Enhancement Effect of Sea Urchin Grow-out Cages in Lucero, Bolinao, Pangasinan

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ABSTRACT

A preliminary study was conducted on the environmental impact of sea urchin (*Tripneustes gratilla Linnaeas*) grow-out culture in Lucero, Bolinao, Pangasinan. It was hypothesized that the feces generated by the caged urchins (~6,000 individuals at any one time) might cause localised sediment organic enrichment and subsequent shifts in benthic faunal communities. Results from preliminary surveys conducted in April and August of 1999 indicated minimal impact of sea urchin grow-out culture on the local reef flat community. Some enhancement of faunal abundance and sediment organic matter content in the cage area were noted; however, the impact was limited to a radius of 5-25 meters from the grow-out cages. The enhancement effects appeared to be seasonal occurrences that were dependent on local currents and degree of wave exposure. Epiphyte biomass, total suspended solids, sediment grain size, and relative water movement seemed largely unaffected by sea urchin grow-out culture. However, more frequent and thorough samplings are needed to validate these initial results. The presence of localised enrichment in sediment organic content and epibenthic faunal density suggest the possibility of converting the sea urchin grow-out area into polyculture systems that would make more efficient use of the food resources available while minimizing potential anthropogenic impacts on the environment.

Keywords: sea urchin, aquaculture, environmental impact, enhancement effect, organic enrichment

INTRODUCTION

Numerous studies have documented the impact of aquaculture activities on the marine environment (reviewed in Buschmann and others 1996). For the most part, research has been centered on the effects of fish farms and mussel farms on the sediment and water column. Nutrients and waste emanating from fish farms may cause localised changes in the physical and chemical characteristics of the sediment, elevating organic matter content, nitrogen and phosphorous levels, and sediment metabolism and sulfate reduction (Findlay and others 1995, Holmer and Kristensen 1992, Karakassis and others 1998). These changes in physicochemical parameters may in turn cause shifts in benthic faunal assemblages and increase epibenthic faunal densities (Findlay and others 1995, Karakassis and others 1999). While mussel farming generally has less environmental impact than fish farming, biodeposition from mussel lines may also result in local increases in sediment nutrient and organic matter content, consequently changing the structure of benthic communities (Castel and others 1989, Grant and others 1995, Hatcher and others 1994). High nutrient levels in the water column can also cause eutrophication and

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increase algal epiphyte biomass. Large epiphyte loads may have detrimental effects on the productivity of submerged macrophytes through shading and reduced nutrient availability (Duarte 1995, Frankovich and Fourqurean 1997, Wear and others 1999).

The grow-out culture of the commercially-important sea urchin *Tripneustes gratilla* is an emerging technology currently being refined and promoted in Bolinao, Pangasinan by the University of the Philippines - Marine Science Institute (UP-MSI). The UP-MSI's sea urchin research project aims to aid in the recovery of natural spawning populations of *T. gratilla* that were severely depleted in the early 1990s because of uncontrolled harvesting of fishery stocks (reviewed in Juinio-Meñez and others 1998). While grow-out culture in sea pens is deemed a very promising fishery management strategy (Juinio-Meñez and others 1998), the potential impact of small-scale sea urchin cage culture on the local environment has yet to be studied. *T. gratilla* are herbivores that consume approximately 20% of their body weight in plant matter per day (Bangi, unpubl. data), and produce correspondingly large amounts of feces on a daily basis. Their feces have been shown to contain large amounts of ammonium that enhance the nitrogen levels of the water column (Koike and others 1987) and to contribute to the biodeposition of organic matter in the sediment. The culture pens in the main pilot grow-out site in Lucero, Bolinao occupy an area of 64 m^2 and typically hold up to 6,000 sea urchins at any one time. Hence, cage grow-out in this site may have a significant impact on the local reef flat community. However, it is postulated that the overall effect of small-scale sea urchin culture is minimal compared to finfish culture because only natural, not artificial algal feeds (e.g., the brown seaweed *Sargassum* sp.) are used.

This paper presents the initial findings of a study on the environmental impact of a small-scale sea urchin grow-out culture on a shallow seagrass reef flat. To quantify the impact, the following parameters were assessed: epibenthic faunal abundances, epiphyte biomass, sediment grain size, total sediment organic matter, total suspended solids, and relative water movement with respect to distance from the grow-out cages.

METHODOLOGY

Study area and sampling station

The study was conducted on a seagrass bed along a reef flat in Bo. Lucero, Bolinao, Pangasinan, where sea urchin pens were set up three years ago (Fig. 1). Four 50-m transects radiating from the grow-out cages (two transects are parallel to the shore, and the other two are perpendicular to the shore) were established. In each transect, permanent sampling stations were set up at 0 (right beside the cages), 5, 25, and 50 meters from the cages. Samplings of all parameters were done in triplicate, in April and August 1999 (the 50-m stations were not sampled in August, except for the total suspended solids, as detailed below).

Benthic macrofauna

Using a 0.25 m^2 quadrat, the benthic macrofauna were collected, sorted into epiphytic ("leaf") or epibenthic ("sediment") component, stored in plastic bags, preserved in 10% buffered formalin, identified to genus

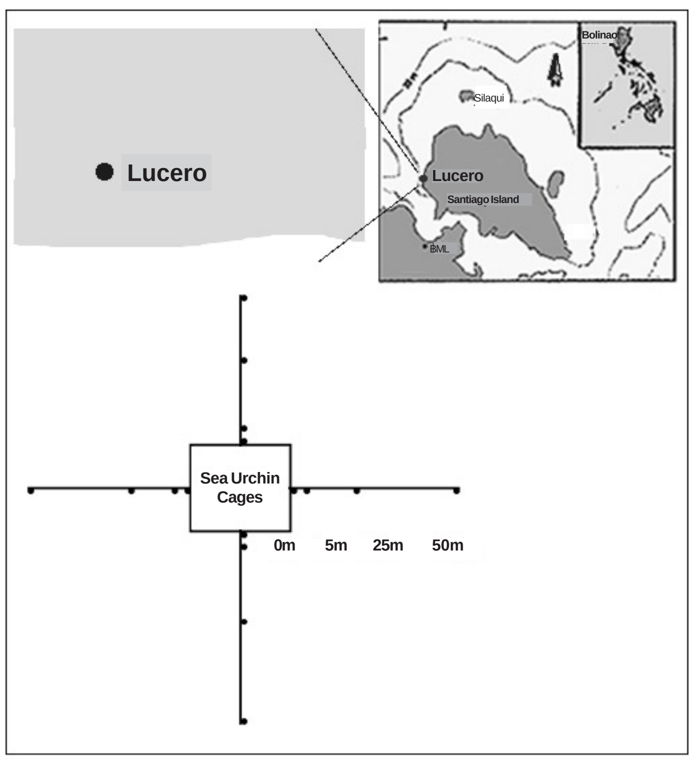


Fig. 1. Diagram showing experimental sampling design. Inset: Location map of study site in Lucero, Bolinao, Pangasinan

level (when possible), and counted. Their faunal density data were expressed in number of animals per m^2. Two-way ANOVA ($p<0.05$) was used to determine significance of results.

Epiflora (seagrass epiphytes)

Shoots of the dominant, seagrass *Enhalus acoroides*, were collected from all sampling stations for epiphyte biomass studies. These were preserved in 10% buffered formalin upon reaching the laboratory. The epiphyte were carefully scraped off from every excised centimeter of the seagrass blade. Their biomass were measured after drying in the oven to constant weight at 60°C. Two-way ANOVA ($p<0.05$) was used to test the significance of variation in epiphyte dry weights with respect to the distance from the grow-out site and the transect surveyed.

Sediment analyses

Sediment samples were obtained using cylindrical corers and were immediately placed on ice and stored at 20ºC upon reaching the laboratory. The upper layer (0-1 cm) was analyzed separately from the lower layer (1-5 cm). To determine sediment grain sizes, dried sediments were wet-sieved and graded using the Wentworth scale (Buchanan 1984).

Total sediment organic matter (TOM) was calculated as the difference between the weight of oven dried sediment and its ash (Buchanan 1984). Two-way ANOVA ($p<0.05$) was used to analyse results. The dependent variable was the percent organic matter content of the sediment while the independent variables were the transect sampled and the distance from the cages. Scatter plots were also constructed relating TOM and abundance of total fauna, gastropods, and the major taxa (*Strombus* sp., *Columbella* sp., and hermit crabs). The % TOM was assumed to be the independent variable while faunal density, the dependent variable.

Total suspended solids

One-liter samples of surface seawater were obtained from extreme sides of the transect (0 m and 50 m). These were filtered and the particulate material obtained was oven-dried to constant weight.

Water movement

The degree of water movement in all sampling stations was determined using clod cards (Doty 1971).

RESULTS

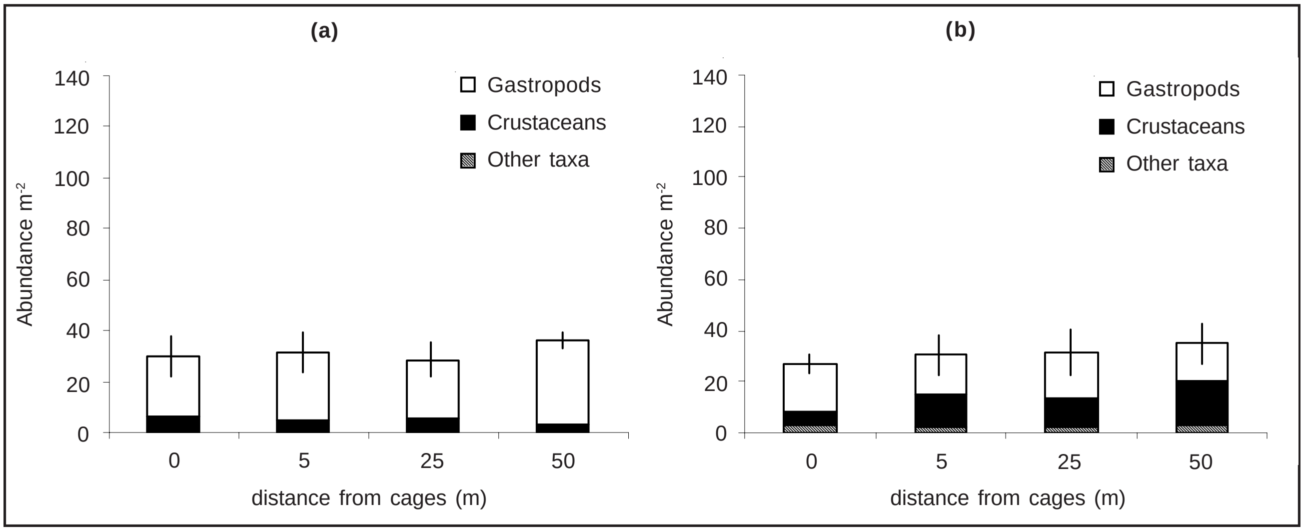
Benthic macrofauna

Total epibenthic fauna was higher in August (105 ± 1.63 to 213 ± 6.15 individuals m^{-2}) than in April (57 ± 11.63 to 71 ± 9.68 individuals m^{-2}) when the small (~1 mm shell length) gastropods *Columbella* sp.were dominant. Crustaceans (mainly hermit crabs) constituted the second most abundant group, followed by the holothurians (Figs. 2 and 3).

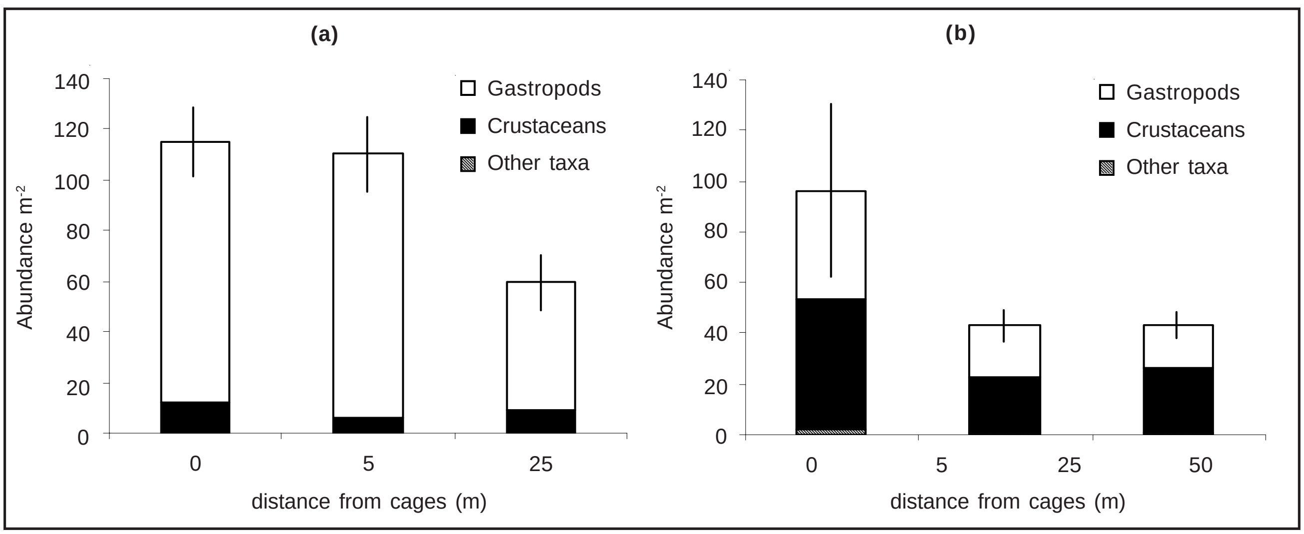
In April, total epibenthic faunal density, both leaf- and sediment-associated epibenthic fauna, were not significantly affected by distance from the grow-out cages (Fig. 4a). However, values differed significantly between transects ($p<0.05$). The interaction of distance and transect was not significant. Likewise, total gastropod density was not significantly affected by distance (Fig. 4b). Transect was a significant factor for leaf-associated but not for the sediment-associated. The interaction of gastropod density, transect and distance was not significant.

In August, total faunal density was significantly affected by distance from the cages for both leaf- and sediment-associated fauna (Fig.5a).Neither transect, nor the interaction of transect and distance significantly affected total faunal density ($p<0.05$). The density of leaf-associated fauna was significantly lower at 25 m than at 5 m and beside the grow-out area (Tukey's HSD test, $p<0.05$).

The density of leaf-associated gastropods was significantly affected by distance (Fig.5b), but not by transect nor the interaction of distance and transect ($p<0.05$). Gastropod densities at 5 m from the cages were significantly different from densities at 25 m



Figs. 2a & b. Average composition and abundance (± s.e.) of epifauna collected from (a) seagrass leaf blades and (b) sediment substrate, April 1999



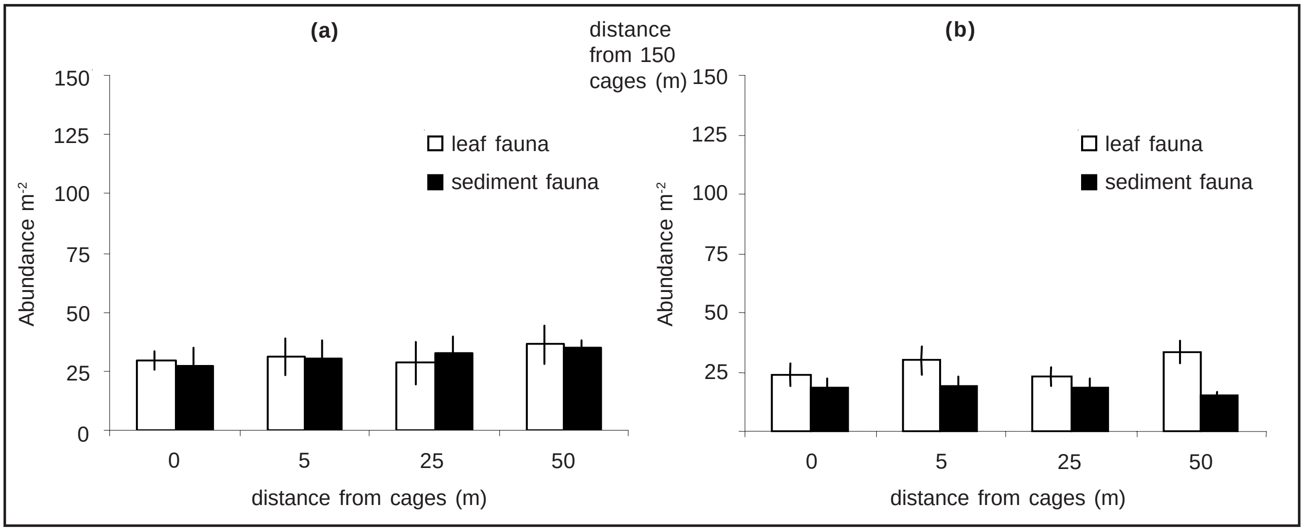
Figs. 3a & b. Average composition and abundance (± s.e.) of epifauna collected from (a) seagrass leaf blades and (b) sediment substrate, August 1999

(Tukey's HSD test, $p<0.05$). Analysis of variance of densities of the dominant leaf-associated gastropod, *Columbella* sp., showed that densities of collumbelids were not significantly affected by distance but by the transect. The interaction of distance and transect was not significant.

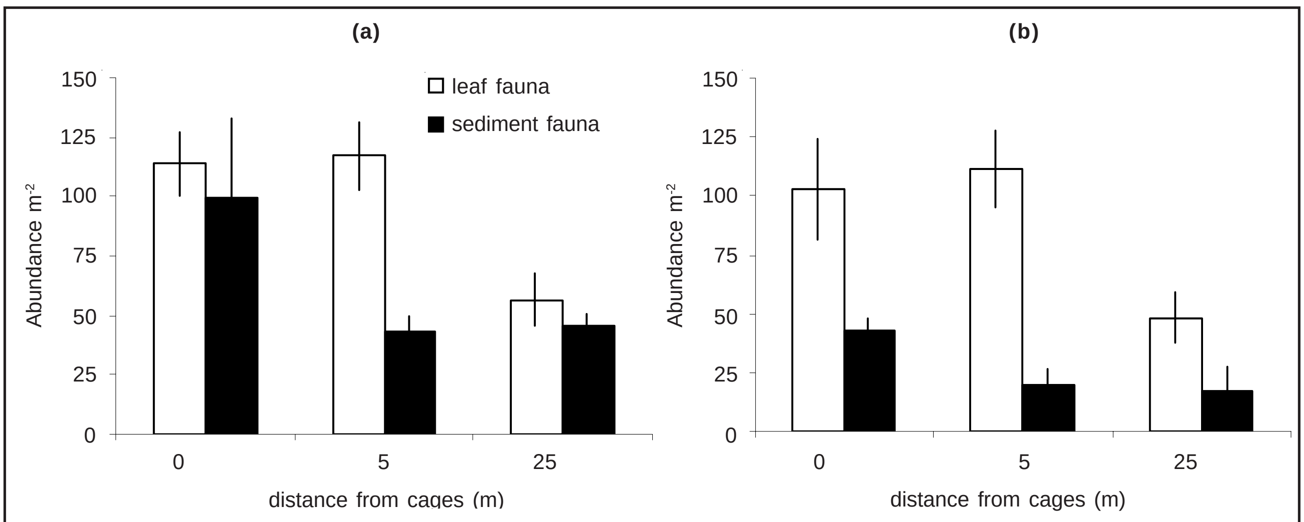
On the other hand, the density of sediment-associated gastropods was affected significantly ($p<0.05$) by transect, but not by distance nor the interaction of distance and transect. Densities of the dominant sediment-associated gastropods, *Strombus* sp., were significantly ($p<0.05$) affected by distance from the cages, transect, and the interaction of distance and transect. *Strombus* sp. densities were significantly higher beside the cages than at distances of 5 meters and 25 meters from the cages (Tukey's HSD test, $p<0.05$) (Fig. 5c).

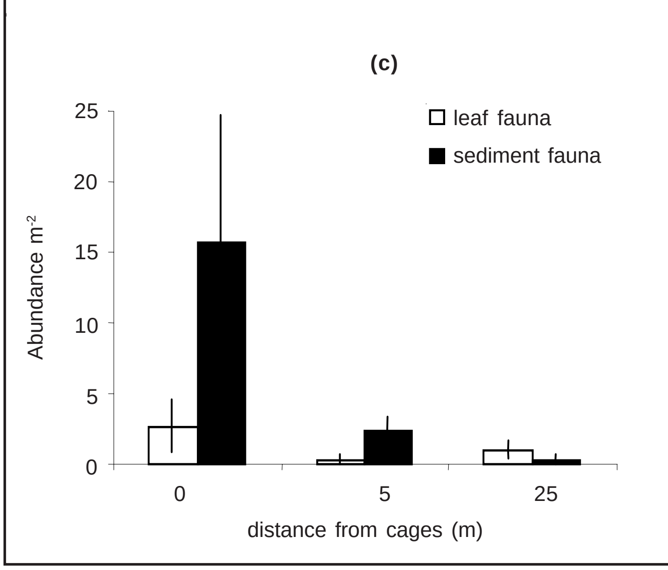
Sediment analyses

Fine sand grains predominated in the sediment across all sampling stations for both April and August. Average organic matter levels were higher in August (6.98 ±



Figs. 4a & b. Mean abundance (± s.e.) of (a) all faunal taxa and (b) all gastropod taxa, April 1999





Figs. 5a, b, & c. Mean abundance (± s.e.) of (a) all fauna taxa (b) all gastropod taxa, and (c) *Strombus* sp, August 1999

0.78%) than in April (5.78 ± 0.35%). During both months, average TOM was consistently higher in the top layer of the sediment (8.68±1.74% in April, 6.07± 0.40% in August) than in the lower sediment layer (6.89±0.35% in April, 5.49± 0.26% in August).

Moreover, total organic matter in the lower sediment layer was not significantly affected by the distance and transect, nor by the interaction of distance and transect. In April, TOM of the top sediment layer was significantly ($p<0.05$) affected by distance from the cages, but not by transect or the interaction of distance and transect. Tukey's HSD test ($p<0.05$) showed that TOM levels were significantly higher beside the cages than 50 meters from the cages (Fig. 6a). However, in August, organic matter levels of the upper sediment layer were not significantly different with respect to distance, transect, or the interaction of distance and transect (Fig. 6b).

Scatter plots of TOM in the upper sediment layer vs. abundance of epibenthic fauna are shown in Figs. 7 a-d. In April 1999, total faunal density varied inversely with the percent total organic matter of the top sediment layer (R^2=69.3%, Fig. 7a). In August, however, TOM levels did not show a good fit with total faunal densities (R^2=26.6%, Fig. 7b). Likewise, little variation in the densities of total gastropods (Fig. 7c-d), *Strombus* sp., *Columbella* sp., and hermit crabs was explained by percent TOM on either sampling date.

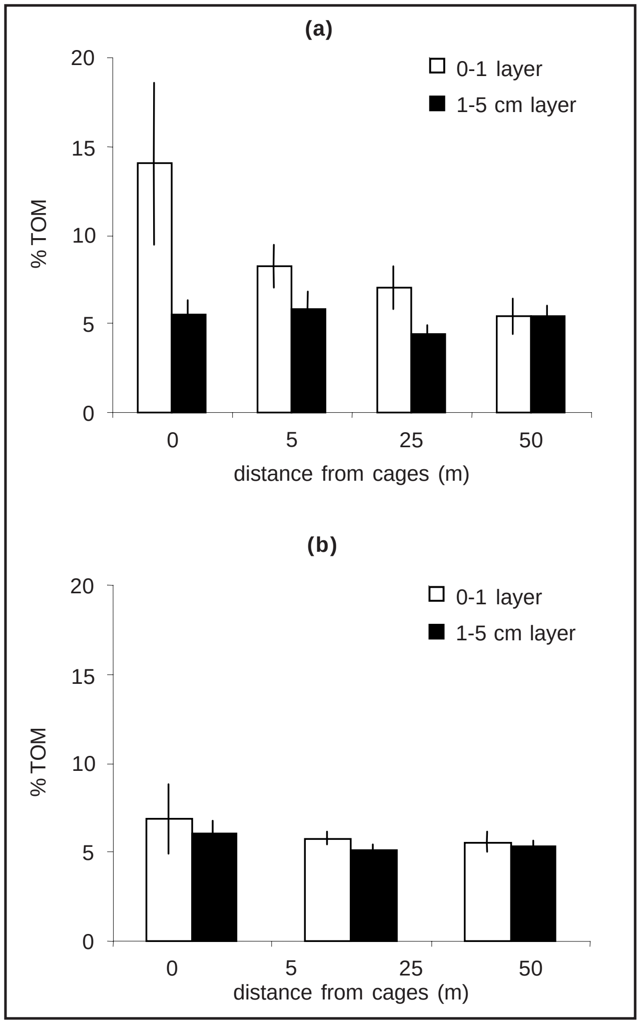
Seagrass epiphyte biomass

Average epiphyte biomass did not vary in the two sampling periods (3.00mg ±0.55 SE in April; 3.08mg ±0.31 SE in August). There was no significant difference in epiphyte biomass with respect to distance, transect, or the interaction of distance and transect for either sampling date (Figs. 8a & b).

Total suspended solids (TSS) and water movement

Amount of TSS was higher at 50 m from the cages than beside the cages. The TSS levels were higher in April (12.89±1.66 g SE) than in August (7.94g ±0.74 SE).

Average clod card dissolution rates were higher in April (5.10g/h±0.04 SE) than in August (2.86g/h±0.05 SE), indicating higher water movement in April than in August: Very little spatial variation in water movement was observed, however, with consistently lower values recorded beside the cages.

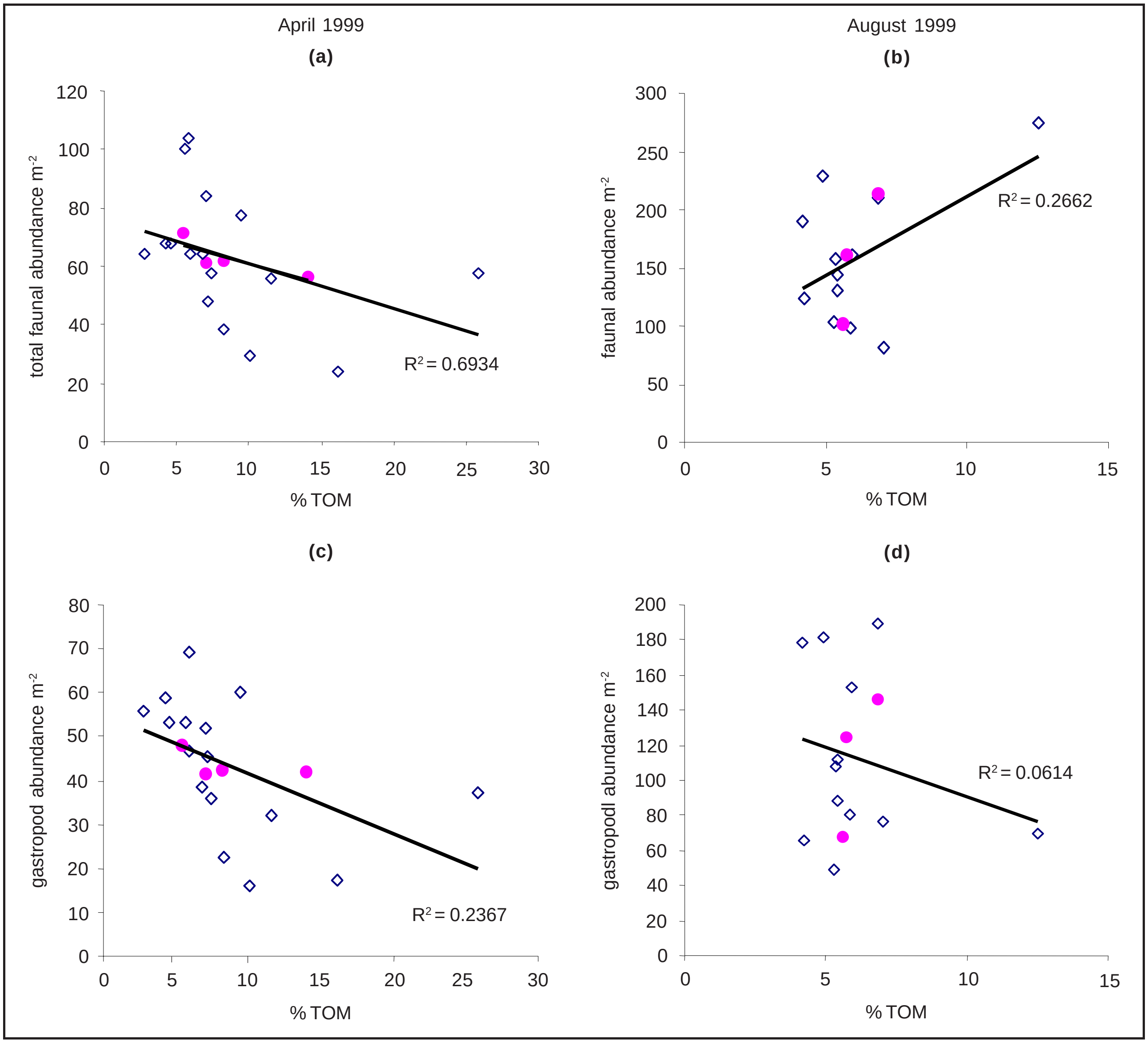


Figs. 6a & b. Average percent total organic matter (± s.e.) in the sediment, in (a) April and (b) August 1999

DISCUSSION

Data on faunal densities and sediment total organic matter indicated the presence of enrichment in the vicinity of the sea urchin grow-out cages. The epibenthic faunal density, notably, of the edible gastropod *Strombus* sp., was significantly higher around the cage area in August while no faunal enhancement was observed in April. On the other hand, TOM in the upper sediment layer was significantly elevated in the vicinity of the sea urchin cages in April, but not in August. The results suggest that the enhancement effect may be temporally variable due to seasonality or changes in tidal regimes.

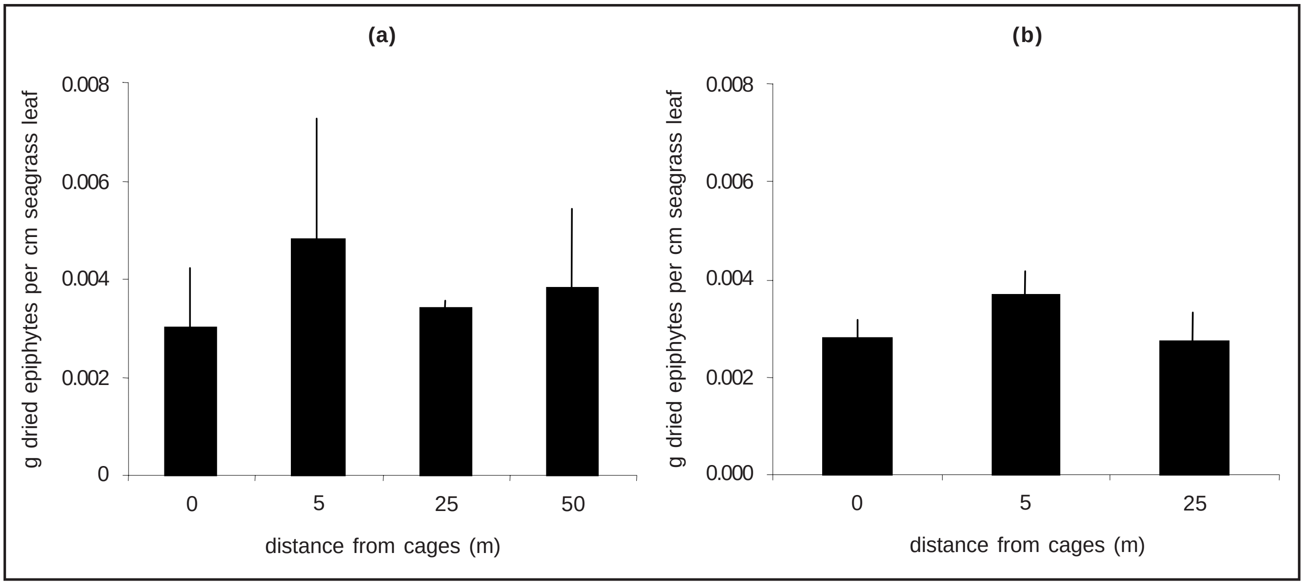
The enrichment effect in TOM and faunal abundances was limited to a radius of about 5-25 meters from the cages, suggesting the minimal effect of the culture activity. The often significant differences in faunal abundances between the transects, however, did not pinpoint specific transects as being consistently different



Figs. 7a, b, c, & d. Scatter plots of %TOM vs. total faunal abundance (a & b) and total gastropod abundance (c & d). Open squares are individual data points, filled circles represent mean values

from the others. These results indicate heterogeneous distribution of organic matter and fauna in the seagrass bed surveyed. In addition, organic material generated by the urchins may be distributed assymetrically around the cages because of prevailing local currents. Lucero has relatively strong water currents and wave exposure (Agawin and others 1996), hence it was possible for cage grow-out in this area to have less potential ecological impact than in other, more protected, sites in Bolinao. Buschmann et al. (1996) similarly noted that between-site differences in current strength is an important factor determining the degree of impact of aquaculture activities in coastal areas.

High TOM levels did not cause an increase in epibenthic fauna, suggesting that sea urchin detritus may not have been palatable for the taxa surveyed, or that food supply was not limited in the area during the survey period. Scatter plots showed that in April, increased %TOM in the sediment actually depressed total faunal densities. It was possible that elevated TOM rendered the substrate unsuitable for epibenthic fauna. However, in



Figs. 8a & b. Average epiphyte dry (± s.e.) per 1-cm length of *Enhalus acoroides* leaf blade, in (a) April and (b) August 1999

August, total faunal abundance varied less with TOM. Also, during both sampling periods, no significant trend was observed between TOM and densities of gastropods, *Strombus* sp., *Columbella* sp., and hermit crabs. It appeared that any inhibitory effect that TOM may have on the epibenthic fauna was temporally variable and limited in scale.

Unlike finfish and mussel cultivation, sea urchin grow-out culture appeared to have no effect on parameters such as epiphyte biomass and total suspended solids as was previously reported (see review of Buschmann and others 1996). The nutrient and organic input from the culture activity may not have been of sufficient magnitude as to have a significant impact on these factors.

Evidence of the presence of organic enrichment in the cage area has important implications for future directions in sea urchin grow-out research. Excess organic matter generated by the cages may be utilized in a more efficient manner by setting up a polyculture system within the culture area. The feasibility of culturing edible holothurians and gastropods that can utilize sea urchin detritus as food alongside the sea urchins should be explored. Aside from increasing profitability, such polyculture system would likely have the least impact on the environment because of rapid and efficient recycling of wastes within the system.

Future studies should survey more parameters, (i.e., faunal biomass, infaunal and microbial community structure, dissolved nutrients in the water column, dissolved oxygen, sediment metabolism, and sulfate reduction), that may be more sensitive to localized enhancement effects. More surveys should also be undertaken to provide a more complete picture of the impact of the sea urchin cages across different times of the year. Most importantly, future studies should include an unimpacted “control” site alongside the “experimental” sea urchin grow-out site.

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