

Deterioration of Soft Bottom Macroinfaunal Communities in a Milkfish Mariculture Zone off Bolinao-Anda, Pangasinan (NW Philippines)

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Abstract—Aside from eutrophic waters, organically-enriched sediments have become evident during the last two decades of fish cage and net-pen farming in Bolinao-Anda, Pangasinan (NW Philippines). To determine the impact of mariculture-derived enrichment on soft bottom sediment communities, faunal composition and sediment properties were examined for two periods, 2003 and 2008. In 2003, macroinfauna were depauperate in sediments of the farming sites while a “lightly-enriched” community harbored the Control station. In 2008, sediments were apparently and grossly polluted in the farming sites and were devoid of macroinfauna. Moreover, intensive mariculture appears to have expanded in its area of impact because *Beggiatoa* became evident in the Control station. Measures to mitigate local and large-scale impacts may need to be taken to allow for benthic recovery and possibly sustain mariculture in the area.

Keywords: macroinfauna, mariculture, organic matter, redox potential, Bolinao-Anda, Philippines

INTRODUCTION

Finfish culture in net-pens and floating cages off coastal waters intensified in the Asia-Pacific during the last two decades. In the Philippines, this farming system expanded from the late 1990s, particularly in coastal waters off Pangasinan (NW Philippines), the biggest producer of milkfish (*Chanos chanos*) in the country. While milkfish mariculture may contribute significantly to the Philippine economy (cf., DA-BFAR, 2010), the practice of intensive farming, has been linked to persisting eutrophic conditions (DMEQC, 2004; San Diego-McGlone *et al.*, 2008) and incidences of algal blooms and fish kills (Yap *et al.*, 2004; Azanza *et al.*, 2005). Particularly in Bolinao, sediment properties have also deteriorated (Holmer *et al.*, 2002; Reichardt *et al.*, 2007; EMMA, 2008; Santander *et al.*, 2008; David *et al.*, 2009). The adjacent municipality of Anda (Pangasinan) adopted a similar farming system in its nearshore waters, and has also had incidences of major fish kills since February 2002 (Azanza *et al.*, 2005; San Diego-McGlone

et al., 2008).

In this study, we describe the macroinfaunal benthos in the mariculture zone off Bolinao-Anda and relate faunal data with sediment parameters, to determine the impact of intensive farming practice on soft bottom sediment communities. Apart from changing bottom granulometry, uneaten feeds deposited to the bottom eventually decomposed and caused hypoxia in near-bottom waters, hence, potentially affect the benthos negatively (Wildish and Pohle, 2005).

METHODS

Study site—the Bolinao-Anda mariculture zone

The zone for net-pen and cage farming of milkfish has over 700 operational farming units, with the cages lined mostly along the Guiguivanen Channel in the north and most net-pens along the east of mainland Bolinao and the north of Anda (Fig. 1). Bamboo stakes have been built next to the net-pens in the middle of the passage off Luna (Bolinao), from which over 1,500 tonnes of mussels may be harvested annually (EMMA, 2008); fyke nets have also been set up next to net-pens.

The mariculture zone is generally shallow and water transparencies, measured as Secchi depth, were between 1.0 and 3.0 m (EMMA, 2008). Predicted flushing time was about 4 days through the Guiguivanen Channel and the narrow southern strait off Catubig and at least 9 days within the wider passage off Luna (Magdaong, 2008). Water temperatures and salinity measured from 26 to 32°C and from 33 to 35 psu, respectively (DMEQC, 2004). Eutrophic conditions were indicated by the significant increase in the concentrations of ammonia, nitrite, nitrate, and phosphate in the water column (San Diego-McGlone *et al.*, 2008). Bottom sediments are generally muddy (mean 75% of sediment composition) with organic contents between 6 and 20% (Siringan *et al.*, 2008). Bottom flow was found to be governed by tides, with flood tides influencing the flow through the narrow exits and ebb tides exerting more influence in the middle of the passage off Luna (Bolinao) (Siringan *et al.*, 2008).

Field sampling

Samples were collected from stations next to floating cages (Cg1 to Cg5) and net-pens (P1 to P4) and from Control stations in the Guiguivanen Channel (Cn1, Cn2) and off Pilar (Cn3) (Fig. 1). Mean depths in the farming stations were from 3 m (with net-pens, except P4) to ~12 m (with cages); the Control stations were ~14 m deep on average. In June 2003, only the stations north of the mariculture zone (Cg1, Cg2, P1, P2) and the Control station (Cn1) sited ~500 m away from Cg2 were sampled. In February 2008, repeated collections were made from stations above and from additional stations located in the southern half of the mariculture zone (Cg3, Cg4, Cg5, P3, P4) including Cn2 and Cn3 (Fig. 1). Stations Cn2 and Cn3 were established to serve as *Beggiatoa*-free reference sites.

An Ekman grab (bottom area = 0.02 m²) was used to sample the bottom

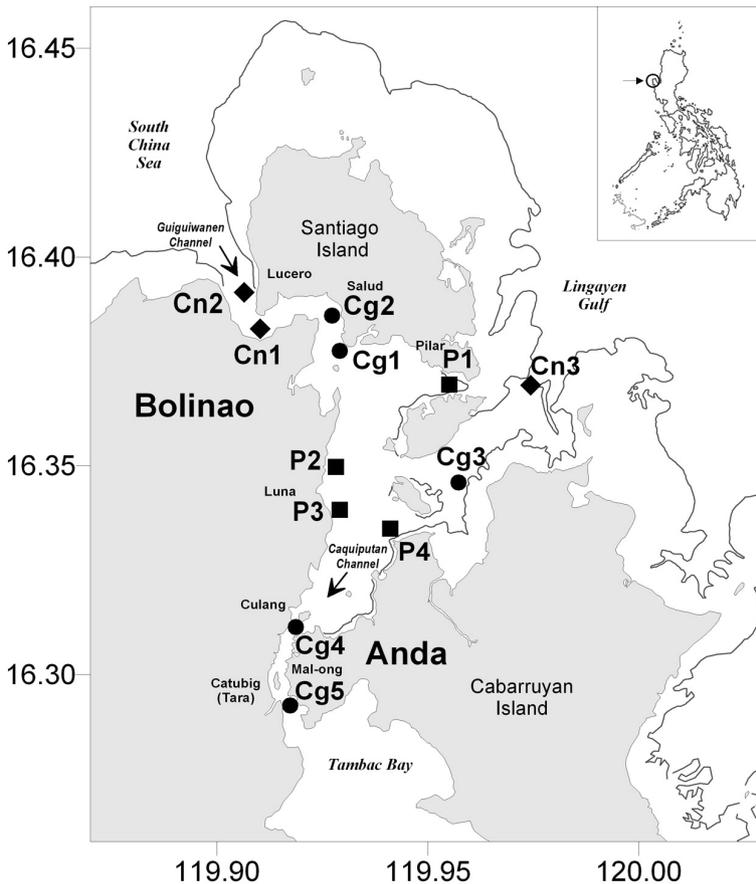


Fig. 1. Bolinao-Anda (Pangasinan, NW Philippines)—Benthos sampling stations next to floating fish cages (●, Cg1 to Cg5) and net-pens (■, P1 to P4) in the mariculture zone, and Control stations (◆) in the Guiguivanen Channel (Cn1, Cn2) and off Pilar (Cn3).

sediments ($n = 4$ per station). Sample color and the presence of sulphidic odor and of *Beggiatoa* were noted. From each of three samples intended for macroinfaunal analysis, core subsamples were obtained for the determination of organic matter content before transferring into marked and doubled plastic bags. In 2008, a fourth subsample was drawn out for measurements of relative redox potentials. The fourth grab sample was taken for the analysis of grain size composition.

Laboratory processing

Macrofaunal organisms were extracted by carefully passing small quantities of the samples successively through a 500- μ mesh sieve. All retained animals and materials were transferred to polyethylene bottles and then preserved with 10%

Table 1. Benthos stations outside (control; Cn1 to Cn3) and next to floating cages (Cg1 to Cg5) and net-pens (P1 to P4) in the mariculture zone off Bolinao-Anda (Pangasinan, NW Philippines). Data are means; numbers in parentheses are standard errors ($n = 2$). Legend: TOM, total organic matter; ^B denotes the presence of *Beggiatoa* on the sediment surface.

Station	Depth (m)	Sediment grain size composition and total organic matter content, %							
		2003				2008			
		Granules	Sand	Mud	TOM	Granules	Sand	Mud	TOM
Cn1	14	0.5	8.7	90.8	13.0	0.8	63.0	36.3	^B 16.5 (1.8)
Cn2	18	—	—	—	—	0.7	53.4	45.9	11.3 (0.6)
Cn3	9	—	—	—	—	0.2	64.5	35.3	3.5 (0.1)
Cg1	12	0.4	1.9	97.6	1.0	0.2	63.7	36.2	^B 15.3 (0.8)
Cg2	12	2.3	6.8	90.8	13.0	1.3	62.3	36.4	^B 3.3 (0.01)
Cg3	13	—	—	—	—	2.4	59.7	37.9	^B 5.4 (0.6)
Cg4	10	—	—	—	—	1.0	50.3	48.8	4.7 (0.1)
Cg5	12	—	—	—	—	1.0	63.5	35.5	7.5 (0.9)
P1	3	6.9	4.1	89.0	1.3	3.5	50.5	46.0	^B 26.6 (3.1)
P2	2	0.03	1.1	98.8	12.8	1.8	69.6	28.6	^B 9.7 (2.5)
P3	4	—	—	—	—	3.6	80.1	16.3	2.6 (0.1)
P4	12	—	—	—	4.3	4.1	48.9	47.0	6.7 (0.8)

borax-buffered and Rose-Bengal stained formalin in seawater (Holme and McIntyre, 1984). During sorting, all stained organisms were picked out under a stereozoom microscope, identified down to the lowest possible taxon based on gross morphological characters, and then counted.

Total organic matter was measured as loss from dry sediments on ignition at 550°C (Buchanan, 1984). Grain size composition was determined after soaking the pre-dried muddy samples overnight in tap water mixed with aqueous Calgon (Buchanan, 1984). These were passed through a stack of sieves with mesh apertures from 2 mm down to 63 μ , representing the lower limits of the Udden-Wentworth scale (cf., Leeder, 1982), and then oven-dried to constant weight at 105°C. The silt-clay fraction was calculated as the difference between the sample dry weight before sieving and the pooled dry weights of the fractions.

Using an Orion probe attached to a Cyberscan pH/mV meter, relative redox potentials were measured from the surface and at every 1-cm interval down the sediment core subsample. Readings were adjusted by adding +200 mV to correct for the Ag/AgCl reference electrode.

RESULTS AND DISCUSSION

Sediment environment—organic matter, grain size structure, redox potentials

For 2003, all sediments were muddy ($93 \pm 2\%$ SEM; Table 1)—those from stations in the farming zone were black and with strong sulphide odor, in contrast to sediments in the Control station (Cn1; gray to dark gray and without the sulphide odor). Larger grains—rubble, shells of mussels (*Perna viridis*) and shell

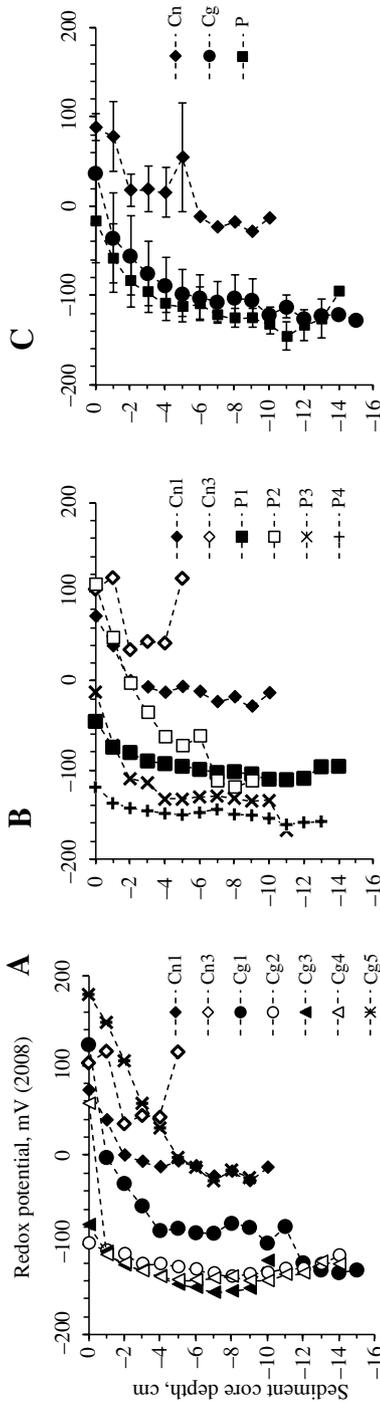


Fig. 2. Profiles of relative redox potentials (in mV) measured in sediment cores from fish cage stations (A) and net-pen stations (B) in 2008. Data are means of two samples (standard error bars were excluded in A and B for clarity). Mean redox profiles of sediments next to cages (Cg) and net-pens (P) relative to sediments in the Control stations are shown in C (\pm SEM).

grits from small bivalves—and sand, which included undissolved fish feeds, were minimal (Table 1). Organic matter contents were below 5% in stations with relatively dispersed farming units (Cg1 and P1) and were over 10% in Cg2 and P2, where farming units were aggregated (Table 1). Proportions obtained in the Control station Cn1 were high at 13% (Table 1).

For 2008, the strong sulphide odor was evident in all samples, except those from the new Control stations (Cn2, Cn3). Dense white films of the bacteria *Beggiatoa* laminated the stations north of the mariculture zone—Cg2, Cg1, P1, P2, and P3—including Cn1, indicating an expansion of the area with reducing sediments when compared to observations in 2005 and 2006 (EMMA, 2008). Sandy components occurred with mud in the samples (Table 1), contributed by shell grits and by sediment movement during periods of inclement weather. The range for organic matter contents were from <3 to 27%, with generally higher values in stations where *Beggiatoa* occurred. Redox potentials indicated very reducing sediments (range from -168 to 57 mV) in Stations Cg2, Cg3, Cg4, P1, P3, and P4 (Figs. 2A and B). The top layers of sediment cores from Cg1, Cg5, and P2 were not as reducing (range from -131 to 179 mV), possibly due to the net movement of bottom water in the sites that may have prevented stagnant conditions. Sediments in Station Cn1 tended towards a slightly reducing state, with redox potentials close to 0 mV from 2 cm and down the core. Station Cn3 had positive readings in its profile, as expected. Overall, bottom sediments next to the fish cages and net-pens were more reducing by 24 to 89% (Fig. 2C) than those in the Control stations, albeit Station Cn1 exhibiting slightly reducing conditions. A recent study showed that even at 50 m from the farming units, sediments were already at a reducing state, with organic matter contents between 13 and 18% (Tentia *et al.*, 2008). These characteristics clearly indicate poor sediment quality in the farming area.

Macroinfaunal communities

Sediments of the mariculture zone in Bolinao have poor benthos quality and were almost defaunated in areas with intense operations (i.e., in the case of crowded units). In 2003, sediment bottoms in Stations Cg1, Cg2, and P1 were depauperate of organisms—there were at most only two taxa found, each with 1 individual per 0.02 m² (Table 2). Only three taxa represented the macroinfauna—Families Onuphidae (Polychaeta), Nassariidae (Mollusca, Gastropoda), and *Onchnesoma* sp. (Aspidosiphonidae, Sipunculida). Eleven taxa composed the benthic community in the Control station (Cn1), with significant contributions from spionid polychaetes. Peracarid and decapod crustaceans also occurred in these sediments.

For 2008, only Station Cg5 in the mariculture zone was found with a community composed of 13 taxa and dominated by gammaridean amphipods (304 individuals per 0.02 m²; Table 2). This faunal group has preference for oxygenated substrates (cf., Nacorda and Yap, 1997) and may have thrived since positive redox potentials were obtained from the surface sediments (0 to 5 cm deep; Fig. 2). Also, the faster net bottom flow into the narrow exit to Tambac Bay

Table 2. The composition of sediment macroinfaunal assemblages from the benthos stations sampled in June 2003 and February 2008 in the mariculture zone off Bolinao-Anda (Pangasinan, NW Philippines). Numbers in the parentheses are mean counts per grab ($n = 3$; bottom area = 0.02 m^2). Legend: F., Family; Io., Infraorder; O., Order; So., Suborder.

2003	2008		
Station Cn1	Station Cn1	Station Cn3	Station Cg5
F. Spionidae (54)	F. Spionidae (7)	F. Capitellidae (46)	So. Gammaridea (304)
O. Cumacea (7)		F. Cirratulidae (8)	F. Spionidae (100)
F. Capitellidae (5)	Station Cn2	F. Sternaspidae (5)	F. Paraonidae (23)
F. Nephtyidae (5)	F. Cirratulidae (31)	Sipunculida sp. 1 (5)	F. Sabellidae (18)
F. Golfingiidae (3)	F. Capitellidae (4)	F. Tellinidae (4)	F. Capitellidae (17)
F. Hesionidae (2)	F. Chaetopteridae (3)	F. Chaetopteridae (3)	F. Solenidae (12)
F. Cirratulidae (1)	Gastropoda sp. 2 (3)	F. Spionidae (3)	F. Hesionidae (9)
F. Nereididae (1)	F. Nephtyidae (2)	F. Eunicidae (2)	F. Nereididae (2)
O. Calanoida (2)	F. Pilargiidae (2)	F. Glyceridae (2)	F. Pilargiidae (2)
Io. Caridea (1)	F. Spionidae (2)	F. Hesionidae (2)	F. Cirratulidae (1)
Io. Thalassinidea (1)	O. Cumacea (2)	O. Harpacticoida (2)	F. Phyllodocidae (1)
	F. Tellinidae (2)	So. Gammaridea (2)	F. Terebellidae (1)
Station Cg1	F. Hesionidae (1)	O. Paguroidea (2)	<i>Modiolus</i> sp. (1)
F. Onuphidae (1)	F. Sabellidae (1)	P. Nemertea (2)	
F. Aspidosiphonidae (1)	F. Sigalionidae (1)	F. Ampharetidae (1)	Station P1
	F. Sternaspidae (1)	F. Amphinomidae (1)	F. Dorvilleidae (1)
Station Cg2	F. Syllidae (1)	F. Aphroditidae (1)	F. Spionidae (1)
F. Nassariidae (1)	So. Gammaridea (1)	F. Chrysopetalidae (1)	
	Io. Brachyura (1)	F. Cossuridae (1)	
	F. Nassariidae (1)	F. Dorvilleidae (1)	
	Sipunculida sp. 2 (1)	F. Lumbrineridae (1)	
		F. Nephtyidae (1)	
		F. Pectinariidae? (1)	
		F. Pilargiidae (1)	
		F. Sabellidae (1)	
		F. Syllidae (1)	
		Polychaeta sp. 1 (1)	
		O. Cumacea (1)	
		Io. Caridea? (1)	
		Io. Thalassinidea (1)	
		F. Aspidosiphonidae (1)	

(cf., Magdaong, 2008; Siringan *et al.*, 2008) may have prevented bottom conditions to be stagnant and allow for fauna to proliferate. The spionid polychaetes were the next abundant taxa (100 individuals per 0.02 m^2) in Station Cg5 and were the sole taxon that occurred in Station Cn1, albeit few in number. Opportunistic spionids (and capitellids) are known to tolerate pollution and these outnumber and exclude other taxa (Pocklington and Wells, 1992).

The diversity and abundance of infaunal organisms was evident in the new Control stations, Cn2 and Cn3. There were 18 and 31 taxa, respectively, and the communities were dominated by cirratulid and capitellid polychaetes (Table 2). The dominance of spionid polychaetes and the presence of capitellid and cirratulid polychaetes have been reported to indicate “moderately enriched” sediments

(Nickell *et al.*, 1998), but the presence of non-enrichment indicators such as decapod crustaceans pushes Cn1 towards the “lightly-enriched” category, albeit the fauna quite poor (Nickell, pers. com.). Further, the polychaetes have significantly diminished even in the Control station Cn1, when taxonomic lists were compared with data obtained in 1987 (cf., Yap *et al.*, 1987). All the other stations in the mariculture zone—Cg1 to Cg4, P2 to P4—were devoid of macroinfaunal organisms, a case indicating severe organic pollution.

Our study shows that macroinfaunal community structure has deteriorated in response to excessive organic loading, and that organisms have been eliminated in sediments laminated by *Beggiatoa* within the mariculture zone. Bottom and porewaters are likely to be hypoxic to anoxic in this case, and only few infaunal organisms tolerate this environment (cf., Rosenberg, 2001; Gray and Elliott, 2009). If mariculture were to continue, measures to mitigate local impacts may have to be adopted, e.g., improving feed quality and feeding scheme (BFAR-PHILMINAQ, 2007) to reduce sedimentation. Large-scale mitigation measures may require fallowing, as has been applied in some areas (e.g., Karakassis *et al.*, 1999).

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