Total Suspended Solids and Sedimentation Rate in Calape Bay (Bohol Island, Central Philippines) After Three Decades of Mariculture Activities

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Calape Bay is a declared mariculture zone under the local government unit of Calape in Bohol Island, Central Philippines. A survey was conducted in December 2011 and January 2012 to evaluate its total suspended solids (TSS), sedimentation rate (SR), and suspended total organic matter (TOM). Results show that present TSS values (80-120 mg/L) were 30 to 80 times higher than the values obtained 10 years ago. High TSS values were recorded in areas where fish cages were located. Sedimentation rate showed highest value (18.8 mg/cm^2/day) proximal to the river and lowest value (3.2 mg/cm^2/day) at the marine sanctuary which is 4.2 kilometers from the river mouth. Kruskal-Wallis test established that there was a significant difference of the sedimentation rates among sites (P=0.02). The suspended total organic matter (2.0-8.9%) was higher at the center of the bay where the fish cages were located. The preceding values have exceeded the standards of sustainable water quality set by the Department of Environment and Natural Resources (DENR). This study confirmed that Calape Bay is threatened with organic pollution from internal and external sources after three decades of mariculture activities. If the sustainability of this bay is of primary interest due to its economic benefits to the people who depend on it for fishing, mariculture and navigation, then there is a need to establish a water monitoring system inside the bay the soonest possible time to regulate and maintain a healthy water quality standard for a sustainable aquatic ecosystem. There is also a need to determine the impacts of aquaculture-induced and river-carried sedimentation and organic matter on marine diversity and people's fishing livelihood in and nearby Calape areas.

Keywords: aquaculture, organic matter, sedimentation rate, TSS

INTRODUCTION

Calape Bay is a semi-enclosed body of water in western Bohol Island, Central Philippines. It is a declared mariculture zone under the local government unit of Calape which is bounded on the north and west by Pangangan Island, on the south by the municipality of Loon and on the east by the municipality of Calape. The bay has an average depth of 12.4 m and a maximum depth of 40 m along the outer or mouth portion (Jacinto, 2002). The northern area is shallower between 1 to 3 m deep and gradually slopes at the middle of the bay with a depth of 21-31 m. The highest surface current was 1.6 m/s and predominantly flow out of the bay (UP-MSI, UP-VCC, 2002). The intertidal zone is characterized by muddy and sandy shoreline covered with seagrasses and the northwest portion of the bay is covered with mangroves.

The bay is often used for fishing activities, mariculture and navigation. The operation of fish cages in the bay started in 1982 when BFAR initiated the National Bangus Breeding Project. In 1987, Atlas Corporation established fish cages in the area for grouper culture which was followed by other private operators culturing milkfish broodstock and groupers (Corrales, 2005). Presently, there are forty-nine fish pens and fifty-five fish cages in the bay and the total commercial feeds being given to the caged stocks is approximately 220 kg daily.

Ecological concern on the sustainable use of Calape Bay led to studies by the University of the Philippines, Marine Science Institute (UP–MSI) and University of the Philippines in the Visayas - Cebu College (UPV-CC). Seventeen stations located within the bay were sampled for salinity, dissolved oxygen, phosphate, ammonia, nitrite, nitrate, chlorophyll a, transparency, and total suspended solids (UP MSI-UPVCC, 2002). Corrales (2005) assessed the mechanisms for fish cage operation in Calape Bay, Bohol to come up with a management and regulatory framework to ensure sustainable mariculture operation. Silapan and

Maeda (2007) studied the microbial organisms that can serve as indicator of organic enrichment in Calape, Bay. Average organic matter of surface sediment was 11.4% with maximum value of 15.3% at the mariculture zone located at the center of Calape Bay (Argente *et al*., 2013). In contrast, Bohai Bay in China showed average suspended particulate matter of 13 ppm in the inshore area and a maximum 603 ppm at the bottom of the harbor area (Qiao *et al*., 2011).

A decade had passed since the environmental studies on Calape Bay were done. It is time to revisit the area and collect new data to compare previous information. Four parameters are included in this study, namely: total suspended solids (TSS), sedimentation rate (SR), suspended total organic matter (TOM) and salinity which we believed are related to mariculture activities in semi-enclosed water bodies. Hence, a survey was conducted in December 2011 and January 2012, respectively.

MATERIALS AND METHODS

Fifty sampling stations, representing sites very proximal to fish pens, fish cages, river estuary and shore areas were chosen and their coordinates were recorded using an eTrek™ GPS unit. For each station, samples for surface salinity measurement (i.e., using a hand-held refractometer) and TSS were collected. Sediment traps were installed at the representative sites (i.e., five sets in fishpens/fish corrals, five near the river, five in fish cages, five in nearshore and marine sanctuary).

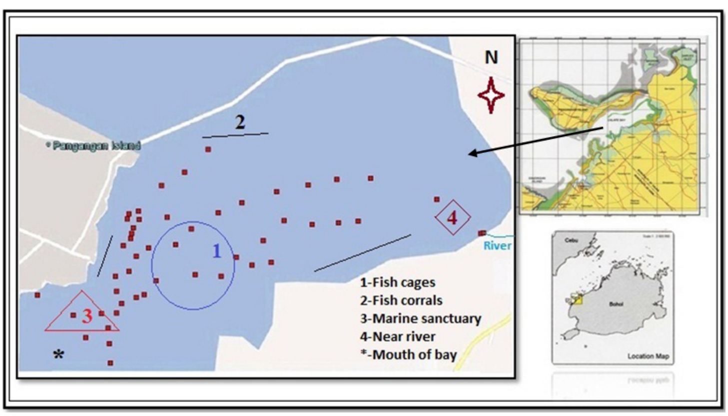

Fig. 1. Map of Calape Bay, Bohol, Central Philippines showing sampling stations in solid squares located near fish cages (1), fish corrals (2), marine sanctuary (3) and estuary (4).

Analysis of TSS followed the standard procedure for total filterable solid (APHA-AWWA-WPCF, 1989) using 4.3 cm diameter glass microfiber filters (GF/C). The residues were dried in an oven at 60°C to constant weight and expressed in mg/L or ppm. Residues were processed further by ashing them in a furnace at 500°C for 2 hours. The loss in weight after ignition over the initial weight represents the total organic matter of the suspended solids and expressed in percent.

Sediment traps made of PVC tubes (2.60 cm diameter and 20.3 cm long) were deployed across the sampling stations. Three adjoining traps were mounted in a pole that was vertically pushed into the substrate. The traps were retrieved after 24 hours. Retrieved traps were then brought to the laboratory and processed following the procedure for total filterable solids. Sedimentation rate expressed as $mg/cm^2/day$ was computed based on the dry weight of the trapped sediments divided by the area of the sediment trap divided by the period of deployment.

Spatial data for the parameters: salinity, TSS, and TOM were gridded and plotted using contour mapping program to generate isoline maps. Sedimentation rates per site were tabulated and graphed. To determine if there was a significant difference among sites, a non-parametric Kruskal-Wallis test was done on the sedimentation rate data at 95% significance level as data did not comply for the assumptions of normality test.

RESULTS

Total suspended solids in Calape Bay, Bohol ranged from 80–120 mg/L with a mean value of 97.6 mg/L (S.D.=9.7, N=50). Higher concentrations were observed near the center of the bay where fish cages were located, and the eastward area where fish corrals abound. The westward areas including the marine sanctuary showed the least concentration.

Surface salinity ranged from 20-34 PSU with a mean value of 28 PSU (S.D.=2.7, N=50). The highest salinity was nearest the mouth of the bay, while the lowest salinity was near Liboron River located east of the bay.

The TOM of Calape Bay ranged from 2.0-8.9% with a mean value of 5% (S.D.=1.5, N=50). Higher TOM concentrations were recorded at the center of the bay where the fish cages were located. The nearshore areas including the fish corrals showed low TOM concentrations between 2-4%.

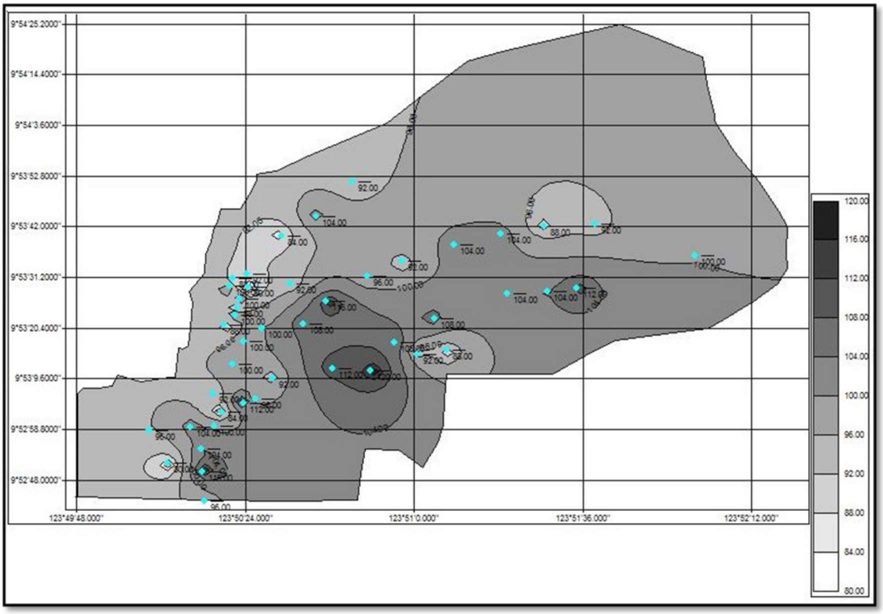

Fig. 2. TSS profile of Calape Bay, Bohol showing high concentrations at the fish cage areas located near the center of the bay.

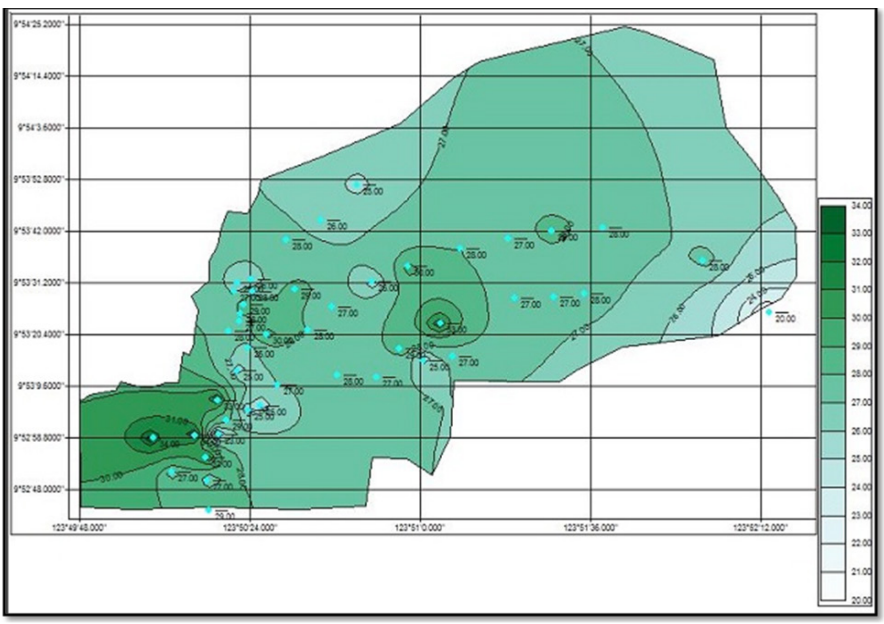

Fig. 3. Salinity profile of Calape Bay, Bohol showing high salinity at the mouth of the bay.

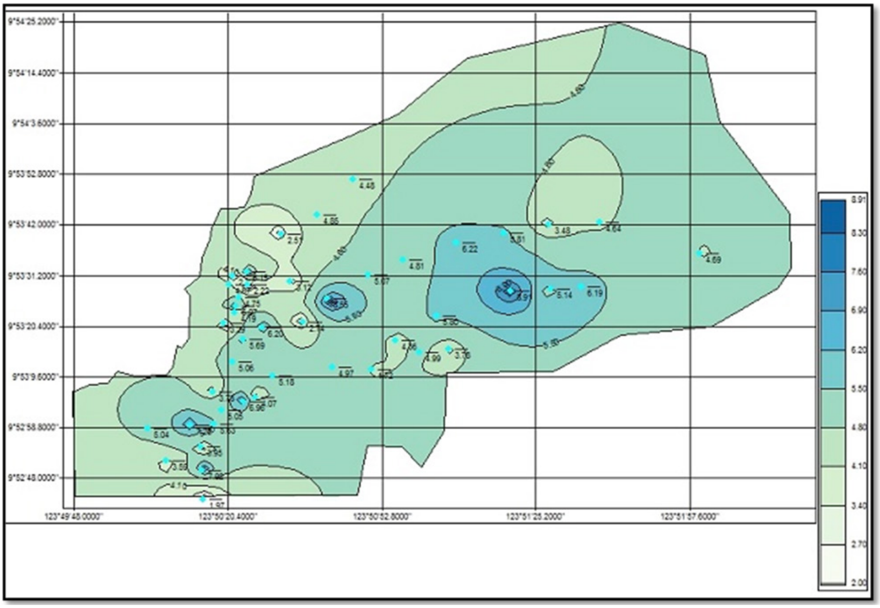

Fig. 4. TOM profile of Calape Bay, Bohol showing high concentrations at the center of the bay.

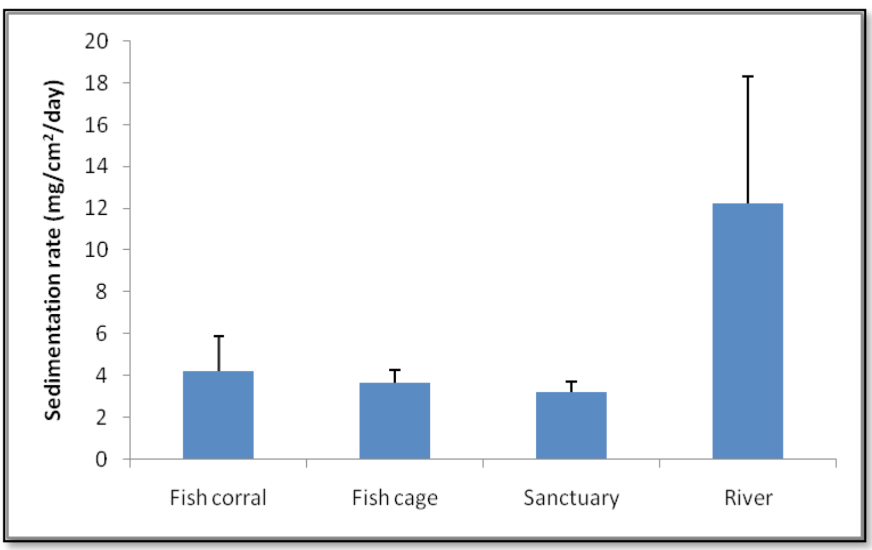

Fig. 5. SR of Calape Bay, Bohol showing highest value at the river area

Sedimentation rate (SR) was highest at the river mouth (18.8 mg/cm^2/day). On the average, the sedimentation rate was 9.8 mg/cm^2/day. The lowest SR was at the sanctuary (mean value=3.2 mg/cm^2/day). Sedimentation rates were significantly higher (2-6 times) at the river mouth (P=0.02, Kruskal-Wallis test) compared to the other stations.

DISCUSSION

The sustainability of Calape Bay as a mariculture zone depends on its water quality which is currently threatened with organic pollution coming from internal (i.e., mariculture activities) and external sources (i.e. riverine inputs). Based on the water usage and classification guideline of the Philippines (DENR DAO # 34, series of 1990) a water body is sustainable if its qualities do not exceed the limit for water quality standard that it sets. Since Calape Bay is a mariculture zone, its water classification falls under Class SB (or fishery water class I for spawning of milkfish, *Chanos chanos* and similar species) and Class SC (or fishery water class II for commercial and sustenance fishing), respectively. In the light of this guideline, Calape Bay should not exceed the TSS level of 30 mg/L.

The TSS values in the present study range from 80-120 mg/L which are 30 to 80 times higher than the values obtained 10 years ago (UP MSI-UPVCC, 2002) which ranged from 0-4mg/L. The similarity of this study to the past study is that high TSS is still recorded in the areas where fish cages are located. The current data is comparable to the TSS levels of 76.6 mg/L in the highly impacted fish cage areas in Bolinao, Pangasinan ten years ago (UP-MSI and UPV-CC, 2002). The intensive fish farming practices in Bolinao, Pangasinan led to eutrophication and recurring fish kills (Reichardt *et al.*, 2006; Santander *et al.*, 2008).

The increased TSS in Calape Bay can be attributed to the increasing number of fish cages and fish corral. Daily feed volume seven years ago reached only 106 kg of commercial feed and trash fish were given to the stocks (Corrales, 2005) as compared to the present volume of 220 kg/day, a net increase of 107%. At the time of sampling, the TSS proximal to the river mouth was moderate. However, this might not be the case during heavy downpours in the uplands. River runoffs could be significant input of suspended materials depending on the types of development being done at the source of the river as shown in the study of Qiao *et al.* (2011).

The present surface salinity measurements showed a wider range (20-34 PSU) compared to the measurements ten years ago (34-35 PSU). This difference can be attributed to two factors, namely seasonal conditions and the number of sampling stations. The present study took place during the wet season between December 2011 and January 2012, while the previous study was conducted during the dry season (May 2002). Season plays an important role in the variation of the attributes of an aquatic system (Dudgeon, 1992). Furthermore, the present study had 50 sampling stations and five of these sites were near the river or estuary.

The TOM concentration at the surface water showed higher amount near the fish cages. This observation is correlated with the study of Tentia and San Diego-McGlone (2008) where organic matter in the sediments were higher near the cages in Bolinao, Pangasinan as compared to the area 25-50 meters farther. Organic matter accumulation is the result of feed wastage, fecal matter production and fish excretion from mariculture activities (Wu, 1995; Troell *et al.*, 1999). Its content in the sediments decreased with the distance from the fish cages. This condition could also be true for suspended organic matter if the tidal currents are weak.

As expected, the SR in the bay was higher near the river or estuary area. However, SR figures reported by Corrales (2005) underneath the fish cages showed even higher values (275 $mg/m^2/day$) while those outside the bay were low (5 $mg/m^2/day$) and comparable to the present values recorded near the fish cages, fish corrals and marine sanctuary. In addition, the study of Silapan and Maeda (2007) revealed that the sediments below the mariculture cages of Calape Bay tested positive for the filamentous bacteria, *Beggiatoa* sp. which thrived in H_2S-rich substrate and are indicators of organic pollution in the marine environment (Pereira *et al.*, 2004; Elliott *et al.*, 2006; Santander *et al.*, 2008) that favor bacterial and viral disease outbreaks (Vercelles *et al.*, 2000; Primavera *et al.*, 2006).

Mariculture activities in Calape Bay, if not regulated, can lead to increase in suspended solids concentrations due to the accumulation of feeds and fecal wastes in the area. Various studies (Jarboe, 1995; Wu, 1995; Tover *et al.*, 2000) showed that unregulated fish cultures result to significant amount of nutrients, TSS, and inorganic matter in the surrounding environment. The presence of fish cages and fish corrals could be contributory in hindering the flow of water in and out of the bay. The local government unit of Calape and the Protected Area Management Board (PAMB) should take an active role in the management of the bay, not only in the licensing application of prospective fish cage operators but in the monitoring of water quality within Calape Bay. The TSS has exceeded the limit set by DENR for Class SC waters. Although suspended TOM is less than 10%, the sedimentation rates have increased significantly after three decades of mariculture activities, and should be a matter of some concern. Future studies need to investigate the impacts of high sedimentation and TSS load in Calape Bay on marine diversity, fisheries productivity, and fishers' livelihood.

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REFERENCES

APHA (1989). Standard methods for the examination of water and wastewater. 17th edition. Washington D.C. 517pp.

Argente, F.A.T., Palla, H.P., Narido, C.L., Celedonio, M.A. & Dy, D.T. (2013). Spatial distribution of OM in the surface sediments of Calape Bay, Bohol, Central Philippines, PJS 142 (2):133-141.

Corrales, J.D. (2005). Regulatory framework for fish cage operation in Calape Bay: a recommendation based on environmental and culture conditions. Unpubl. Master's thesis, University of the Philippines in the Visayas – Cebu College, p. 93

Department of Environment and Natural Resources Administrative Order No. 34. Series of 1990. p. 11

Dudgeon, D. (1992). Endangered ecosystems: A review of the conservation status of tropical Asian rivers. Hydrobiologia 248:167-191.

Elliott, J.K., Spear, E. & Willey-Echeverria, S. (2006). Mats of Beggiatoa bacteria reveal that organic pollution from lumber mills inhibits growth of Zostera marina. Marine Ecology 27:372-380.

Jacinto, G.S. (2002). Bolinao fish kill- looking back. Aqua Beat. 2:2.

Jarboe, H.H. (1995). Diel dissolved oxygen consumption and total ammonia nitrogen production by fingerling channel catfish following feeding at different times. Progressive Fish-Culturist. 57(2):156-160.

Pereira, P.M.F., Black, K.D., McLusky, D.S. & Nickell, T.D. (2004). Recovery of sediments after cessation of marine fish farm production. Aquaculture 235:315-331.

Primavera, J.H. (2006). Overcoming the impacts of aquaculture on the coastal zone. Ocean and Coastal Mgt., 49:531-545.

Qiao, L.L., Wang, Y.Z., Li, G.X., Deng, S.G., Liu, Y. & Mu, L. (2011). Distribution of suspended particulate matter in the northern Bohai Bay in summer and its relation with thermocline. Estuarine, Coastal and Shelf Science 93:212-219.

Reichardt, W., San Diego-Mcglone. M.L. & Jacinto, G.S. (2006). Organic pollution and its impact on the microbiology of coastal marine environments: A Philippine perspective. Asian J. of Water, Environment and Pollution 4 (1), 1-9.

Santander, S.M., San Diego-McGlone, M.L. & Reichardt, W. (2008). Indicators of diminished organic matter degradation potential of polychaete burrows in Phillipine mariculture areas. The Philippine Agricultural Scientist 91 (3): 295-300.

Silapan, J. & Maeda, H. (2007). *Beggiatoa* sp. as indicator of organically-enriched fish mariculture site in Calape Bay, Bohol (Central Philippines). UPV J. Nat Sci. 12:35-44.

Tentia, M. C. & San Diego-McGlone, M.L. (2008). Organic matter distribution in the sediments of fishfarm areas in Bolinao, Pangasinan. UPV J. Natural Sci. 13:108-115.

Tovar A., Moreno, C., Manuel-Vez, M.P. & Garcia-Vargas, M. (2000). Environmental implications of intensive marine aquaculture in earthen ponds. Marine Pollution Bulletin. 40(11):981-988.

Troell, M., Ronnback, P., Halling, C., Kautsky, N., & Buschmann, A. (1999). Ecological engineering in aquaculture: Use of seaweeds for removing nutirents from intensive mariculture. *Journal of Applied Phycology*, 11:89-97 Retrieved from https://www.researchgate.net /publication/225842585_ Ecological_ engineering_in_aquaculture_ Use_of_seaweeds_for_ removing_nutrients_ from_intensive_mariculture

UP-MSI & UPV-CC (2002). Development of marine environmental quality criteria for mariculture areas. Second Annual Report, February 2002. Agriculture and Fisheries Modernization Act Project. DA-BAR, Dilliman, Quezon City, 90 pp.

Verceles, L.F., Talaue-McManus, L. & Aliño, P.M. (2000). Participatory monitoring and feedback system: an important entry towards sustainable aquaculture in Bolinao, Northern Philippines. Science Diliman, 12(2): 78-87.

Wu, R.S.S. (1995). The environmental impact of marine fish culture: towards a sustainable future. Marine Pollution Bulletin, 31(4-12):159-166.