community culture method (Hudinaga and Kittaka, 1967) which is used in the large scale production of the prawn larvae is quite established. Recently, the culture of kuruma prawn even in early summer became more popular, possibly to replace some grass prawn culture. The culture of this prawn, however, has some disadvantages. The species is carnivorous, and thus requires more

Table 3
Production and exportation (to Japan) of cultured kuruma prawn, 1986-1990

| | Japan | Taiwan | |
|---|---|---|---|
| Year | Production | Production | Exportation |
| 1986 | 2,434 | 817 | 196 |
| 1987 | 2,882 | 1,330 | 503 |
| 1988 | 3,020 | 3,747 | 1,296 |
| 1989 | 2,813 | 5,784 | 2,067 |
| 1990 | 2,636 | 10,707 | 2,710 |

expensive animal protein as part of its diet. Furthermore, it can only tolerate temperatures of up to 33°C and has a relatively slow growth rate (Liao and Chao, 1983; Liao and Chien, 1990).

## Eel

Compared with milkfish and grass prawn cultures, eel culture started relatively late in Taiwan. Culture on a pilot scale began around 1950 (Fig. 7), with the techniques and production still underdeveloped. Prior to the inception of the industry, elvers, which are the most essential element in eel culture, were used as feeds for ducks. In 1966, culture on a commercial scale was initiated. Over the subsequent decades, the industry grew remarkably well. By 1985, exports were already over 40,000 tons (Table 4). Over 90% of Taiwan's eel production, *i.e.*, live and processed eels, are exported to Japan. The exports account for 50–60% of Japan's total annual eel consumption. Recently, however, the

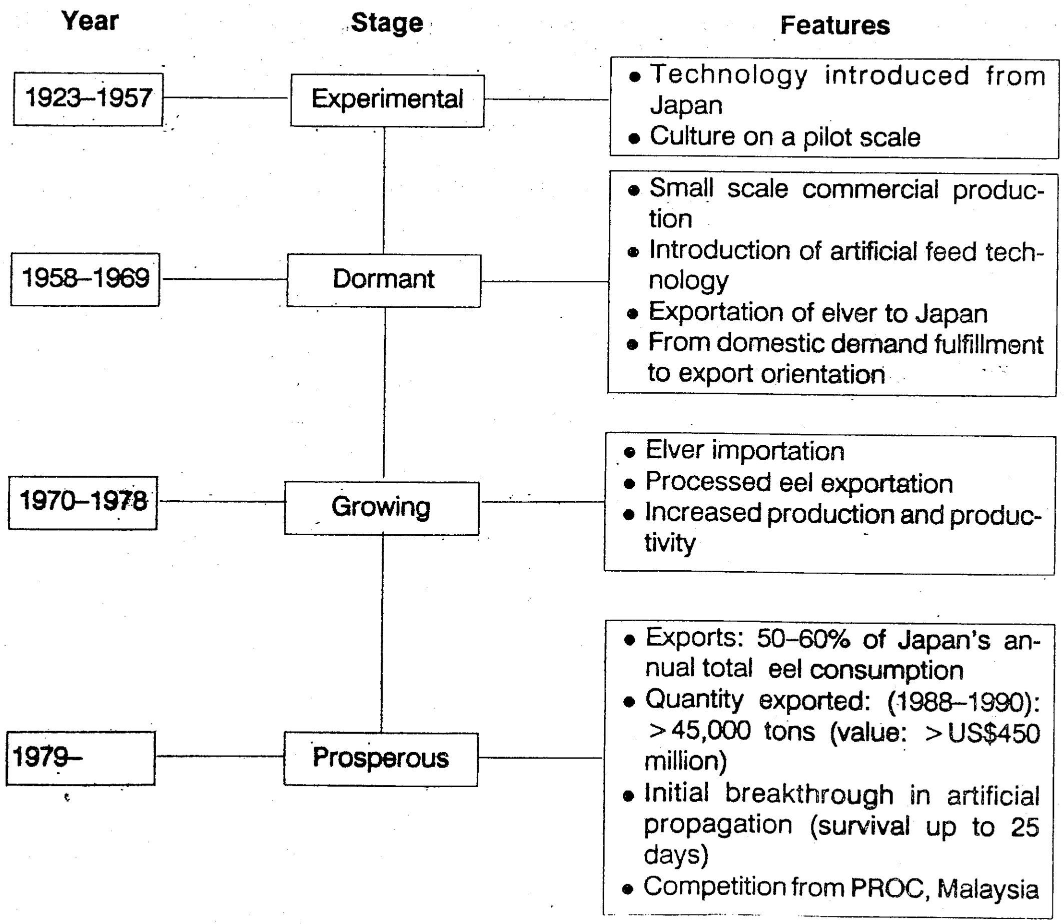


Fig. 7. Development of the eel culture industry in Taiwan.

Table 4
Production and exportation (to Japan) of cultured eel, 1981-1990

| Year | Japan | Taiwan | |
|---|---|---|---|
| | Production* | Export volume* | Export value** |
| 1981 | 33,984 | 30,102 | 191,564 |
| 1982 | 36,642 | 23,701 | 187,136 |
| 1983 | 34,485 | 26,618 | 212,629 |
| 1984 | 38,030 | 26,488 | 217,754 |
| 1985 | 39,568 | 36,170 | 244,168 |
| 1986 | 36,520 | 37,044 | 366,603 |
| 1987 | 36,964 | 35,157 | 380,418 |
| 1988 | 39,558 | 44,133 | 497,645 |
| 1989 | 39,705 | 46,388 | 488,878 |
| 1990 | 38,855 | 54,786 | 454,934 |

* Tons. ** ×US$ 1,000.00

People's Republic of China has posed a threat to Taiwan's dominance in the Japanese eel market because of its cheap labor and abundant elver supply. Likewise, Malaysia has started exporting live eels to Japan. This development caused some changes in the export structure of live and processed eels in Taiwan. Where before 80-90% of its export to Japan were live eels and the rest were processed eel, this has been reversed in recent years. More efforts are being made now to encourage production of high-quality eel products to maintain and expand the overseas market, not only in Japan but also in Europe and the US. In 1989, Taiwan exported over 13,000 tons (29%) of live eels and over 33,000 tons (71%) of processed eels to Japan from a total exportation of 46,388 tons. Export value over the last three years was more than US$ 450 million/year, the highest among the culture species.

**Tilapia**

Tilapia has become the most successfully cultured exotic species in Taiwan. Taiwan's rise to aquaculture prominence is partly due to this success (Liao, 1988b).

The history of tilapia culture spans a period of more than 40 years (Fig. 8). It began in 1944 (Liao and Chen, 1983) when Mozambique tilapia, *Oreochromis mossambicus*, was introduced from Indonesia. However, it failed to establish immediately. In 1946, Mozambique tilapia was re-introduced from Singapore by Chen-Huei Wu and Chi-Chang Kuo (Chen, 1976), two Taiwanese who were then

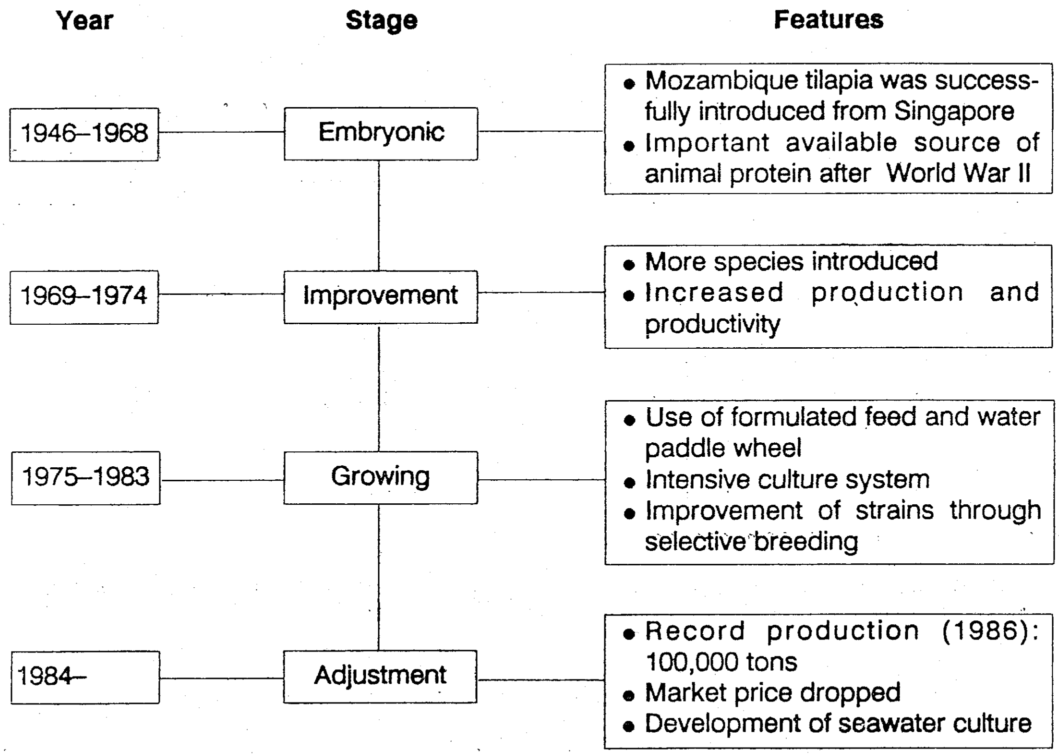


Fig. 8 Development of the tilapia culture industry in Taiwan.

returning from Singapore after World War II. This time, the tilapia, which they first farmed in southern Taiwan, multiplied and spread until they became a common foodfish all over Taiwan. The tilapia provided the main source of animal protein of the Taiwanese right after WW II. The success established a foundation for tilapia culture. In honor of the two Taiwanese, the tilapia is known in Taiwan as *Wu-Kuo Yü* (*yü* means fish in Chinese). By 1969, an annual production of 10,000 tons had already been reached (Liao and Chen, 1983), and in 1986, the production reached a record 100,000 tons (Liao and Shyu, 1992). *Tilapia zillii* from South Africa; *O. niloticus* from Japan; and *O. aureus* from Israel were introduced in 1963, 1966, and 1974, respectively (Liao and Chen, 1983). The introduction of *O. niloticus* and *O. aureus* resulted in a dramatic increase in the quantity of tilapia production from 1966 to 1986. In recent years, however, production declined considerably. This was indirectly attributed to the overproduction in previous years which resulted in significant price drops. Subsequently, this brought a decline in the number of tilapia aquafarmers.

Eight tilapia species are presently

cultured in Taiwan, namely, *O. mossambicus*, *O. niloticus*, *O. aureus*, *O. hornorum*, two strains of red tilapias, and hybrids of *O. mossambicus*$\times$*O. niloticus* and *O. niloticus*$\times$*O. aureus*.

Originally, two different types of tilapia culture were practiced in Taiwan. One was the extensive practice in highly eutrophic waters where tilapia are stocked along with small numbers of such fishes as carp and mullet in ponds provided with organic fertilizers. Thus they grew principally on natural food available in the pond (Liao and Chen, 1983). The other was an intensive monoculture, which is now the exclusive culture method practiced. The fish grow mainly on formulated feed. Paddlewheel aerators to supply sufficient dissolved oxygen and an abundant supply of water for exchange are provided.

In the intensive monoculture system, fingerlings with a body weight of 0.01 g can be grown to a marketable size of 600 g within six months. Thinning is frequently used to segregate fish of different sizes, to culture them separately and ensure an even faster growth. There are generally three stages involved in the course of culture, which are (1) nursing the fry from a size of 0.1 to 1 g during the first month; (2) rearing fish from a size of 1 g to 20 g during the second month; and (3) growing the fish from a size of 20 g to 600 g in the next four months. At the start of the last stage of culture, about 40,000 fish with an average body weight of 20 g are stocked into a one-hectare pond, and these usually grow to an average size of 600 g after four months. With a survival rate of 90%, and two crops a year, an annual production of 30 tons per hectare can be reached (Liao and Chen, 1983). In an octagonal pond system, on the other hand, with a surface area of 100 $m^2$ and a depth of 1.2 m, 3-4 tons/pond/crop or 6-8 tons/pond/yr can be produced. In a floating net-cage system, with a cage size of 7m$\times$7m$\times$2.5 m and net mesh size of 1 cm, 4.3-5.4 tons/cage/year can be reached (Liao and Chen, 1983).

The success of tilapia culture in Taiwan is mainly attributed to the favorable climatic and geographical conditions, development of formulated feeds, and introduction of suitable species. The improvement of culture techniques such as artificial hatching and the mass production of monosex fry and the development of floating net-cage culture have also contributed to this success.

Considering the advantages such as the possibility of rearing the fish to a size of over 1 kg or an attractive and favorable reddish color, the relatively cheap cost of tilapia feed, and the continued improvement in culture techniques, tilapia culture still remains promising despite the decreasing interest of aquafarmers to culture it. Furthermore, tilapia cultured in seawater has a delicious taste similar to that of sea bream, *Acanthopagrus* spp. Thus, tilapia could serve as a good substitute for sea bream, which is in high demand specially in the Japanese market. The demand for red tilapia in the American market has also been rising steadily.

**Hard clam**

The hard clam, *Meretrix lusoria*, was introduced from Japan about 50 years ago (Fig. 9). It is a bivalvian species that inhabits in sublittoral to littoral zones of sandy shores.

Until recently, seedlings used for culture in Taiwan were only collected from the wild. The techniques for the artificial propagation of hard clam were established in 1983 (Yang and Ting, 1984). Since then, hard clam culture farmers now depend totally on artificial propagation for their supply of seedlings.

Hard clam culture in Taiwan is mainly of the pond culture type. The structure of the culture ponds is similar to those of milkfish and grass prawn culture ponds. About 1,000 kg/ha of seeds are stocked to cover half of the pond. The other half is used for propagating planktonic organisms, which are the main food source of the clams. Much attention is given toward controlling the benthic environment to prevent the generation of toxic materials

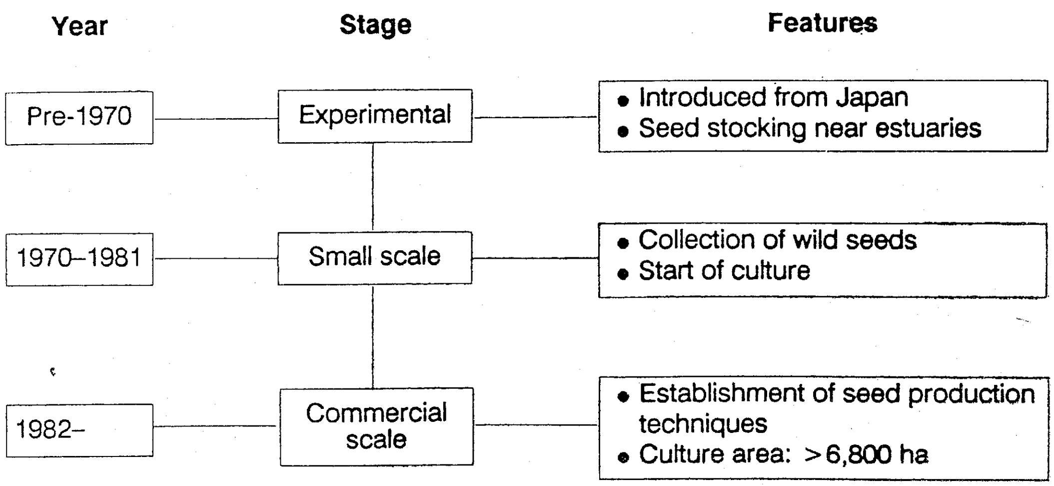


Fig. 9. Development of the hard clam industry in Taiwan.

caused by insufficient oxygen concentration. Salinity is maintained at a range of 15-25‰. A light brown color for water is maintained. To ensure good water quality and sufficient supply of plankton, pond water is changed at a 2-3-day in-interval. It takes 6-8 months for culturing the seeds to market-size individuals.

Mechanical harvesters are now used to collect clams to save on labor and time. In 1990, total culture production of hard clam reached 18,521 tons, worth approximately US$ 40 million. Total culture area is more than 6,800 ha.

**Other species**

In addition to the cultured species discussed, there are other species being cultured which are gradually attaining importance. The following are just three of these species.

*Grouper*

The culture of groupers is fast gaining economic importance and popularity in Taiwan. In 1989, total culture production of groupers reached 1,000 tons, which is approximately worth US$ 6 million. The total culture area is about 240 ha. Grouper culture was previously concentrated only in the Pescadores, where an abundant supply of fish larvae is available. It is now widely practiced in Taiwan. Out of a total of 32 grouper species of the Genus *Epinephelus* reported to exist in Taiwan (Lee, 1990), the most widely cultured species and more economically important is the malabar rockcod, *Epinephelus malabaricus* (Chao *et al.*, 1992).

*Mudskipper*

The mudskipper, *Boleophthalmus pectinirostris*, is a delicacy among the people of Taiwan and is one of the most high priced fish (Chen, 1976; Chen, 1990). It is a brackish-water goby and is a small fish, measuring 12-15 cm in total length, and weighing only 20-50 g. The total culture area was only about 700 ha in 1988; it increased to about 3,000 ha in 1989. This expansion is mainly attributed to the high demand from consumers and high market prices. Production level already reached 2,000 tons in 1989.

*Frog*

The tiger frog, *Rana tigrina pantherina*, occurs naturally in rice paddies in Taiwan. Locally this frog is known as "water chicken" and is a highly priced food item

(Chen, 1990). Before the species declined following human destruction of its natural habitat, it was captured and sold as food. At present, all the marketed frogs are of aquaculture origin. The market size of this frog is only 40-60 g although it can reach 11 cm and 150 g in the wild. At present, the frog culture industry is concentrated in southern Taiwan, particularly in the Pingtung area, with an annual production of about 2,000 tons.

The bullfrog, *Rana catesbeiana*, is one of the largest frogs. With a maximum size exceeding 1 kg, this frog is a gourmet's delight. Bullfrog culture developed in Taiwan in the late 1950s. In 30 years, its culture has gone through at least two stages of successes and failures (Chen, 1990). Initially most of the operations were hatchery or brooder production in nature. The industry declined as the bullfrog failed to capture the domestic market, and the price of frogs in the international market was not attractive enough to warrant exportation. Following this was the emergence of the culture of the native tiger frog. The rapid improvement in living standards in Taiwan in recent years has exerted persistent pressure on the aquaculture industry to come up with more varieties of gourmet foods. This resulted in the resurgence of bullfrog culture.

## PROSPECTS FOR THE FUTURE

Aquaculture has been widely and extensively developed and practiced in Taiwan for over three centuries. The Taiwanese experience is noted for its high degree of development, both in technology and production. Several techniques to culture a wide variety of profitable species almost completely under the aquafarmer's control have already been established. Taiwan's aquaculture production accounts for 25-30% of its total fisheries production. Taiwan is also among the top producers of several culture species in the world. There also exist several sub-businesses and related and support industries which have contributed to this development. The setback suffered in the prawn culture industry in 1988, for example, was put to an advantage by the feed export industry, which has grown two-fold since 1987 (Fig. 10).

The aquaculture industry in Taiwan is generally characterized as having an intensive culture system, systematic management, capital intensive investment, and innovative approach toward species selection

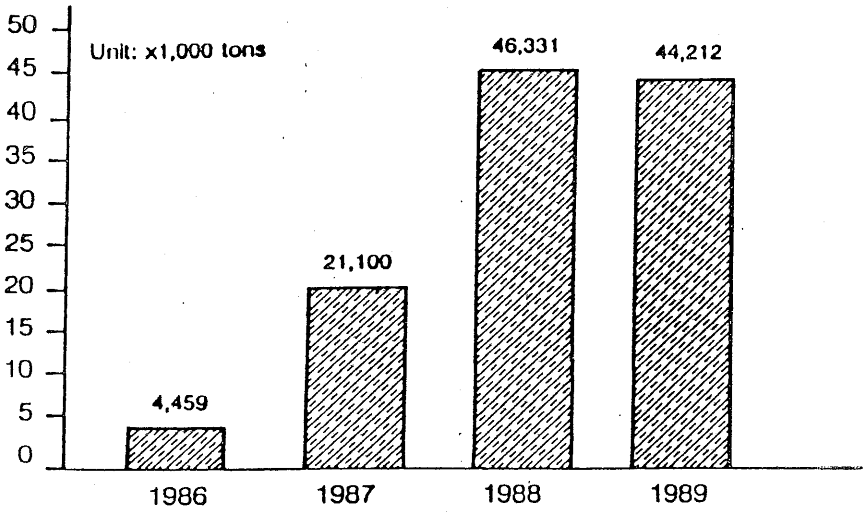


Fig. 10. Aquaculture feed exports of Taiwan.

and variation and culture pattern. The long history of aquacultural practices, good water and soil quality, suitable climatic conditions, fairly high availability of fry, and deligent aquafarmers as well as other actors of the industry such as scientists have all contributed to the steady growth of aquaculture.

With the expectation that capture fisheries production will soon level off or even decrease due to the establishment of the exclusive economic zone and the lack of interest among young Taiwanese to enter into the fishing industy as seamen, the present trend of progressive and accelerated development in aquaculture must continue. Expanding the area for aquaculture, however, is unlikely because of the limited freshwater resources and regulations on the land use for aquaculture.

Strictly speaking, aquaculture is restricted only to the use of systems in which the animal is under the control of the aquafarmer throughout its life. There is, however, a recent and important branch of aquaculture which does not fall within this definition—stock enhancement, a system where the aquatic animal is reared on the farm to a certain size and released into the sea or other large bodies of water such as lakes and reservoirs, where they achieve the major part of their body growth and where they complete their life cycle.

Just as in other fishing countries, Taiwan has a 200 mile economic zone which is even several times larger than its limited land. Thus stock enhancement has been gaining importance as traditional fishing zones are being severely reduced due to the imposition by other fishing countries of their own exclusive economic zones. Furthermore, stock enhancement is not limited by land pressures. It takes advantage of the natural environment of the aquatic animal, using it as a large aquatic pasture. No pond or maintenance of optimal conditions are necessary as the aquatic animal is already in its natural environment. The resources are virtually under man's control.

To ensure this momentum of aquaculture development into the future, a concerted effort must be directed towards a sound and balanced development. Reflecting on past accomplishments and mistakes can be helpful.

**Mass propagation and culture techniques**

The method most often used in the fish culture industry for inducing maturation and spawning is the injection or implanting of reproductive hormones. This practice is, however, questionable because it inflicts physiological stress and injures the fish, particularly during stripping, making it susceptible to diseases, sometimes even causing death (Liao *et al.*, 1972). Physiological, nutritional, ecological and endocrinological approaches should be considered. Other methods, for instance, controlling environmental conditions such as temperature, salinity, photoperiod, nutrition, space, presence of substrates, and water current velocity or waterflow should also be considered. Healthy and fertile spawners can be used to produce good-quality larvae and stronger stocks.

In grass prawn, one difficulty often met by hatcheries is obtaining mature spawners. Since no breakthrough has yet been achieved in maturing spawners in captivity, unilateral eyestalk ablation of the females are routinely used to mature spawners. This method, however, goes against the natural physiology of the prawn and there is some evidence that it affects the quality of eggs in successive spawnings (Liao, 1984, 1988c; Lin and Ting, 1986).

In fish, there are advanced approaches to induce the maturation of oocytes *in vitro* to obtain ripened eggs (Adachi *et al.*, 1988), hopefully in a large scale, and to manipulate the sperm bank but not the broodstock for offering desirable male genes at any place and at any time.

Further extension and application of these scientific breakthroughs should be conducted.

Mass propagation techniques should also be established and existing hatchery facilities and techniques improved. A more reliable and predictable source of fry should also be determined for an aquaculture industry to be successful.

Likewise, a steady supply of live feeds should also be ensured. The nutritional value of live feeds like rotifers and *Artemia* can be upgraded by enriching them with polyunsaturated fatty acids mixed with other ingredients or microalgae. Culture techniques for live feeds should also be improved.

Formulated diets likewise should be improved, made more complete and specific to each stage of the growth of each culture species, aside from meeting their nutritional needs. This, however, cannot be accomplished unless the basic digestive physiology and feeding behavior of target species are better understood. It should cover such aspects as improved formulations and cost-effectiveness of formulated diets.

In the future, feeds of high quality should be developed at low cost and, as much as possible, should make use of locally available resources and waste materials like those left after aquacultural products have been processed.

Being a relatively new field, aquacultural engineering is one area which offers a lot of room for innovative research. For instance, more functional designs of ponds and other culture units are needed to ensure proper water exchange and circulation. The interplay of different factors, such as shape and size, and the various needs of the culture species, should be considered. A challenge facing researchers is the development of engineering techniques which will maximize use of such resources as water, land and labor. Resource maximization should ultimately reduce costs substantially.

Mechanization should also be considered, especially that labor cost in Taiwan is increasing steadily. Machines can be designed and created to perform such routine tasks as feeding and water quality assessment. Computers can also be used for monitoring purposes, particularly in intensive systems.

Management techniques should also be updated and aim towards the repeatable, predictable, and stable production of seedstock and market-size aquatic products. These entail overcoming environmental unpredictabilities by improving management of culture systems.

Aquaculture is estimated to be consuming 12% of the total freshwater supply in Taiwan. At the rate groundwater usage is going, the tapping of 5 m of groundwater can cause about 1 m of land subsidence (Chen, 1990). The recycling of water used in aquaculture to save freshwater should be given more emphasis. Overall regional planning for aquaculture purposes through proper allocation of land and water has thus far been undertaken.

**Species diversification**

A variety of species are already under culture in Taiwan. There is still a need, however, for more culture species, hybridization and selective breeding for several reasons. A further diversification of culture species would benefit both consumers and producers. While consumers will have more products to choose from, producers will not be so dependent on a limited number of species. Hybridization and selection could help produce larger and more disease-resistant strains, and thus increase the level of production.

The immense possibilities and exciting opportunities offered by biotechnology should also be further explored. Recent breakthroughs in biotechnological research have produced transgenic fish. Experiments have so far showed the potential of transgenic fish production in the selection of fish for commercial exploitation (Maclean *et al.*, 1988). While transgenism may create some "wonder fish", it may also create problems. Experience in the livestock sector shows that transgenic livestock had, among others, incidence of diabetes, gastric ulcers and high metabolic rates. The application of transgenism in aquaculture should thus be judicious.

**Disease and parasite control**

Diseases that afflict culture species are caused by several factors such as an intensive practice of aquaculture. This practice calls for high stocking densities and increased application of feeds, which inevitably result in the deterioration of water quality. Consequently, aquaculture organisms become more susceptible to diseases. Poor quarantine performed on imported exotic species also introduces diseases. Diseases cause high mortality and significant economic losses. Thus effective preventive measures such as vaccines should be developed.

Disease prevention through the use of an improved diet, more efficient management of the culture environment, and highly reliable system of sanitation should also be explored. A more nutritive and balanced diet can make the culture species more resistant to diseases, so that even if they may be viral carriers, they are not vulnerable or susceptible to secondary infection. A properly managed culture environment means better water quality and pond bottom. Effective sanitation systems should be instituted to protect hatchery facilities and processing plants against contamination by harmful microorganisms. Some hatcheries install disinfecting footbaths at their entrances. For water sterilization, ultraviolet light, ozone, or other chemicals are used. More of these devices and sanitary measures should be developed. Likewise, pathogens and other causative agents and preventive measures should be looked into. The prevention rather than the cure should be emphasized in the management.

Diseases can also be caused indirectly by pollution. The increasing threat posed by industrial pollution in estuaries will hamper the development of aquaculture seriously. Environmental impact assessments should be carried out and an effective pollution monitoring system established. Furthermore, proper regulations should be imposed.

**Aquacultural economics**

Aquaculture has grown to a very specialized field with its own unique problems and issues distinct from agriculture where it evolved. Its practice has created and provided several topics and issues of its own concern that should now be addressed. Where before economics in aquaculture was discussed only as an incidental derivative of agricultural economics, the aquaculture issues that need attention have become immense and unique. For example, aquacultural price policies or resource allocation problems are very distinct from that of agriculture. Some species under culture in Taiwan are for the export market such that price policies should also consider outside factors such as the international marketing environment. Cost of production in aquaculture are also generally higher because of the intensive nature of the culture system. Thus aquacultural economics should be formally established and its scope expanded.

In Taiwan, the use of paid labor is often uneconomical and most of the aquafarms are family-based. Characteristically, aquafarms are small, with from less than one hectare to several hectares of family inherited water surface, and are run mainly by family members. For this reason, land and labor are often excluded from the estimate of operating expenses. An aquafarmer often enjoys profit but in reality he is operating at a loss. The importance of aquacultural economics should be extended to the rural areas. This should also include teaching simple bookkeeping procedures or business administration to aquafarmers.

On the other hand, enthusiastic aquafarmers rush into a seemingly "lucrative" enterprise because of the earlier successes of other aquafarmers. Although they obtained successful harvests, they failed to make profit. This was the case recently in milkfish culture. Many aquafarmers ventured into milkfish culture, thus flooding the market. Because of this, prices went down while the cost of production remained the same or even increased. A sound management and marketing system should be established. Likewise, quality, not quantity, of production should be emphasized. Small-scale aquafarmers should also be protected and given a fair chance at the market. Such assistance may be provided by establishing effective marketing strategies and producers' cooperatives or an insurance system, just like what is being established in agriculture.

**Government policies**

Aquaculture has been playing a very important role in national development as a source of food for the common man. The government should, therefore, delineate a national policy for aquaculture. The government should be supportive to, not competitive with, the industry. In Taiwan, the first private grass prawn and giant freshwater prawn hatcheries were set up with the assistance of scientists—a fine example of cooperation between private industry and government-backed research.

Aquaculture can only continue to develop if it is adequately backed by an able leadership and qualified fisheries personnel of all ranks. Aquaculture has grown so fast that training and educational institutions could scarcely keep pace with it. Aquaculture badly needs more adequately trained aquafarm managers, hatchery experts and other technicians, and professional aquafarmers, and yet fisheries educational institutions have been slow to respond to this need. Because of this, much of the training in aquaculture is presently carried out through short courses and seminars and through other less formal and institutionalized ways. Private companies often have to accommodate people interested in learning aquaculture techniques and methods into on-the-job training arrangements. The government should recognize the importance of aquaculture by strengthening the existing training and educational setups.

More policy studies are needed, so that proper planning of the development of aquaculture industries may take place. Licensing of aquafarmers should be institutionalized to prevent price structure collapse from overproduction, as well as mismanagement of aquaculture concerns. Setting up of a national regulatory body or mechanisms may also be necessary.

The majority of aquaculture farms are widely scattered. Thus, it is very difficult for concerned government institutions to provide supervision and guidance to the aquafarmers. Special aquaculture zones should be established and carefully planned and designed by the joint efforts of concerned organizations and specialists. Zoning can facilitate management and control and monitoring or gathering of production statistics. The concentration of aquaculture enterprises into zones would also facilitate the development of systematic plans to reduce the impacts of pollution as well as the construction costs per unit area. In this special zone, public inlet and outlet systems should be constructed to avoid the pollution of natural environment caused by the effluence from the zone itself, avoid the threat imposed by industrial waste disposal, and reduce the construction costs for each aquafarmer in the zone.

Consequently, proper zoning will result in a faster and more efficient transfer of technology. Aquafarmers would be given the opportunity to maximize the benefits of his labor, if a centralized processing and marketing of products will be implemented. This would subsequently result into a more efficient use of manpower and enhance more active cooperation among aquafarmers.

**Research and technology transfer**

There is a growing need to encourage extensive information exchange to help spread the benefits of aquaculture. Thus, the frequency of contacts such as conferences, workshops and symposia should be increased, because the more information is exchanged, the greater the chances of aquaculture development. Likewise, such contacts will afford the younger generations the wisdom of the older ones.

For aquaculture to develop further, it should be supported by the availability of updated scientific and technical information and research results. Research should also be well-managed, that is, it should be coordinated to avoid any duplication, and consequently maximize research costs. Although some coordination and cooperation do exist, what with the frequency with which national or international meetings or staff exchange programs are organized, these are still far too inadequate.

## OUTLOOK

Aquaculture in Taiwan has a history of over 300 years. Currently, Taiwan has some 70 main and 35 candidate culture species, which include finfishes, reptiles, amphibians, crustaceans, echinoderms, molluscs, and seaweeds. As a result of the impressive output in some of its culture species, Taiwan has gained distinction and prominence in the aquaculture world.

The Taiwanese experience in aquaculture can be characterized in three ways. First is flexibility. The setback of one species is not a deterrent to the success of other species. The setback experienced in the grass prawn industry has encouraged the culture of the kuruma prawn, the export volume alone of which already exceeds the total production in Japan (Table 3). Likewise, the setback caused a decreased used of feeds in the domestic market. This, however, did not deter the producers from exporting their products, thus doubling export figures (Fig. 10).

Second is capability. People in the industry are capable of bringing it to greater heights. Despite stiff competitions from other eel-producing countries, the value of Taiwan's eel export to Japan from 1988 to 1990 was more than US$ 450 million/year (Table 4).

Third is potentiality. With a favorable climate and a wide variety of species under culture, the possibilities for growth and expansion are high.

The importance of aquaculture as well as aquatic resources protection is increasing as a result of reduced fishing grounds and water pollution of the aquatic environment.

In response to this, Taiwan is embarking on a stock enhancement program which will be intensified after a series of exhaustive tests are completed, to determine and prevent the possibility of any adverse impact on the environment. Although it does not fall strictly within the typical definition of aquaculture, stock enhancement, nevertheless, offers several possibilities for aquaculture. By artificially rearing the aquatic organism's larvae in the laboratories, nurturing them in the nursery, and then releasing them into the sea where they complete their growth phase and can be recaptured for harvest, aquaculture could be established and fisheries production could become higher. Thus stock enhancement will not only play a considerable impact on future fisheries production but also help alleviate the worsening situation in the world's aquatic resources. The ultimate aim in the industry, however, is that production should come totally from their cultivation, just like what is being established in the livestock industry.

The proverb, "Give a man a fish and you feed him for a day. Teach him how to fish and you feed him for a lifetime", clearly points out the active and positive philosophy that has been guiding the people in Taiwan in their development of aquaculture. Taiwan has been helping its people help themselves for centuries. It is now at a stage where it is capable of sharing with the rest of the world its experience in aquaculture. It is hoped that this address has been able to point out some directions for others to take in undertaking their own experience in aquaculture.

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**Note:** At the time of the preparation of this paper, some references had already been scheduled for publication. The dates and other information of the concerned references (indicated with an asterisk) have been updated in this current reference list to reflect the bibliographic elements of the published papers.