Comparison of abundance and diversity of benthic macroinvertebrates between disturbed and non-disturbed seagrass-algal beds in central Philippines

[1]Billy T. Wagey, [1]Reni L. Kreckhoff, [2]Abner A. Bucol

[1] Faculty of Fisheries and Marine Science, Sam Ratulangi University, Jl. Kampus Unsrat, Bahu, Manado, Indonesia; [2] Negros Oriental State University Main Campus I, Kagawasan Ave., Dumagute City, Philippines. Corresponding author: B. T. Wagey, billywagey@unsrat.ac.id

Abstract. In this paper, we describe patterns in abundance and diversity of macroinvertebrates in seagrass-algal beds with varying degrees of exploitation and pollution in Dumaguete City and Siquijor Island, central Philippines. The densities of commonly harvested taxa of macroinvertebrates were comparable to the findings of other investigators in the study region. However, commercially important species of strombids (*Lambis* and *Strombus*) were absent in the seagrass beds of Dumaguete reflecting overexploitation while in this site large aggregate of the sea urchin *Diadema setosum* were found, probably indicating either absence of potential predators or low level of exploitation. It would be of immense importance for future studies to consider monitoring population densities of gleaned or targeted species over time or between seasons (wet and dry) and different monsoon (southwest, northwest, and interim) periods. Because of the apparent influence of pollution from sewage, we recommend that physico-chemical parameters (nitrate, phosphate, salinity, temperature) should also be monitored, especially in seagrass-algal beds of Dumaguete and adjacent localities.
Key Words: exploitation, fishery, gastropods, mollusks, pollution, sea urchin.

Introduction. Macroinvertebrates make up a significant portion of different kinds of fisheries in the Philippines, comprising at least 10% of all fishery landings (Ciasico et al 2006). Many of them are commercially important species (del Norte-Campos et al 2005; Floren 2003), that have become the target of many fishing gears (del Norte-Campos et al 2003) such as gleaning. Gleaning in highly-accessible fishing grounds (seagrass beds) requires the least of implements, and as such, is a highly favored fishing method for coastal communities.

Despite the importance of gleaning, there is a general lack of information in the country on this type of fishing method except for the works of Nieves et al (2010) in Lagonoy Gulf, Luzon, Alcala and Alcazar (1984) in Bais Bay, Negros Oriental, Schoppe et al (1998) on the Cuatro Islas, Leyte, and del Norte-Campos et al (2003) on Malalison Island, Antique. One of the heavily gleaned but poorly studied macroinvertebrates are the conch shells of the Family Strombidae (Ciasico et al 2006), especially the genus *Lambis*, both in the Philippines (Barut et al 2004) and elsewhere (Allen and McKenna 2001).

In Siquijor where more than two thirds of the population (c. 88,000) lives in coastal barangays and small-scale fisheries contribute significantly to income and food security. Such dependence to fisheries caused exploitation of coastal resources such as finfish and shellfish (Bendijo et al 2004). Recently, Wagey (2014) reported a collapse in the local abalone fishery presumably due to overexploitation. Wagey & Bucol (2016), using indigenous ecological knowledge approach, described a significant decline in catch-per-unit effort of strombids in the northwestern Siquijor, again, due to overharvesting of targeted species. Likewise, Bucol (2016) described harvesting of macroinvertebrates (e.g. sea urchins, gastropods) in Siquijor but the status of such fisheries as well as their standing stocks remain to be assessed in details. A few studies (e.g. population density assessment) have been done on selected commercially important species such as the spider conch *Lambis* sp., including Hermosilia & Narido (2007).

The goal of this paper is to describe patterns in density and diversity of benthic macroinvertebrates in the seagrass-algal beds of Dumaguete (heavily exploited and polluted sites) and Siquijor (non-polluted sites), central Philippines. Because most species in seagrass-algal beds are widespread and once abundant prior to exploitation, surveying a highly disturbed seagrass beds would provide insights as to what species have been locally depleted through exploitation or affected by pollution.

Material and Method. Between March to April 2014, we conducted the survey in two contrasting marine environments, specifically seagrass and/or algal beds situated in (1) Dumaguete sites (Piapi and Agan-an, Figure 1a) representing seagrass-algal communities subjected to anthropogenic disturbances, being in an urban environment, such as organic pollution (e.g. sewage) and intensive harvesting of edible macroinvertebrates; and (2) western Siquijor Island (Figure 1b) representing areas without immediate source of pollutants, covering the Barangays of Tambisan (9°11′10.16″N, 123°27′14.01″E), municipality of San Juan to the north of Alibangbang (9°13′32.13″N, 123°27′55.81″E) which is partly part of the municipality of Siquijor. A previous study (Kaczmarsky & Richardson 2011) showed that the level of organic pollutants (total nitrogen and phosphate in water) ranged from 6.3-14.6 to 0.18-0.98 μmol L^{-1}, respectively. While there is no available data on nitrates and phosphates in Siquijor sites, apparently these sampling sites were bereft of potential pollution sources given its distance from densely populated areas.

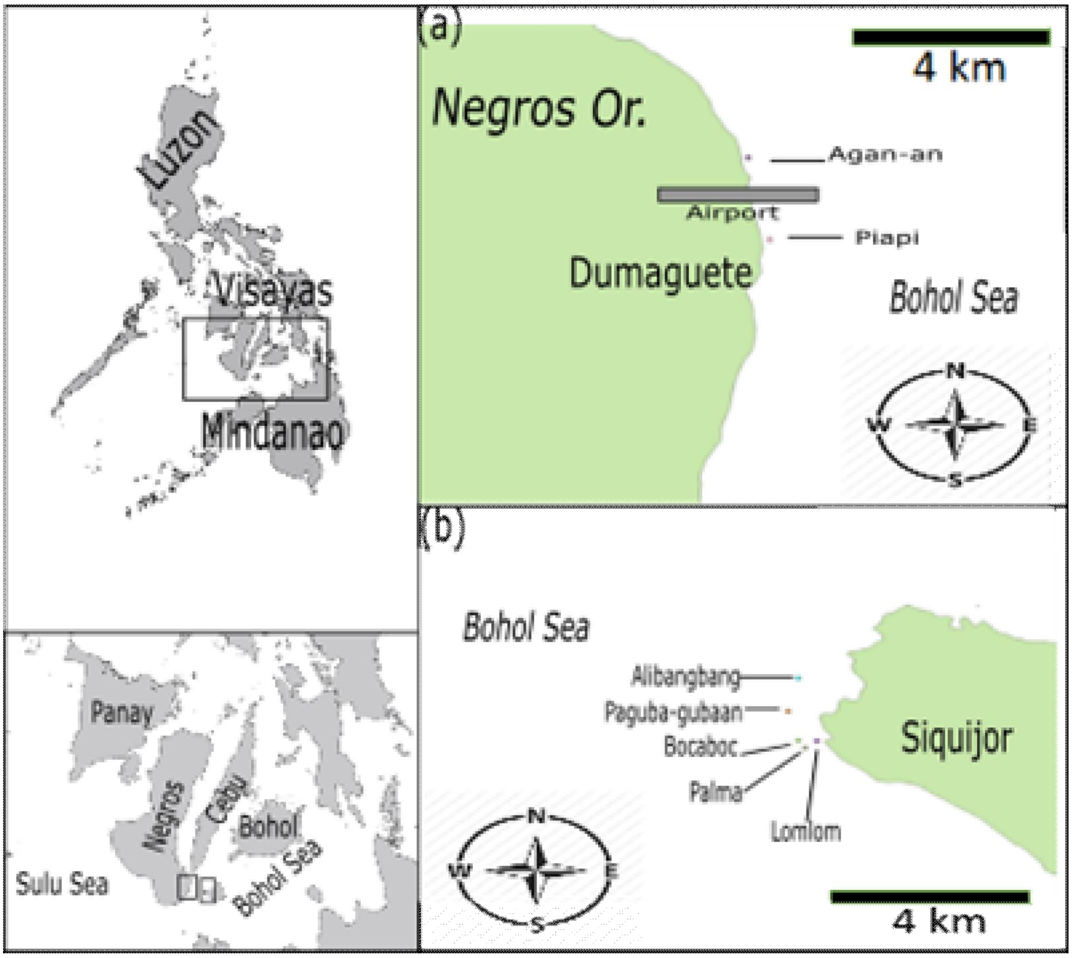

Figure 1. Map showing the location of the study sites in Dumaguete (a), and the northwestern coast of Siquijor (b).

Dumaguete sites

Piapi. This site is ~200 m from a densely populated coastline where untreated sewage directly flows in front of patchy seagrass-algal beds. Generally, *Cymodocea rotundata* dominated the shallow intertidal and continues offshore near the survey site, where *Halodule uninervis* and *H. pinifolia* mixed with *Cymodocea serrulata* and *Thalassia hemprichii*. Few patches of *Halophila minor* can also be seen especially near sandy patches. During lowest tides, gleaners usually flock into this area to glean edible macroinvertebrates (mainly strombids and sea urchins). The sea urchin *Tripneustes gratilla* are targeted here for its roe, often sold at Php 80-120/bottle or just consumed locally.

Agan-an. This site, located north of the Dumaguete Airport jetty, is often visited by local tourists, especially during weekends. As a result, most of the segrass-algal beds are now found at ~100 m offshore. Edible macroinvertebrates are also gleaned in patches of *Thalassia-Syringodium* beds. Like Piapi, the site is right in front of dense households, which directly discharge household wastes into the sea. Moreover, immediately south of the airport jetty, both solid and liquid wastes are drained from the interior of the city through the Mojon Creek.

Siquijor sites

Alibangbang. This site is a rock awash located 1.52 km to the west of Solong-on wharf. It is separated by the latter through a 400 m-wide lagoon. Benthic composition of this site is mainly macroalgae (*Sargassum polycystum* and *Padina* spp.).

Pagubagubaan. This reef flat was mainly an algal-dominated site. Species such as *Ulva reticulata* (green alga) and *Portieria hornemannii* and other red algae (*Galaxaura*) dominate the limestone platform. This site is located 0.68 km offshore from Tambisan wharf.

Bocaboc. This has similar features to Alibangbang site but the rocky outcropping (rock awash) is wider. It is also algal-dominated but adjacent to the continuous seagrass bed, known locally as lollom.

Lomlom. This is a continuous seagrass meadows that extend from the adjacent barangay of Paliton to the north of Lapac embayment, ending as it reached the lagoon. The seagrasses *Enhalus acoroides*, *Syringodium isoetifolium*, and *T. hemprechii* are the dominant species.

Palma. This site is similar to Pagubagubaan in terms of general features but dominated by *Sargassum polycystum* and *Turbinaria* instead of the brown (*Padina* spp.) and red algae (e.g. *P. hornemannii*).

Sampling techniques. Benthic composition was assessed using the point intercept method as described by English et al (1997) along at least three 50 m-transects laid perpendicular to the contour of the shoreline. Using the same transect line, sampling of macroinvertebrates was done by counting any visible macroinvertebrates found on each side (2 m), thus covering a census area of 200 m^2 per transect, as modified from other authors (e.g. Hermosilia & Narido 2007). These transects were laid on the substrate in both intertidal and subtidal zones of each sampling site. Once transects are laid, the gleaners (at least two) collect individuals of macroinvertebrates (including other commercial gastropods) within the 200 m^2 while swimming using improvised goggles and fins.

Except for the sea urchin *Diadema setosum*, all individuals were placed in labeled net bags. After every collection, the bags containing the shells were brought on shore for species identification (e.g. Abbott & Dance 2000) and counting. Density (expressed as the average number of individuals/200 m^2) were determined from the number of individuals of each species found on three transects.

Diversity. To compare diversity of macroinvertebrates between sites, the Shannon-Weiner Index was used:

$$H = -\sum_{i=1}^{s} pi \ln pi$$

where pi = proportion of individuals belonging to i^{th} species; ln = natural logarithm and s = the number of species.

Analyses. A One-way ANOVA was used to compare abundance across the survey sites. Analyses were carried out in either PAST3 (Hammer 2013) and RStudio 3.2.5 (R Core Team 2013) softwares. Prior to ANOVAs, data were checked to conform to parametric assumptions (normality, homogeneity of variance, outliers) using the *car* and *nortest* packages in R. Otherwise, data were log transformed or log (x+1) to remove zero counts (Zar 1999). In cases where transformation was not enough to meet parametric assumptions, the non-parametric equivalent (Kruskall-Wallis test) was used. Multivariate ordination analyses such as PCA (principal component analysis) and CCA (canonical correspondence analysis) were performed either using the *ggfortify* package in R or in PAST3. Interpretation of CCA generally followed Ter Braak (1986).

Results

Benthic composition. As shown in Figure 2, the benthic composition of most sites are mainly macroalgae (ALG) and seagrass (SG) beds with few sites with considerable extent of sand and rubble.

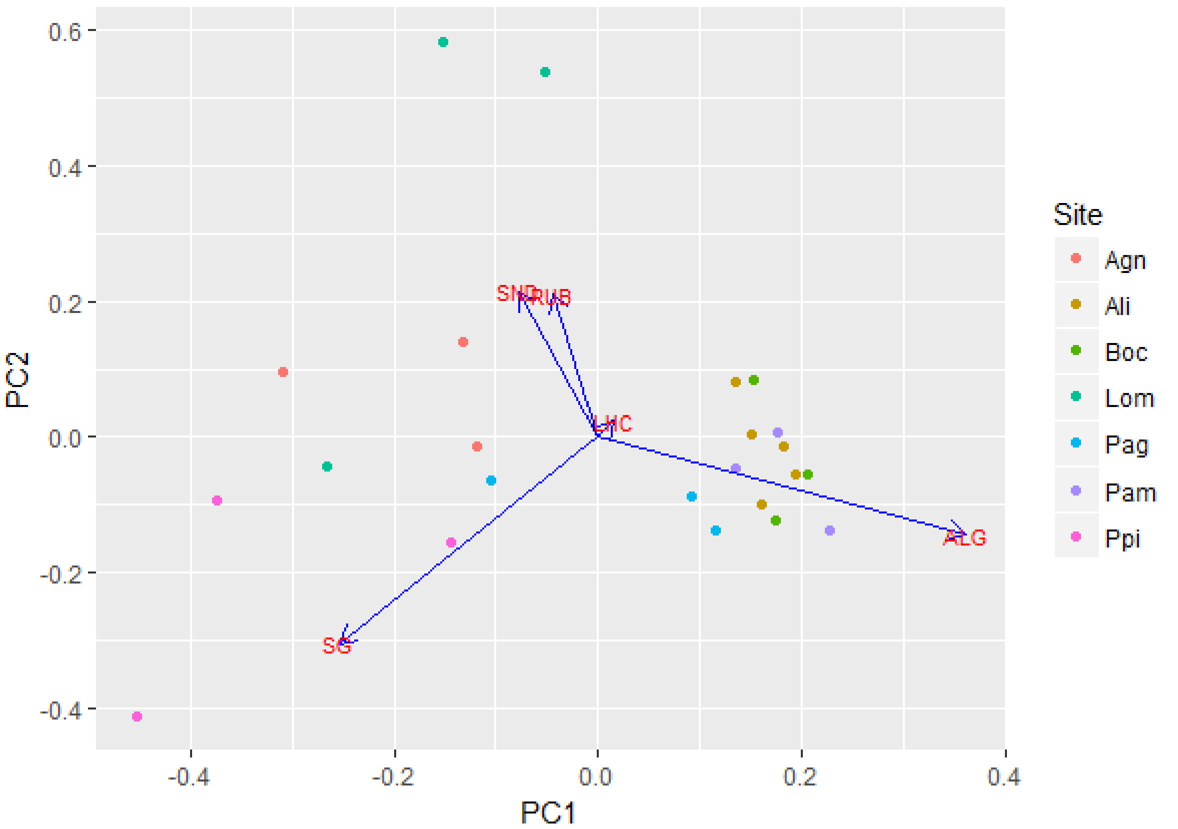

Figure 2. PCA biplot showing the major benthic categories and the study sites (Agn = Agan-an, Ali = Alibangbang, Boc = Bocaboc, Lom = Lomlom, Pag = Pagubagubaan, Pam = Palma, Ppi = Piapi).

Density of macroinvertebrates. Overall density estimates of macroinvertebrates (Figure 3) revealed a remarkable increased density in Piapi, Dumaguete, which was mainly attributed to high counts of the needle-spine urchin (*D. setosum*). This species congregate in high numbers in the seagrass beds of Piapi. This caused a skewed data, thus precluding the use of parametric tests. Kruskall-Wallis Test revealed a significant difference ($p < 0.05$) in sample medians ($\chi^2 = 16.38$, $p = 0.01185$). A subsequent post hoc (Mann-Whitney U) test indicate that the significant difference was attributable to Pagubagubaan site in Siquijor.

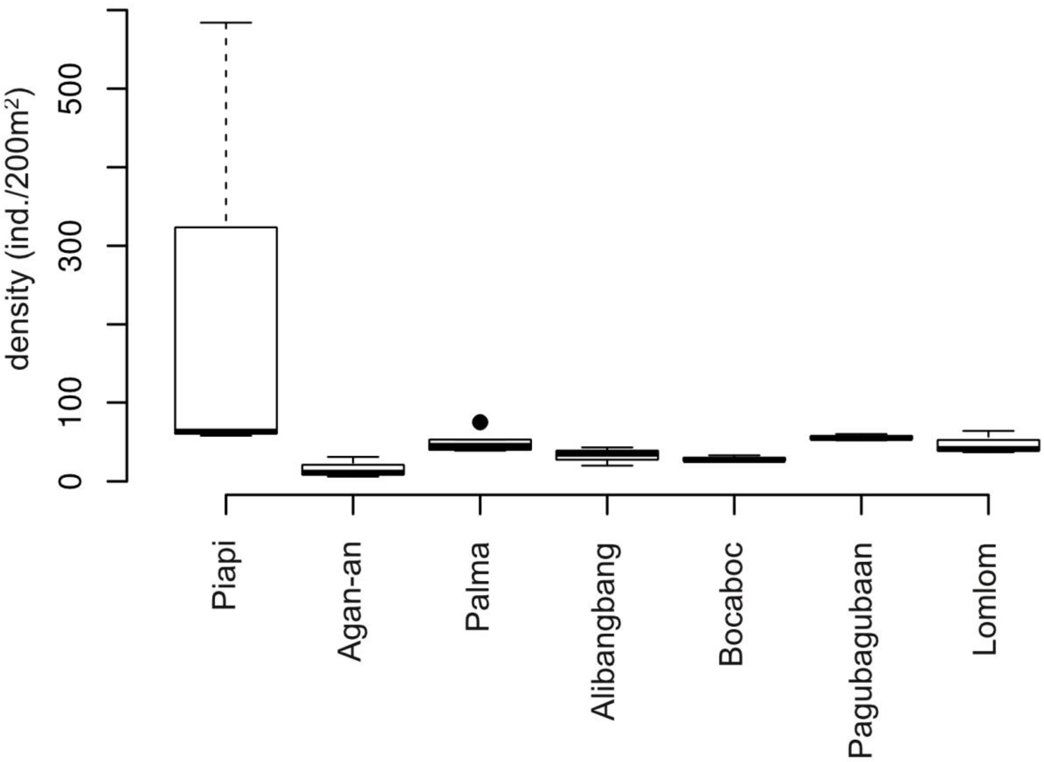

Figure 3. Overall density of macroinvertebrates in all sampling sites.

Densities of four harvested invertebrate taxa (*Lambis* spp., *Strombus* spp., *T. gratilla*, and *D. setosum*) are shown in Figure 4. *Lambis* spp. and *Strombus* spp. were apparently absent in the two sites in Dumaguete while still relatively abundant in Siquijor sites. Although *T. gratilla* and *D. setosum* were found in both islands, they were found in low densities in Siquijor where they are harvested on a daily basis by the locals. In contrast, these two echinoid species were found in higher densities in Dumaguete where harvesting was likely minimal and in the case of *D. setosum*, not targeted by the local urchin gleaners. One-Way ANOVA revealed of the four taxa, significant difference in mean densities was detected only in *Lambis* spp. and *T. gratilla* (Table 1).

Table 1

Summary of One-Way ANOVA on mean density of taxa between sites (Df - degrees of freedom, SS - sum of squares)

Taxa	*Df*	*SS*	*F-value*	*p-value*	*Significance*	*Post hoc (Tukey's HSD)*
Lambis spp.	6	2.139	4.193	0.0101	*	
Strombus spp.	6	1.52	1.925	0.138	n.s.	
Tripneustes gratilla	6	5.375	4.517	0.00731	**	Piapi>Pagubagubaan, Palma
Diadema setosum	6	3.336	1.48	0.247	n.s.	

Significance codes: 0.001 '**'; 0.01 '*'; 0.05 (n.s.) not significant at 0.05.

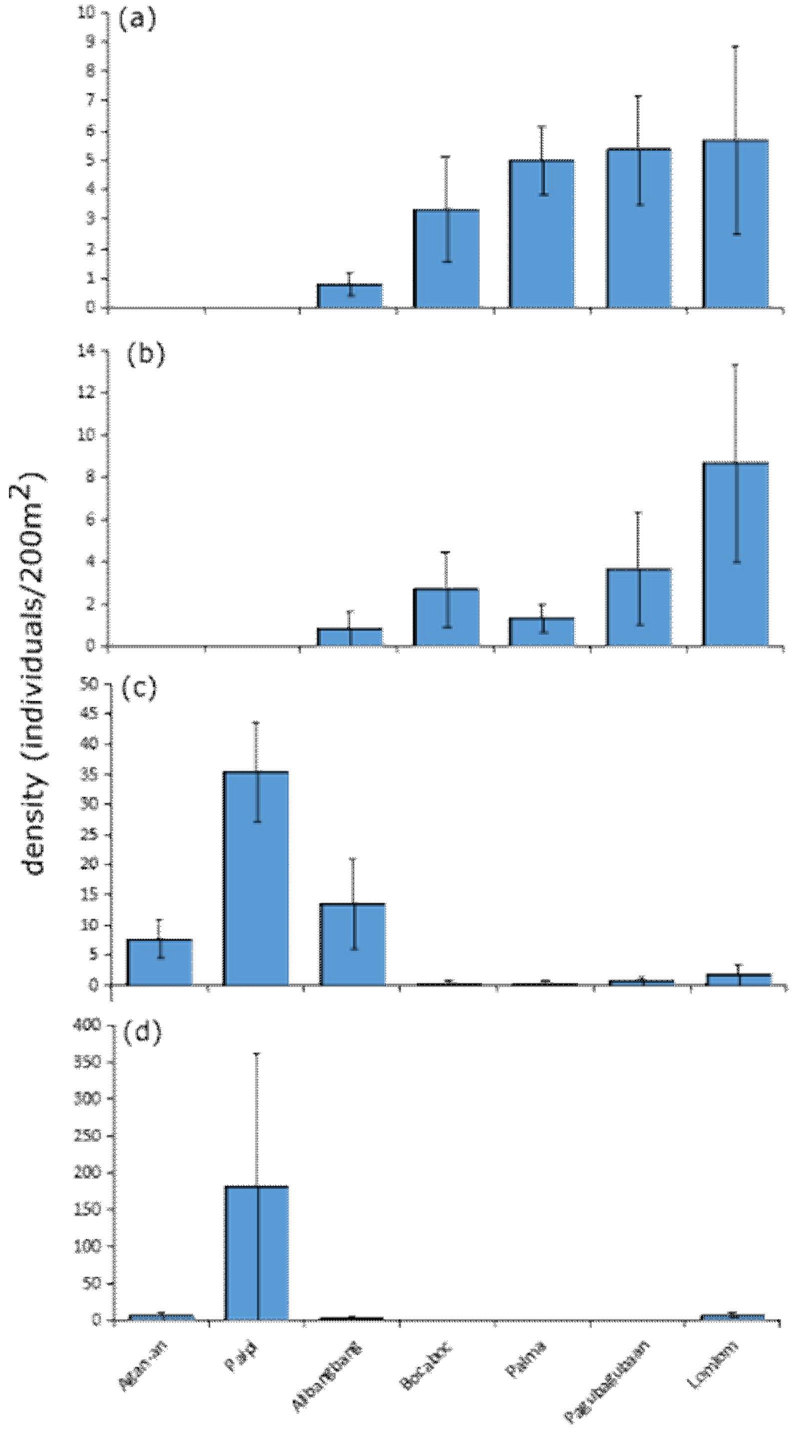

Figure 4. Density of harvested macroinvertebrates (a = *Lambis* spp., b = *Strombus* spp., c = *Tripneustes gratilla*; and d = *Diadema setosum*) in all sampling sites.

Diversity (plot bar chart of Shannon-Weinner H). Of all sites surveyed, Piapi and Agan-an showed lowest Shannon-Weiner H indices comparably lower than all sites in Siquijor (Figure 5).

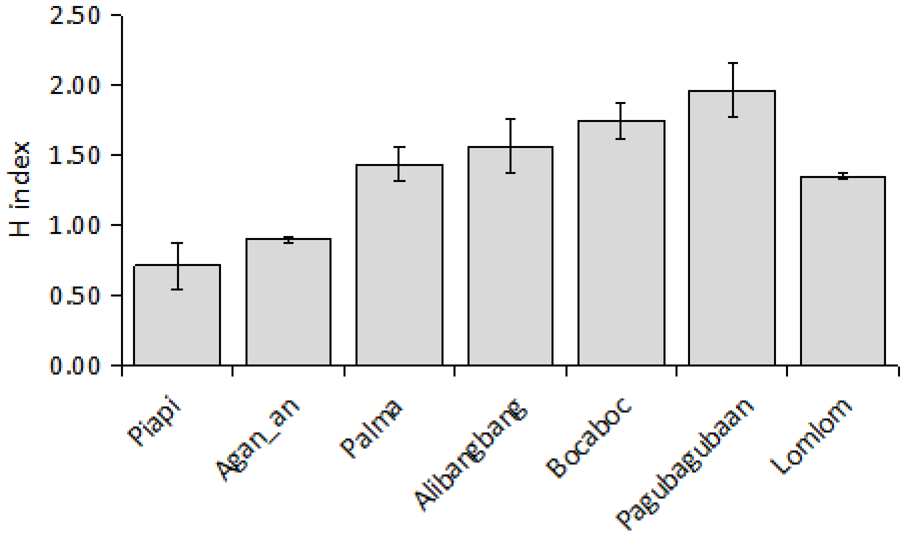

Figure 5. S-W Diversity indeces of macroinvertebrates in all sampling sites.

Community structure. At least 14 taxa (rarely encountered were not included in the analysis) were subjected to canonical correspondence analysis (CCA). CCA revealed (Figure 6) that the variation in the abundance of macroinvertebrates was mainly explained by the first axis (69.76%) with eigenvalue of 0.17757. Of the species subjected to CCA, *D. setosum* was mainly influenced by the presence of macroalgae while sand has a strong negative influence to its abundance. On the other hand, *T. gratilla* was strongly influenced by seagrass cover (Axis 2, eigenvalue = 2.64). Live coral cover, which was evident only in one site and rubble had little to moderate influence on any species. Commercially-important species of macroinvertebrates found in the study area are shown in Figures 7 and 8.

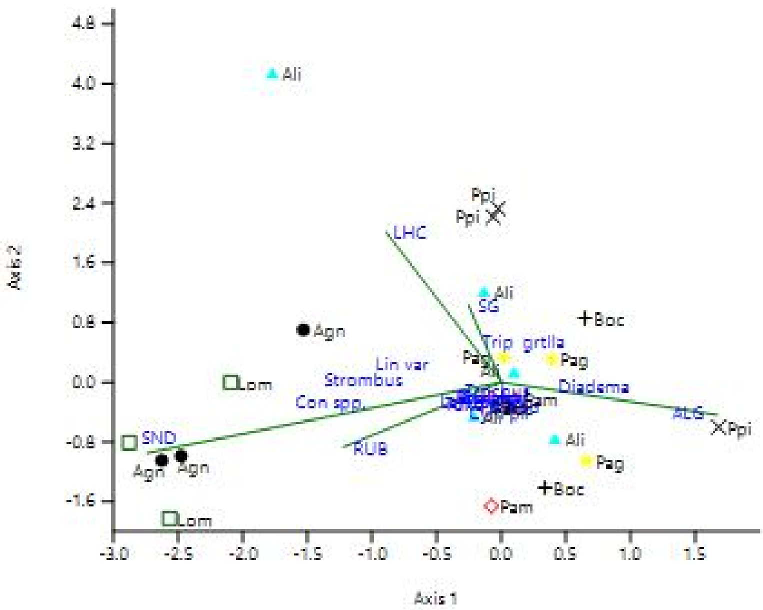

Figure 6. CCA bi-plot showing the influence of benthic composition on abundance of species.

Figure 7. Macroinvertebrates (Family Strombidae) species encountered during the survey: a. *Lambis chiragra* (adult); b. *L. chiragra* (juvenile); c. *L. lambis*; d. *L. scorpius*; e. *Strombus lentiginosus*; f. *S. sinuatus*.

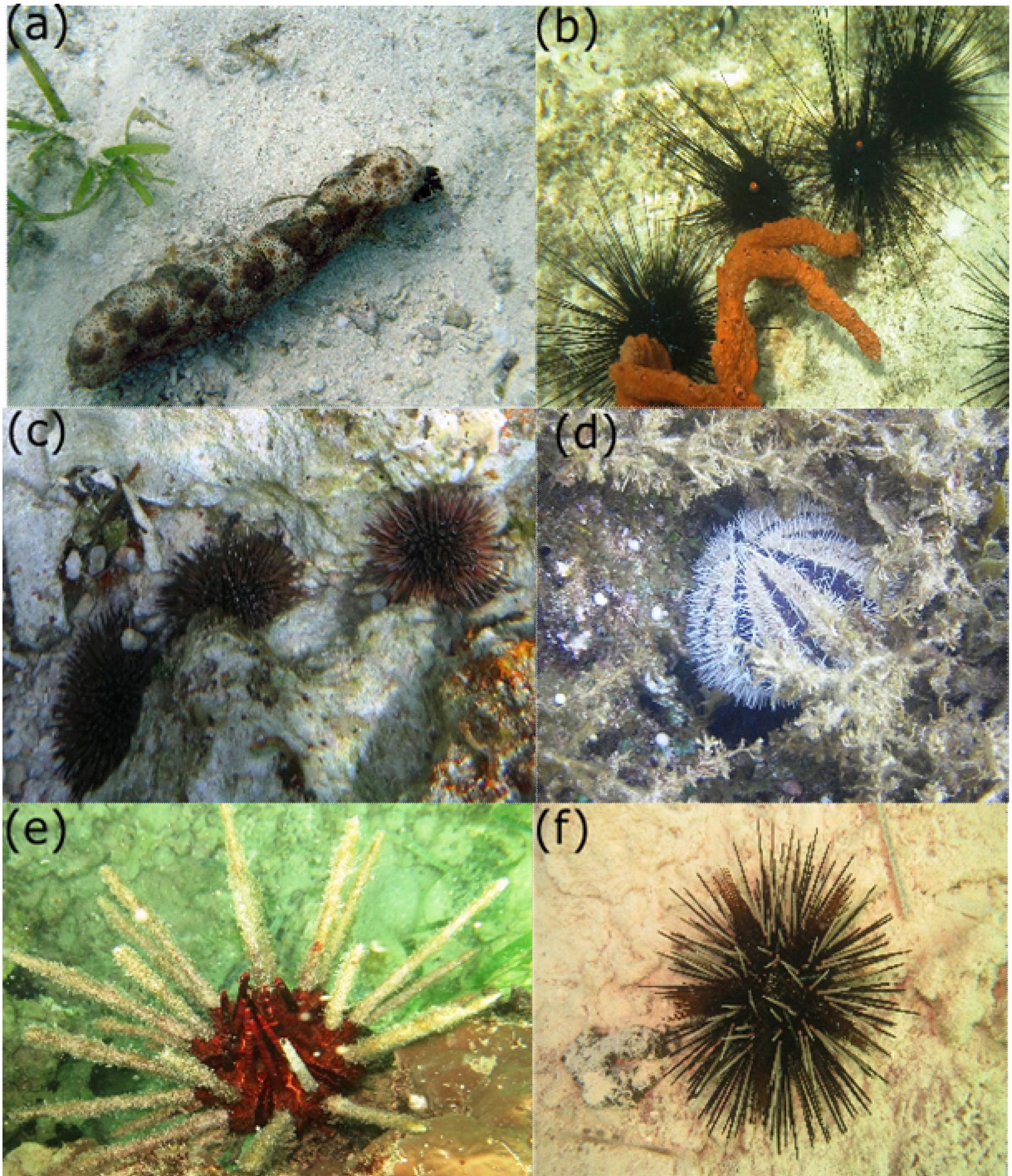

Figure 8. Macroinvertebrates (Echinodermata) species encountered during the survey: a. *Pearsonothuria graeffei*; b. *Diadema setosum*; c. *Echinometra mathaei*; d. *Tripneustes gratilla*; e. *Heterocentrotus mammillatus*; f. *Echinothrix calamaris*.

Discussion. The main implication of this study is that we were able to assess the status of macroinvertebrates in selected localities, two of which were located near urban areas where pollution and overexploitation are apparent. We also identified targeted taxa (e.g. *Lambis* species) that may face local depletion due to these two major anthropogenic factors. In the seagrass-algal beds of Dumaguete where *D. setosum* was not harvested and potential fish predators (Lethrinidae, Balistidae) are heavily fished, massive congregate of this species were found, suggesting trophic cascades effect (Wallner-Hahn et al 2015) which may also affect above-ground biomass of seagrasses. The impact of sea urchin on the algal and seagrass biomass is well-known in experimental studies (e.g. Alcoverro & Mariani 2002; Eklöf et al 2008; Ishikawa et al 2016).

The densities of commonly harvested taxa of macroinvertebrates were comparable to the findings of other investigators in the study region such as Hermosilia & Narido (2007) in Panglao Bay, Bohol for gastropods. The mean population densities of *Strombus* in this study (< 10 ind/200 m^2) was lower compared to the densities of this genus in Samar (Ciasico et al 2006). In terms of the number of species, our results were lower (18 species only) compared to the reports elsewhere such as in Indonesia by Litaay (2006) where they identified 29 species. This might be attributed to fact that we only sampled in one season (dry season) in each locality.

There are five species of *Lambis* in the Philippines, two of which were not encountered by this study (*L. crocata* and *L. millipeda*), both are becoming rare and are sold individually at Php 10-15 pesos per shell depending on the quality. The three species encountered in this survey had very low density, which parallels with the findings of other studies. Hermosilia & Narido (2007) found out that roughly 78% of the commercial gastropods (including *Lambis* spp.) in Panglao Bay had very low population density of about one individual/100 m^2. Of the three species, only *L. lambis* was observed in all sites in Siquijor, suggesting a gradual decline in abundance. Abundance of *L. lambis*, however, does not vary significantly between sites. It is of interest to note that *L. chiragra* and *L. scorpius* were of very low densities and absent in one or two sites. These species are regularly harvested by the local gleaners for the local market (Wagey & Bucol 2016). Based on the traditional ecological knowledge of the local fishers and gleaners with an age bracket of 70-80 years old, prior to and immediately after the 2nd World War, in an hour of gleaning at least a 20-30 kg basket can be filled immediately with the three species of *Lambis* combined. If this estimate by the locals is accurate, it would mean a significant decline because at present, on average, each person can only accumulate about 1 kg per hour of intensive gleaning (Wagey & Bucol 2016).

One of the most commercially important sea urchins in the Philippines is *T. gratilla,* which was the subject to re-stocking in northern Philippines following depletion in the 1990s (Juinio-Meñez et al 2008). It is being harvested in central Philippine islands (including Negros and Siquijor), due to its pleasant roe and ease of harvesting by bare hands, especially around new moon when their gonads (roe) are enlarged (Wagey & Bucol 2016; Bucol 2016).

Conclusions. This study described the status of standing stocks of macroinvertebrates in seagrass-algal beds subjected to varying degrees of pollution and exploitation. Exploited macroinvertebrates were found in low densities where they are harvested.

It would be of immense importance for future studies to consider monitoring population densities of gleaned or targeted species over time or between seasons (wet and dry) and different monsoon (southwest, northwest, and interim) periods. Because of the apparent influence of pollution from sewage, we recommend that physico-chemical parameters (nitrate, phosphate, salinity, temperature) should also be monitored, especially in seagrass-algal beds of Dumaguete and adjacent localities.

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References

Abbott R. T., Dance S. D., 2000 Compendium of seashells, a full-color guide to more than 4,200 of the world’s marine seashells. Melbourne, American Malacologists, Inc., 424 pp.

Alcala A. C., Alcazar S., 1984 Edible molluscs, crustaceans, and holothurians from North and South Bais Bays, Negros Oriental, Philippines. Silliman Journal 31(1-4):25-45.

Alcoverro T., Mariani S., 2002 Effects of sea urchin grazing on seagrass (*Thalassodendron ciliatum*) beds of a Kenyan lagoon. Marine Ecology Progress Series 226:255-263.

Allen G. R., McKenna S. A., 2001 RAP 20: marine rapid assessment of the Togean and Banggai Islands, Sulawesi, Indonesia. RAP Bulletin of Biological Assessment, Conservation International, Washington, 145 pp.

Barut N. C., Santos M. D., Garces L. R., 2004 Overview of Philippine marine fisheries. In: Turbulent seas: the status of Philippine marine fisheries. Department of Agriculture - Bureau of Fisheries and Aquatic Resources. Coastal Resource Management Project of the Department of Environment and Natural Resources, Cebu City, Philippines, pp. 22-31.

Bendijo R., Alcala M. L. R., Ablong W., 2004 Siquijor coastal environment profile. Coastal Resource Management Project, Cebu City, 365 pp.

Bucol A. A., 2016 Diminishing sustainability of traditional fishing practices in Siquijor Island, central Philippines. Traditional Marine Resource Management and Knowledge Information Bulletin 36:3-12.

Ciasico M. N. A., Villaluz E. A., Geraldino P. J. L., Dy D. T., Diola A. G., 2006 Initial stock assessment of four *Strombus* species (Mollusca: Gastropoda) in Eastern Samar (Central Philippines) with notes on their fishery. The Philippine Scientist 43:52-68.

del Norte-Campos A. G. C., Declarador M. B., Beldia R. A., 2003 Catch composition, harvest and effort estimation of gleaned macroinvertebrates in Malalison Island, northwestern Panay. UPV Journal of Natural Sciences 8(1-2):129-141.

del Norte-Campos A. G. C., Campos W. L., Villarta K. A., 2005 A survey of macro-invertebrate gleaning in the Banate Bay intertidal area, Eastern Panay Island. Science Diliman 17(2):11-20.

Eklöf J. S., De la Torre-Castro M., Gullström M., Uku J., Muthiga N., Lyimo T., Bandeira S. O., 2008 Sea urchin overgrazing of seagrasses: a review of current knowledge on causes, consequences, and management. Estuarine, Coastal and Shelf Science 79(4):569-580.

English S. S., Wilkinson C. R., Baker V. V., 1997 Survey manual for tropical marine resources. Second edition, Australian Institute of Marine Science, Townsville, 390 pp.

Floren A. S., 2003 The Philippine shell industry with focus on Mactan, Cebu. Coastal Resource Management Project of the Department of Environment and Natural Resources, 50 pp.

Hammer Ø., 2013 PAST Paleontological Statistics Version 3.0: Reference Manual. University of Oslo. Oslo, 253 pp.

Hermosilia J. J., Narido C. I., 2007 Population assessment of commercial gastropods and the nature of gastropod fishery in Panglao Bay, Bohol, Philippines. An Interdisciplinary Research Journal 18(2):1-9.

Ishikawa T., Maegawa M., Kurashima A., 2016 Effect of sea urchin (*Diadema setosum*) density on algal composition and biomass in cage experiments. Plankton and Benthos Research 11(4):112-119.

Juinio-Menez M. A., Bangi H. G., Malay M. C., Pastor D., 2008 Enhancing the recovery of depleted *Tripneustes gratilla* stocks through grow-out culture and restocking. Reviews in Fisheries Science 16(1-3):35-43.

Kaczmarsky L., Richardson L. L., 2011 Do elevated nutrients and organic carbon on Philippine reefs increase the prevalence of coral disease? Coral Reefs 30(1):253-257.

Litaay M., 2006 Macroinvertebrates associated with seagrass at Awerange and Labuange Bays, South Sulawesi. TORANI 15(5):359-367.

Nieves P. M., de Jesus S. C., Macale A. M. B., Pelea J. M. D., 2010 An assessment of macro-invertebrate gleaning in fisheries on the Albay Side of Lagonoy Gulf. Kuroshio Science 4(1):27-35.

R Core Team, 2013 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org/. Accessed: June, 2016.

Schoppe S., Gatus J., Milan P., Seronay R. A., 1998 Gleaning activities on the islands of Apid, Digyo, and Mahaba, Inopacan, Leyte, Philippines. The Philippine Scientist 35:130-140.
Ter Braak C. J. F., 1986 Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67(5):1167-1179.
Wagey B. T., 2014 The collapse of donkey's ear abalone (*Haliotis asinina*) fishery in Siquijor, Philippines. e-Journal Budidaya Perairan 2(2):1-6.
Wagey B. T., Bucol A. A., 2016 Indigenous ecological knowledge (IEK) on the utilization and conservation of coastal resources in Siquijor Island, central Philippines. Ecology, Environment and Conservation 22(3):111-118.
Wallner-Hahn S., de la Torre-Castro M., Eklöf J. S., Gullström M., Muthiga N. A., Uku J., 2015 Cascade effects and sea-urchin overgrazing: an analysis of drivers behind the exploitation of sea urchin predators for management improvement. Ocean and Coastal Management 107:16-27.
Zar J. H., 1999 Biostatistical analysis. Fourth edition, Prentice Hall, Upper Saddle River, New Jersey, USA, pp. 592-663.

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Authors:
Billy Theodorus Wagey, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota Manado 95114, Indonesia, e-mail: billywagey@unsrat.ac.id
Reni Lucia Krechoff, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota Manado 95114, Indonesia, e-mail: reni.lucia@yahoo.com
Abner A. Bucol, Negros Oriental State University, Main Campus I, Kagawasan Ave., 6200 Dumaguete City, Negros Oriental, Philippines, e-mail: abnerbucol2017@gmail.com

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