Stocking, Enhancement, and Mariculture of *Penaeus orientalis* and Other Species in Shanghai and Zhejiang Provinces, China

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Introduction

Fish as a Source of Food

Marine and freshwater landings from capture and culture fisheries in the People's Republic of China (PRC) have steadily increased since 1982 (Fig. 1A). In 1991 the combined landings of >21,000,000 t were dominated by capture landings (61.9%). Per-capita consumption of fish of all kinds in the PRC was 18.1 kg/yr in 1991, with 6.9 kg/yr from culture and 11.2 kg/yr from capture fisheries. Landings from mariculture in 1991 provided the smallest contribution: only 3.2 kg/yr (17.9% of total landings).

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ABSTRACT—China's marine aquaculture landings provide only 18% of its combined freshwater and marine capture and culture landings, at a per-capita consumption of only 3.2 kg/yr out of a total of 18.1 kg/yr. We described development and some of the results of long-term mariculture and stocking/enhancement projects that have been underway for up to 20 years in the Hangzhou Bay area. Penaeus orientalis *(also referred to as* P. chinensis*) stocking provided up to 400 t/yr, at a total cost-benefit ratio of up to 8 Yuan of landed shrimp per Yuan invested in shrimp stocking. Over 40 t of* Penaeus orientalis *were produced commercially in 1993, with proceeds being used to fund mariculture and fisheries research. Large-scale edible jellyfish restocking is also underway, while semicommercial culture of abalone,* Haliotis diversicolor, *has been successful. Technical problems limiting mariculture have been solved successfully for some species.*

Culture landings are dominated by freshwater fish (48.7%; Fig. 1A), mostly from small farms and aquaculture facilities. Mollusks and crustaceans (almost entirely marine) provide important contributions to culture landings (2.2% and 15.3%, respectively, Fig. 1B), while marine fish form a very small portion of the total (only 0.6%). Algae (>90% *Laminaria japonica*) provide 34.1% of culture landings, but are harvested directly, generally without any significant associated culture or farming activities. Table 1 provides a more detailed breakdown of culture landings by species.

Attempts at fisheries stocking and enhancement have been made in the PRC but have contributed only a negligible proportion of the landings. This paper describes results of attempts to increase landings by stocking shrimp, *Penaeus orientalis* (also referred to as *P. chinensis*), and enhancing jellyfish, *Rhopilema esculenta,* landings in Zhejiang Province, which landed >1,300,000 t from capture fisheries in 1991, compared to <40,000 t from mariculture landings.[1] Information is also provided about some of the mariculture activities in Zhejiang Province.

[1] Unpublished data, East China Sea Fisheries Research Institute, Shanghai; Zhejiang Marine Fisheries Bureau, Hangzhou; Asian Development Bank, 1993 [unpubl. rep. on the Zhoushan Fisheries, 340 p.]

Table 1.—Aquaculture landings (1,000 t) by species in the PRC and in percent total culture landings, 1993 (FAO, 1994).

Species	Landings (1,000 t)	Percent of total
Freshwater fish		
Carassius carassius	254.3	2.4
Cirrhinus mulitorella	81.0	0.8
Ctenopharyngodon idella	1,231.8	11.8
Cyprinus carpio	706.1	6.8
Hypophthalmichthys molitrix	1,540.7	14.8
Hypophthalmichthys nobilis	770.4	7.4
Mylopharyngodon piceus	51.8	0.5
Parabramis pekinensis	181.5	1.7
Oreochromis (Tilapia) niloticus	157.2	1.5
Subtotal	4,974.9	47.8
Marine Fish, Subtotal	58.7	0.6
Marine Crustaceans		
Eriocheir sinensis	9.5	0.1
Penaeus chinensis	206.9	2.0
Other marine crustaceans	8.6	0.1
Subtotal	225.0	2.2
Marine mollusks		
Crassostrea gigas	123.0	1.2
Mytilidae	538.9	5.2
Pecten yessoensis	338.0	3.2
Anadara granosa	41.6	0.4
Solen spp	198.6	1.9
Venerupis japonica	270.5	2.6
Other mollusks	86.9	0.8
Subtotal	1,597.4	15.3
Algae		
Laminaria japonica	2,964.8	28.5
Porphyra tenera	159.0	1.5
Other algae	429.4	4.1
Subtotal	3,553.2	34.1
Grand Total	10,409.1	100.0

Study Area

The study area, located in the Zhoushan Islands, is situated in Hangzhou Bay, on the East China Sea (Fig. 2). Coastal waters are generally turbid and of low salinity (<25‰) in Hangzhou Bay and around the Zhoushan Islands, and show a temperature range of 4–11°C in February and 26–28°C in August (Ning,

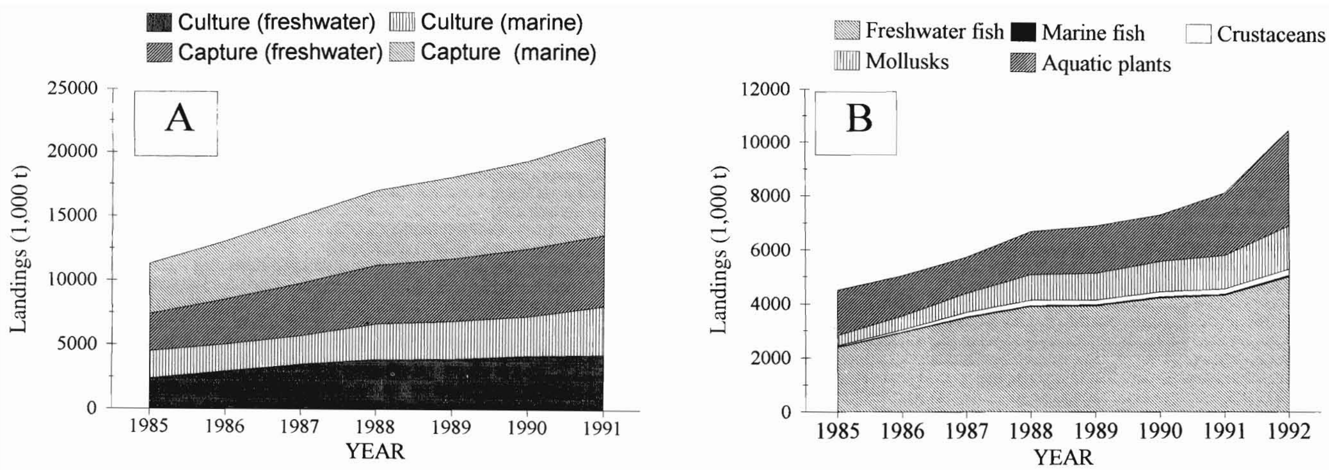


Figure 1. — A: People's Republic of China (PRC) culture and capture landings, 1985–91. Data from FAO (1992). B: Composition of PRC culture landings by general type, 1985–91. Data from FAO (1992).

1994). Oceanographic structures in Hangzhou Bay and the East China Sea are very complex, with water from the Changjiang (Yangtze) River, which has an inflow of >28,000 m^3/sec, providing an important and perhaps dominant influence in coastal waters. Smaller inflows come from the Qian Tang (1,100 m^3/sec), the Huangpoo (>300 m^3/sec), and other rivers entering Hangzhou Bay from the west such as the Casejiang and the Yongjiang (230 m^3/sec). Depending on the time of year, coastal waters in the study area are also influenced by the mixing of different water masses coming from the plume of the Changjiang and the Taiwan Warm Current, an inshore branch of the Kuroshio Current (Second Institute of Oceanography, unpubl. rep.). In summer, incursions of warm, clear, and salty Taiwan Warm Current water may move westwards from the East China Sea, bringing clearer, more transparent waters across the Zhoushan Archipelago and into Hangzhou Bay. These incursions may cause red tides in some years, impacting aquaculture activities. Red tides are probably related to nutrient flows into the study area from the Changjiang River basin, and to agricultural and industrial pollutants entering the study area from the west. A full description of the study area and its characteristics is given in ADB[2] and in WB.[3]

Zhejiang Marine Fisheries Research Institue (ZMFRI)

ZMFRI was established and started its research program in the early 1950's. Since then it has carried out fisheries research on a variety of stocks including the large yellow croaker, *Pseudosciaena crocea*; the small yellow croaker, *P. polyactis*; and the edible jellyfish, *Rhopilema esculenta*, in Zhejiang Province and especially in the Zhoushan Archipelago. Mariculture research started in the early 1960's, and in 1972 an important mariculture program was started in ZMFRI's laboratories in Shenjiamen (Fig. 2) on Zhoushan Island. Work continued there until 1984. By 1979 the effects of increasing industrialization of Hangzhou Bay on the general conditions in and around the Zhoushan Archipelago, together with the establishment of important shipyards, a large fishery, freezer plants, and related industrial developments in Shenjiamen, led to reduced water quality at the ZMFRI's laboratories. This impacted mariculture development. Therefore in 1984 the Xixuan Aquatic Experimental Station was established on Xixuan Island, about 10 n.mi. and 30–45 minutes by sea from Shenjiamen (Fig. 2). Xixuan Island has an area of 0.45 km^2, of which 0.15 km^2 is devoted to culture ponds, principally to *Penaeus orientalis* spawning and grow-out. As the techniques for large-scale mariculture and restocking of *P. orientalis* were successfully mastered, additional tanks have been built to allow mariculture research, grow-out, and restocking of the following species: jellyfish, *Rhopilema esculenta*; abalone, *Haliotis diversicolor* and *H. discus*; Gulf scallop, *Agropecten irradians*; black porgy, *Mylio macrocepahalus czerkskii*; and grouper, *Epinephelus awaara.*

An important part of the Xixuan Island culture facility is the capability to produce live food for cultures, based on large-scale phytoplankton and zooplankton production of *Phaeodactylum tricornutum, Chaetoceros calcitrans, Skeletonema costatum,* and *Brachionus plicatilis.* Up to about 1,000 t/yr of phytoplankton is produced at various densities, usually at about 4 ml/l. These organisms are used to feed the newly hatched and young stages of the cultured organisms.

Stocking and Enhancement

The crustacean fishery in the East China Sea landed about 131,000 t in

[2] Asian Development Bank. 1993. Final Report of the Zhoushan Island Fisheries Project (unpubl.)

[3] World Bank. 1995. Final report of the Hangzhou Bay Project (unpubl.). This presents a recent multidisciplinary, synthetic review about the water quality and oceanography of Hangzhou Bay and the East China Sea fisheries.

1956 (the first year for which landings data are available), increasing to about 884,000 t in 1994. The species composition of these landings is not monitored but is known to be dominated by crabs and palaemonid shrimp, with <1% being composed of penaeids. The only penaeid fished in commercially important amounts is *P. orientalis* which is taken regularly from a very small stock located near the mouth of the Changjiang. This stock has provided a fishery with significant but small (<1,000 t/yr) landings over the last 20–30 years (WB,[3] Chen[4]). This stock has been used by Chinese scientists in Zhoushan and Shanghai as a source for broodstock when needed.

Stocking in Xiang Shan Bay

P. orientalis was stocked by releasing large numbers of 3.0–4.0 cm TL (total length) shrimp cultured at the Shenjiamen Laboratory (until about 1983) and at the Xixuan Mariculture Station from 1985 onwards, in Xiang Shan Bay, an area where *P. orientalis* never occurred prior to stocking. Catches of *P. orientalis* resulting from stocking were estimated by two different methods: direct interviews with fishermen provided estimates of the numbers of *P. orientalis* recaptured; and landings data compiled by local Fisheries Management Bureaus, through weighing of catches at the landing places and estimating the catch in metric tons fresh weight (Table 2). Low releases and catches occurred until 1986 when the new facilities at the Xixuan station came fully on line. Numbers of *P. orientalis* released exceeded 100,000,000/yr for the first time in 1986, and declined from about 1991 when numbers stocked were decreased. By 1993 when stocking ceased, landings of *P. orientalis* were again very low, with negligible landings in 1994.

Releases of small shrimp occurred in May–June, and recaptures of juveniles in the commercial fishery occurred from July to December when shrimp reached 10–12 cm TL (Table 3). Larger, mature shrimp were taken in small numbers, usually in the mouth of Xiang Shan Bay in March and April of the following year. Mature shrimp left the Xiang Shan mouth fishing grounds or died out of the population by May. No mature prawn were ever taken in the fishery from May onward when recruitment would be expected in a natural population. Conditions in the sea were suitable for grow-out but, in spite of the occurrence of some mature individuals in the population, the restocked *P. orientalis* population was not reproduc-

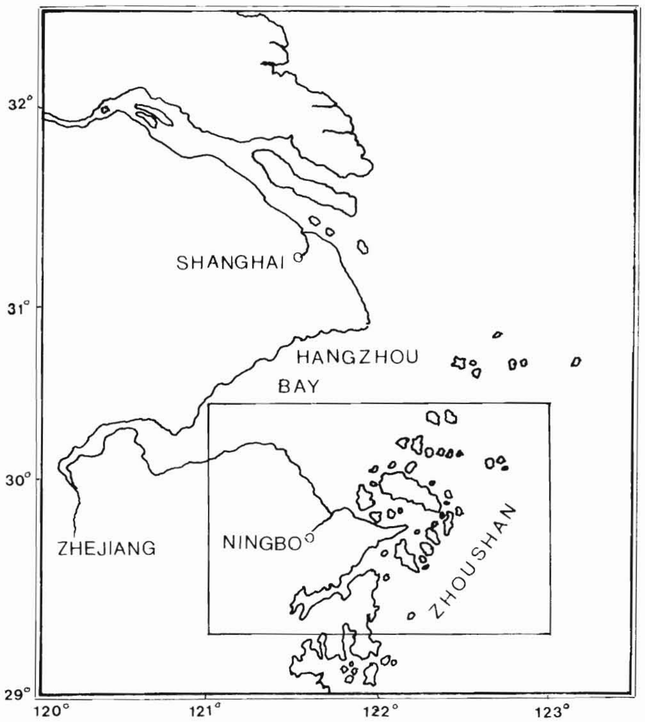
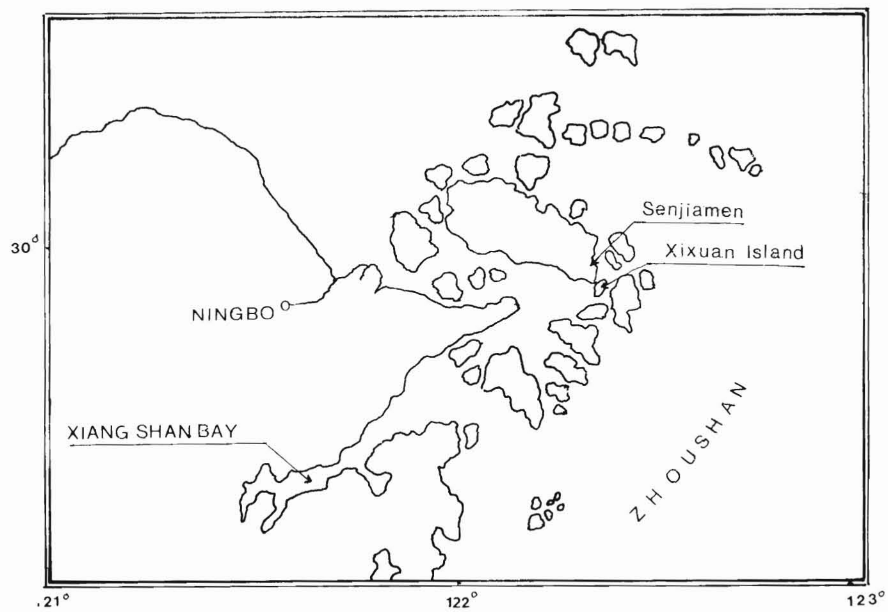


Figure 2. — Location of the study area. Inset: Location of research stations and areas in the southern Zhoushan Islands.



[4] W. Z. Chen, East China Sea Fisheries Research Institute, 300 Jun Gong Lu, Shanghai, 200090, PRC.

Table 2.—Numbers of *P. orientalis* released and landings in Xiang, Shan Bay.

Year	Released (×10,000)	Catch (t)	Year	Released (×10,000)	Catch (t)
1982	239.2	5.0	1988	15,644.3	329.0
1983	164.5	7.0	1989	16,218.0	228.0
1984	793.9	15.8	1990	14,874.2	265.0
1985	0.0	4.4	1991	9,158.0	158.0
1986	13,873.2	135.0	1992	10,950.0	163.0
1987	22,483.0	398.0	1993	0.0	27.0

Table 3.—Relation between numbers of juvenile *P. orientalis* released and numbers recaptured by the fishery.

	Releases (×10,000)			Catch of juveniles (×10,000)			Catch of matures (×10,000)			
Year	April/May	July	August	Sept.–Oct.	Nov.–Dec.	Mar.–Apr.	Total No. landed	% of the releases landed	Matures as % of recaptures	Matures as % of releases
1986	13,873.2	709.0	125.0	67.0	35.0	7.0	943.0	6.8	0.00	0.000
1987	22,483.0	1,083.0	167.0	156.7	243.0	24.0	1,673.4	7.4	1.43	0.1067
1988	15,644.3	1,707.0	208.4	67.2	75.0	12.0	2,069.6	13.3	0.58	0.0767
1989	16,218.0	1,174.0	167.0	112.0	75.0	15.0	1,543.0	10.5	0.97	0.0925
1990	14,874.2	1,005.0	132.0	120.0	63.0	12.0	1,332.0	9.1	0.90	0.0807

tively successful, nor were large numbers of ripe individuals taken in or near Xiang Shan Bay at any time. Ripe individuals provided only 0.05–0.15% of all *P. orientalis* taken in the commercial catches.

The lack of any *P. orientalis* in Xiang Shan Bay prior to the initiation of restocking in 1982, the decline to nearly zero landings in 1994 after restocking was suspended in 1990, together with results of the tagging experiments, show conclusively that the landings were obtained solely from the stocking operation. Stocking studies reported outside of China are mostly hampered by the need to estimate the amount of shrimp landed that originated from the natural and the restocked shrimp. Such separation of shrimp taken in commercial catches is technically demanding and often leads to difficulties not encountered in the Xiang Shan Bay project as noted by Kurata (1981) working on *Penaeus japonicus* in the Inland Seto Sea of Japan.

The success of *P. orientalis* restocking in Xiang Shan Bay over more than a decade is shown in Table 2: when numbers of released shrimp exceeded 100,000,000/yr, landings were over about 100 t/yr. Figure 3 shows the least squares regression of total *P. orientalis* catch in Xiang Shan Bay on the numbers of restocked juveniles of the same cohort: the regression is highly significant ($r = 0.9637$ at 9 df; $t = 11.4159$, $P < 0.00001$ for the slope; $t = 0.1791$, $P = 0.8614$ for the intercept, which was not significantly different from zero; F ratio for the model was 130.3/6.71, $P < 0.00001$; $R^2 = 92.87\%$). The residuals showed no pattern; the largest deviations from the predicted values occurred in 1986 and in 1988. In 1986, unusually low landings occurred (135 t observed and about 245 t predicted from the model), and were probably caused by technical difficulties associated with training staff during the first massive releases of small juvenile *P. orientalis*. In 1988, landings were about 65 t higher than predicted by the model: survival was the highest on record in that year (Table 3), probably because of unusually favorable environmental conditions and/or an earlier than usual opening of the Xiang Shan Bay fishery in that year.

The relation between catch and numbers of 3.0–4.0 cm TL juveniles released (Fig. 3) was:

$$\text{Catch} = 3.0696 + 0.000001679 \times N \quad (1)$$

where Catch = total catch in t/yr of *P. orientalis* from July to the following April, and N = the number of 3.0–4.0 cm TL juveniles released in May–June. The linear relation between Catch and N shows that catches do not decline with increasing numbers of shrimp into Xiang Shan Bay, i.e. diminishing returns did not occur over the observed range of numbers released. Equation (1) also estimates that around 596,000 juveniles must be released to provide about 1.0 t of *P. orientalis*. This compares with about 200,000 fry needed to produce 1.0 t of *P. japonicus* in the Inland Seto Sea restocking of *P. japonicus* (estimated from data in Kurata (1981)). The lower number of fry required to produce 1.0 t of *P. japonicus* is probably due to use of large, specially designed nursery grounds that were used to allow the shrimp to become accustomed to life in the sea and to protect them from high initial predation in Japan. This step was not taken in China.

The cost:benefit (C:B) ratio increases in a roughly linear fashion with the numbers of juvenile *P. orientalis* released (Fig. 4); although the data are sparse, they suggest clearly that large catches and high profits could be obtained from a larger operation. At some level >225,000,000 juvenile *P. orientalis*, diseconomies from scale will occur (i.e. the C:B ratio will cease to increase, and may even decrease, with number of juveniles released; Fig. 4). At some unknown level of releases, the catch will cease to rise proportionately to the numbers of shrimp released (Fig. 3). However, available data do not allow any estimate of the levels at which these limitations on stocking will occur. Perhaps stocking would become uneconomic in the range from 2–3 times to 10 times the present levels, giving a possible range for stocked landings in the region of 800–4,000 t/yr. A strategy of slowly increasing stocking numbers would allow identification of a level of releases that can produce high landings combined with a profitable C:B ratio.

Enhancement of Jellyfish Landings in Zhoushan

Jellyfish were abundant in the 1960's and 1970's but landings in Zhoushan fell drastically from a mean of 8,800 t/yr in the 1960's to a mean of 800 t/yr in the 1980's and to <200 t/yr in 1991–92. This decline was thought to be caused by a combination of overfishing and pollution.

Because of the long-term trend toward lower landings, ZMFRI established a jellyfish restocking project in

Table 4.—Cost:Benefit (C:B) ratios.

Year	Releases (×10,000)	Landings (t)	C:B (Yn/Yn)
1986	13,872.2	135.0	1:3.0
1987	22,483.0	398.0	1:7.8
1988	15,644.3	329.0	1:5.7
1989	16,218.0	280.0	1:5.7
1989	14,874.2	265.0	1:5.9
Mean			1:5.2

1983. Several years of fundamental research provided the basic biological knowledge needed. Growth from the fertilized egg to about 1.0 cm disc size takes about 1.0 month (Fig. 5), with a survival of about 90%, and 1.0 cm jellyfish are restocked in February or March. By May they reach 10–20 cm and by August about 50 cm. Fishermen reported significantly greater landings in 1990–92 following experimental releases of up to 100,000,000 1.0 cm jellyfish at the beginning of each year. Preliminary cost-benefit analysis shows that C:B ratios for jellyfish restocking range from 1:2 to 1:4, depending on numbers released, mortality rates, and the size at harvest.

Mariculture for Seed and Grow-out

Penaeus orientalis

Restocking was phased out at the Xixuan Island mariculture facility, starting in 1990 and was suspended in 1993. Culture tanks were then used to hold a limited number of shrimp and grow them from the 3–4 cm TL size at which they were previously released into Xiang Shan Bay in May–June, to about 12 cm TL which is reached around October or November; they are then harvested and sold commercially. In November of 1993 > 40 t of *P. orientalis* were harvested and sold for about Yuan 1,600,000.[5] Profits (>Yuan 1,000,000) were used to finance mariculture and assessment research.

Haliotis diversicolor, H. discus

Abalone are very much appreciated in all parts of China and a combination of expanding demand, increasing prices, and falling catches from abalone capture fisheries has led to interest in abalone mariculture. *H. diversicolor* and *H. discus* are being produced at pilot culture levels at the Xixuan Island mariculture facility. Spawning occurs in May, and growth to about 2.0 cm TL takes about 1.0 yr (Fig. 6). In 1993, about 10,000 abalone of 2.0 cm TL, surplus to research requirements, were sold to fishermen/small-holders at 1.0 Yuan/individual, and smaller numbers have been sold over the last few years. The small abalone are held in grow out tanks for up to two years by small-holders and will reach the commercial size of about 5.0 cm TL in about 2 years (i.e. at a total age of about 3.0 yr) when they are worth about Yuan 10–15 each; survival rates are usually about 80%. An average profit of about Yuan 70,000, on a sale of 10,000 individuals, may be made in 2 years: $(10{,}000 \times 10 \times 0.8) - 10{,}000 =$ Yuan 70,000. This provides a satisfactory margin for small-scale grow out by farmers. The commercial-scale viability of the *Haliotis* spp. cultures will be determined when large-scale sales of seed are carried out during the next 3–5 years.

Gulf Scallop, *A. irradians*

A. irradians reaches 6–7 cm TL in nature but landings from wild stocks are now very low. The preferred commercial size is about 5.0 cm TL. *A. irradians* spawns in March–April at temperatures

[5] 40 Yuan/kg, i.e. ca US$4.65/kg; US$1.00 = Chinese Yuan 8.62 in 1995.

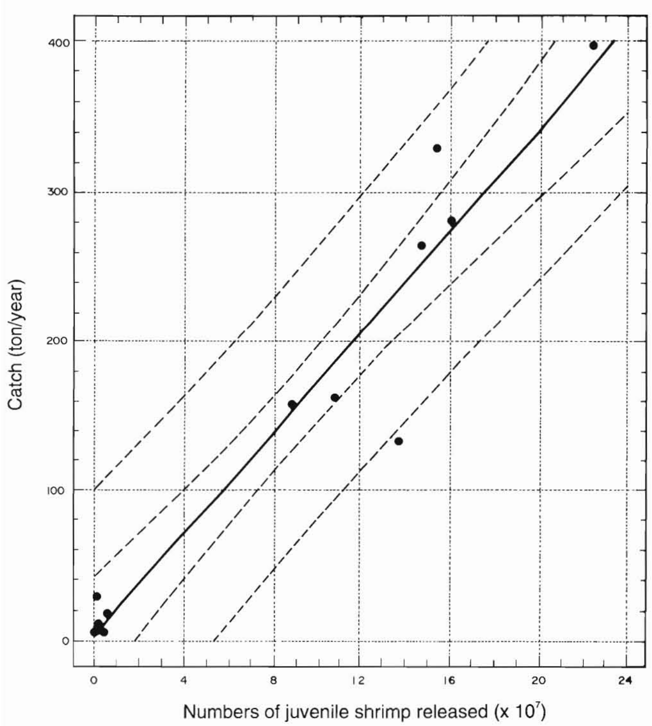


Figure 3. — Relation between numbers of juvenile (3–4 cm TL) *P. orientalis* stocked in Xiang Shan Bay in April/May, and the landings of stocked *P. orientalis* from June until the following March/April. Number = number $\times 10^7$ of juvenile *P. orientalis*; Catch = *P. orientalis* landings from Xiang Shan Bay, t/yr.

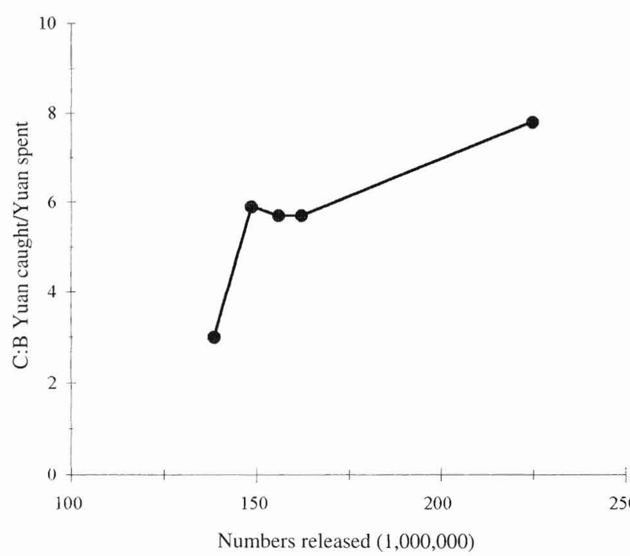


Figure 4. — Cost:Benefit (C:B) ratio for *P. orientalis* restocking in Xiang Shan Bay, 1986–89.

of about 20-25°C and reaches commercial size by about November, when they are worth about Yuan 6.0-1 O.O/kg. Spat settle a few hours after spawning and reach about 0.1 cm TL in less than a month, i.e. around April-May, when they are sold to fishermen for Yuan 0.02/ individual. Around 20,000,000 small *A. irradians* were sold in April-May 1993 for a total of Yuan 400,000. Survival during grow-out to market size by small-holders varies from 10 to 20%. The small-holders who grow the A. *irradians* are mostly low-income farmers and fishermen who operate very small, part-time enterprises, so that a substantial (cash) addition to family income for many families is made by a small grow-out operation.

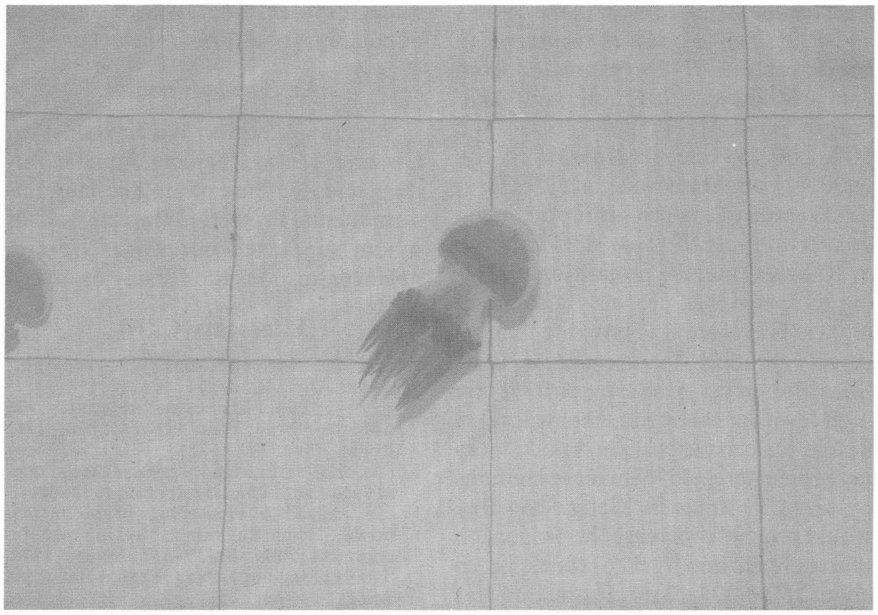


Figure 5. - Edible jellyfish, *Rhopilema esculema,* about 1.0 cm disc diameter and ready for restocking, produced at the Xixuan Island Mariculture Station, Zhejiang Marine Fisheries Institute.

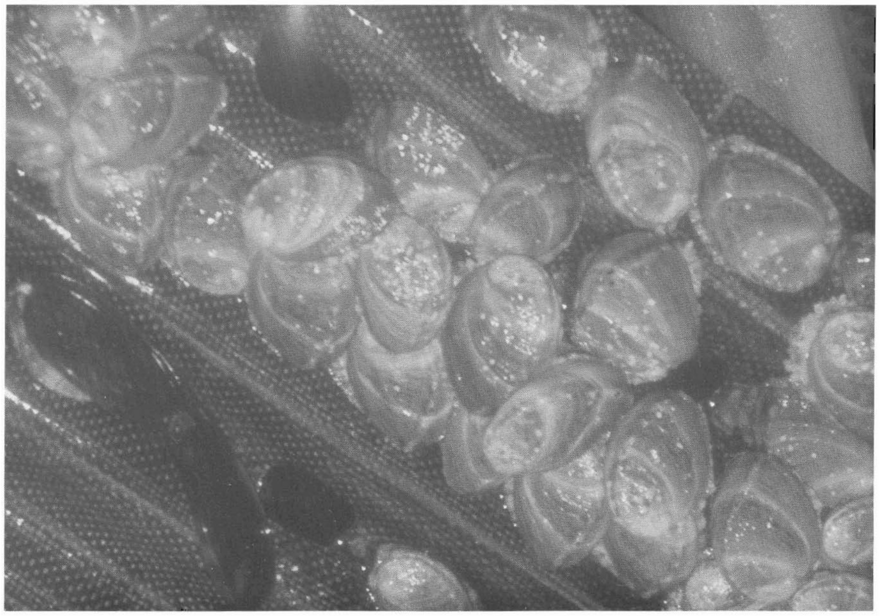


Figure 6. - Cultured abalone about 2.0 cm TL (1.0 year old), produced at the Xixuan Island Mariculture Station, Zhejiang Marine Fisheries Institute.

Experimental Cultures

In addition to the larger scale activities described above, experimental cultures have been started on two species of fish: *M. macrocepahalus* and *Epinephelus awaara.* The former porgy grows to a maximum of around 3--4 kg total weight (TW) and the latter to around 10 kg TW, although cultured fish would be harvested at a smaller size. Work is currently aimed at achieving:

1) routine spawning on as large a scale as desired in a controlled environment,
2) grow-out to desired sizes in controlled conditions, and
3) determining in detail the technology required for successful, large scale restocking and growth to market size.

Technology obtained through systematic research in this way will be used by the end of the next decade or so as the basis for commercial production of these species.

Discussion

Constraints on *P. orientalis* Stocking

The mean C:B ratio from *P orientalis* restocking in Xiang Shan Bay was 1:5.2, i.e. Yuan 5.2 earned for each Yuan 1.0 spent (Fig. 3). This compares favorably with the C:B ratio for *P japonicus* restocking in the Inland Seto Sea of Japan, which was only 1.0: 1.79 (i.e. Yen 1.0 spent on restocking per Yen l.79 earned from the commercial fishery (Kurata, 1981)). The cost of restocking in China was probably reduced by cheap labor, and perhaps also because there was no need to construct the special nursery grounds used in Japan for releasing *P japonicus* into the sea. Chinese and Japanese data cited here include all costs of production and so are comparable.

The new economic policy in the PRC, based on the market economy, led to withdrawal of financial support from the Xiang Shan Bay stocking project in 1993. This occurred in spite of the technical and economic successes, largely because there was no practical way for government funding agencies to recover the costs of stocking from the income generated by the fishermen who harvested the shrimp. Many of the fishermen operating in Xiang Shan Bay are, however, organized into cooperatives, each of which has access to certain fishing areas. It is conceivable that a new stocking project might eventually be financed through cooperatives which, in collaboration with the Provincial Government and by means of co-management structures, could control access to trawling and gill netting in Xiang Shan Bay. Funding for *P. orientalis* stocking could eventually be provided by the people benefiting from the landings. It is likely that financing the re-stocking of other species, such as jellyfish, could be tackled in this way. This approach cannot be undertaken successfully without a complete biological and socioeconomic survey; nevertheless, it is already clear that the constraints on successful *P. orientalis* stocking are likely to be mainly financial, rather than technical or economic.

Establishment of a *P. orientalis* Breeding Population

A second reason for withdrawing financial support from the *P. orientalis* Xiang Shan Bay stocking project was its failure to establish a self-perpetuating, reproductive stock of shrimp. The highest captures of mature *P. orientalis* from Xiang Shan Bay occurred from the May–June 1987 restocking: 240,000 were taken in March–April of 1988, giving a survival rate of 0.1% (Table 3). These 240,000 individuals were spread over an area of around 150 km,^{2} near the mouth of Xiang Shan Bay; i.e. at an average density of about 1,600 shrimp/km^2 (625 m^2/shrimp) or (assuming a mean weight of about 20 g/shrimp) about 32 kg/km.^{2} These levels are low compared with the levels at which mature shrimp occur in well known shrimp fisheries, e.g. about 200–500 kg/km^2 for *P. semisulcatus* in Kuwait in the 1960's and *P. stylirostris* and *P. vannamei* in Mexico in the 1970's (estimated from data in Mathews, 1981), around 100 kg/km^2 in Saudi Arabia in the 1980's and 100–200 kg/km^2 in Kuwait in the 1990's (from Mathews et al., 1993).

Densities of mature shrimp are much greater in most of these stocks (by up to 10 times) and the proportion surviving to spawn was probably also much higher. Therefore it is possible that the density of adult *P. orientalis* in Xiang Shan Bay never reached a sufficiently high level for mating and spawning on a large scale to be feasible. A new stocking project targeted to increase landings by up to 10 times in Xiang Shan Bay would probably increase the proportion of mature shrimp by 5–10 times, i.e. to about 250–500 kg/km^2. If stocking was accompanied by protection of those fishing grounds characterized by especially high numbers of adults from excessive effort, it is possible that the density might become high enough for massive spawning to occur naturally. A self-maintaining population might eventually be established.

The cost of fisheries enhancement is significant, and the analysis suggests that it would be prudent to carry out ecological research prior to any continuation of *P. orientalis* enhancement in Xiang Shan Bay. This could include 1) comparative studies of environmental conditions in Xiang Shan Bay and in areas where *P. orientalis* is well established and 2) research on the relation between recruitment of young shrimp and the density of spawners that produce them in areas where endemic populations of *P. orientalis* occur.

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