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

Billy T. Wagey, Reni L. Kreckhoff, Abner A. Bucol

Faculty of Fisheries and Marine Science, Sam Ratulangi University, Jl. Kampus Unsrat, Bahu, Manado, Indonesia; 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).](image-url)
**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 seagrass-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 m² 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 m² 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 m²) 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:

\[ H = -\sum_{i=1}^{s} p_i \ln p_i \]

where \( p_i \) = 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).](image-url)
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

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Df</th>
<th>SS</th>
<th>F-value</th>
<th>p-value</th>
<th>Significance</th>
<th>Post hoc (Tukey’s HSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambis spp.</td>
<td>6</td>
<td>2.139</td>
<td>4.193</td>
<td>0.0101</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Strombus spp.</td>
<td>6</td>
<td>1.52</td>
<td>1.925</td>
<td>0.138</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Tripneustes gratilla</td>
<td>6</td>
<td>5.375</td>
<td>4.517</td>
<td>0.00731</td>
<td>**</td>
<td>Piapi&gt;Pagubagubaan, Palma</td>
</tr>
<tr>
<td>Diadema setosum</td>
<td>6</td>
<td>3.336</td>
<td>1.48</td>
<td>0.247</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

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-Weiner 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 indicies 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*. 

**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 congregates 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 m²) 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 m². 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-Meñeze 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.

**Acknowledgments.** We thank the local fishers of Tambisan, San Juan, who participated during surveys. This study was supported in part by Marine Biology Laboratory, Faculty of Fisheries and Marine Science, Universitas Sam Ratulangi (UNSRAT), Manado, Indonesia through Dr. B. Wagey.

**References**


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.


