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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

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1. Introduction

The abalone industry in the Philippines began in 1971 (BCS, 1972), with volume and total export values reaching more than 400 tonnes and US$ 5 million in 1997, respectively (FAYD, 2000). The entire Philippine abalone industry depends solely on the harvesting of natural stocks (Tahil and Juinio-Menez, 1999).

In northern Negros Occidental, Philippines, abalone harvesting was introduced in 1982 by visiting fishermen from Santa Rosa, Cebu (the neighboring island). Similar to the global trend towards declining abalone fisheries (Tahil and Juinio-Menez, 1999; Wallace, 1999), the Philippine fishery has undergone rapid exploitation, and is vulnerable to wild-stock depletion because of uncontrolled fishing. Moreover, abalone gleaning is tremendously destructive to fragile coral

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reefs because it requires overturning of substrate using an iron hook. Therefore, measures to protect the reef ecosystem and the abalone stocks have been initiated.

Marine protected areas (MPA) are becoming prominent worldwide as a tool to protect biologically rich habitats, to resolve user conflicts, to restore overexploited stocks and degraded areas (Alcala and Russ, 1990; Russ and Alcala, 1996; Agardy, 1999), and to empower local communities (White et al., 1994; Katon et al., 1999). Hence, MPA are advocated as a tool for coastal fisheries management (Roberts and Polunin, 1991; Agardy, 1994). White et al. (2002) defined MPA as areas in the marine environment, whether coastal or offshore, protected and set aside for management and conservation measures that can either be de jure or de facto. Currently, the Philippines have established 439 MPA (Pajaro et al., 1999). Despite the recognized importance and potential of MPA to contribute to conservation and sustainable use of coastal resources in the Philippines, few coastal management projects have been evaluated with sufficient scientific rigor to determine outcomes (White et al., 2002).

This study evaluates the effectiveness of enforced reef protection in the Sagay Marine Reserve (SMR), Negros Occidental, western Philippines, using the donkey's ear abalone *Haliotis asinina* L. (Mollusca: Gastropoda) stock as a biological indicator. *H. asinina* is the most common haliotid in the Philippines, and has formed the major basis of the abalone fishery production in the country due to its relatively large size. This species is also a good candidate for aquaculture due to its high growth rate (Capinpin et al., 1998; Fermin et al., 2000; Madrones-Ladja and Polohan, 2001). Rowley (1994) and Roberts and Polunin (1991) stated that changes in the abundance and sizes of target species are the simplest and most observable variable to measure the impact of MPA with a history of fisheries exploitation. In this study, we focus on density, size and sexual maturity of abalone stock, and compare those parameters between protected reefs and unprotected reefs. In addition, sex ratios and biometric relations of *H. asinina* are reported.

It is important to clarify that this study does not evaluate the effectiveness of the MPA per se. As earlier discussed, MPA have been shown to be potentially effective conservation strategies. Rather, this study emphasizes the effectiveness of *enforcement* of protection on the abalone population. With the understanding that 'paper parks' are often severely incapable of protecting resources, we sought to understand if enforcement and protection of reefs in an MPA achieves superior results to having unprotected reefs in an MPA.

1.1. Physical and biological aspects of the marine resources in the SMR

Sagay city is located at the northern tip of the island of Negros Occidental at 10°53′51″N and 123°24′53″E. This portion of the country is well known for abundant marine resources. The municipal waters of Sagay extend over 32,000 ha and include sand cays, islands, shoals, coral reefs, extensive sea grass meadows and mangrove forests (Fig. 1). The SMR encompasses all municipal waters of Sagay. The overall protection and monitoring of the SMR is assigned to the bantay-dagat (literally "sea watchers", i.e. sea police) who are the de jure monitors.[1] Several reef systems are present in the SMR, and this study focused on four: two protected reefs (Carbin and Maca) and two unprotected reefs (Panal and Molocaboc).

1.2. Carbin Reef (protected)

Carbin Reef is approximately 200 ha in area, with a sand cay at the southern portion. The most abundant substrate type is dead coral, extending to the north, east and west from the cay. A sandy bottom extends to the south. Twenty-eight genera of scleractinian corals have been recorded in Carbin Reef, with the dominant form being massive (*Porites* spp.) and submassive types (*Favia stelligera*). A dense growth of *Sargassum* spp. was also observed on the northwestern end of the reef. A reef watchtower was built on Carbin Reef in 1983, and is actively utilized by the bantay-dagat (Fig. 2).

[1] The bantay-dagat initially was comprised of community volunteers receiving no compensation, and in some coastal towns of the Philippines this is still the case. In the SMR, the bantay-dagat are Sagay City employees who receive training related to legal and police matters and are given a certificate as official bantay-dagat. They have the legal authority to apprehend and arrest violators. About 80% of the SMR budget is allocated to 50 bantay-dagat officers.

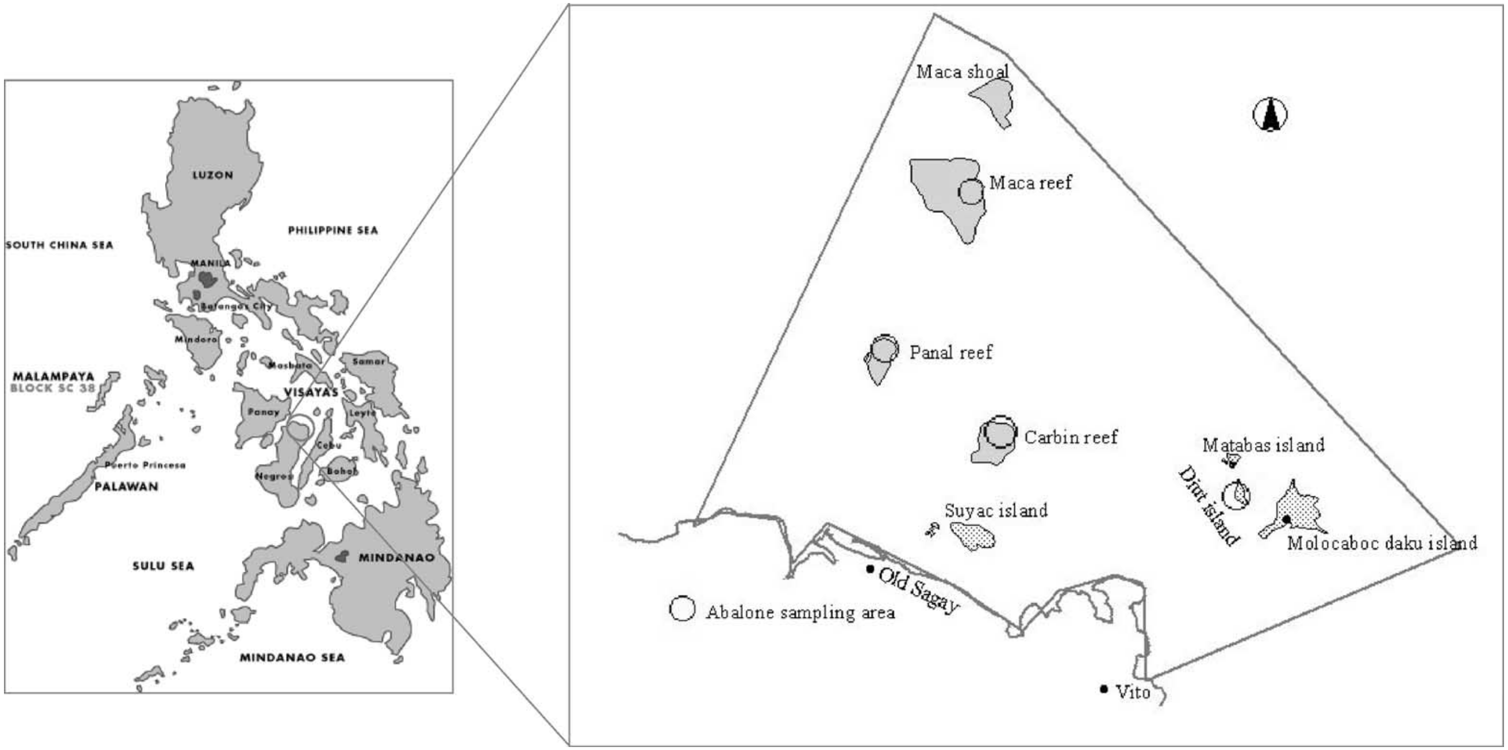

Fig. 1. Map of the Sagay Marine Reserve, Negros Occidental, Philippines.

Fig. 2. Carbin Reef sand cay during low tide, with the watchtower to the right. Note the white Styrofoam buoy with flag that serves as the boundary for the Carbin Reef sanctuary.

1.3. Maca Reef (protected)

Maca Reef is approximately 1000 ha, with patches of coral communities dominated by *Porites* spp. at the shallow eastern side and at the northwest side of the area. The reef extends approximately 0.8 km in all directions from the sand cay, outside of which extends a sand flat starting at 13 m depth. The southern part of the reef is fringed by shallow and extensive sandy bottom. Thirty-one genera of scleractinian corals have been recorded in Maca Reef. A reef watchtower for the bantay-dagat was built on Maca Reef in 1992, and is actively used by them.

1.4. Panal Reef (unprotected)

Panal Reef is approximately 100 ha, with the majority of coral cover in the west portion. Nineteen genera of scleractinian corals have been recorded in Panal Reef. The shallow portion is dominated by *Acropora* spp. Silt was evident in the water column during the survey because the reef is near the mouth of Himugaan River and its tributaries. At the time of this study there was no watchtower in Panal Reef, although construction was scheduled to begin in mid-2002.

1.5. Molocaboc Reef (unprotected)

Molocaboc Reef surrounds Molocaboc Island, one of two inhabited islands in the SMR. The population of Molocaboc Island is 3951 with 723 households in 2000. The dominant reef substrate is bedrock with *Sargassum* spp. and *Padina* spp. as prevalent algal species. Beyond 15 m depth, *Fungia* spp. dominated the reef area. There were 31 genera of scleractinian corals recorded in this reef. A watchtower was built in 1994 but it has not served the same purpose as the watchtowers in Carbin and Maca Reefs. The Molocaboc watchtower was originally scheduled to be built on the unpopulated northern coast, but due to local politics it was built on the south coast, where it now serves as a boat dock for the village. Molocaboc Reef is essentially unprotected.

1.6. History of marine protection in Sagay

Before 1983, all sites were open access. In 1983, Carbin Reef was established as a sanctuary (no-take zone) by virtue of Municipal Ordinance Number 2. The sanctuary was later extended to Maca and Panal Reefs in 1991 through Municipal Resolution Number 85. In 1995, the entire 32,000 ha were gazetted as Sagay Marine Reserve, and thereby included into the National Integrated Protected Area System (NIPAS) of the Philippines by virtue of Presidential Proclamation 592 under the category of Protected Seascape.[2] The

[2] NIPAS is the classification and administration of all designated protected areas in the country aimed mainly for conservation. Under the definition of R.A. 7586, the 'protected seascapes' category is defined as areas of national significance which are characterized by the harmonious interaction of man and land (and body of water) while providing opportunities for public enjoyment through recreation and tourism within the normal lifestyle and economic activity of these areas.

Table 1
History of protection of different study reefs located within SMR

Reef name	Official protection history	Actual protection level
Carbin	Established as a no-take zone in 1983. Strict protection began in 1995	Open access before 1983. Low–moderate 1983–1995. High since 1995
Maca	Established as a no-take zone in 1991. Strict protection began in 1995	Open access before 1991. Low–moderate 1991–1995. High since 1995
Panal	Established as a no-take zone in 1991 but never enforced	Open access to present day
Molocaboc	Established as a multiple-use zone in 1995	Open access to present day

Republic Act No. 9106 otherwise known as the 'Sagay Marine Law' was signed into law in April 2001, making the protection of Sagay waters part of the law of the country. This led to higher investments in enforcement with the objective of increased reef protection. However, protection was not uniformly administered, and Panal and Molocaboc Reefs remained de facto open access resources, so harvesting of abalone continued unabated (Table 1).

It is justifiable to assume that all sites were of similar biological condition prior to 1983, given the extensive, heavy and non-specialized pattern of exploitation by gleaners. For this study, Carbin and Maca Reefs were classified as protected reefs, given the fact that monitoring and enforcement commenced in earnest by 1995 (and in low to moderate levels in preceding years). Panal and Molocaboc Reefs were classified as unprotected reefs, although they reside within the Sagay Marine Reserve and are de jure protected areas. The analysis presented here examines the impact of reef protection on the populations of *H. asinina*, despite the lack of quantitative data on abalone populations prior to 1995.

2. Methods

A survey of abalone stock was conducted during April and May 2002. Abalone populations were surveyed using a series of 50 m × 2 m strip transects, approximately 30 m apart on each reef. Seven replicate transects were surveyed on each reef. Each transect was subdivided into twenty-five 2 m × 2 m quadrats along the transect line. All abalone encountered within each quadrat were gently removed, put in a pre-labeled netted bag, and placed in a basin with seawater. Shell length was measured with a plastic vernier caliper to the nearest 1.0 mm while fresh weight was measured to the nearest 0.1 g using an Ohaus® LS200 balance. The sex and gonad development stage (GDS) of each animal were visually examined; GDS was scored from 1 to 4, similar to the methodology of Singhagraiwan and Doi (1993) (Table 2). Scoring involved visual inspection of the gonads and evaluating the relative gonad cover over the hepatopancreas. A ripe ovary is colored dark green while a mature testis is milky white. After data collection, all collected abalone were returned to the location from which they had been removed.

The survey was usually undertaken in the daytime during low tide. When water levels were low, abalone were collected by walking along the transect. When the water level was high enough, a mask and snorkel were used. A local abalone fisher with 13 years of experience (but with more than 45 years in Molocaboc) was hired to assist during the sampling.

2.1. Data analysis

The main analysis was twofold. First, we tested whether there was a difference in population densities between the protected and the unprotected reefs. Second, we compared the average animal size between

Table 2
Characteristics of each gonadal development stage (GDS) of *H. asinina* (modified from Singhagraiwan and Doi, 1992)

GDS	Characteristics
1	Gonad is not visible. Abalone is either a juvenile or a spent mature abalone
2	Pre-mature gonad covering a small portion of the hepatopancreas
3	Partially mature gonad covering about 25% of the hepatopancreas
4	Fully mature gonad covering about 50% of the hepatopancreas

protected and unprotected reefs. For abundance data, we used a parametric ANOVA with a Duncan's multiple range test to make paired reef comparisons. For mean animal size, we used a non-parametric Kruskal–Wallis ANOVA across reefs. These two analyses evaluated whether enforcement in the SMR has resulted in measurable population differences.

The total number of male and female abalone in each reef was subjected to a χ^2 goodness-of-fit-test to test the null hypothesis that the male to female sex ratio of abalone was 1:1. To test whether the sex ratio of abalone differed with cohort age, the shell length measurements of individuals from the four reefs were divided into three size classes (20–39.9, 40.0–59.9, and 60.0–79.9 mm), and the observed frequencies of both male and female in each class size were subjected to a χ^2 goodness-of-fit-test. This analysis provided information on the reproductive status of the population.

Paired data of shell length (mm) and wet weight (g) were subject to linear regression (both variables log-10 transformed to linearize the regression). A significant predictive relationship would allow future research to reduce field workloads when calculating animal size.

3. Results

Although this study focussed on *H. asinina* populations, we also encountered *H. ovina* on the reef. Prior to this survey, *H. ovina* had never been recorded in the SMR; therefore, this survey resulted in a new distributional record for *H. ovina*. However, for the population analyses here, we consider only *H. asinina*.

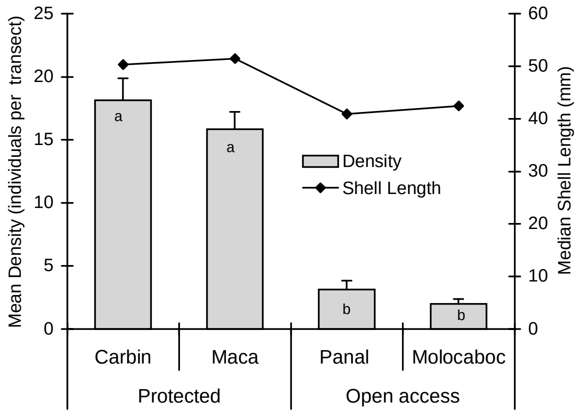

Fig. 3. Mean density (per 100 m^2) and median size (mm) of abalone in Sagay. Error bars are standard error of the mean. Bars with dissimilar letters are significantly different according to a Duncan's multiple range test.

3.1. Abalone densities and sizes

Altogether, 268 individuals of *H. asinina* were collected from the four reef sites (Table 3). Abalone densities varied significantly across the four sites, and were higher in the two protected reefs than on unprotected reefs (Table 3, Fig. 3; one-way ANOVA $P < 0.001$). Duncan's multiple range test revealed that abalone densities on protected reefs did not differ statistically but were significantly higher compared to the abalone densities on unprotected reefs, which themselves did not differ from each other. Animal size (shell length) differed across reefs (Fig. 3, Kruskal–Wallis ANOVA, $P < 0.05$). Overall, abalone on the protected reefs were more abundant and larger than those found on the open-access reefs.

Table 3
Number of males and females abalone collected per reef and the χ^2 for differences from an expected sex ratio of 1:1

Protection	Reef	Total no. of males	Total no. of females	χ^2 of sex ratio	Mean abalone density (no. per 100 m^2)
Protected	Carbin	77	46	$P < 0.01$	18.1
	Maca	42	68	$P < 0.05$	15.8
Unprotected	Panal	1	20	$P < 0.001$	3.1
	Molocaboc	6	8	n.s.	2.0
Total		126	142	n.s.	
One-way ANOVA of densities across all four sites					$P < 0.001$

Table 4
Numbers of males and females in each class size and the χ^2 values from an expected sex ratio of 1:1[a]

Class size (mm)	Males	Females	χ^2
20.0–39.9	7	25	$P < 0.005$
40.0–59.9	102	102	n.s.
60.0–79.9	17	15	n.s.
Total	126	142	n.s.

[a] Data are aggregated across reefs.

3.2. Sex ratio

The sex ratio varied across the four reefs. On Carbin Reef, significantly more males than females were found, but on Maca and Panal Reefs there were more females than males (Table 3). The sex ratio did not deviate from a 1:1 ratio at Molocaboc, but sample size was low. There seemed to be no consistent trend of sex ratio with the amount of reef protection given, because conflicting results were found on the two protected reefs.

We investigated whether sex ratio changed across animal size class (i.e., with age). Animals were grouped into three size classes based on shell length: 20.0–39.9, 40.0–59.9, and 60.0–79.9 mm. Results of a χ^2 test in each size class revealed that for the smallest size class, sex ratio significantly deviated from the 1:1 ratio, with females being in greater abundance (Table 4).

3.3. Gonad development stage (GDS)

The majority of individuals collected exhibited a GDS of 3 or 4, indicating sexual maturity (Fig. 4). There was no difference in the proportion of individuals in each GDS class between sexes (χ^2, $P > 0.05$). These data suggest that the populations were spawning (or near to spawning) during the months of April and May 2002.

3.4. Biometric relations

There was a highly significant linear relationship between the log-transformed length and log-transformed wet weight of *H. asinina* (Fig. 5). With an R^2 value of 0.87, this relationship is sufficiently robust to use with future field research on this species.

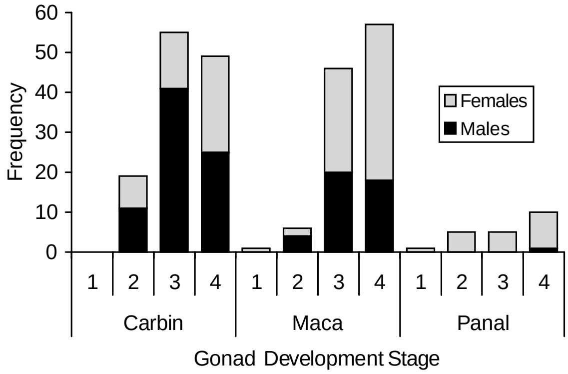

Fig. 4. GDS of sampled *H. asinina* in Sagay Marine Reserve, Philippines. Due to low sample size, Molocaboc Reef is not included in this figure.

4. Discussion

4.1. Impacts of the SMR on abalone populations

Marine reserves generally contribute to fisheries conservation and enhancement by providing safe havens where sufficient stock of spawning individuals act as a source of propagules to replenish nearby exploited areas (Wallace, 1999), and by serving as a buffer against management errors and recruitment failure (Lembo, 1999). For instance, Rogers-Bennett and Pearse (2001) reported that MPA maintained the positive sheltering interactions between adult urchins and juvenile abalone. Moreover, effective monitoring has been shown to be crucial in conservation and protection of biological resources (Ostrom, 1991; Bohnsack, 1996; Jensen, 2000). This study provides evidence of the positive impact of enforcement of the Sagay Marine Reserve on abalone populations through the "safe haven" effect. The two reefs that were monitored and protected by the bantay-dagat exhibited significantly higher abalone densities, and were on average larger than on open-access reefs. This difference is attributable to the enforcement of protective management intervention, in particular the presence of an inhabited reef watchtower on Carbin and Maca Reefs. There are no empirical data of *H. asinina* densities in unexploited reefs systems, so it is not possible to determine the level of this species' recovery on the protected reefs. Nevertheless, it is clear that protection has resulted in more

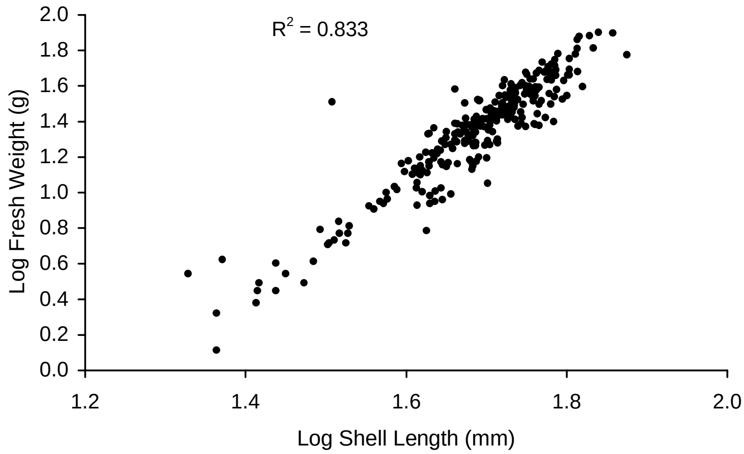

Fig. 5. Length–weight relationships of *H. asinina* (male and female) in Sagay Marine Reserve, Philippines.

robust *H. asinina* populations than on unprotected reefs.

Haliotids are broadcast aggregate spawners requiring high densities to ensure fertilization (Clavier, 1992). Tegner (1992) indicated that the natural recovery of severely reduced abalone populations could be a very slow process, due to the low reproductive efficiency of widely dispersed adult populations coupled with short larval dispersal distances. Recruitment of juveniles to the population will largely depend on the density of local brood stocks, and in the case of SMR, harvesting activities by people. For example, a study by Wallace (1999) on the impact of MPA of the northern abalone *Haliotis kamtschatkana* showed that only in areas where harvest was completely prohibited were significant changes to local abalone populations found. In the SMR, abalone gleaners harvest only animals with a shell length greater than 30 mm, because this is the size limit of abalone accepted in the market. Moreover, because Carbin and Maca Reefs were under strict protection for seven years (with low to moderate protection for several years prior), in the absence of other juvenile mortality vectors we would expect juvenile recruitment on the protected reefs (with adequate broodstock). In all four reefs, however, the populations exhibited low juvenile densities (Table 4).

Previous abalone surveys also found populations skewed to the left with a prevalence of large size classes and with few juveniles (Wells and Keesing, 1989, 1990; Wells and Mulvay, 1995). We recognize several possible contributors to low numbers of juveniles found at our sites. First, the low densities of broodstock could be partially responsible for the low levels of recruitment observed during the surveys. Tegner (1992) suggested that abalone recruitment might cease if the adult population falls below a certain threshold. It is possible that all SMR reefs were near this threshold before the initiation of strict protection. Research needs to address whether such a threshold exists, and if such a phenomenon may be happening in Sagay.

Second, abalone juveniles may have been overlooked during the survey due to their small size and cryptic behavior. For *H. roei*, Wells and Keesing (1997) proposed that juveniles grow fast hence explaining low frequencies of juveniles during surveys.

Third, recent natural climatological phenomena may have affected recovery and recruitment of abalone populations in the protected reefs. Three typhoons striking the Philippines in 1995 (Nitang, Ruping and Rosing) caused extensive reef devastation in the SMR. This was followed in 1997 by an El Niño. In 2001, the typhoons Feria, Jolina and Nanang struck the Negros Occidental, again causing massive disturbance to the coral reef systems in Sagay. Interviews with local fishermen revealed that before these typhoons struck SMR, the west and northwest sections of Carbin Reef were abalone habitat; but at the time of this study these areas were sandy bottom. Moreover, these climatological phenomena caused extensive coral bleaching, while siltation and pollution from coastal settlements, sugar lands and sugar mills were also threats to the area. Clearly, the SMR is in an area of high environmental dynamism. This dynamism, both natural and human-induced, is expected to have strong impacts on the depleted abalone population (Pimm et al., 1988).

Finally, laboratory and hatchery experiments indicate that *H. asinina* juveniles have a low survival rate around the time of settling and metamorphosis (Poomtong et al., 1997). This may also be the case in natural populations.

Possibly recruitment could be enhanced by the application of 'larval collectors' on all reef sites (Rodda et al., 1997). However, this solution may pose problems in the unprotected reefs since 'larval collectors' will also function as fish aggregating devices (FADs), which would subsequently attract fishers. Another alternative is stock enhancement, through a reseeding approach. Currently, the Aquaculture Department of Southeast Asian Fisheries Development Center (SEAFDEC-AQD) is conducting experimental release of hatchery-produced juveniles in the SMR (with broodstock collected from the same site).

Thus, while our results indicate that the establishment and protection of the SMR have resulted in the recovery of the abalone populations to levels above the unprotected reefs, recruitment appears limited in all sites and may indicate a slow recovery. The rate of recovery of abalone stock in the SMR will depend on human enforcement, demographic properties of the population, reproductive success, and stochastic natural factors. The baseline data reported here should contribute to effective monitoring of the SMR abalone recovery in the future.

4.2. Population dynamic considerations

Several authors reported that the sex ratio of natural *H. asinina* populations is approximately 1:1 (Sungthong et al., 1991; Jarayabhand and Paphavasit, 1996; Capinpin et al., 1998). Hayashi (1980) (cited in Mgaya, 1995) also reported a 1:1 sex ratio for *H. tuberculata* over 90 mm. In this research, the overall sex ratio did not differ from 1:1, although there were significantly more females than males in the smallest size class. There may be two reasons for this. First, these results may be in agreement with the observations of Tutshulte and Connell (1981) who suggested that there was a natural preponderance of female abalone at earlier ages and males at older stages. Girard (1972, cited in Mgaya, 1995) reported a preponderance of females in juveniles of *H. tuberculata*, which changed to 1:1 sex ratio at larger sizes, thus postulating the possibility of sex change. However, the sex-change hypothesis was not supported by Shepherd and Laws (1974), who found no evidence of sex reversal of haliotids in their study of five sympatric species of abalone in southern Australia (*Haliotis cyclobates*, *H. laevigata*, *H. roei*, *H. rubber*, and *H. scalaris*). They explained instead that the sex ratio might change with increasing size due to differential mortality, growth, or differential sampling of the sexes due to behavioral differences.

Second, there may have been misidentification of males as females in the smaller size classes, due to possible differences in age at sexual maturity. Hayashi (1980) (cited in Mgaya, 1995) found higher densities of female *H. tuberculata* in smaller size classes, and recommended that juvenile females should be classified as 'putative females', because of possible differences in maturity rates.

In this study, the smallest sexually mature male and female were 26.0 and 23.1 mm SL, respectively. Capinpin et al. (1998) reported that wild *H. asinina* attained sexual maturity at 40.6 mm SL for both males and females; although, they added that it might be because not enough smaller size wild abalone were collected. For hatchery-reared *H. asinina*, males and females reached sexual maturity at 35.0 and 35.9 mm SL, respectively (Capinpin et al., 1998). The relatively small size of sexually mature *H. asinina* in the present study may indicate that fishing pressure has been too high over a long period of time. In this case only the individuals that reproduce at a small size get a chance to reproduce and, provided size at sexual maturity is an inherited character, the size at first spawning will decrease. One option for management would be restocking with broodstock from populations with a larger size at first spawning.

We collected GDS information to get a 'snapshot' of the reproductive status of *H. asinina* in the SMR during April and May 2002. The results, when put in context of other studies, suggest that further research should be conducted on the reproductive ecology of *H. asinina* in the SMR. In the present study, most abalone collected in the Carbin and Maca Reefs had mature gonads, with GDS of 3–4. Individuals from the Panal and Molocaboc Reefs, although few, were also mostly ripe. These results suggest that abalone in the SMR are capable of spawning in or around April and May. This agrees with Fermin et al. (2000), who reported that the highest number of spawnings by captive *H. asinina* in the Philippines occurred during April, coinciding in summer months with warmest water temperature. The result also agrees with Counihan et al. (2001) who reported that the spawning season of the natural population of *H. Asinina* in the Great Barrier reef, Australia occurred during October–April, coinciding with warmest water temperature. In contrast, Capinpin et al. (1998) found that ripe wild *H. asinina* (Philippines) were collected in all but the months of April, May and June, while Singhagraiwan and Doi (1992) reported a low spawning of captive *H. asinina* in Thailand during these periods. The variability in results suggests that research across the entire year needs to be undertaken in order to more precisely document the reproductive ecology of *H. asinina* in the SMR. This can lead to improved management of the species by supporting recommendations for closed and open seasons, based on site-specific reproductive ecology.

5. Conclusions

The size and abundance of *H. asinina* in the protected reefs were significantly higher than in unprotected reefs. This is evidence of the positive impact of enforced protection on the abalone population, and agrees with other studies that no-take MPA can enhance the size and abundance of target species. However, this effect is localized and is dependant on effective monitoring by the bantay-dagat. The constant monitoring and enforcement of protective rules contributed considerably to the recovery of the population to levels above the unprotected reef. Monitoring and enforcement were facilitated by the presence of watchtowers. Hence, this study supports the argument that investment in monitoring watchtowers (and regular monitors) is an efficient and necessary use of funds. Recruitment appeared limited; measures for improving recruitment are needed to accelerate population recovery. When combined with improved protection, we expect that the present impact of SMR implementation on abalone populations would be even greater. However, it should be noted that MPA are not the ultimate panacea for resource degradation in the coastal and marine environment; efficient conservation usually requires support and participation of local stakeholders or resource appropriators (e.g. Wescott, 1988). Therefore, the strict enforcement of no-take zones in the SMR should be coupled with zones of multiple use, wherein local fishers can maintain their livelihoods and benefit from the replenishment zones of the protected reefs.

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