SEAFDEC/AQD Stock Enhancement Initiatives: Release Strategies Established

***Ma. Junemie Hazel Lebata-Ramos**, Ellen Flor Doyola-Solis, Rema Sibong, Joemel Sumbing**
SEAFDEC Aquaculture Department
Tigbauan, Iloilo, Philippines
email: jlebata@seafdec.org.ph

Jeff Bogart Abroguena
Center for Environment and Water - Marine Studies Section
King Fahd University of Petroleum and Minerals, Dhahran 31261, Kingdom of Saudi Arabia

August Santillan
AECOM Arabia, Bin Sulaiman Center, Al Rawdah Street, Jeddah 2149, Kingdom of Saudi Arabia

Mark Dimzon
Waikiki Aquarium, University of Hawaii, 2777 Kalakaua Avenue
Honolulu, Hawaii 96815-4027, USA

Abstract

SEAFDEC/AQD's Stock Enhancement Program started in 2001 with the first stock enhancement initiative on mud crab *Scylla* spp. funded by the European Commission. This was followed by another stock enhancement program in 2005 supported by the Government of Japan Trust Fund with seahorses *Hippocampus* spp., giant clam *Tridacna gigas*, abalone *Haliotis asinina*, and sea cucumbers *Holothuria* spp. as priority species. This paper discusses the release strategies that have been established for giant clam, abalone and mud crab.

Introduction

The problem of reduced productivity from many of the world's coastal and marine wild fisheries is caused by overfishing in all its forms (Pauly, 1988) and the degradation of the ecosystems through coastal development and destructive fishing methods (Bell *et al.*, 2005). Declining fisheries production have been reported for plaice *Pleuronectes platessa* as early as 1880 in the North Sea (Gulland and Carroz, 1968); scallop *Patinopecten yessoensis* since 1920s in Mutsu Bay and 1930s in Hokkaido (Ventilla, 1982); red abalone *Haliotis rufescens* since 1968 in California (Gaffney *et al*., 1996); and blue crab *Callinectes sapidus*, since 1993 in Chesapeake Bay (Zmora *et al*., 2005), to name a few. To boost production, scientists and fisheries managers have been looking at ways of enhancing fish stocks for over a century (Blaxter, 2000). Replenishing depleted stocks may be done first, by regulating fishing effort; second, by restoring degraded nursery and spawning habitats; or third, through stock enhancement (Blankenship and Leber, 1995). Stock enhancement using individuals reared in aquaculture facilities is becoming a popular method of supplementing depleted stocks *(Bert et al*., 2003). However, according to Bell and Nash (2004), the capability to produce and release juveniles from these aquaculture facilities is not enough reason to conduct stock enhancement.

Stock enhancement is a multidisciplinary technique that takes into consideration many factors and needs the involvement of different experts. Stock enhancement success, according to Bell *et al*. (2005), depends on knowing enough about the ecology of the species, its nursery habitat, and the survival of cultured juveniles in the wild. This means gathering information about the population of the species concerned and its habitat prior to any attempts on stock enhancement. It has been stressed by Gulland and Carroz (1968) that the essential basis of any management is the proper biological understanding of the state of the stocks concerned and emphasised that proper management requires good scientific knowledge based on adequate data.

Blaxter (2000) further added appropriate size-at-release, season of release and area for release as keys to stock enhancement success. To ensure successful use of the stock enhancement concept and avoid repeating past mistakes, Blankenship and Leber (1995) proposed ten components of a so-called "responsible approach to marine stock enhancement" which embrace logical and conscientious strategies for applying aquaculture technology to help conserve and expand natural resources.

To summarize, any stock enhancement activity changes the status quo of an ecosystem or the habitat involved. However, given the substantial damage these ecosystems have suffered due to anthropogenic activities and the depletion of fisheries resources in these ecosystems due to overfishing, the impact of adding juveniles aiming at improving production of the target species should not be a cause of great concern provided that this activity is conducted responsibly and that this will not cause further degradation to the ecosystem and its diversity. This paper reports the stock enhancement and restocking initiatives of SEAFDEC Aquaculture Department on the giant clam *Tridacna gigas*, abalone *Haliotis asinina*, and mud crabs *Scylla* spp.

Activities/Results

Giant Clam, Tridacna gigas

The study was conducted in 1) Carbin Reef in Sagay Marine Reserve, Sagay City, Negros Occidental; 2) Kawit Reef in Malalison Island, Culasi, Antique; and 3) Igang Marine Station of SEAFDEC/AQD in Igang, Nueva Valencia, Guimaras, all in central Philippines. *T. gigas* juveniles were purchased from the Bolinao Marine Laboratory of the University of the Philippines Marine Science Institute. These clams were spawned in October 2004 by parent stocks obtained from Solomon Islands and Australia ages 9 yr and 2 mo and 13 yr and 10 mo, respectively, during spawning (Mingoa-Licuanan, pers. comm.).

During transport, clams were wrapped in moist cheesecloth bags, placed in oxygen-filled transparent transport bags and into styroboxes provided with ice enough to cool the clams during the long trip. Upon arrival in the study sites, clams were first acclimatized then brought to the ocean nurseries for stocking (refer to Lebata-Ramos et al., 2010 for details). Clams were measured monthly for growth (shell length, SL) and survival (individual counting to account for mortalities). Clams were regularly brushed to remove epiphytic organisms growing on their shells. Fouling organisms on the net of the cages and on the concrete slab substrates were also removed by brushing. Upon reaching ≥20 cm SL, clams in ocean nurseries were tagged and transferred to the adjacent reefs. According to Mingoa-Licuanan and Gomez (2007), upon reaching 15-cm SL, clams become less vulnerable to predation and as they grow bigger, predation-related mortality becomes less and they are ready for grow-out. Hence, the target size-at-release should be ≥20 cm SL.

Table 1 shows the number and mean shell lengths of giant clams initially stocked in ocean nurseries in different restocking areas. At this nursery phase, clams reared in Igang Marine Station had the highest survival of 92%. Clams reared in Kawit Reef suffered the highest mortality caused by two strong typhoons that affected the area. Half of the stocks were lost in the first typhoon and most of the remaining ones were lost six months later when another typhoon hit. Monitoring of clams in Kawit Reef stopped because only 11 clams were left. Survival of the clams that were transferred from the ocean nurseries to the reefs upon reaching the escape size of 20 cm SL was high both in Carbin Reef (98.6%) and SEAFDEC Igang Marine Station (94.9%).

Table 1. Giant clams *Tridacna gigas* stocked in Carbin Reef, Kawit Reef and Igang Marine Station

PARAMETERS	Carbin Reef	Kawit Reef	Igang Marine Station
Initial stocks (n)	605	506	300
Mean shell length (cm SL) at stocking	9.05	10.14	12.18
Survival in the ocean nursery (%)	423 (69.9%)	11 (2.17%)*	276 (92%)
Survival in the reef one year after transfer from the ocean nursery (%)	417 (98.6%)		262 (94.9%)
Mean shell length one year after transfer from the ocean nursery (cm)	35.35		31.02

Of the water parameters monitored (**Table 2**), only temperature and depth significantly differ between sites. Igang Marine Station was the shallowest among the sites and had the warmest temperature. Clams had the highest survival and the best growth rate in this site.

Table 2. Mean±SE (range) of water parameters recorded from each site during the duration of the nursery phase

PARAMETERS	Carbin Reef	Kawit Reef	Igang Marine Station	Statistical Analysis
Temperature (°C)	29.26±0.20[ab] (26.8-31.5)	28.61±0.30[b] (25.0-30.5)	29.52±0.24[a] (26.3-31.0)	ANOVA, p<0.05
Salinity (ppt)	33.29±0.32 (27.3-36.7)	33.95±0.32 (30.9-36.2)	33.33±0.28 (29.5-36.4)	Not significant
TSS (mg/L)	84.01±7.04 (0.0-202.4)	79.60±6.68 (3.4-139.8)	84.43±5.21 (24.8-31.0)	Not significant
Chlorophyll a (mg/L)	0.0015±0.0002 (0-0.003)	0.0012±0.0004 (0-0.003)	0.0010±0.0002 (0-0.003)	Not significant
Light intensity (Klux)	7.78±1.52 (2.7-21.8)	--	10.04±1.17 (3.0-17.8)	Not significant
Mean depth (m)	2.43±0.16[b] (1.1-3.9)	6.34±0.12[a] (5.3-7.3)	1.89±0.10[c] (1.1-2.8)	ANOVA, p<0.001

Abalone, Haliotis asinina

The study site, Sagay Marine Reserve (SMR) in Sagay City, Negros Occidental, Philippines, has been described in earlier studies of Maliao *et al.* (2004), Okuzawa *et al.* (2008) and Lebata-Ramos *et al.* (2010). Carbin Reef, one of the four "no-take" zone reefs, was chosen as the site for stock enhancement of abalone. The reef flat, approx. 20 ha, is exposed during low tide when the water level goes beyond 0.3 m depth above chart datum (Lebata-Ramos *et al*., 2010). On the eastern side of Carbin Reef ten 50x2 m belt transects were permanently set up from the southernmost edge of the reef going up north at 100 m apart. Release and monitoring of wild and HR abalone were done inside these belt transects.

Trial Release (HR1) - Diet-tagged abalone (n=1,010) measuring 2.1-3.0 cm SL were obtained from the SEAFDEC/AQD Abalone Hatchery. Tagging was done following Gallardo et al. (2003).

Abalone were transported to the site following Buen-Ursua and Ludevese (2011). Upon arriving at Carbin Reef, abalone, still in transport modules, were transferred to cylindrical net containers and placed in the deeper portion of the reef for onsite acclimation. Every day, each module was checked for mortality and abalone fed with *Gracilariopsis heteroclada*. Abalone were released after an acclimation mortality of <0.5% was attained. Transport modules were placed on each of the pre-installed transects at one module every 5-m interval. This was done on a neap tide in the day to keep them away from predatory reef crabs, which usually emerge when the water is very low and the reef flat exposed. Movement of abalone from the modules to the reef was monitored daily until all of them have moved out. All empty modules were then removed from the release site.

Monitoring was carried out either at dawn or dusk, during the last hour of a major tide of spring tide when the water was ebbing until the onset of high tide. All abalone found inside the belt transect were collected and classified as wild or HR. Individual SL and body weight (g BW) were measured, and sex and sexual maturation determined following Singhagraiwan and Doi (1993). Wild stocks were then tagged with numbered dymotape to determine individual recaptures and both wild and HR abalone returned to their respective transects.

Final Release (HR2) - Abalone (n=2,625), measuring 1.5-2.5-cm SL, were obtained from the SEAFDEC/AQD Abalone Hatchery. This batch (HR2) was tagged with two bands to differentiate them from HR1 abalone released in July 2008. When most of the abalone attained at least 3 cm SL, diet tags were supplemented with individually numbered dymotapes for individual identification.

Transport, acclimation, release and monitoring followed the protocols employed during the release trial (HR1). Growth, total percent recapture, and duration between release and recapture were calculated from the number of recaptured individuals for wild, HR1, and HR2 abalone. Acclimation mortality in HR1 was 14.36%. In HR2, acclimation mortality was lower at 3.50%. The same trend was observed for both HR1 and HR2 where the highest mortality was recorded on day 1 and decreased until day 3 when mortality of <0.5% was attained (**Fig. 1**). Utilization of PVC pipe transport modules as temporary shelter during release was more pronounced in HR1, where almost 19% of the abalone did not move away from the modules on day 1. In HR2, only 4.67% of the released abalone remained in or on the modules during the first 24 hr (**Fig. 2**).

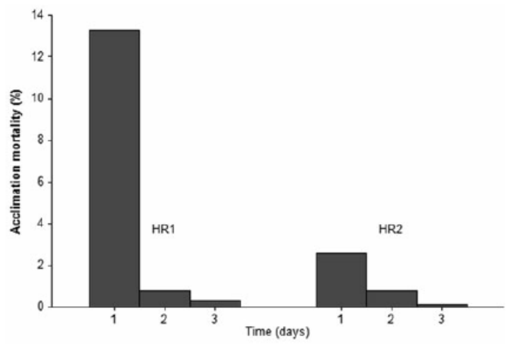

Fig. 1. Acclimation mortality from trial (HR1) and final (HR2) releases of hatchery-reared abalone *Haliotis asinina* in Carbin Reef, Sagay Marine Reserve, Negros Occidental, Philippines (lifted from Lebata-Ramos *et al*., 2013)

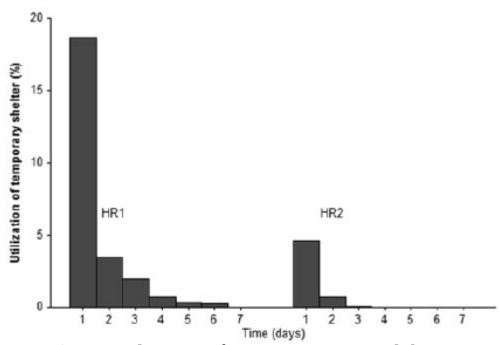

Fig. 2. Utilization of PVC transport modules as temporary shelter during trial (HR1) and final (HR2) releases of hatchery-reared abalone *Haliotis asinina* in Carbin Reef, Sagay Marine Reserve, Negros Occidental, Philippines (lifted from Lebata-Ramos *et al*., 2013)

Of the 239 wild abalone tagged and released from August 2008 to March 2011, a total of 19 individuals (ind) or 7.95% were recaptured. Recapture of abalone ranged 24-278 days after release. For the same period, of the 856 HR1 and 2396 HR2 abalone released, 14 (1.64%) and 155 (6.47%) ind have been recaptured, respectively. Recaptures for both HR1 and HR2 were obtained 26-513 days post-release. All wild abalone were recaptured in transects where they were previously captured and returned. Just like their wild conspecifics, most HR abalone were recaptured from transects where they were released.

Mean growth rates of wild abalone recaptured were 0.25±0.06 cm SL and 4.02±0.64 g BW mo^{-1} with maximum growth rates of 0.7 cm SL and 11.56 g BW mo^{-1}, respectively. Growth rates for HR1 were 0.27±0.04 cm SL mo^{-1} with a maximum of 0.52 cm and 4.6±1.37 g BW mo^{-1} with a maximum of 23.44 g. Growth rates for HR2 were 0.35±0.01 cm SL mo^{-1} with a maximum of 0.92 cm and 3.80±0.23 g BW mo^{-1} with a maximum of 12.46 g. Growth rates were comparable in both wild and hatchery-reared abalone released in the wild.

Mud crabs, Scylla *spp.*

The study was done in a 70.2-ha basin mangrove system located in Naisud and Bugtong Bato, Ibajay, Aklan, Philippines. Three release areas were chosen in the upper reaches of the three main branches of Naisud River. The mangrove area surrounding the river was divided into six fishery monitoring areas (refer to Lebata *et al*., 2009).

Wild *Scylla olivacea* crabs were obtained from the replanted mangroves in New Buswang, Kalibo, Aklan and described in detail in Walton *et al*. (2006). Batches of *S. olivacea*, measuring 30-79.9 mm carapace width (CW), were caught over a period of 4-5 days during spring tides within the duration of the release trials. Wild-caught crabs were tagged on the last day of each spring tide collection period. Hatchery-reared (HR) *S. olivacea* and *S. serrata* crabs were obtained from the Crustacean Hatchery of SEAFDEC/AQD. Hatchery-reared crabs were either released directly from the hatchery to the mangroves (HR-unconditioned) or first transferred to earthen ponds in Dumangas Brackishwater Station of SEAFDEC/AQD and reared for 1-1.5 mo before release (HR-conditioned). Except for the first batch of HR-unconditioned *S. serrata* (20-mm CW), both HR-unconditioned and HR-conditioned crabs measuring at least 30 mm CW were tagged for release. Tagging, release, and monitoring of recaptures were done following Lebata *et al*. (2009).

Release of hatchery-reared mud crabs in the wild has increased the overall yield by 46% from April 2002 to November 2005. An overall increase of 51% in CPUE number and 42% in CPUE biomass were recorded for the same period. The percentage of recaptured *Scylla* spp. in total monthly catches ranged from 11.9% (June 2004) to 62.3% (May 2005). Of the two *Scylla* spp. from different sources, wild-released *S. olivacea* had the highest recapture rates of 55.9% and HR-unconditioned *S. serrata* had the lowest at 12.5%. This supports the hypothesis that survival is higher in wild-released than in hatchery-reared crabs. Of the 12 size classes of *Scylla* spp., there was an increasing trend in percentage recapture observed from the smallest size class (20.0-24.9-mm CW; no recaptures) to 65.0-69.9-mm CW (54.2% recapture). This trend was observed in all batches of released crabs, regardless of species or source.

Lessons Learnt

Lessons learned from the different species released for stock enhancement:

Giant Clam, *Tridacna gigas*

1. Clams should be reared in ocean nurseries until the escape size of at least 20 cm SL
2. Clams should be reared in shallow reefs, 1.0-2.0 m deep during low tide
3. Among the sites where the clams were released, the site with warmer water gave better growth rates

Abalone, *Haliotis asinina*

1. Abalone may be batch tagged using the diet tagging techniques developed by Gallardo et al. (2003) or individually tagged using numbered dymotape before release to be able to differentiate them from their wild conspecifics
2. Abalone should be released at a minimum size of 3 cm SL
3. Abalone should be acclimated onsite before release for at least 3 days to eliminate mortalities caused by transport stress
4. Abalone should not be forcibly removed from the transport pipes during release; these pipes will serve as their temporary shelter in the wild and should be removed only from the site when all abalone have moved out voluntarily

Mud Crabs, *Scylla* spp.

1. Mangrove forest complexity affects mud crab density in the wild hence baseline assessment of stocks is very important before conducting release
2. Mangrove restoration enhances mud crab population in the wild and stock enhancement should only be considered only if habitat restoration doesn't work
3. Should there be a need for stock enhancement, translocation of wild crabs proved to be more effective than releasing hatchery-reared crabs
4. If hatchery-reared crabs will be released, they should be conditioned in ponds for at least 1 month before release
5. Crabs should be tagged internally because external tags won't work on animals that molt
6. Crabs should be released at a minimum size of 4.5 cm carapace width

Recommendations and Way Forward

As a general recommendation, baseline assessment of the population of the target species for release should be conducted first before considering any stock enhancement activity. This should include assessment of the habitat for presence of food and shelter for the stocks to be released. Possible predators that may prey on the released stocks should also be considered during site assessment. Animals for release should be tagged to differentiate them from their wild conspecifics. In areas where poaching is prevalent, secured areas such as marine protected areas, sanctuaries and the like are the recommended sites for release to provide stocks with some form of protection. Proper information dissemination should be employed before release for all stakeholders to be aware of the proposed activity which may, in one way or the other, affect their livelihood. Considering the many considerations before proper stock enhancement could be implemented, other options on increasing population or fisheries stocks should be considered before considering stock enhancement.

REFERENCES

Bell, J., Nash, W., 2004. When should restocking and stock enhancement be used to manage sea cucumber fisheries?, in: Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J.F., Mercier, A. (Eds.), Advances in Sea Cucumber Aquaculture and Management, FAO Fisheries Technical Paper No. 463. FAO of the United Nations, Rome (Italy), pp 173-179

Bell, J.D., Rothlisberg, P.C., Munro, J.L., Loneragan, N.R., Nash, W.J., Ward, R.D., Andrew, N.L., 2005. Restocking and Stock Enhancement of Marine Invertebrate Fisheries, in: Southward, A.J., Young, C.M., Fuiman, L.A. (Eds.), Advances in Marine Biology. Elsevier Academic Press, San Diego (U.S.A.), pp 374

Bert, T.M., McMichael, R.H.J., Cody, R.P., Forstchen, A.B., Halstead, W.G., O'Hop, J., Ransier, J.M., Tringali, M.D., Winner, B.L., Kennedy, F.S., Leber, K.M., Neidig, C.L., 2003. Evaluating stock enhancement strategies: a multi-disciplinary approach, in: Nakamura, Y., McVey, J.P., Leber, K.M., Neidig, C., Fox, S., Churchill, K. (Eds.), Thirtieth U.S.-Japan Meeting on Aquaculture: Ecology of Aquaculture Species and Enhancement of Stock. Mote Marine Laboratory, Sarasota, Florida (USA), pp 105-126

Blankenship, H.L., Leber, K.M., 1995. A responsible approach to marine stock enhancement. American Fisheries Society Symposium 15:167-175

Blaxter, J.H.S., 2000. The Enhancement of Marine Fish Stocks, in: Southward, A.J., Tyler, P.A., Young, C.M., Fuiman, L.A. (**Eds**.), Advances in Marine Biology. Academic Press, London (United Kingdom), 54 p

Buen-Ursua, S.M.A., Ludevese, G., 2011. Temperature and size range for the transport of juvenile donkey's ear abalone *Haliotis asinina* Linne. Aquaculture Research 42: 1206-1213

Gallardo, W.G., Bautista-Teruel, M.N., Fermin, A.C., Marte, C.L., 2003. Shell marking by artificial feeding of the tropical abalone *Haliotis asinina* Linne juveniles for sea ranching and stock enhancement. Aquaculture Research 34: 839-842

Gaffney, P.M., Rubin, V.P., Hedgecock, D., Powers, D.A., Morris, G., Hereford, L., 1996. Genetic effects of artificial propagation--Signals from wild and hatchery populations of red abalone in California. Aquaculture 143: 257-266

Gulland, J.A., Carroz, J.E., 1968. Management of fishery resources, in: Russell, S.F.S., Yonge, S.M. (**Eds.**), Advances in Marine Biology. Academic Press Inc., London (United Kingdom) 71 p

Lebata, M.J.H.L., Le Vay, L., Walton, M.E., Biñas, J.B., Quinitio, E.T., Rodriguez, E.M., Primavera, J.H., 2009. Evaluation of hatchery-based enhancement of the mud crab, *Scylla* spp., fisheries in mangroves: comparison of species and release strategies. Marine and Freshwater Research 60: 58-69

Lebata-Ramos, M.J.H.L., Okuzawa, K., Maliao, R.J., Abroguena, J.B.R., Doyola-Solis, E.F.C., Dimzon, M.D.N., Dacles, T.U., 2010. Growth and survival of hatchery-bred giant clams (*Tridacna gigas*) in an ocean nursery in Sagay Marine Reserve, Philippines. Aquaculture International 18: 19-33

Maliao, R.J., Webb, E.L., Jensen, K.R., 2004. A survey of stock of the donkey's ear abalone, *Haliotis asinina* L. in the Sagay Marine Reserve, Philippines: evaluating the effectiveness of marine protected area enforcement. Fisheries Research 66: 343-353

Mingoa-Licuanan, S.S., Gomez, E.D., 2007. Giant clam hatchery, ocean nursery and stock enhancement. SEAFDEC Aquaculture Department, Iloilo

Okuzawa, K., Maliao, R.J., Quinitio, E.T., Buen-Ursua, S.M.A., Lebata, M.J.H.L., Gallardo, W.G., Garcia, L.M.B., Primavera, J.H., 2008. Stock enhancement program of threatened species in Southeast Asia. Reviews in Fisheries Science 16: 394-402

Pauly, D., 1988. Some definitions of overfishing relevant to coastal zone management in Southeast Asia. Tropical Coastal Area Management 3: 14-15

Singhagraiwan, T., Doi. M., 1993. Seed Production and Culture of Tropical Abalone, *Haliotis asinina* Linne. Bangkok: Eastern Marine Fisheries Development Center (EMDEC), Department of Fisheries and Japan International Cooperation Agency (JICA)

Ventilla, R.F., 1982. The scallop industry in Japan, in: Blaxter, J.H.S., Russell, S.F.S., Yonge, S.M. (Eds.), Advances in Marine Biology. Academic Press Inc., London (United Kingdom), pp 309-382

Walton, M.E., Le Vay, L., Lebata, J.H., Binas, J., Primavera, J.H., 2006. Seasonal abundance, distribution and recruitment of mud crabs (*Scylla* spp.) in replanted mangroves. Estuarine, Coastal and Shelf Science 66: 493-500

Zmora, O., Findiesen, A., Stubblefield, J., Frenkel, V., Zohar, Y., 2005. Large-scale production of the blue crab *Callinectes sapidus*. Aquaculture 244: 129-139