Sedimentation Rate in Fringing Reefs of Honda Bay, Puerto Princesa City, Palawan, Philippines with Reference to Coral Reef Condition

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ABSTRACT

The study was conducted to determine and compare the rate of sedimentation in two fringing reefs in Honda Bay during two seasons, to discuss sedimentation rate in relation to selected environmental parameters, to determine the coral cover in the two stations, to compare it with data from 2000 and to explain eventual changes in coral cover in relation to the selected environmental parameters, especially sedimentation. The study was conducted from March 1, 2003 to November 30, 2003. Two stations, Bush and Meara Islands, in Honda Bay were established. Each station was mounted with three sets of 3-replicated sediment traps that were collected one week after installation. Each station was further assessed in terms of coral cover. The average sedimentation rates in Honda Bay during dry and wet season were 3.50 and 10.00 mg/cm^2/day, respectively. The sedimentation rates in the two islands did not show significant difference at 5% level of significance. Benthic cover of both Bush and Meara was higher in 2003 than in 2000. The fact that coral cover is able to recover despite sedimentation seems to indicate that sedimentation has not yet reached critical levels in Honda Bay.

Keywords: Coral reefs, sedimentation, Honda Bay, Philippines

INTRODUCTION

Sediment is a particularly troublesome pollutant in coral reefs. It clouds seawater, which reduces photosynthesis of zooxanthellae that live in a mutualistic relationship with many species of corals. In water clouded by sediment, the amount of food available to corals is reduced. Particularly, heavy sedimentation can bury a reef, choking the life out of it. According to El-Swaify (2000), movement of sediment to low lying and shoreline areas after erosive storms – which often takes only a few hours or even minutes – can induce serious impairment to habitat quality. As a result, deposited sediments in the coastal area may create valuable deltas and islands which may lead to the change of the morphological structure of the coastal ecosystem (personal observation).

Of the 27,000 km^2 of Philippine reefs, 60% lies on the shelf surrounding the large western island of Palawan (White, 2001). Honda Bay is one of the important fishing grounds and tourist destinations in Palawan. Destructive fishing methods, overexploitation and devastating land-based activities that cause erosion and siltation resulted in a decrease of fish catch per unit effort from 36.5 kg in 1985 to 8.4 kg in 1989 (Sandalo, 1994) and to 5 kg in 1996 (ICLARM, 1996). Live cover in coral reefs is currently estimated to be 36.5% (Gonzales, in press). The protection of Honda Bay's marine resources has been the concern of the Department of Environment and Natural Resources (DENR), the Fisheries Resource Management Project (FRMP)

and some non-governmental organizations (e.g., Environmental Legal Assistance Center) particularly in the barangays of San Jose, Santa Lourdes, Tagburos, Babuyan and Manalo (Gonzales, 2000). Indicators of the success of their efforts, such as a decrease in fishing pressure, an increase in fish stocks and the rehabilitation of coral cover, have been observed, though not sufficiently monitored. FRMP started a monitoring program of coastal ecosystems and fishes in 2000 (FRMP, 2001) which was not continued. Thereafter, Palla (2003) conducted the only other recent study; he analyzed the population dynamics of demersal fishes in Puerto Princesa and Honda Bay.

Despite the claim of some authors that one of the causes of coral cover reduction in Palawan is siltation and erosion (Cruz et al., 1988 as cited by FRMP, 2001), studies related to erosion, siltation and sedimentation and its potential impact on the coastal ecosystems have no concrete evidence. In fact, the present study is the first that ever looked into sedimentation in Honda Bay.

To describe the status of sedimentation in Honda Bay, this study was conducted with the following objectives: 1) to determine and compare the rate of sedimentation between Bush and Meara Island in Honda Bay during the two seasons, 2) to discuss sedimentation rate in relation to selected environmental parameters, 3) to determine the coral cover in the two stations and to compare it with data collected in 2000, 4) to explain eventual changes in coral cover in relation to the selected environmental parameters, especially sedimentation.

MATERIALS AND METHODS

Locale of the study

Honda Bay is one of the bays of Puerto Princesa City, which is a major fishing ground of both artisanal and commercial fishers (Fig. 1). It is a land indentation embayment with an area of approximately 280 km^2 located northeast of mainland Palawan between $9^O50'$ to $10^O00'$ N latitude and $118^O44'$ to $119^O00'$ E longitude. It is composed of several islands and islets and has a coastline of 100 km. The islands are small, ranging from 0.0125 to 0.45 km^2 (Fig. 1). Honda Bay is surrounded by 18 coastal barangays. Six major rivers, namely Bacungan, Tandayak, Babuyan, Tanabag, Langugan and Tapul and numerous small tributaries drain into the bay (Fig. 1). During rainy season, these rivers carry high amounts of sediments into the bay (personal observation).

Two reef sites were selected near the islands of Bush and Meara (Fig. 1). Bush Island is located near Bgy. Sta. Cruz and is 1.70 km away from the shoreline of mainland Palawan, lying at $118^O47.268'$ E longitude and $9^O55.272'$ N latitude. Meara is approximately 3.00 km from the nearest shore and 4.40 km from Bush Island. It is located at $118^O46.410'$ E longitude and $9^O53.304'$ N latitude. At each of these islands, a sampling station was established along a demarcated coral transect, which was assessed in terms of coral cover by FRMP in 2000.

The two stations were assessed in terms of sedimentation rate, water temperature, salinity, depth, pH and total dissolved solids. The stations were further assessed in terms of coral cover. Sampling of physical and chemical parameters was conducted thrice during the dry season (April, May and June 2003) and thrice during rainy months (August, September and November 2003). Sampling was conducted within one day. The coral cover at the reef stations was assessed on May 31, 2003 when the visibility was high and the sea was calm.

Three sets of sediment traps (length: 11.50 cm; diameter: 5.00 cm) were installed in each station with three pseudo-replicates / sub-samples per set

(Hurlbert 1984) (i.e., a set was composed of three individual traps) on the same day. The traps were installed along a 100-m transect line, 1 m away from the FRMP-markers. The three replicates were mounted close (0.30 m) to each other. During the samplings in April, May and June, sediment traps were left for one month at the sites. However, during the remaining samplings (i.e., August, September and November), traps were only left for 24 hours at the sampling sites. Direct comparison on the result will probably not be possible due to the time difference in the deployment of traps. Traps were sealed with cellophane before removing them from the rod to prevent loss of material while bringing the sample to the surface. In the laboratory, the content of the traps was filtered to

separate the sediment from seawater. Samples were dried overnight in an oven at 60ºC. Dried samples were weighed to the nearest milligram. Sediment traps were thoroughly cleaned of encrusting organisms before re-use.

Water temperature, salinity, depth, pH and total dissolved solids were measured during the collection of sediment traps. Parameters were determined at the subsurface of the place where sediment traps were installed. Triplicate readings were taken using the following measuring devices: standard mercury thermometer, pH meter (CORNING – Checkmate ™ II) and conductivity meter (CORNING – Checkmate ™ II) for salinity and total dissolved solids.

The Line Intercept Transect (LIT) method described by English et al. (1997) which was utilized by the FRMP Team in 2000 was used in assessing benthic lifeforms. In each station, a 100 m transect line was laid along the reef crest at 6-7 m depth. To ensure that transects are laid exactly in the same position previously used by the FRMP Team, their concrete markers – which were found at 5-m intervals – were used.

The following lifeform categories and codes modified after UNEP (1993) and English et al. (1997) were used in this study: hard coral (HC), soft coral (SC), sponge (SP), others (OT), dead corals with algae (DCA), sand (S), rock (RCK) and rubble (R).

For the three replicate sets, the mean (± SD) amount of sediment was calculated. The mean sedimentation rate was determined in mg/cm^2/day. For comparative reasons, the overall mean sedimentation rate in Honda Bay was converted into g/m^2/day. Analysis of Variance (ANOVA) was used

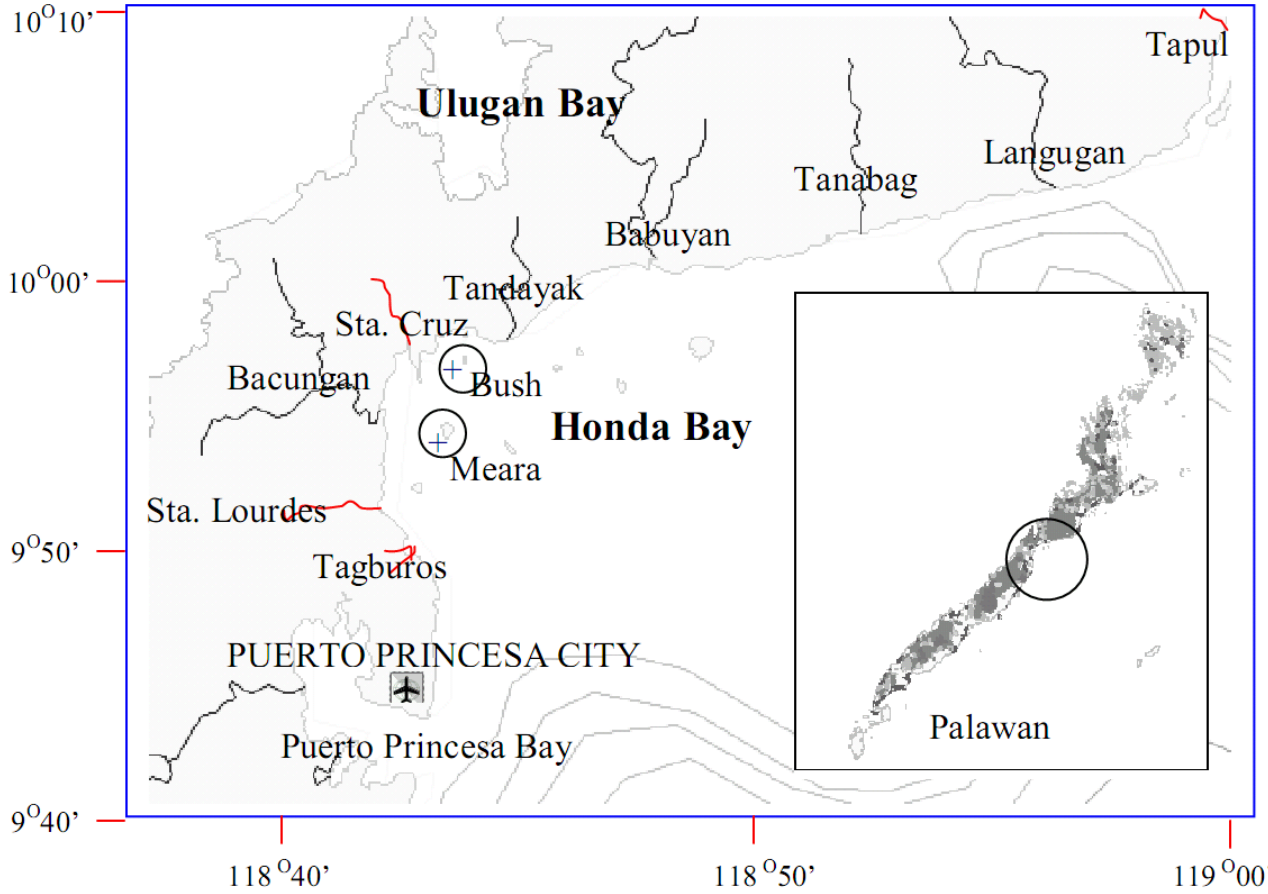

Figure 1. Map showing Palawan (lower right), the study area and the location of the sampling sites (+) in Honday Bay, Puerto Princesa City.

to determine eventual differences in sedimentation rate between the two stations, and between the data gathered during the dry (1st three sets of data) and rainy season (2nd three sets of data) at 5% level of significance. Mean physico-chemical parameters were correlated with sedimentation. Line intercept transect (LIT) data was used to analyze the percentage of the different lifeforms. Results were then summarized into two major categories: biotic and abiotic.

RESULTS

Sedimentation Rate

The monthly sedimentation rate in Bush Island ranged from 2.00 to 21.00 mg/cm^2/day while in Meara Island it ranged from 2.00 to 16.00 mg/cm^2/day (Fig. 2).

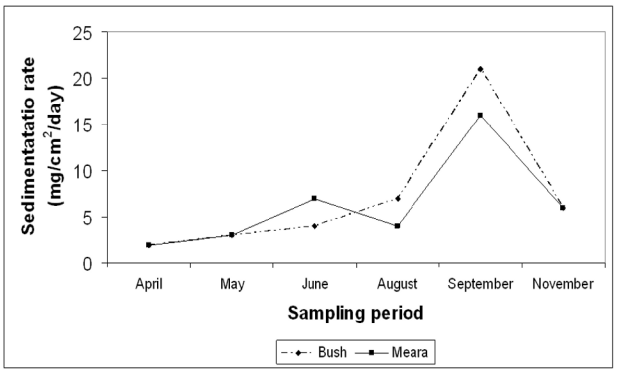

Figure 2. Mean sedimentation rate at the two reef stations during the six (6) sampling events.

The overall mean sedimentation rate was 7.10 and 6.50 mg/cm^2/day for Bush and Meara Islands, respectively. Between the sites, sedimentation was higher (7.00 mg/cm^2/day) in Bush Island than in Meara Island (6.00 mg/cm^2/day) (Tab. 1). Differences in sedimentation rate between sampling events (6 events) and sampling seasons (wet & dry) in Bush Island were not significant. On the other hand, significant differences were detected in Meara Island between sampling events and also between sampling seasons. Between the stations in Bush and Meara Islands, no significant differences were established in both sampling events and sampling seasons.

Total dissolved solids were high in the two island stations (Bush Island, 24.88 ± 0.31 mg/l; Meara Island, 24.98 ± 0.29 mg/l). The correlation of TDS with the sedimentation rate in Bush Island was low (r = 0.37) and with that of Meara Island was negatively high (r = -0.80). Salinity readings were relatively stable in the two islands, i.e., Meara Island (32.71 ± 0.41 ppt) and Bush Island (32.61 ± 0.41 ppt). It was moderately correlated with the sedimentation rates in the two islands (r=0.50). The values of the correlation coefficient (r) in both islands were not significantly different. Mean temperatures at Bush and Meara islands were 30.19ºC and 29.43ºC, respectively. The mean pH readings in the two stations were slightly basic. The pH reading was almost similar in both islands with 8.36 in Meara and 8.44 in Bush Island (Tab. 2). The correlation coefficients (r) between pH and the sedimentation rates of both islands, Bush and Meara, were relatively high (i.e., r=0.90 for Meara and r=0.99 for Bush).

Table 1. Mean sedimentation (mg/cm^2/day) during dry and wet season in the different stations in Honda Bay, Puerto Princesa City.

Season	Station	
	Bush	**Meara**
Dry	3.00	4.00
Wet	11.00	9.00
Mean	**7.00**	**6.50**

Coral Cover

The hard coral cover had the largest contribution to the benthic category. In Bush Island, hard corals contributed 45.83% and in Meara Island 43.20% to the benthic community (Tab. 3). In both islands soft coral cover was 3.80%. The abiotic components contributed 35.52% and 48.30% to the total benthic lifeforms of the two islands wherein dead corals covered with algae and rubble contributed most for both islands (Tab. 3).

DISCUSSION

Sedimentation Rate

Average sedimentation in Honda Bay was higher (6.80 mg/cm^2/day) compared to Dona Paula Bay, west coast of India (Bhaskar et al., 2000) which ranged from 0.11 to 1.34 mg/cm^2/day (PVC pipe used had a diameter of 20.00 cm) with an average of

Table 2. Mean of the physico-chemical parameters considered in Bush and Meara islands in Honda Bay, Puerto Princesa City.

Physico-chemical parameters	Sampling Season				Average	
	Bush Island		Meara Island		Bush Island	Meara Island
	Dry	Wet	Dry	Wet		
Temperature (°C)	30.57	29.80	29.83	29.03	30.19	29.43
Salinity (ppt)	32.43	32.80	32.83	32.60	32.61	32.71
pH	8.14	8.75	8.14	8.58	8.44	8.36
Total dissolved solid (mg/l)	24.75	25.00	25.05	24.90	24.88	24.98

0.54 mg/cm^2/day. However, direct comparison may not be advisable due to differences in trap designs, exposure periods and hydrological aspects of the different marine environments.
A study conducted by Aliño (1983) in three areas (Matab-ang, Bato and Looc) in Toledo City, Cebu using 5 cm × 20 cm PVC pipe revealed an average sedimentation of 16.20, 10.10 and 33.50 mg/cm^2/day, respectively. Compared with these values the two island stations in Honda Bay had relatively low values. In Singapore, increasing coastal development has been claimed to cause increasing levels of sedimentation. Studies of Chan (1980 as cited by Lane, 1991) revealed a sedimentation rate of 3.00-6.00 mg/cm^2/day in 1979. Later studies found sedimentation to be at 5.45 mg/cm^2/day (Lane, 1991; Low and Chow, 1994). Their data is similar to those gathered from Honda Bay. Sediments collected in both islands were composed of sand, shell fragments and organic matter.

Table 3. Benthic lifeform cover (%) in Bush and Meara Islands in 2000 (FRMP,2001) and 2003 (this study).

Benthic Categories	Bush		Meara	
	2000	2003	2000	2003
HC	40.65	45.83	25.65	43.20
SC	2.90	3.80	0.20	3.82
SP	4.05	0.00	6.45	0.00
OT	0.30	17.84	0.85	4.68
DC	0.00	0.00	0.40	0.00
DCA	5.80	12.72	3.70	33.00
S	0.00	6.50	0.00	7.50
R	17.60	13.30	9.15	7.80
RCK	17.00	0.00	24.45	0.00
SI	0.00	0.00	1.00	0.00

HC=Hard coral, SC=Soft coral, SP=Sponge, OT=Others, DC=Recently dead corals, DCA=Dead corals with algae, S=Sand, R=Rubble, RCK=Rock, SI=Silt

Total dissolved solids (TDS) are minerals (salt) in the water. They are high in saltwater in line with salinity. Sedimentation brought in from watersheds with high mineral content could eventually increase TDS. However, total dissolved solid values during dry and wet season at both islands were almost the same, which shows that freshwater does not influence the water quality of both islands as evidenced by its high and relatively stable salinity. Salinity had no significant changes between dry and wet season at both islands under study. pH in both islands was higher during wet season. Although a lot of basic ions are deposited in the coastal environment during the onset of the rainy days, saltwater has the capacity to normalize pH. The pH measurements in both islands are typical for the characteristics of the stations, wherein the stations are well buffered with pH above 8. A pH of 8.1 to 8.3 is typical for seawater (Lalli & Parson 1997).

Coral Cover

A study conducted by FRMP in 2000 using the same method revealed that hard coral cover in Bush and Meara Islands was 40.65% and 25.65%, respectively. With regards to soft coral cover, it was 2.90% in Bush Island and 0.20% in Meara (Tab. 3). In both island sites, hard corals and sponges constituted the largest biotic components. Likewise, rock, sand and rubble contributed to almost 50% of the abiotic components in both islands.

Live coral cover went down after El Niño in 1997 and 1998. In 2000, coral cover in Honda Bay was probably not yet back to its previous state, though there was recovery in 2003. From 2000 to 2003, the biotic component had increased in both sites (Fig. 3).The fact that they are able to recover despite sedimentation seems to indicate that sedimentation has not yet reached critical levels. Live coral cover in Honda Bay is higher compared to coral cover in

nearby provinces. In Romblon, live coral cover was 17.92% and in Mindoro, it was 19.94% (SPCP-ASTI, 1999). Earlier assessment of Honda Bay, particularly the islands of Fondeado, Arrecife, Snake, Pandan and Canyon showed that the live coral cover ranged from 19.38 to 50.63% (SPCP-ASTI, 1999). Assessment of live coral cover in Palawan in 1981 using transect/quadrat method had a value of 12-40.80% (Gomez, 1981). In Port Barton, San Vicente, Palawan, live coral cover had an average value of 27.17% (PhilReefs, 2003) which is lower compared to the live coral cover in 1981. It was only in Panglao Island (45.18%) and Bais Bay (50.26%) where the live coral cover was almost similar with live coral cover in Honda Bay (Aliño et al., 2002). The Philippines has an average coral cover of 25 to 49.90% (White and Trinidad, 1998).

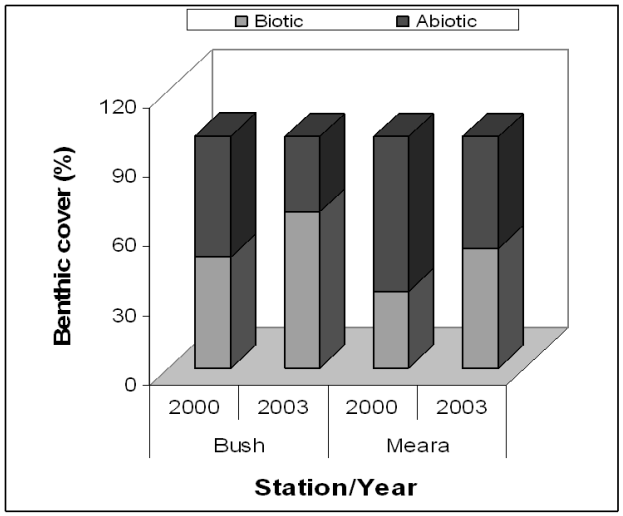

Figure 3. Relative contribution of biotic and abiotic components in the reefs of Bush and Meara Islands in years 2000 and 2003.

Other factors that may favor the growth of corals in Honda Bay are the temperature, salinity and pH. The two island stations, Bush and Meara, had a mean temperature of 30.19°C and 29.43°C, respectively. These values are within the minimum and the maximum temperature requirement for corals to exist (18-35°C) (Sale, 1991; Tait and Dipper, 1998; Fabricus and Alderslade, 2001). The salinity measured at the two stations seems to be quite stable and the difference between dry and wet seasons is negligible (Tab. 2). This indicates that no freshwater reaches the island stations from the nearby river systems. The values measured are typical for marine waters of this geographical region. Corals are favorably grown in areas with a salinity of 32-38 ppt with an average of 35 ppt. (Lalli and Parsons, 1997). pH, like any other water quality parameters, can also affect the growth of corals. A value of 8.1-8.3 is normal for seawater because it is always well buffered. pH in Bush Island ranged from 8 to 9.69 while in Meara Island, it ranged from 8.11 to 8.99. Mean pH in Bush Island was 8.44 while in Meara Island it was 8.36.

The fact that coral cover is able to recover despite sedimentation seems to indicate that sedimentation has not yet reached critical levels in Honda Bay.

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REFERENCES

Aliño, P.M., Miclat, E.F.B., Nañola, C.N., Quiaoit, H.A.R., Campos, R.T. (eds.) 2002. Atlas of Philippines Coral Reefs. Goodwill Trading Co., Inc. (Goodwill Bookstore). Quezon City, Philippines. 264 pp.

Aliño, P.F., 1983. The effects of mine tailings on the structure of coral communities in Toledo, Cebu. MS thesis in Marine Biology, University of the Philippines. 105 pp.

Bhaskar, D.V., Cardozo, E, Giriyan, A, Garg, A., Bhosle, N.B. 2000. Sedimentation of particulate matter in the Dona Paula Bay, west coast of India during November to May 1995 to 1997. *Estuaries.* 23(5): 722 - 734.

Reef Information Network of the Philippines (PhilReefs), 2003. Philippine coral reefs through time: Workshop proceedings. Second of the Atlas of Philippine Coral Reefs Series. Coral Reefs Information Network of the Philippines, University of the Philippines-Marine Science Institute. Quezon City, Philippines and Marine Park Center, Tokyo, Japan. 197 pp.

El-Swaify, S.A., 2000. Operative processes for sediment-based watershed degradation in small, tropical volcanic island ecosystem. Pages 35-49 In: R. Lal (ed.), Integrated

Watershed Management in the Global Ecosystem. Soil and Water Conservation Society. CRC Press. USA. pp. 395.

English, S., Wilkinson, C., Baker, V. 1997. Survey Manual for Tropical Marine Resources. 2nd edition. Australian Institute of Marine Science. Townsville, Australia. 390 pp.

Fabricus, K., Alderslade, P. 2001. Soft Corals and Sea Fans. A comprehensive guide to the tropical shallow-water genera of the Central-West Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Queensland, Australia. 264 pp.

Gomez, E.D., Alcala, A.C., San Diego, A.C. 1981. Status of Philippine Coral Reefs. *Prodeeding of the 4th International Coral Reef Symposium, Manila.* 1:275-282. Marine Science Center, University of the Philippines, Diliman, Quezon City, Philippines

Gonzales, B.J. 2000. Puerto Princesa City Integrated Coastal Resource Management Network. A concept paper. FRMP-Puerto Princesa City. 9 pp.

Gonzales, B.J. in press. Puerto Princesa Bay and Honda Bay, Palawan: An ecological profile. In: BFAR Turbulence, 15 pp.

Hurlbert, S. H. 1984. Pseudoreplication and design of ecological field experiments. *Ecological Monographs* 54: 187-211. Ecological Society of America

FRMP, 2001. Resource and Social Assessment of Honda Bay and Puerto Princesa Bay: A Terminal Report, Philippines DENR, 635 pp.

ICLARM (International Center for Living Aquatic Resources Management). 1996. Resource and ecological assessment of Honda Bay, Palawan, Philippines, ICLARM, Makati City, Philippines

Lalli, M.C., Parsons, T.R. 1997. Biological Oceanography. 2nd edition. Butterworth- Heinemann. Woburn, Great Britain, 314 pp.

Lane, D.J.W. 1991. Growth of scleractinian corals on sediment –stressed reefs in Singapore. In: Alcala, A.C. (ed.) *Proceedings of the Regional Symposium in Living Resources in Coastal Areas.* University of the Philippines, Manila, pp. 97-106

Low, J.K.Y., Chow, L.M . 1994a. Sedimentation rates in Singapore waters. In: Sudara, S., Wilkinson, C.R. & L.M. Chow (eds.). *Proceedings 3rd ASEAN-Australia Symposium on Living Coastal Resources.* Vol.: 2 Research Papers. Chulalongkorn University, Bangkok, Thailand, May 1994.

Palla, H.P., 2003. Population dynamics of demersal fishes in Honda Bay, Palawan, Philippines. MS thesis in International Studies in Aquatic Tropical Ecology. University of Bremen, Federal Republic of Germany, 65 pp

Sale, P.F. 1991. The Ecology of Fishes on Coral Reefs. Academic Press. San Diego, New York, 754 pp.

Sandalo, R.M. 1994. Community-based coastal resources management: The Palawan experience, p. 165-181. In Pomeroy, R.S. (ed.). Community management and common property of coastal fisheries in Asia and the Pacific: Concepts, methods and experiences. *ICLARM Conf. Proc.* 45, 189 pp.

Spalding, M.D., Ravilious, C., Green, E.P. 2001. World Atlas of Coral Reefs. University of California Press, USA, 424 pp.

SPCP-ASTI 1999. A report on the rapid resource assessment in some coastal areas of north and west Sulu Sea. Department of Environment and Natural Resources – DOST-Philippine Council for Aquatic and Marine Research and Development, 404 pp.

Tait, R.V., Dipper, F.A. 1998. Elements of Marine Ecology. Butterworth-Heinemann. Woburn, 462 pp.

UNEP, 1993. Monitoring Coral Reefs for Global Change: Reference Methods for Marine Pollution Studies No. 61, 72 pp.

White, A.T. 2001. Philippine Coral Reefs. A Natural History Guide, 2nd edition. Bookmark, Inc., Hong Kong, 276 pp.

White, A.T., Trinidad, A.C. 1998. The Values of Philippines Coastal Resources: Why protection and management are critical. Coastal Resource Management Project. Department of Environment and Natural Resources. United States Agency for International Development. Cebu City, Philippines, 96 pp.