The Potential Role of Restocking and Stock Enhancement in the Management of Marine Invertebrate Fisheries in the Philippines[1,2]

JOHANN BELL
LEN GARCES
The WorldFish Center
P.O. Box 500 GPO, 10670 Penang
Malaysia

Introduction

Throughout Southeast Asia, capture fisheries are no longer yielding their potential harvests - in many cases, the abundance of valuable species has been reduced to 10% of previous levels (Silvestre *et al.*, in press). The result is that coastal fisheries are not supporting as many livelihoods as they could. This problem has been caused by overfishing, harvesting methods that damage the habitats supporting fish and invertebrates, and a general deterioration of inshore ecosystems (Silvestre and Pauly 1997; Talaue-McManus 2000). Overfishing is particularly severe in the case of many invertebrates, which are easy to collect due to their shallow distribution and sedentary habits. The coastal fisheries of the Philippines are suffering the same problems as those elsewhere in the region: catches have declined dramatically, and several of the most valuable species are now rare (Pauly *et al.* 1989; Barut *et al.* 1997).

The solution to overfishing is easy to identify, but difficult to implement. Basically, arrangements need to be made for fewer people to fish so that stocks can recover to levels that will enable them to provide greater yields (Hall 1999). This will involve hardship for the displaced fishers in the short to medium-term, and so they should be given some form of property rights as an incentive to make the sacrifices needed to restore stocks to more productive levels (i.e., they need to be the beneficiaries of the restored stock).

This remedial action is not easy for governments to implement because it involves loss of jobs for a period. The development of aquaculture promises to ease some of the pain of having to ask people to leave capture fisheries by providing alternative livelihoods in a fisheries-related sector. However, the development of aquaculture will not absorb all the effort that needs to be removed from fisheries to restore them to more productive levels.

The decisions facing many fisheries managers now center around questions like: how many people need to stop fishing?; how much of the fished area should be closed to allow recovery?; how long should these areas remain closed?; or perhaps even how long does the fishery need to be closed completely to allow recovery? Understandably, managers are under pressure to minimize the time needed to restore fisheries so that jobs can be made available as soon as possible. However, even with the application of stringent measures like a total moratorium on fishing, the time needed for recovery cannot always be predicted well due to great annual variation in the natural supply of larvae. Even under the best scenario, it may take several years before the remnant stock produces a year-class strong enough to replenish the stock (Doherty 1999). In some situations, multiple generation times may be needed for replenishment to the required level.

The desire to restore overfished stocks in the shortest possible time has led some managers to consider the use of restocking programs, where cultured juveniles are released to augment the remnant wild stock, thereby reducing the time needed to re-create a relatively large spawning biomass. The potential benefit of a restocking program must, however, be balanced

[1] This paper can be cited as follows: BELL, J. and L. GARCES. 2004. The potential role of restocking and stock enhancement in the management of marine invertebrate fisheries in the Philippines, p. 246-251. *In* DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). In turbulent seas: The status of Philippine marine fisheries. Coastal Resource Management Project, Cebu City, Philippines. 378 p.
[2] WorldFish Contribution No. 1694.

against the costs involved in producing large numbers of juveniles in hatcheries fit for survival in the wild, and there must be confidence that the intervention will make a significant and cost-effective reduction in the time required for recovery of spawning biomass. To make such decisions, managers need several pieces of information about the biology of the target species. This information is presented below[3].

Information Needed to Assess the Potential Benefits of Restocking

Stock delineation

A thorough understanding of the size and distribution of the stock(s) supporting a fishery is an important information needed to assess the need for restocking to design a responsible restocking program. In particular, managers need to know whether the fishery is based on a single homogeneous stock, or composed of multiple, largely self-recruiting population. A good indication of stock structure can be provided by a thorough analysis of the genetic population structure of the species, although some stocks can still be divided into relatively isolated units even when gene frequencies are generally homogeneous. Thus, other tools may also be needed to help determine stock delineation, e.g., multivariate comparison of morphometrics or species composition of parasites. Stock delineation equips managers to understand whether spawning biomass needs to be rebuilt for all, or just certain components, of the stock.

Stock assessments

Once the stock structure of the fishery has been identified, the status (stock size and age/size structure) of the population(s) should be identified. Only then can managers assess whether the spawning biomass of the population(s) is so low that it is unlikely to recover quickly enough simply by implementing conventional management measures, e.g., a total moratorium on fishing, or whether restocking will also be required to restore the number of spawning animals to levels that will once again allow regular substantial harvests to be made. Restocking is normally an expensive option, so restoration of spawning biomass should be based on other forms of management whenever possible, provided they will be effective within acceptable timeframes.

This process involves estimating how long it will take the spawning biomass of each population to recover with and without restocking (Heppell and Crowder 1998). To do this, the desired level of spawning biomass needs to be identified (e.g., 50% of the virgin level), and the data need to be collected that will enable the potential contribution of restocking to be assessed. These data include: remnant stock size, generation time, fecundity, annual variability in the settlement success of postlarvae, natural mortality at different life history stages, and behavior of the species that may affect spawning success or survival at low population density. Different restocking scenarios, e.g., variations in the frequency, number and survival rate of released animals, and the subsequent survival of their F1, F2, F3 progeny, should also be examined.

Capacity of hatcheries to produce sufficient juveniles

If the modeling described above indicates that restocking will be beneficial, an assessment then needs to be made to determine whether the existing hatcheries have the capacity to produce the required number of juveniles. Where the capacity of hatcheries is limited and it is not possible to invest in additional facilities, it may be necessary to produce juveniles over a longer period. This will mean that the restocking model developed above will need to be adjusted.

Other Components of a Responsible Restocking Program

If the decision is made to proceed with a restocking program, careful attention will also need to be paid to: (1) how juveniles are produced and released; (2) managing the restocked population(s); and (3) determining relative contributions of restocking to restoration of spawning biomass (Blankenship and Leber 1995; Munro and Bell 1997). A summary of the actions needed to complete these components of a responsible restocking program is set out below.

Hatchery protocols to maintain the genetic diversity of the stock. The hatchery practices needed to reduce the likelihood that the natural gene frequencies could be changed as a result of relatively large releases of cultured juveniles are described by Munro and Bell (1997) and references therein. These protocols include using large numbers of broodstock, replacing spawning animals regularly, ensuring that

[3]The following section is taken largely from Bell (in press) and Bell and Jamu (in press).

most broodstock spawn and preventing selective breeding among broodstock. If there are problems achieving any of these requirements, they can usually be solved by releasing multiple cohorts derived from different parents. This results in a cumulative released population that has gene frequencies representative of the original wild stock. Where the analysis of stock structure indicates that there is more than one population unit in the fishery, juveniles should only be released in the area where the broodstock were collected. This will involve applying the protocols outlined above to separate groups of broodstock from each population unit.

Requirements of released juveniles. The cultured juveniles must be released in ways and at times where they can avoid predators and find food to ensure their greatest possible chance of surviving and contributing to spawning biomass. This involves sound understanding of the distribution and abundance of their predators, and identification of nursery habitats that provide protection. Field experiments should then be done to identify optimal release strategies (Blankenship and Leber 1995).

Quarantine procedures. All batches of cultured juveniles to be released should be tested to ensure that they meet acceptable levels for pathogens and parasites prior to stocking. This will not only help safeguard the remnant wild stock against any diseases promoted under hatchery conditions, but it will also reduce risks to other species because pathogens are often more virulent in atypical hosts (Munro and Bell 1997 and references therein).

Management measures to maximize benefits. Investment in hatchery production will be wasted unless measures are taken to manage juveniles released in a restocking program. This will often involve a total moratorium on the catching of species until there has been recovery of spawning biomass to the desired level. However, this is not easy when the species under restoration is part of a multispecies fishery and vulnerable as by-catch. In such cases, gear modifications, and spatial and seasonal closures for fisheries or other species may also be needed to protect target species. An effective moratorium on the capture of target species until replenishment occurs is likely to cause short-term hardship for fishers. Thus, it is important to explain to them the longer-term benefits of restocking and the need for restraint, otherwise, many people may assume that the release of animals means that there will now be more to catch. It is also important to let fishers know that future harvests will have to be set at lower levels, otherwise, overfishing and stock reduction will reoccur.

Allocation of property or access rights to fishers prior to the moratorium will provide them with the incentive to comply because they will be the ultimate beneficiaries. However, the hardship that a restocking program imposes on fishers in the short to medium-term needs to be recognized. If necessary, other incentives may need to be provided to create alternative, related livelihoods (e.g., aquaculture). Where such resources or occupations are unavailable, well-enforced temporary exit arrangements with appropriate financial compensation may be necessary.

Determining the contribution of restocking to recovery. An important part of responsible application of a restocking program is to measure the success of intervention, to be certain exactly how recovery occurred and to determine the contribution made by restocking. A genetic tag is needed for this purpose, because the F1, F2, F3, etc. generations derived from released animals must be tracked so that their contribution to the restored biomass can be assessed compared to those individuals derived from the original remnant wild stock.

How does Stock Enhancement Differ from Restocking?

Whereas restocking is a potential tool for restoring the spawning biomass of a severely overexploited fishery, stock enhancement is intended to increase and/or stabilize the production of an operational fishery. Stock enhancement is a process used to overcome recruitment limitation, which occurs when the natural supply of juveniles fails to fill the carrying capacity of the habitat (Doherty 1999; Bell, in press). The result of recruitment limitation is that nursery habitats usually do not support as many juvenile fish and invertebrates as they could. Stock enhancement can help to correct this situation by adding more juveniles to optimize production from fishery (Bell, in press).

Information Needed to Assess the Potential Benefits of Stock Enhancement

As described above, stock enhancement should only be contemplated where there is good evidence that production is often limited by recruitment limitation. Large variation in the abundance of juveniles settling among years, continued rapid growth of new recruits and the persistence of strong year-classes are strong indicators that the habitats could support more juveniles than they receive naturally (Munro and Bell 1997; Doherty 1999). A prime task of managers considering stock enhancement is to identify those years where insufficient juveniles occur naturally to produce optimum yields. This must be done as early as possible in the settlement season using well-designed sampling programs for assessing the abundance of settling postlarvae. The process for determining how many juveniles are required to optimize production each year is explained in detail by Bell (in press). The important points to note about the process of stock enhancement are that: (1) it can provide managers with the ability to manipulate the age-structure of a fishery to create optimum harvest regimes; and (2) in most cases, careful consideration of how many juveniles to add will result in release of fewer juveniles than the habitat can support that year.

Other Components of a Responsible Stock Enhancement Program

Many of the steps involved in developing and implementing a stock enhancement program in a responsible way are the same as those outlined above for restocking programs above (but see also Blankenship and Leber 1995). A key difference to restocking, however, concerns management of released animals. In contrast to restocking, the management of stock enhancement programs needs to pay more attention to the number of juveniles released, to supporting measures to increase productivity, and to the development of regulations to optimize the biological, social and financial sustainability of the fishery.

In general, enhanced stocks do not require specialized management, provided the animals are released at the size, and in the habitat and time of year, that optimizes survival and cost. The cultured animals simply add to the stock available for capture and should be managed together with the wild individuals to maximize yield per recruit using conventional measures. However, several aspects of management, which may need particular attention, are as follows:

Maintaining a sufficient spawning biomass for replenishment. Excessive harvests of adults will reduce the scope for natural replenishment and increase the cost of producing cultured juveniles to provide the optimum number of one-year old animals each year. Thus, any perception on the part of fishers that the release of juveniles can be relied on to correct excess harvesting must be combated by monitoring of capture regulations.

Rotational fishing. An additional measure used to assist natural replenishment in some fisheries, e.g., for scallops in Japan (Masuda and Tsukamoto 1998), is rotational fishing. This management tool provides ample opportunity for reproduction when the number of areas fished sequentially exceeds the number of years it takes the species to reach maturity.

Integration with aquaculture. Opportunities for stock enhancement can be expected from some of the current initiatives to use wild-caught juveniles for aquaculture (Hair *et al.* 2002). For example, proposals to use the settling larvae of rock lobsters (puerulus) for aquaculture in Tasmania, Australia, has led to arrangements where a greater proportion of puerulus than would survive normally are to be returned to the wild at a larger size by farmers, thus enhancing the stock (D. Mills, pers. comm.).

Artificial habitats. For certain species, production can be increased further by providing additional habitat or reducing predation. Inshore herbivorous species associated with hard substrata, e.g., abalone, turban snails and sea urchins, are obvious candidates for increase of production through addition of artificial substrata. The artificial structures capable of providing additional habitat for a wide range of species are described by Grove *et al.* (1994) and Morikawa (1999).

Removal of predators. More productive conditions can also be created for some species by actively removing predators. This has been done effectively for enhanced scallop fisheries in Japan (Ventilla 1982). However, such manipulations should be guided by sound judgements about the overall effects on the ecosystem (FAO 2003).

Status and Potential for Restocking and Stock Enhancement in the Philippines

As outlined above, a key prerequisite for including restocking or stock enhancement among the measures available to managers to restore and increase the production of coastal fisheries is availability of large numbers of cultured juveniles. In many, but certainly not all, cases this will depend on cost-effective methods for the mass production of juveniles in hatcheries. The Philippines is well positioned to supply juveniles of several species, and to develop hatchery technology for others. The status of hatchery technology for marine invertebrates in the Philippines is summarized in Table 1.

The culture of giant clams in the Philippines was started in 1985 by the University of the Philippines-Marine Science Institute (UP-MSI) in collaboration with the Silliman University Marine Laboratory in Dumaguete City and the Australian Centre for International Agriculture Research (ACIAR). Production of juvenile giant clams in a responsible way has now been in progress for many years and restocking efforts for *Tridacna gigas* are currently in progress in various parts of the country.

Culture of the sea cucumber, *Holothuria scabra*, is still at the research and development stage. However, there are plans to transfer technology from elsewhere

Table 1. Status of hatchery technology for marine invertebrates in the Philippines.

Species	Status of Hatchery Methods	Institutions	Restocking and Stock Enhancement Applications	References
Giant clams (*Tridacna gigas, T. derasa, T. squamosa, T. maxima, T. crocea, Hippopus hippopus, H. porcelanus*)	Hatchery and ocean nursery methods developed since 1985	UP-MSI in collaboration with SEAFDEC, Silliman University, NGOs	Restocking of *T. gigas* and *T. derasa* at various locations in the Philippines, e.g., Silaqui Island, Hundred Islands (Pangasinan), Puerto Galera (Oriental Mindoro), Fortune Island, Arthurs Rock (Batangas), Sanga-Sanga (Tawi-Tawi), San Salvacion Island, Subic Bay (Zambales) and Kalayaan Islands (Palawan)	Gomez and Belda (1988); Mingoa-Licuanan and Gomez (1996); Surtida and Buendia (2000);SEAFDEC (2001)
Sea cucumber (*Holothuria scabra*)	Hatchery methods under development at experimental scale	UP-MSI	Proposed restocking in Lingayen Gulf (Pangasinan) as part of the Fisheries and Ocean Resources Governance Project; possibly also in Quezon province and Mindanao	P. Aliño and A. Uychiaoco (pers. comm.)
Sea urchin (*Tripneustes gratilla*)	Hatchery and growout methods developed since 1996	UP-MSI	Restocking at Bolinao (Pangasinan)	Juinio-Meñez *et al.* (1998); SEAFDEC (2001)
Abalone (*Haliotis asinina*)	Hatchery and growout developed since 1997; artificial diet developed in 1998 to tag juveniles prior to restocking; experimental restocking methods under development	SEAFDEC	Sagay Marine Reserve	SEAFDEC (2001)
Top shell (*Trochus niloticus*)	Hatchery developed since 2000; "diet-tagging" methods also developed in collaboration with a private hatchery in Palawan; experimental restocking methods under investigation	SEAFDEC	Sagay Marine Reserve (Negros Occidental)	SEAFDEC (2001)
Window-pane shell (*Placuna placenta*)	Experimental restocking methods under development	SEAFDEC	Panay Gulf	SEAFDEC (2001)
Shrimp (*Penaeus monodon*)	Hatchery and growout methods well developed	SEAFDEC	None to date	Primavera (1993); Surtida (2000)
Mud crab (*Scylla* sp.)	Technical and economic feasibility of hatchery and growout methods currently being tested	SEAFDEC	None to date	Agbayani (2001)

in the region to restock depleted populations of this species in Lingayen Gulf, Quezon province and Mindanao if assessments indicate that this form of management is warranted.

The propagation and growout of the sea urchin, *Tripneustes gratilla,* have also been underway at UP-MSI. Current efforts to restock this species to establish a viable spawning population have shown positive results at a marine park in Bolinao, Pangasinan.

At the Southeast Asian Fisheries Development Center (SEAFDEC), adoption and refinement of hatchery production techniques are underway for abalone (*Haliotis asinine*), top shell, (*Trochus niloticus)* and window-pane shell (*Placuna placenta*). For abalone and top shell, restocking experiments are in progress at a marine reserve in Sagay, Negros Occidental. An artificial diet has been developed to "diet-tag" juveniles of these two species prior to restocking. Research involving window-pane shell is focused mainly on developing restocking techniques in Panay Gulf. There, adult wild shells are stocked in pens in an attempt to increase spawning success.

SEAFDEC has also developed hatchery and culture technologies for shrimp, *Penaeus monodon,* and mud crab, *Scylla serrata*. Although this technology was developed to provide "seed" for growout in aquaculture, it could also be used for stock enhancement programs if the need arises.

References

Agbayani, R.F. 2001. Production economics and marketing of mud crabs in the Philippines. Asian Fish. Sci. 14(2): 201-210.

Barut, N.C., M.D. Santos and L.R. Garces. 1997. Overview of Philippine marine fisheries, p. 62-71. *In* G. Silvestre and D. Pauly (eds.) Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, 208 p.

Bell, J.D. (In press). Management of restocking and stock enhancement programs: The need for different approaches. Proceedings of the Second International Symposium on Stock Enhancement and Sea Ranching, January 2002, Kobe, Japan.

Bell, J.D. and D. Jamu. (In press). Assessing the potential for restocking, habitat enhancement, fish sanctuaries and aquaculture to restore production of *Chambo* in Malawi. Proceedings of the Malawi National Strategy to Restore Production of *Chambo*.

Blankenship, H.L. and K.M. Leber. 1995. A responsible approach to marine stock enhancement. Trans. Am. Fish. Soc. Symp. 15: 167-175.

Doherty, P.J. 1999. Recruitment limitation is the theoretical basis for stock enhancement in marine populations, p. 9-21. *In* B.R. Howell, E. Moksness and T. Svasand (eds.) Stock enhancement and sea ranching. Fishing News Books, Blackwell Science, Oxford, UK.

FAO (Food and Agriculture Organization). 2003. Fisheries management 2. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries 4 (Supplement 2). FAO, Rome. 112 p.

Gomez, E.D. and C.A. Belda. 1988. Growth of giant clams in Bolinao, Philippines, p. 178-182. *In* J.W. Copland and J.S. Lucas (eds.) Giant clams in Asia Pacific. ACIAR Monogr. No. 9.

Grove, R.S., M. Nakamura, H. Kakimoto and C.J. Sonu. 1994. Aquatic habitat technology innovation in Japan. Bull. Mar. Sci. 55: 276-294.

Hair, C., J. Bell and P. Doherty. 2002. The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fishes, p. 327-353. *In* R.R. Stickney and J.P. McVey (eds.) Responsible marine aquaculture. CAB International, New York, USA.

Hall, S.J. 1999. The effects of fishing on marine ecosystem and communities. Fish Biology and Aquatic Resources Series I. Blackwell Science, Oxford, UK. 274 p.

Heppell, S.S. and L.B. Crowder. 1998. Prognostic evaluation of enhancement programs using population models and life history analysis, p. 495-507. *In* C. Coleman, J. Travis and A.B. Thistle (eds.) Proceedings I of the International Symposium on Fisheries Ecology - Marine Stock Enhancement: A New Perspective. Bull. Mar. Sci. 62. Rosenstiel School of Marine and Atmospheric Science, Florida, USA.

Juinio-Meñez, M.A., N.D. Macawaris and H.G. Bangi. 1998. Community-based sea urchin (*Tripneustes gratilla*) growout culture as a resource management tool. *In* G.S. Jamieson and A. Campbell (eds.) Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Can. Spec. Publ. Fish. Aquat. Sci. 125: 393-399.

Masuda, R. and K. Tsukamoto. 1998. Stock enhancement in Japan: Review and perspective. Bull. Mar. Sci. 62: 337-358.

Mingoa-Licuanan, S. and E.D. Gomez. 1996. Giant clam culture, p. 281-299. *In* S. De Silva (ed.) Perspectives in Asian fisheries. Asian Fisheries Society, Makati City, Philippines. 497 p.

Morikawa, T. 1999. Status and prospects on the development and improvement of coastal fishing ground. FAO Fish. Circ. No. 943: 136-239.

Munro, J.L. and J.D. Bell. 1997. Enhancement of marine fisheries resources. Rev. Fish. Sci. 5(2): 185-222.

Pauly, D., G. Silvestre and I.R. Smith. 1989. On development, fisheries and dynamite: A brief review of tropical fisheries management. Nat. Resour. Modelling 3(3): 307-329.

Primavera, J.H. 1993. A critical review of shrimp pond culture in the Philippines. Rev. Fish. Sci. 1: 151-201.

SEAFDEC (Southeast Asian Fisheries Development Center). 2001. Philippine experiences in stock enhancement and resource management. SEAFDEC Asian Aquacult. 23 (5-6): 26–33.

Silvestre, G. and D. Pauly. 1997. Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, 208 p.

Silvestre, G., L. Garces, V. Christensen, L. Lachica-Aliño and D. Pauly. (In press). Coastal fishery resources in developing Asian countries: Analyses of stock decline, species assemblages and trophic structures. In G. Silvestre, L. Garces, C. Luna, M. Ahmed, R.A.V. Santos, L. Lachica-Aliño, V. Christensen and D. Pauly (eds.) Assessment and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc.

Surtida, M.B. 2000. Trochus: the mollusk for button. SEAFDEC Asian Aquacult. 22 (4): 21.

Surtida, M.B. and R.Y. Buendia. 2000. Farming the giant clam. SEAFDEC Asian Aquacult. 22 (4): 18-19.

Talaue-McManus, L. 2000. Transboundary diagnostic analysis for the South China Sea. EAS/RCU Tech. Rep. Ser. No. 14. UNEP, Bangkok, Thailand.

Ventilla, R.F. 1982. The scallop industry in Japan. Adv. Mar. Biol. 20: 309-382.