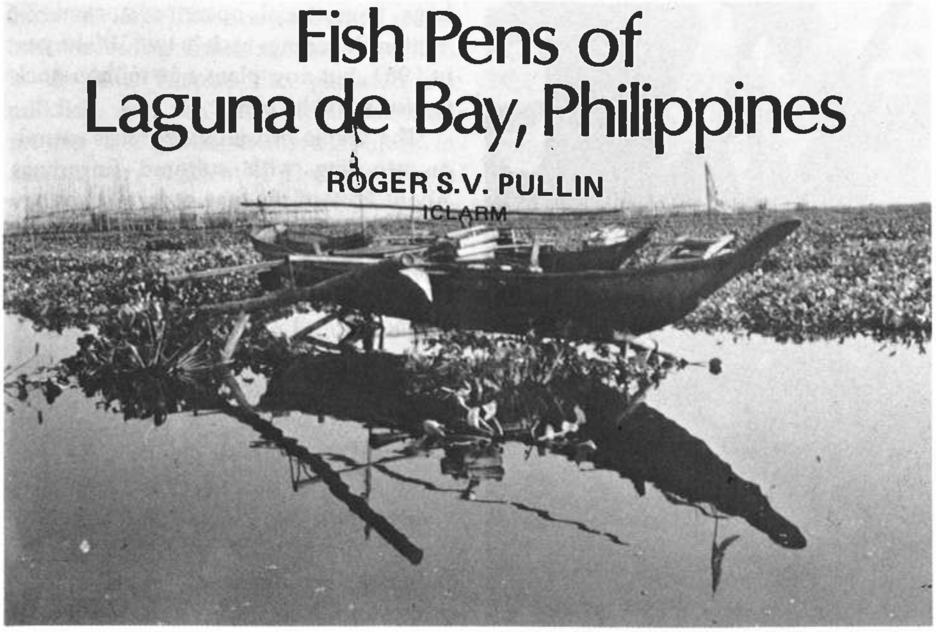
Fish Pens of Laguna de Bay, Philippines

ROGER S.V. PULLIN
ICLARM



Laguna de Bay, the largest lake in the Philippines, has a catchment of about 290,000 ha, a surface area of about 90,000 ha, an average depth of 2.8 m and temperatures of 22-34°C, with little or no thermal stratification. Its waters are frequently turbid due to wind-stirred bottom sediments, detritus, inflowing silt-laden streams and dense plankton. It is slightly brackish (< 5‰) during the dry season, when its level falls and waters from the Pasig river and Manila Bay containing high levels of nutrient wastes enter during high-tide periods (see map).

Rapid expansion

A public corporation, the Laguna Lake Development Authority (LLDA), was created in 1966 for management of the lake's resources, drainage and flood control. In 1970, with capture fisheries declining, probably from overexploitation, the LLDA constructed a 38-ha pen in the lake and stocked it with 150,000 milkfish *(Chanos chanos)* fingerlings. They were nursed on a supplemental diet of rice bran, copra meal and soya bean meal and then released to the pen to graze on natural plankton. After a total culture period of 5 months, the yield was 700 kg/ha, at an average weight of 350 g. The projected annual yield from this trial was 1,500 kg/ha—about 3.5 times the prevailing lake fish catch.

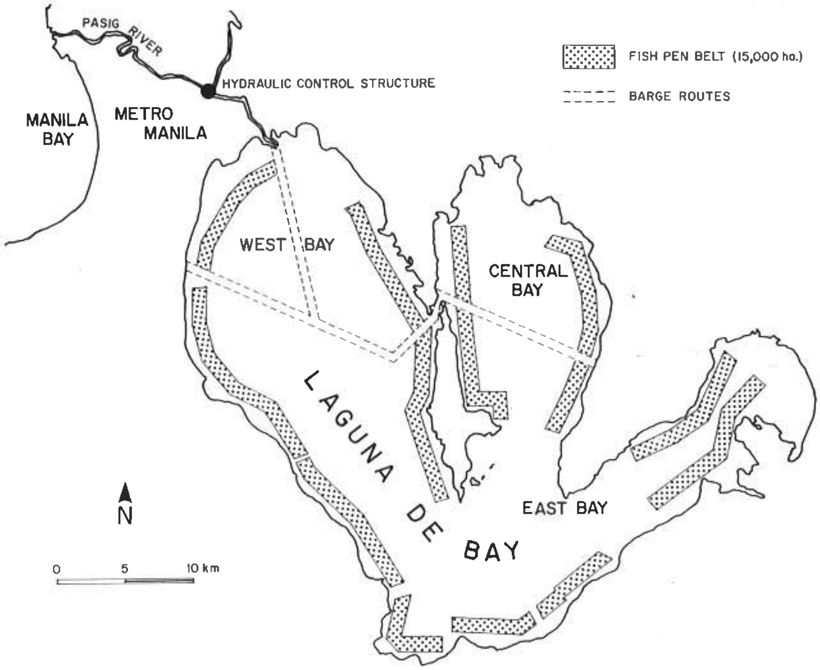
By 1973, private entrepreneurs had constructed about 4,800 ha of pens and by 1974, about 7,000 ha, which is also the current figure. It was temporarily reduced to 2,600 ha in 1977 following fishkills in 1975 and typhoons in 1976. The most striking recent trends have been increasing milkfish pen size (up to 400 ha) and direct release of fingerlings.

The pens are made up of two rows of 5-m deep polyethylene netting, 100- and 500-mesh. Netting exposed to sunlight lasts only about 2 years, submerged netting up to 5 years. Supports are bamboo, although anahaw *(Livistonia rotundifolia)* is becoming popular.

Tilapia *(Sarotherodon niloticus)* were also introduced and have been cultured since the early 1960s. Culture has expanded tremendously only in the last few years. Tilapia are grown in smaller pens or cages, relying on natural feed. The LLDA have no current estimate of the culture area but it is probably at least 1,000 ha.

Yields

Reliable data on milkfish yields are scarce. Current reported yields range from 4 to 7 t/ha with up to 80% survival from fingerlings to harvested fish. At harvest, a seine net is drawn into and over a staked lift net from which the fish are transferred by dip nets into water-filled boats with



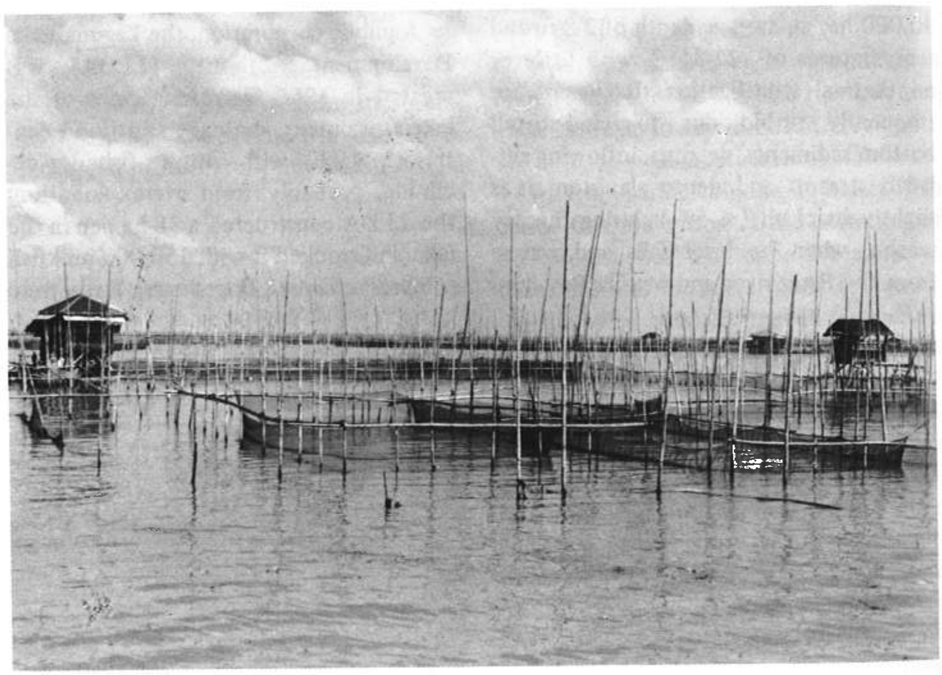
Map of Laguna de Bay showing fish pen belt, barge routes and location of hydraulic control structure to use the lake for water supply. ***Right***: The working life and typhoon resistance of large pens are being increased by the use of anahaw pen poles instead of bamboo.

recirculation pumps (petuyas) containing ice blocks. They are then transported down the Pasig River to Navotas fish market, a journey of about three hours.

Reports have reached LLDA of enormous yields from tilapia pen culture. From a 4-ha pen near Matibac, a private operator has claimed a total harvest of 200 t of tilapia after stocking with 2.5 million 2-month old fingerlings and about 4 months growout, with no supplemental feeding! With 80% survival and harvesting

at 100 g, this represents a density of about 17 fish (1.7 kg) per m^3. For comparison, repeatable yields of one ton are claimed after 4 to 5 months growout from 2-month old fingerlings stocked at 2,500 to 3,600 in an 8 x 9 x 3-m deep cage with *ad hoc* supplemental feeding (mainly rice bran) and 80% survival. These reports require confirmation.

Petuya, *left*, bangos are dip-netted directly into the petuya, *top*, and tilapia pens, *below*.



Production cycle

The milkfish industry depends for seed on collection of wild fry from coasts throughout the Philippine archipelago. They are grown to fingerlings in brackish-water nursery ponds mainly in Malabon and Bulacan (north of Manila) and are transported to the lake through Manila Bay and up the Pasig River in petuyas, a journey of 50-100 km. Mortality associated with transportation and stocking can be as high as 25 to 50% possibly due to lack of acclimatization to large salinity changes. Recent reports suggest that acclimatization and nursing of fry in fresh water and transportation by road in oxygenated bags can reduce stocking mortality to as little as 3%.

Stocking and harvesting operations go on all-year round. A typical culture cycle is: stocking in July, harvesting 20-30% of the fish at 170-200 g in October and the remainder during November with immediate restocking. Stocking densities vary. One large commercial operator stocked 3-5 million fingerlings each in two 100-ha pens in 1981, but now plans a 16 million stocking for a 200-ha pen.

The tilapia pen industry relies entirely on stocking with cultured fingerlings. About 25% of the cage operators are now self-sufficient, using breeding cages and small lakeside ponds, but the remainder buy from commercial and government hatcheries.

Natural food

Milkfish production results primarily from filter feeding on phytoplankton, although zooplankton, benthos, and filamentous algae are also consumed. Obviously, plankton density and water exchange through the pens are the key factors. The dominant phytoplankton groups in the lake vary seasonally. During the summer, blue-green algae are usually dominant, but shifts between blue-green and green algae, diatoms and zooplankton abundance can occur throughout the year. This unpredictable and uncontrollable situation can pose problems. As in fertilized pond fish culture, the required water conditions can be described as 'green, but not too green.' The lake can develop dense algal blooms, particularly of the blue-green alga *Microcystis* which may cause localized oxygen depletion with risk of fishkills.

The other main feeding niche is detrital, derived from dead plankton and other decomposing organic materials. This produces the large historical catches of snails, bottom-feeding fishes and other benthos in the lake. Tilapias filter plankton like milkfish, but can also utilize bacterial protein and other nitrogen sources in detritus very efficiently. The large tilapia yields claimed from pens probably derive from both plankton and detritus and may not be sustainable, especially if pens are crowded together.

The use of fish pens in Laguna de Bay, especially the very large milkfish units, can be viewed as a form of ranching, in which fingerlings are released into a natural, productive lake partitioned for easy harvesting.

The industry is not without problems: typhoon damage, especially from wind-blown concentrations of water hyacinth, kills of milkfish due to oxygen depletion, theft and conflicts between fishermen and pen operators. Over the last few years, the LLDA has assumed full statutory control of the industry and had designated an offshore fish pen belt of about 15,000 ha.

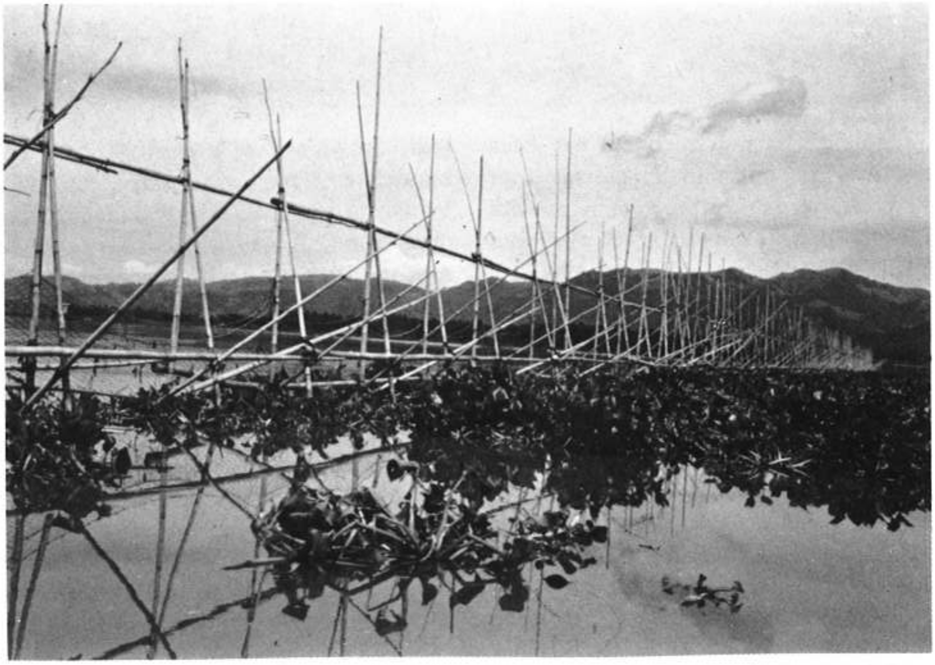
The future

There is a controversy over factors limiting productivity. The lake's present annual primary productivity, (C^{14}) 780 g C/m^3, is lower than that of some other tropical lakes (Lake George, Uganda; ca. 1,000 g C/m^3) and fertilized fish ponds (1,460-2920 g C/m^3). However, one view is: Laguna is hypereutrophic and requires pollution control. A hydraulic control structure (gated dam and lock) is being built on the Pasig River to use the lake for water supply. This will stop future saline intrusions. The opposing view is that the lake could turn over much higher nutrient loads if it were less turbid–the saltwater river intrusions are said to have a beneficial clearing effect on the lake waters. This, it is argued, creates conditions favoring a balanced production of phytoplankton and zooplankton and discourages dangerously dense blooms of the blue-green alga *Microcystis*, which can kill fish by depleting the water of oxygen. The issue is complicated by observations of blooms of an *Anabaena* species which fixes atmospheric nitrogen.

With so many variables, it is all but impossible to formulate an optimum nutrient budget for the fish pen industry. It has been shown, however, that under turbid conditions, dissolved nutrients in the water column are not being converted in biomass as rapidly as they should be in a tropical lake. It will be interesting to see whether pollution control and the dam-gate complex have a smoothing or enhancing effect on plankton bloom and collapse cycles in the long-term.

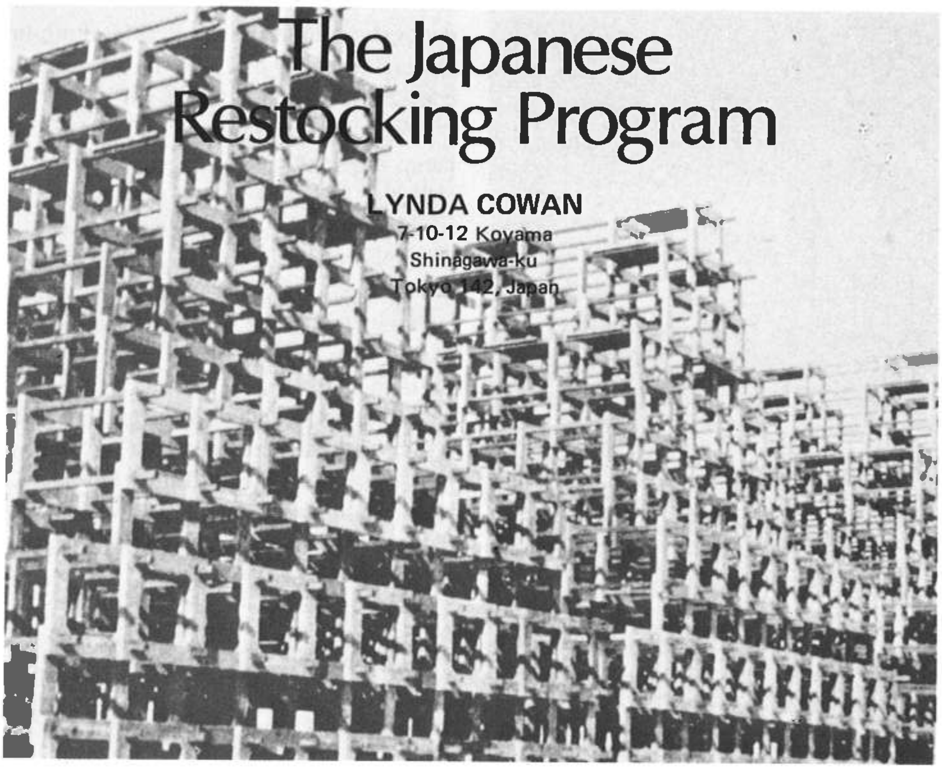
Whatever the long-term effects of the dam, the lake will continue to receive large nutrient waste loadings from human settlements and agricultural run-off. Mean orthophosphate levels of 0.01 to 0.1 ppm and projected rise in annual nitrogen loading to 11,200 t by the year 2000 (5,000 tons in 1975) give an idea of the nutrient inflow.

Perhaps the most interesting question is the future balance between tilapia and milkfish production. As things look, feeding versatility, resistance to low dissolved oxygen and increasing market acceptance favor the tilapia. ○



Photos by Roger Pullin.

Bangos pens, *upper*, water hyacinth barrier, *lower*.



The Japanese Restocking Program

LYNDA COWAN
7-10-12 Koyama
Shinagawa-ku
Tokyo 142, Japan

In scale of operations, variety of species produced, amount of financial backing, and degree of popular and official support, the Japanese fisheries restocking program (saibai gyogyo) is unique. From its birth in 1962 when the government established two hatcheries on the Seto Inland Sea, it has undergone continuous expansion. By 1982, some 37 coastal prefectures are scheduled to have sea farming centers operating. Seven national centers have been opened and five more are under construction. There are also 11 other semi-government or private hatcheries.

Although salmon ranching has been practiced in northern Japan for over 80 years, the present program began with kuruma prawn restocking in the Seto Inland Sea, where overfishing, extensive foreshore reclamation and pollution had led to severe declines in catches of several luxury species. The first project aimed at stocking 100 million prawns in the five years to 1970. Just eight years later, Japanese hatcheries were producing 12 million fish seedings (15 species excluding salmon), 470 million crustaceans (five species), 13 million molluscs (ten species) and 800,000 echinoderms (two species), annually, mostly for restocking purposes.

The establishment of a network of hatcheries for fishery restocking is complemented by a ¥200 billion program for development of the coastal environment, including construction of artificial tidelands and reefs, breakwaters and fishladders, cleaning of the sea floor, removal of predators and propagation of seaweed beds. Each hatchery complex has cost between ¥300 and 1,600 billion to construct. In 1981, the budget allocation for saibai gyogyo is ¥4.6 billion.

Despite considerable differences in capacity and sophistication of rearing facilities in the various centers, hatchery procedures for most species are standardized. Spawning of broodstock may be natural, e.g., prawns (shrimp), crab and bream, or artificial, e.g., abalone and salmon. Larval feeding regimes for carnivorous species begin with rotifers (preceded by diatoms for kuruma prawn), supplemented later with *Artemia* nauplii, and followed by minced flesh of trash fish, clam and krill, or artificial feed at the early juvenile stages. Water quality is maintained by filtration, aeration and/or mechanical stirring, water exchange, and the action of microorganisms grown in the rearing water, such as marine bacteria and the alga *Chlorella*. Typical survival rates from hatching to harvest of juveniles are 15-30% for prawns, 5-15% for bream, and 10-50% for crabs. After harvest, seedlings are either transferred to an intermediate rearing facility or are stocked directly into the sea.

Kuruma prawn *(Penaeus japonicus)* restocking

In early restocking trials, prawn fry were released directly into the sea or into shallow pools on the beaches at low tide. Twenty-four hour mortality was found to be almost 50%, with most losses attributable to predation by gobies and flatfish. Intermediate rearing methods were introduced to protect the vulnerable hatchery-bred seedlings from immediate post-release predation while they adopted behavior appropriate to the natural environment, e.g., nocturnalism, food search and capture and burrowing.

In intermediate rearing, the prawn fry are usually stocked at a size of 13-15 mm into net enclosures or artificial ponds in the beach zone, and are released after about two weeks when 30 mm long. Enclosures are first treated with fish poisons to remove predators. Stocking densities are 400-2,000 per square meter. Survival after two weeks ranges from 30% to 80%. Artificial feed is provided daily. Stocking density on the artificial tideland is much lower, about 100 per square meter. Feed is not provided and the fry gradually move out to deeper water as they grow.

Estimation of the contribution of restocking to commercial catches is still fraught with difficulties. Because only larger (5 cm and over) prawns can be tagged, mark-recapture studies give only an approximate recovery rate, in addition to information about dispersal. Hatchery recruits in inshore gill net catches can often be distinguished from wild recruits by size-frequency distribution analyses. For offshore trawl fisheries which catch recruits from many different nursery

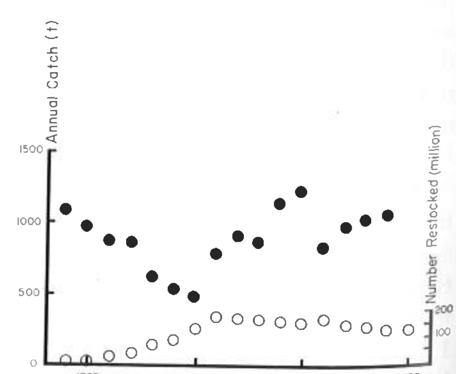


Fig. 1. Apparent correlation between prawn catch and seedlings stocked in the Seto Inland Sea.

grounds, the only method is to examine catch statistics before and after liberation.

Tag-recapture investigations have produced recovery rates of 1-6% for prawns of 5-8 cm size, and 35-41% for large prawns (16 cm and over). Combined data from gill netters and trawlers indicate recovery rates of 0.7% to 5.7%.

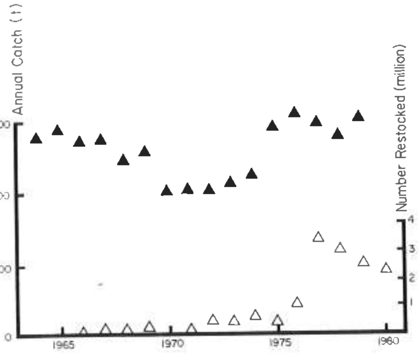


Fig. 2. Increases in catch of red sea bream, attributed largely to restocking.

In Niigata Prefecture, since the start of a restocking program in which the number of seedlings released increased from 90,000 in 1977 to 1.1 million in 1980, the annual catch has steadily risen from 21,000 to 50,000 t, and catch/boat per day is 3.8 times higher. However, as previous catches have fluctuated in the range of 14,000 to 56,000 t, this trend will have to be manifested for several more years before it can be regarded confidently.

Fifteen years of restocking prawns in the Seto Inland Sea has produced the apparent correlation shown in Figure 1.

Red sea bream *(Pagrus major)* restocking

The restocking program for *P. major* is comparatively small-scale: 1978 seedling production for restocking was 4.3 million, about 1% of prawn seed production. This difference is partly due to the protracted period of intermediate rearing needed for bream. After hatchery rearing to 10-15 mm size, the fish fry are maintained for 3-4 weeks in floating net cages in the sea until they reach 2-3 cm, the minimum restocking size. Some are reared for further 3-6 months and are tagged at a size of 8-10 cm before release. Pelleted food is given throughout the intermediate rearing period. Survival of up to 63% has been reported. Intermediate rearing of fry has also been done in converted salt fields and in a fenced-off bay. In the latter case, acoustic conditioning was used to lure the fish out of the bay to over-winter in deeper water.

A 4-year mark-recapture investigation by five Inland Sea prefectures recovered 8% of 206,000 released fish or their tags. Other recoveries based on size-frequency data ranged from 20% for second-year fish, to 16% for third- and 5% for fourth-year fish.

The sea bream population in the Inland Sea has been estimated at 1.6 to 2.3 million fish. From 1970 to 1974, annual catches were at their lowest level ever, about 2,000 tons. In 1975, restocking was intensified and annual catches soon exceeded the pre-1970 levels, as shown in Figure 2. This rapid rise was not observed in other areas of Japan and is attributed largely to the restocking program. However, even with the use of the most optimistic recovery rates, the maximum contribution of hatchery output to annual catches is only 1.4% in terms of tonnage.

The restocking program shows every sign of becoming a permanent integral part of Japanese fisheries.

To produce an increase distinguished from natural fluctuations, 5 to 10 million seedlings would have to be restocked annually in the Inland Sea alone.

Blue crab *(Portunus trituberculatus)* restocking

Intermediate rearing of blue crab seedlings is complicated by the aggressive

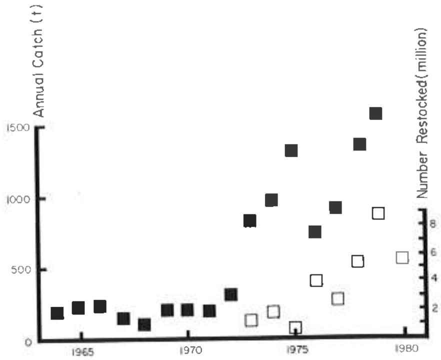
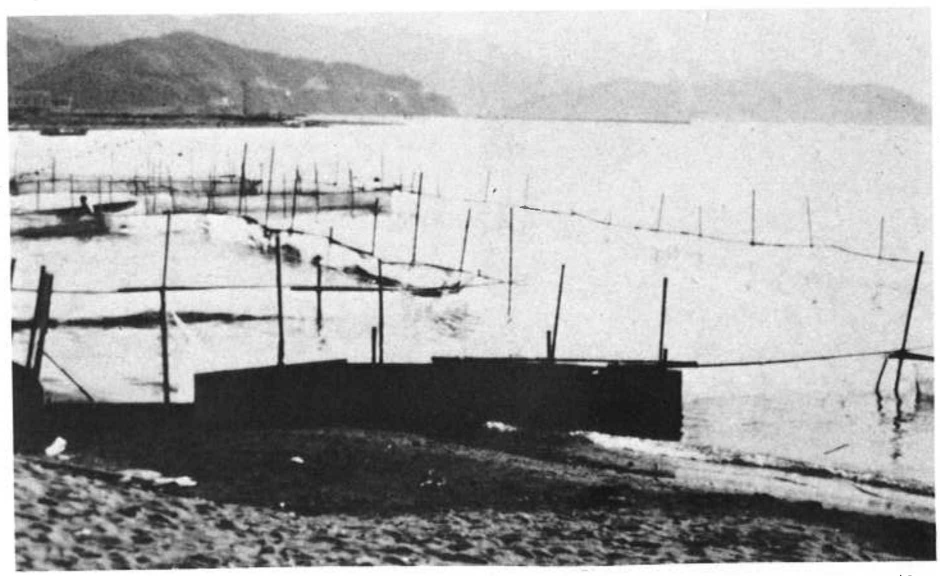


Fig. 3. Blue crab catch shows a relationship with seven years of restocking the Inland Sea.

nature of this species. Even at moderate densities and high food levels in hatchery rearing, cannibalism can eliminate 50% of juvenile crabs during molt periods. To reduce mortality during transportation and intermediate rearing of the seedlings, lengths of 'kinran'—nylon rope interwoven with thousands of shorter strands—are provided as refuge.

Intermediate rearing facilities include artificial tidelands, ponds and canvas tanks on land, intertidal net-fence enclosures and net baskets, and rafts with suspended kinran ropes. The early, juvenile-stage crabs are usually held for 2 weeks before release. Survival in the ponds, tanks, net



Simple net enclosure for intermediate rearing.

baskets and enclosures ranges from about 30% to 56% while survival and movement of crabs in the open raft and tideland systems are still not clear.

A 2-year tagging study on large (9-17 cm) crabs produced recapture rates of up to 22%. But such studies are hampered by the lack of a suitable tag that will last through more than one molt. Reasonably distinctive size-frequency patterns for restocked crabs in the western end of the Seto Inland Sea permitted researchers there to calculate 1979 recovery rates, which were 4-13%, and to infer restocked proportions of the annual çatch in the region, at 49% to 87%. Figure 3 shows an apparent relationship to annual catch during the seven years in which crab restocking has been carried out in the Inland Sea.

Value of the restocking program

Considering the billions of yen that have been committed to this scheme, the as-yet inconclusive nature of the returns for the first 10 to 15 years of restocking may seem surprising. However, the general consensus within the organization is that it is still early in the era of the saibai gyogyo; in the meantime, all efforts are directed at overcoming immediate problems. These efforts include the development of techniques of mass production for new species such as spanish mackerel, squid, tuna and king crab; improvement of intermediate rearing methods; the search for effective tags for the juvenile stages, and cooperative multi-prefecture follow-up surveys of migratory species.

Using available recovery rates, some tentative cost-benefit studies have been attempted. The net profit per individual prawn restocked at Aijo, Shikoku, is estimated at ¥5 for gill netters and ¥20 for offshore trawlers. Profit per-fish for bream in Oita Prefecture is ¥214. For crabs in the western Seto Inland Sea, a model has been developed relating rearing costs, market price, recovery rates and break-even points, which shows that a recovery rate of only 1.2% would be sufficient to break even.

Although recent catch increases may have been partially due to other factors such as environmental improvement, the Japanese fishing industry in general is convinced of the potential benefits of restocking. Not surprisingly in a nation dependent on the sea for 50% of its protein, the impressive new hatcheries have come to acquire considerable political value. Thus, the saibai gyogyo program shows every sign of becoming a permanent integral part of Japanese fisheries. ○

Photos by Lynda Cowan.

From top: Direct stocking at Okayama. 'Kinran' and polytank for transporting seedlings. Production of *Artemia* nauplii for food during larval rearing at Fukui. Modern prefectural hatchery at Aichi. Indoor abalone rearing tanks. *Above photo* shows the intermediate rearing pen with framed nets at Fukui. All signs point to the Japanese restocking program becoming an integral part of the country's fisheries.