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STOCK ENHANCEMENT OF ABALONE (*Haliotis asinina*) IN ANDA, PANGASINAN, NORTHERN PHILIPPINES

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ABSTRACT
A small-scale stock enhancement experiment was conducted to determine behavioral differences, growth and recovery rates of hatchery-reared abalone juveniles as compared to wild abalone in Imondayon and Imbo, both in Anda, Pangasinan, northern Philippines. Results showed that there were behavioral differences between hatchery-reared and wild abalone, with wild abalone being able to disperse into the surrounding environment immediately upon deployment (within 24 h). Recovery rates gradually decreased from the start up to 105 days and was found to be 0-4% after 105 days for both sites. Better recovery rates of 3-4% for both hatchery-reared and wild-abalone were observed in Imondayon after 105 days. Growth rates of seeded abalone into the wild were found to be similar to those cultured in tanks. The lack of the preferred red seaweed in the release site may have lead the stocked abalone to leave their original position which could partly explain the low recovery rates.

KEYWORDS: Abalone; Stock Enhancement; Pangasinan; *Haliotis asinina*; Behavior; Growth; Movement

INTRODUCTION

Fisheries managers worldwide are searching for sustainable ways to restore depleted stocks and increase production to help meet the projected global demand for fish and shellfish. One management strategy is stock enhancement. Stock enhancement refers to the release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimize harvests by overcoming recruitment limitation (Bell *et al.*, 2008). Because of increasing seafood demand together with the decline or stabilization of most of the global marine fishery resources and increasing proficiency in aquaculture, there is great interest in reseeding and stock enhancement programs around the world (Mustafa, 2003; Lorenzen *et al*., 2010). One species that has great potential for stock enhancement is the abalone. Abalone is a traditional food in eastern Asia, with its meat fetching high prices. As a result, most abalone fisheries around the world have experienced a decline in catch. Abalone are vulnerable to fishing pressure because they move slowly and over limited distances, making them prone to overharvesting. Moreover, poor management (i.e., no size limits on harvest and unregulated fishing effort) may also lead to loss or decline of wild stocks. Because of the interest on abalone, many experimental field studies were conducted including mark-recapture studies to measure growth, movement and mortality, and studies on predation, parasites, feeding, and behavior. For *H. asinina*, the most notable field study was done by Lebata-Ramos *et al.* (2013).

Wild abalone fisheries in the Philippines started in the 1970s, peaked in 1995 at 483 metric tons, and from then on started to decline (FAO, 2011). As wild resources started to dwindle, the lucrative returns of the abalone industry led to the development of hatchery propagation of *H. asinina*, with the first hatchery technology in the country developed at the Aquaculture Department of the Southeast Asian Fisheries Development Center in the 1990s (Capinpin and Hosoya, 1995; Capinpin *et al*., 1998). As seed production and culture of abalone became available, focus shifted to using hatchery-produced seeds for release into the wild for stock enhancement. In 2005, SEAFDEC/AQD identified abalone as one of the species for its five-year stock enhancement program (Primavera *et al*., 2006). Thus, while aquaculture aims at boosting fisheries production, stock enhancement focuses on enhancing wild population. Stock enhancement has been employed in attempts to rebuild collapsed populations or to prevent the decline of current stocks (Dixon *et al*., 2006; Hamasaki and Kitada, 2008). It is one of the principal means, aside from regulating fishing effort and protecting and restoring habitats, by which fisheries can be sustained and improved (Blankenship and Leber, 1995; Blaxter, 2000; Bell *et al*., 2008), but usually it should be the last resort as releasing juveniles into the wild for stock enhancement is expensive. Moreover, stock enhancement should only be resorted to when there is clear evidence that the natural population is recruitment-limited (Bell, 2004) and unless other management strategies have failed. Better yet, enhancements should be done alongside other management strategies (Bartley *et al*., 2004; Bell, 2004). There are

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enough examples of ineffective releases to demonstrate that restocking and stock enhancement programs will not work for some species, or in some places (Bell, 2004; Hamasaki and Kitada, 2008; Lorenzen, 2008). Hence, small-scale experiments should be conducted prior to releasing large quantities of hatchery-produced abalone because of site differences in terms of topographical complexity, current regimes, presence of predators, and many other unknown factors. Releasing hatchery-reared abalone for stock enhancement is not a new concept and has been done primarily in Japan (Saito, 1984; Kojima, 1995; Hamasaki and Kitada, 2008; Hara *et al*., 2008), Mexico (Gutierrez-Gonzalez and Perez-Enriquez, 2005), New Zealand (Tong *et al*., 1987; Schiel, 1993), Australia (Dixon *et al*., 2006; James *et al*., 2007; Goodsell *et al*., 2006; Chick, 2010), and the United States (Rogers-Bennett and Pearse, 1998; Burton and Tegner, 2000), to name a few. In stock enhancement programs, a potential source of mortality is behavioral differences of cultured and wild abalone (Schiel and Welden, 1987), with hatchery-reared abalone being more prone to predation than wild abalone. The objective of the study was to conduct a small-scale experiment to determine behavioral differences, growth and recovery rates of hatchery-reared abalone juveniles as compared to wild abalone in Imondayon and Imbo, both in Anda, Pangasinan, northern Philippines.

MATERIALS AND METHODS

Experimental Animals: Blankenship and Leber (1995) outlined ten principles for a responsible marine stock enhancement program, which have gained widespread acceptance and further updated by Lorenzen *et al.* (2010). Among these responsible approaches is using native stocks so as to avoid deleterious genetic effects on wild population. Hence, the hatchery-reared abalone juveniles used in this study were produced using brood stock of local origin (Anda, Pangasinan).

Sixty one (61) hatchery-reared juveniles were obtained from the Bureau of Fisheries and Aquatic Resources – Region 3, Technology Outreach Station for Marine Water Development (BFAR-3 TOS-MW) in Bamban, Masinloc, Zambales. Parent stocks of these juveniles came from Anda, Pangasinan, the stock enhancement site in this study. At the same time 46 small abalone from the wild were collected from the rocky reefs of Tondol and Carot, also both in Anda, Pangasinan. Both groups of abalone were tagged using dymo that are numbered to allow for individual identification. They were acclimated in sea cages and fed with *Hydropuntia edulis (= Gracilaria edulis*) for two weeks prior to the start of the experiment.

On 11 November 2014, one set of 30 hatchery-reared juveniles (28.82 ± 3.05 mm SL) and 25 wild abalone (40.05±4.33 mm SL) and another set of 31 hatchery-reared juveniles (27.22±3.31 mm SL) and 21 wild abalone (41.08±4.78 mm SL) were released in Imondayon and Imbo, respectively.

Release Sites/Methods: The tagged abalone were placed inside cut PVC pipes and transported to the release site within 1 h. Upon arrival at the site, the cut PVC pipes were lodged beneath rocks and crevices, and the abalone were allowed to stay inside the PVC pipes to afford some protection against predators. After 24 h, the PVC pipes were checked for the number of abalone that was still inside the PVC pipes as well as those in the vicinity of the release site. The site was also checked for the presence of dead shells that may be due to predators. The GPS coordinates of the release site is shown in Table 1. Both release sites have rocky bottoms, however, Imbo was observed to be more topographically complex, with the presence of larger rocks and boulders. The two sites are known fishing grounds for *H. asinina*. Hence, efforts were made to ensure that the stocked abalone are not harvested by fishers by informing them of the experiment.

Table 1. Coordinates of the release site.

Release Site	Coordinates
Imondayon	N 16°19’23.8” E 120°01’52.7”
Imbo	N 16°19’22.0” E 120°00’37.8”

Seaweed Abundance in the Release Sites: In both release sites, the seaweed abundance was estimated using the method developed by Saito and Atobe (1970). Five replicate quadrats (50 cm X 50 cm) were randomly placed in each of the release sites to describe community structure and estimate seaweed abundance (percent cover) of the two areas.

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Behavior, Growth and Recovery: After initial deployment of both groups of abalone, the two sites were revisited after one day to assess movement and behavior of seeded abalone. The two sites were again revisited after 16, 37, 77, and 105 days to assess movement, behavior, and growth and recovery rate of abalone. Growth rates were assessed using the formula used by earlier authors for comparison (Capinpin and Corre, 1996; Capinpin *et al*., 1999).
The two sites were extensively searched by two divers for about 1.5 h each, covering at least 10 m radius from the release site. Once recovered, the shell length was measured using a Vernier caliper and returned to the original position where they were found.

RESULTS

Seaweed Abundance: Table 2 shows that the most abundant seaweeds in the release sites were the brown algae, *Sargassum* sp. and *Turbinaria ornata* with percentage covers of 18.00 and 17.36 in Imondayon and 27.75 and 7.05 in Imbo, respectively. Other less abundant algae were *Amphiroa foliacea* (5.89%), *Padina minor* (1.46%), and *Dictyota* sp. (0.38%) in Imondayon and *Amphiroa foliacea* (0.75%) in Imbo.

Table 2. Percent cover of various algae using the transect-quadrat method of Saito and Atobe (1970).

Species	Quadrats					
Imondayon	1	2	3	4	5	Mean±SD
Sargassum sp.	39.00	7.50	6.00	12.00	25.50	18.00±14.03
Turbinaria ornata	1.69	27.00	27.00	22.13	9.00	17.36±11.45
Amphiroa foliacea	1.13	1.31	6.75	10.50	9.75	5.89±4.49
Padina minor	0.56	1.50	1.50	3.00	0.75	1.46±0.96
Dictyota sp.	0.75	0.19	0.38	0.38	0.19	0.38±0.23
Imbo						
Saragassum sp.	5.25	63.00	21.00	16.50	33.00	27.75±22.07
Turbinaria ornata	24.00	0.00	9.00	0.00	2.25	7.05±10.17
Amphiroa foliacea	0.00	0.00	3.00	0.00	0.75	0.75±1.30

Behavior, Growth and Recovery

Imondayon: On 11 November 2014, a total of thirty (30) hatchery-produced and twenty-five (25) wild-caught specimens were released. After one day, both hatchery-reared and wild-caught specimens left the PVC pipes. Seen within 1 m vicinity of the release site among the underside of rocks were 5 wild-caught and >10 hatchery-reared abalone. No empty or dead shells were observed. After 16 days (27 November 2014), a total of 12 hatchery-reared individuals were recovered (40% recovery rate) within 10-m radius of the release site, with 4 lost tags but it can be identified clearly as hatchery-reared because of its dark brown shell coloration. Only two tagged wild-caught specimens were recovered (8% recovery rate). In terms of growth rate, 6 of the tagged hatchery-reared specimens grew an average of 1.38 mm (0.5, 2.1, 2.3, 1.6, 1.4, 0.4 mm). This is equivalent to 86.46 µm/day, which is comparable to growth of hatchery-reared abalone in tanks but lower than that cultured in net cages set in the sea. On the other hand, only 1 of the tagged wild-caught had grown (0.4 mm), for a growth rate of 23.53 µm/day, which is very slow compared to growth rates of cultured abalone in tanks or sea cages (Capinpin and Corre, 1996; Capinpin *et al*., 1999). It is interesting to note that hatchery-reared specimens were below the minimum size at maturity whereas the wild-caught counterparts were larger (>35 mm SL, size at maturity for this species) (Capinpin *et al*., 1998). This explains the slower growth rate as most energy is channeled to gonad development rather than somatic growth.

After 37 days (18 December 2014), only 5 hatchery-reared specimens were recovered for a 16.67% recovery rate. These recovered abalone moved about 10 m from the exact release site. Three of these recovered hatchery specimens lost their tags. The two hatchery-reared specimens with intact tags grew 2.9 mm (2.8 and 3.0 mm) for a growth rate of 78.38 µm/day in shell length, similar to growth rate of cultured abalone in tanks (Capinpin and Corre, 1996). On the other hand, no wild-caught specimens were recovered from the site. No empty shells were recovered in the site. It was noted too that the site was inundated by sand, smothering the release site, because of strong waves which is characteristic of sea conditions during the northeast monsoon (“amihan”).

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After 77 days (27 January 2015), only two hatchery-reared juveniles with lost tags were found (6.67% recovery rate) and only one tagged wild abalone was recovered (4% recovery rate). The tagged wild abalone grew from 42.0 mm to 45.0 mm, for a growth increment of 3 mm, equivalent to only 38.96 µm/day in shell length.

After 105 days (24 February), only one hatchery-reared with no tag was retrieved (3.22% recovery rate) and only one tagged wild abalone was retrieved (4% recovery rate). The tagged wild abalone grew from 42.0 mm to 49.1 mm after 105 days, for a growth increment of 7.1 mm. This is equivalent to a growth rate of 67.62 µm/day in terms of shell length. This was the same abalone retrieved during the last sampling.

Imbo: On 11 November 2014, a total of thirty-one (31) hatchery-produced and twenty-one (21) wild-caught specimens were released in Imbo. After one day, all the wild-caught specimens left the PVC pipes, 3 of them still visible in the immediate vicinity of the release site. On the other hand, 7 hatchery-reared ones were still inside the PVC pipes, the rest dispersed in the surrounding area. No empty shell or dead shells were observed.

After 16 days, a total of only 3 wild-caught specimens were recovered (14.28% recovery rate) whereas no hatchery-reared specimens were recovered (0% recovery rate). In addition, 2 empty shells of wild-caught specimens were collected during the search, but no empty shells of hatchery-reared counterparts were found. The empty shells of wild-caught specimens were whole and not broken into pieces. According to interviews with fishers, the shells were probably eaten by octopus ("pugita") since other predators such as crabs would tear apart the shells. The release site in Imbo is more topographically complex, which makes it a more favorable hiding place for octopuses. In terms of growth rate of recovered 3 wild specimens, they grew an average of 1.40 mm, equivalent to 87.5 µm/day which is closely similar to growth of cultured abalone in tanks (Capinpin and Corre, 1996).

After 37 days, only one hatchery-reared specimen was recovered in Imbo (3.22% recovery rate). It was noted previously during the last sampling (16 days post-release) that there was no recovered hatchery-produced juvenile found in the release site. It grew from a size of 30.6 mm to 34.8 mm after 37 days, or 113.51 µm/day in terms of shell length. This is comparable to growth rate in tanks. It was difficult to survey at this time because of strong waves and poor visibility. No wild-caught specimens were retrieved during the survey.

After 77 days, no hatchery-produced juveniles and only two (2) tagged wild-caught specimens were recovered (0% and 9.52% recovery rate, respectively) in the site. One grew from 41.7 mm to 51.00 mm whereas the other grew from 39.0 mm to 51.00 mm. The average growth for both was 10.65 mm, equivalent to 138.31 µm/day, considered to be high and comparable to growth of cultured abalone in sea cages with strong water movement.

No more hatchery-reared or wild-caught abalone were retrieved after 105 days post-release on 24 February 2015 (0% recovery rate).

DISCUSSION

Seaweed Abundance: In experiments on food utilization by *H. asinina* on 9 species of macraolage, Upatham *et al.* (1998) reported that fastest growth and highest survival rates were obtained using the red alga *Gracilaria tenuistipitata*, followed by other red algae, *Acanthophora spicifera, Gracilaria salicornia,* and *G. fisheri*. In contrast, the brown alga *Padina minor*, *Sargassum polycystum* and the green alga *Caulerpa racemosa* gave poor growth and survival rates. In the present study, red algae were not observed among the benthic seaweed flora, although encrusting turf algae were observed, which may have also provided the nutritional needs of the abalone, along with other drift algae. The lack of the preferred red algae may also be an incentive for the stocked abalone of both groups to leave their original position to look for preferred algae, which could partly explain the low recovery rates.

Various authors observed that abalone do not move over large areas and that once an optimum habitat was located and not disturbed, they tend not to move (Tarr, 1995). However, Werner *et al*. (1995) observed that lack of food was found to have a significant effect on the moving activity of abalone, even on sand bottoms under laboratory conditions.

Behavior, Movement and Recovery: In the present study, hatchery-reared and wild abalone behaved differently with wild abalone dispersing immediately into their surroundings after one day. In Imondayon, although all hatchery-reared

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abalone left the PVC pipes after 24 h, many of them were observed in the immediate vicinity and in Imbo, 26% (7/31) of them were found still inside the PVC pipes. The wild abalone released in both areas were able to disperse into the natural habitat faster than the hatchery-reared counterparts.

In a laboratory experiment, Schiel and Welden (1987) observed that hatchery-reared and wild abalone juveniles differed in their movement patterns, with wild animals moving rapidly to concealed positions within the reefs and most cultured abalones remaining in their original positions for several hours, resulting to hatchery-reared juveniles being more preyed upon by different predators. Similar results were observed by Lebata-Ramos *et al.* (2013) in that 5-19% of hatchery-reared juveniles stayed in the PVC pipes after one day. However, they observed that hatchery-reared abalone gradually moved out of the PVC pipes within a few days. Likewise, they observed mortality up to 14% during first day of release due to transport stress, which decreased to <0.5% after 3 days. In the present study, both abalone groups were acclimated for two weeks in sea cages and transported within an hour from the acclimation cages to the release site. Hence, no mortality from stress was observed immediately upon the release of abalone in the two sites.

Furthermore, Schiel and Welden (1987) stated that abalone fresh from the hatchery suffered significantly higher mortality and were more sluggish in their responses to predators than hatchery-reared abalone that had been acclimated to the presence of predators under laboratory conditions. The results suggest, however, that cultured abalone may acclimate relatively quickly to a new environment, which may be useful for future attempts at transplanting these animals. Lebata-Ramos *et al.* (2013) observed that all wild and hatchery-reared abalone were recaptured in transects where they were initially released, indicating limited movement, except for one abalone having moved from one transect to another for a distance of 100 m. Just like their wild conspecifics, most hatchery abalone were recaptured from transects where they were released. They also observed close association of abalone with dead branching corals with encrusting algal substrate.

It is important to note, however, that the displacement of one abalone for 100 m, was from an area with low cover (0.94%) to a higher cover (9.84%) of dead branching corals with encrusting algae. This showed the abalones' capability to explore other areas in the absence of an appropriate habitat and/or absence of food. Abalone preference for these types of substrate may be due to the shelter the coral branches provide and the sustenance they get from encrusting algae (Lebata-Ramos *et al.*, 2013). Aside from dead branching corals with encrusting algae, abalone also preferred dead massive and mushroom corals with algae, both for grazing, and rock crevices for hiding from predators. Juvenile *H. asinina* are very cryptic because of their small size, coloration, nocturnal activity and the complexity of the reef surface that they inhabit. Because of this, there is the tendency that a significant proportion of the stocked abalone are overlooked by an observer. Castell *et al*. (1996) compared the recapture rates of cultured topshell, *Trochus niloticus*, a closely similar cryptic mollusk, with only a numbered tag with that of flagged topshells (having both tag and an additional bright-colored tape) in 2 areas (Orpheus Island, Australia and Moso Island, Vanuatu) after 2-3 days. They observed higher recapture rates of flagged topshells in both areas which implies that survival rates could be underestimated by as much as 30% at Orpheus Island and 19% at Moso Island. Other studies indicate that up to 70% of small abalone can be missed during a census (Shepherd, 1990; Tanaka *et al*., 1991). This partly explains the "unaccounted" specimens in the present study. To account for this discrepancy, Castell *et al.* (1996) recommends the estimation of sighting probability of stocked juveniles as an essential component of seeding experiments for appropriate correction of estimated survival rates and that sighting probability varies with different localities and sizes of juveniles used. Other causes of "accounted specimens" may be predation and dispersion.

Growth Rates: Lebata-Ramos *et al.* (2013) observed mean growth rates of wild abalone at 0.25 ± 0.06 cm SL per month (83.33 µm/day) and hatchery-reared abalone at 0.27±0.04 to 0.35±0.01 cm SL per month (90.00-116.67 µm/day). This is generally similar to growth rates of hatchery-reared and wild-caught abalone in the present study, except for some individuals exhibiting relatively slow growth rates. Moreover, the above growth rates observed in the present study are similar to growth rates of hatchery-reared abalone juveniles in tanks (Capinpin and Corre, 1996) with limited water exchange.

Stock enhancement has the potential to help restore depleted populations of marine organisms with similar life histories, although it is very expensive to implement. Hence, small-scale experiments need to be done prior to large-scale stock enhancement programs to identify the most suitable sites that will enhance the survivorship of released stocks and maximize the benefit from such program. For instance, good survival of released juveniles at one site is no guarantee that the methods can be transferred to other sites (Brennan *et al.,* 2008, Purcell and Simutoga, 2008). In other words, there are site differences which may result to variable results, hence the importance of small-scale experiments (Bell, 2004).

Use of PVC modules: The use of cut PVC pipes in stock enhancement is beneficial because the seeded abalone is allowed to adjust to the new environment without the immediate risk of predation. Survival of abalone seeded in this way has been reported to be much higher than that with conventional techniques, particularly for small size classes. The use of modules minimizes physical handling during transport and release. Pipes were integral to the successful release of juveniles in New South Wales, providing a simple, cost-effective, and efficient method for release of large numbers of abalone to natural reefs (Chick, 2010). Based on their findings, Lebata-Ramos *et al.* (2013) recommended the use of PVC pipes for $\geq$3 cm SL abalone, three-day onsite acclimation, and at least one-week monitoring of abalone movement from transport modules after release may be employed in future releases. Site selection for seeding abalone should certainly include habitat considerations to prevent emigration of the seed (Werner *et al*., 1995), with types of substratum and food supply as major factors. Lorenzen (2008) stated that investments in restocking and stock enhancement should not be made unless they are likely to add value to other forms of management). In other words, it is best to conduct stock enhancement of abalone, in conjunction with other management strategies (Bartley *et al.*, 2004; Bell, 2004; Aguilar *et al*., 2008). In the case of abalone, this may include setting up and strict enforcement of marine reserves, legal size limits (i.e. 5 cm for *H. asinina*) that can be harvested and traded in the market, and setting up of mariculture cages to create dense breeding populations in strategic areas, as well as ban in the destruction of rocks and other illegal fishing practices (Capinpin, 2012).

CONCLUSION

Stock enhancement should only be contemplated where there is good evidence that production is often limited by recruitment limitation (Bell, 2004). Our recent data in 2014 showed very low adult densities of 1-2 per 250m^2 belt transect in Cabungan, Imbo, and Imondayon in Anda, Pangasinan (unpublished data), which were lower than earlier assessments in 2012 (Capinpin, 2013). Hence, stock enhancement can have the potential to promote the recovery of the population. Our data showed recovery rates of 3-4% for both hatchery-reared and wild abalone in this study in one site (Imondayon) after 105 days, which is slightly lower than those reported in other earlier studies (6.46% hatchery-reared and 7.97% for wild abalone; Lebata *et al*., 2013). Bell (2004) mentioned that successful implementation of stock enhancement in one location is no guarantee that it can be replicated elsewhere. Hence, prior to transferring enhancement technology to a new site, managers would be wise to conduct small-scale pilot studies to verify that the methods can be relied on to deliver the expected results.

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