stock enhancement in Japan and Taiwan

Stock enhancement has been recognized as one of the essential strategies that can sustain and increase the resources of coastal fisheries. It has been practiced for over a century, with more than 100 species released to date in worldwide programs. Among the countries in Asia, Japan and Taiwan have already established the practice of stock enhancement.

TABLE 1 The main species, number of seedstock produced and released in 1996 in Japan (Imamura 1999)

Common name	Scientific name	No. produced (x 1000)	No. released (x 1000)
Pacific herring	*Clupea pallasi*	2382	[2000+]
Black sea bream	*Acanthopagrus schlegeli*	10566	6952
Red sea bream	*Pagrus major*	30 008	22395
Sandfish	*Arctoscopus japonicus*	7574	6146
Jacopever	*Sebastes schlegeli*	1968	1481
Japanese flounder	*Paralichthys olivaceus*	30831	22626
Mud crab	*Limanda yokohamae*	4594	2793
Ocellate puffer	*Takifugu rubripes*	2409	1721
Striped jack	*Pseudocaranx dentex*	786	402
Yellow tail	*Seriola quinqueradiata*	399	197
Sea bass	*Lateolabrax japonicus*	1642	749
Kuruma prawn	*Penaeus japonicus*	457807	275192
Chinese prawn	*Penaeus chinensis*	2920	2899
Speckled shrimp	*Metapenaeus monocerus*	44435	26627
Mangrove crab	*Scylla serrata*	1142	563
Swimming crab	*Portunus trituberculatus*	61369	34919
Blue crab	*Portunus pelagicus*	3378	983
Japanese abalone	*Sulculus diversicolor*	2599	2240
Disk abalone	*Nordotis discus*	16839	5384
Yezo abalone	*Nordotis discus hannai*	18908	16377
Giant abalone	*Nordotis gigantea*	5031	3214
Spiny top shell	*Batillus cornutus*	3136	2613
Ark shell	*Scapharca broughtonii*	4339	2033
Scallop	*Patinopecten yessoensis*	2792391	2989328
Hard clam	*Meretrix lusoria*	3235	17655*
Hard clam	*Meretrix lamarckii*	2120	2246
Surf clam	*Spisula sachalinensis*	7179	6105
Sea urchin	*Tripneustes gratilla*	190	69
Red sea urchin	*Pseudocentrotus depressus*	4323	3631
Sea urchin	*Strongylocentrotus intermedius*	61851	60647
Sea urchin	*Strongylocentrotus nudus*	8994	12299*
Sea cucumber	*Stichopus japonicus*	6568	5249

*including natural seedlings

Japan

The Japanese Government has been supporting stock enhancement efforts since 1963 to improve coastal resources and ensure income of fishers. Shrimp, fish, and other juveniles have been raised in large quantities under human control, and when these acquire sufficient capability to survive, they are released into the ocean where they can grow and mature. Under this program, the Seto Inland Sea served as a model area for seafarming.

In 1979, the government created an entity, the Japan Sea-Farming Association (JASFA), to operate seafarming centers spread all over Japan and supervise stock enhancement programs in the country.

JASFA started by producing seedlings of those species already reared successfully by private aquaculture traders, such as kuruma prawn. The species for sea farming were then gradually extended to include swimming crab, red sea bream, tiger puffer (*Takifugu rubripes*) and others. It was only in the 1970s when stable production of large quantities of rotifers, the initial feed required by fish and crustacean larvae, was achieved that technical developments for the mass production of seedlings began.

There are about 90 species used for sea farming to date, including those for which seedling production techniques are presently being developed (Table 1). The commercialization of sea farming is advanced for 12 of these species, including red sea bream, Japanese flounder, kuruma prawn, swimming crab, sea urchin and abalone, and the scale of mass production has risen to over 10 million for each of these species. These large-scale sea farming operations include scallop (*Patinopecten yessoensis*) and short neck clam (*Tapes philippinarum*) based on the collection of natural spat.

At present, there are 16 national and 57 local government hatchery facilities distributed throughout the coastal area of Japan. These centers are engaged in technical developments for seedling production and release of seedlings. The regional sea farming center in each prefecture mass produces seedlings of the species for which seedling techniques have been developed. These seedlings are handed over to fisheries cooperative associations or municipal seedling

rearing facilities (intermediate rearing facilities) where they are reared for several weeks until they are large enough to be released.

Under the current basic policy on sea farming in Japan, emphasis is given to the promotion of sea farming, together with the conservation of the environment in the waters surrounding Japan, improvement of coastal fishing grounds, and proper management of fishery resources.

Taiwan

In 1982, the Tungkang Marine Laboratory of the Taiwan Fisheries Research Institute (TFRI) made the coastal waters along the southwestern coast of Taiwan an experimental area for prawn releases to augment the production of its coastal fisheries. A series of ecological studies, including community structure, distribution, reproduction, recruitment, food and feeding, growth, and tagging experiments on commercially important prawns in the area was carried out. Results were used as basis for the establishment of an effective system of prawn stock enhancement.

By considering species composition and commercial value, *Penaeus monodon*, *P. semisulcatus* and *M. ensis* were selected as candidates for stock enhancement in the coastal waters of southwest Taiwan.

Based on the data from ecological studies of penaeid prawns, the key issues identified for prawn release include: the target species; optimal seed size for release; number of seed to be released; timing of release; appropriate site for release; effective method of release; and a conservation system to protect the released animals.

According to Taiwanese researchers, restocking with juvenile prawns can enhance recruitment in open coastal waters. The released juveniles should be of a size that can acclimatize well in coastal waters as well as escape from predators. The site for restocking is also important for stock enhancement. It is assumed that the main distribution area of a species provides the best environment and a sufficient supply of food for that species. Stock enhancement sites should be near this area.

To maintain the genetic balance of a stock and avoid disease transmission, releases are only made for (1) animals that come from spawners caught from the original stock, and (2) specific pathogen-free (SPF) prawns. Taiwan's researchers have also de-

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TABLE 2 Species reported to be associated with success in stock enhancement and sea ranching (Liao 1999; complete reference citation for the last column can be found in Dr. Liao's paper)

Species	Common name	Release size (cm)	Country	References
Atractoscion nobilis	White seabass	-	California, USA	Blankership & Leber 1995
Gadus morhua	Atlantic cod	-	Norway	Svåsand & Meeren 1995
Lates calcarifer	Barramundi	>2.5	Australia	Russel & Rimmer 1997
Mugil cephalus	Striped mullet	>7.0	Hawaii, USA	Leber 1995
Oncorhynchus keta	Chum salmon	5.0	Japan	Kitada 1999
Pagrus major	Red sea bream	8.0	Japan	Kitada 1999
Paralichthys olivaceus	Japanese flounder	7 to 10	Japan	Kitada 1999
Patinopecten yessoensis	Ezo-giant scallop	3.5[1]	Japan	Kitada 1999
Penaeus chinensis	Fleshly prawn	1.0	China	Deng 1997
Penaeus japonicus	Kuruma prawn	1.5	Japan	Kitada 1999
Penaeus monodon	Grass Prawn	12 to 15	Taiwan	Su et al. 1990, Su & Liao 1999
Sciaenops ocellatus	Red drum	-	Texas, USA	Liao et al. 1997

[1]Shell length

TABLE 3 Species released by the Taiwan Fisheries Research Institute (TFRI), 1976 to 1995 (Liao 1999)

Category	Number of species	Quantity (x 10^3)	Species
Fishes	7	693	Red sea bream, black sea bream, goldlined sea bream, thornfish, gray snapper, Japanese eel, marbled eel
Crustaceans	6	29050	Kuruma prawn, grass prawn, sand shrimp, bear prawn, redtail prawn, swimming crab
Molluscs	1	510	Small abalone

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strategies) to control the effects of enhancement. Essentially, adaptive management is the continued use of the above nine key components, to ensure an efficient and wise use of natural resource. ###

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The results suggest that (a) there was a significant genetic differentiation among the wild *P. monodon* populations in the Philippines, and (b) the cultured populations were significantly differentiated from the natural populations. More replicate samples from each of the geographic regions are needed to conclusively determine the possibility of an association between genetic differentiation and the status of mangroves and/or intensity of shrimp culture systems. ###

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veloped monitoring and assessment techniques, especially the use of an effective tag for sub-adult and a coded microwire tag for juvenile prawns. It appears that the prospects for restocking with sub-adults to augment prawn broodstocks in nature are promising. Taiwan's prawns have joined a growing list of successful stock enhancement programs (Table 2).

In addition to prawns, TFRI has experimentally released fingerlings, sub-adults and adults of seven fishes, six crustaceans, and one mollusc from 1976 to 1995 (Table 3). Most released animals were fingerlings except for the Japanese eel (*Anguila japonica* Temminck and Schlegel) and grass prawn (*P. monodon* Fabricius).

Taiwan considers the provision of artificial reefs an effective approach to building a good habitat for fishery resources. Since 1973, both the central and prefectural governments have put more emphasis on constructing artificial reefs to provide fish habitats or substrates.

In addition, a total of 25 fisheries resource protective zones have been set up for fish (anchovy), crustaceans (lobster, kuruma prawn, redtail prawn, grass prawn), molluscs (small abalone, hard clam, *Tapes* spp., purple clam, blood cockle, top shell, pearl shell), echinoderm (sea urchin) and seaweeds (*Porphyra, Gelidium, Meristotheca*). **-- RIYA**

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