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Fish habitats in a small, human-impacted Sibunag mangrove creek (Guimaras, Philippines): a basis for mangrove resource enhancement

Jeff Bogart R. Abrogueña[1, *], Teodora U. Bagarinao[2], Luís Chícharo[1, 3]

[1] Faculty of Marine and Environmental Sciences, University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
[2] Aquaculture Department, Southeast Asian Fisheries Development Center (SEAFDEC/AQD), Tigbauan, Iloilo 5021, Philippines
[3] Centre for Marine and Environmental Research (CIMA-UALG), University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
* Corresponding author. Present address: P.O. Box 1430, Center of Environment and Water-King Fahd University of Petroleum and Minerals, 31261 Dhahran, Saudi Arabia; e-mail: jabroguea@yahoo.com; Telephone: +966-3-860-1135; Fax: +966-3-860-3220

Abstract

The fish assemblage of a small, open access mangrove creek highly influenced by aquaculture farms, was studied for the first time in the Philippines as a baseline of such system as well as examining the degree of ecological disturbance among fish habitats, as basis for the necessity to rehabilitate mangrove resources aiming to balance human activities and mangrove functioning. In total, 475 fishes (total weight = 3875 g) were captured and 50 species representing 32 families were identified. Thirty two species were represented by small numbers (< 5 individuals). Commercial species was considerably high (~23 species) but majority were low grade commercial species. Total species, species diversity and fish abundance consistently showed a decreasing pattern from outside creek to inner creek. Fish habitats exhibited substantial differences following a distinct spatial segregation of fish communities, a dominance of non-shared species and a minimal species overlapping inside the creek, which is attributable to the existing mangrove fragmentation associated with aquaculture ponds in the area. Increasing levels of disturbances were observed within the creek indicating 'stress' as a result of overutilization of mangroves by aquaculture farms. Our results confirmed the need to rehabilitate mangrove resources in this area. The development of mangrove resources through reforestation, coupled by strict regulation of fishing activities and aquaculture ponds will reduce ecological stress in the area and regain gradually a robust mangrove functioning that will improve fish diversity, fisheries and productivity of adjacent coastal systems by creating a suitable fish nursery, feeding ground and refuge habitat.

Key words: fish assemblage, small mangrove creek, disturbance, aquaculture pond, fragmented mangroves.

1. Introduction

Mangroves are capable of enhancing fish biodiversity and fisheries of adjacent systems (Laegdsgaard, Johnson 1995; Mumby *et al.* 2004) through its putative nursery and refuge functioning (Faunce, Serafy 2006; Robertson, Duke 1987), and provisioning of sufficient amounts of food deriving from detrital pathways (Odum, Heald 1972). In addition, ecological features of mangrove such as high structural complexity (Rönnback *et al.* 1999), high turbidity (Cyrus, Blaber 1987) and relative distance to coral reefs (Shulman 1985) creates a suitable habitat for the growth of fish larvae and juveniles by allowing limited predation efficiency of opportunistic feeders. However, the connectivity of mangroves with adjacent coastal systems has been continuously altered following the declining status of mangroves (FAO 2007; Giri *et al.* 2011) due to unavoidable activities of humans around the world (Alongi 2002; Layman *et al.* 2004; Layman *et al.* 2011). In the Philippines, more than half of the country's mangrove has vanished with such disappearance being attributable to the conversion of wild areas into aquaculture farms (Primavera 1995; Primavera 2000) that created immense fragmentation and subsequent modification on the quantity and physiological condition of inhabiting fishes (e.g. Shinnaka *et al.* 2007; Taylor *et al.* 2007). The most critical aspect of mangrove fragmentation is modification of ecological connectivity to adjacent systems which will lead to deterioration of fish biodiversity and collapse of fisheries production.

While conservation-oriented mangrove rehabilitation is an increasing priority in the Philippines (Primavera 2000), understanding mangrove-fish connectivity at various spatial scales (Baran, Hambrey 1998) is necessary to develop a desirable balance between healthy ecosystems and human activities (Robertson, Duke 1990). Mangrove reforestation is a common method to restore ecological integrity of degraded mangroves (Primavera 1995). However, studies on small, human-impacted mangroves are still non-existent in the Philippines. Although a positive correlation of fish/shrimp and mangrove area has been reported (Camacho, Bagarinao 1986; in Primavera 1995), for conservation, there is still a confounding argument as to what degree of effort must be made to restore ecological integrity of denuded mangroves. We believe the answer to such argument should start with the simple basic steps which consist in the acquisition of empirical data (Faunce, Serafy 2006) from impacted sites. Hence, we conducted a brief evaluation of the fish community inhabiting a small mangrove creek known as 'Sibunag creek' which first and foremost is highly impacted by aquaculture ponds. Creeks are water pathways in mangrove forest that ultimately act as fish habitat **(**Mwandya *et al.* 2010**)** especially during low tide (Robertson, Duke 1990). Subsequently, this area is considerably practical for fish surveys because of its accessibility, resulting from the occurrence of particularly denuded mangroves, thus enabling steady data collection. The area is substantially conducive as pilot site because of its clear representation of an impacted mangrove surrounded by series of aquaculture ponds which is a typical setting of an unregulated mangrove in the Philippines. The primary objective of the study was to characterize the fish composition and distribution of each habitat – outside creek, creek mouth and inner creek – creating a baseline of such system and to examine the degree of disturbances and/or stress from these fish habitats thereby creating a scientific basis for evaluating the necessity to rehabilitate the robustness of such system in the Philippines and elsewhere.

2. Material and methods

2.1 Study area

Sibunag Creek (10°26′13″N 122°36′14″E) is located at the southwest portion of Guimaras Island, Central Philippines which is surrounded by Guimaras Strait, Panay Gulf and Sulu Sea (Fig. 1). The main creek channel (unexposed to air) measures around 2.5 km long and 50 to 100 m wide. The water was purely marine because of limited freshwater appearance due to prevailing summer (Fig. 2A). The creek contained minimal influence from human settlements with only about 10 to 15 households (Fig. 2B). As mentioned earlier, the most striking anthropogenic feature was the conversion of large mangrove forests into aquaculture ponds in the vicinity (Fig. 2C). The extent of mangroves varies largely from partially to completely cut and most trees were often fringing the ponds which act as buffer against pond erosion. Several large passive fishing gears (e.g. fish corral) has been standing along adjacent coastlines (Fig. 2D).

Outside creek was situated 50 to 150 m from the coastline and/or 500 m from the creek mouth; creek mouth as intermediate between outer creek and inner creek; and inner creek was approximately 2.5 km to the innermost from creek mouth. Outside creek was highly exposed to large passive fishing gears while creek mouth and inner creek were highly influenced by the presence of aquaculture ponds and artisanal fishing activities such as hook and line, lift nets, and shell gleaning. In terms of mangrove extent, outside creek was characterized by few, fringing *Rhizophora* species approximately < 5 m wide; creek mouth was larger than outside creek with *Rhizophora* species around < 20 m wide and inner creek as largest with < 50 m wide and more diverse species (e.g. *Avicennia*, *Bruguiera*, *Ceriops*, *Excoecaria agallocha*, *Heritiera littoralis*, *Nypa fruticans*, *Rhizophora* and *Sonneratia)*.

2.2. Sampling

Three sampling stations – outside creek (O), creek mouth (C) and inner creek (I) – were established (Fig. 1). Sampling was conducted twice each day during May 14 (spring) and 21 (neap) 2010) to cover high tide and low tide cycle. In total, four sampling (spring high tide, spring low tide, neap high tide and neap low tide) were conducted for each station. Sampling started at outside going to inner creek and ~3 h before peak tide to cover up the entire sampling tide. Fish and environmental variables were sampled simultaneously. Salinity was measured by refractometer (ATAGO®), water temperature by alcohol thermometer, water clarity by secchi disc and water depth by weighted line. For current speed measurement, a plastic bottle was allowed to float at known distance and then finishing time was recorded. Fishes were captured by otter trawl measuring L = 8 m, W = 3 m, H = 0.5 m and trawl net consisting of 10 mm, 12 mm and 16 mm mesh. Trawling time was 10 minutes per sample at

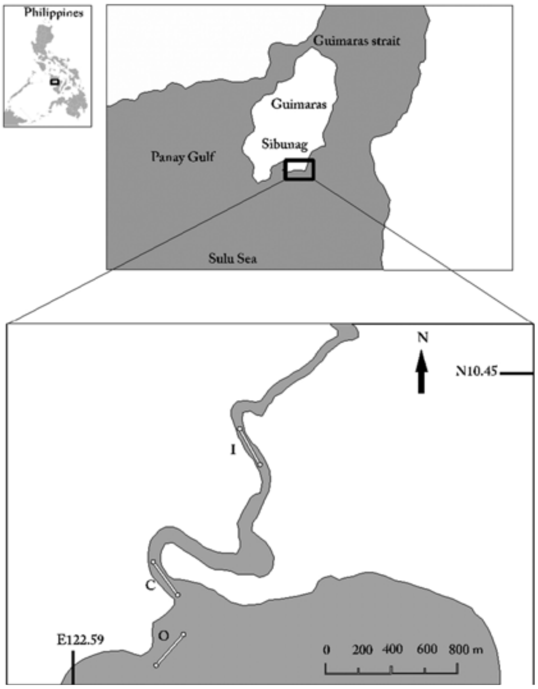

Fig. 1. Map showing the location of the sampling stations: outside creek (*O*), creek mouth (*C*) and inner creek (*I*).

Fig. 2. Representative images of physical setting and human activities in the creek: (A) uppermost portion where freshwater usually drains during wet season but was completely desiccated during summer season; (B) houses and fishing boats in the innermost portion; (C) aquaculture pond along the creek; and (D) fishing gears along outside creek.

~1.84 knots speed. Average travel distance per trawl was ~570 m with an area covered approximately 1710 m^2. In case of entanglement, trawling was temporarily stopped to eliminate unwanted debris and then resumed until 10-minute trawl was finally reached. After which, fishes were harvested, sorted from other fauna and preserved in 10% seawater-formalin (buffered) to prevent $CaCO_3$ degradation. Fish samples were immediately transported to laboratory where species identification was carried out. Fishes were classified to species level, if possible, using identification guide by Carpenter and Niem (1999a; 1999b; 2001a; 2001b) and Masuda *et al.* (1984). Total length (TL) and wet weight (ww) of fish were measured by plastic caliper and top loading balance, respectively.

2.3 Data analysis

Data on fish abundance and biomass for all habitats (as main effect) were tested for spatial differences using one-way analysis of variance (ANOVA, $\alpha = 0.05$). Similarity percentage (SIMPER) analysis was employed for all species using data on species abundance to determine the most typifying species, i.e. species with higher catchability because of high abundance and frequent occurrence (Clarke, Warwick 2001). Data on actual species abundance was used for non-metric multi-dimensional scale (MDS) to examine spatial patterns of fish assemblage among stations (Clarke, Warwick 2001). Prior to MDS, data were transformed to log (x + 1) to narrow the gap between dominant and rare species followed by a similarity triangular matrix of Bray-Curtis similarity index and eventually creation of MDS plot. Similar dataset were used for one-way analysis of similarity (ANOSIM) to corroborate findings of MDS by examining any distinct similarity/dissimilarity among habitats. A follow-up analysis was made for all fish species among habitats by examining qualitatively the non-shared, i.e. fish species present exclusively at certain habitat and shared species, i.e. fish species being present in other stations (Laegdsgaard, Johnson 1995) to determine species overlapping among habitats thereby allowing broad scale analysis on fish habitat differences. Abundance/biomass comparison (ABC) plots were created from the total abundance and biomass of all species among habitats to examine the level of disturbance (Clarke, Warwick 2001). SIMPER, MDS, ANOSIM and ABC plots were analyzed through PRIMER v 5 (Clarke, Warwick 2001).

3. Results

3.1. Environmental variables

Salinity and water temperature were generally stable throughout the creek with values range between 35.7 ± 0.6 to 37.3 ± 2.1 for salinity and 32.8 ± 0.9 to 33.1 ± 1.1 for temperature. Clearer water was observed along outside creek (1.5 ± 0.1 m) whereas more similar turbid water for creek mouth and inner creek (1.2 ± 0.1 m). Stronger current occurred along inner creek but became weaker approaching creek mouth and outside creek. Outside creek was deeper (3.2 ± 1.2 m) compared to creek mouth (2.6 ± 0.7 m) and inner creek (1.6 ± 0.5 m). Sand was the most dominant substrate in outside creek whereas mud dominated creek mouth and inner creek.

3.2. Fish community structure and level of disturbance

After 12 trawl samples, 475 fishes (total weight = 3875 g) representing 50 species and 32 families were captured (Table I). Catches were dominated by Leiognathidae (32%), Teraponidae (9.4%), Haemulidae (9%), Platycephalidae (8.6%) and Mullidae (6.1%). Around 32 out of 50 species belonged to the lowest class abundance (< 5 individuals) (Fig. 3) and of which, greater than 50% were represented by single individual. *Leiognathus blochii* (30%) was the most abundant species but only represented 11.9 % biomass because of its smaller size (Table I), whereas *Pomadasys kaakan* was most dominant for fish biomass (21.3%). Regarding species abundance per stations, five species dominated outside creek: *L. blochii*, *Pelates quadrilineatus*, *Onigocia pedimacula*, *Upeneus tragula* and *Cynoglossus abbreviatus* whereas two species dominated both creek mouth and inner creek: *L. blochii* and *Pomadasys kaakan* (Table I). SIMPER revealed *Leiognathus blochii* as the most typifying species. Total species, species diversity and fish abundance were consistently showed substantial differences and a noticeable decreasing pattern from outside creek going to inner creek (Table I). Contrastingly, fish biomass showed no significant differences among stations. The number of commercial species was generally high with 23 species, however, majority of this species were classified as low grade commercial species (Rönnback *et al.* 1999). Spatial segregation of fish assemblages was observed for MDS with outside creek clearly separate from creek mouth and inner creek (Fig. 4). This finding was even corroborated by significant dissimilarities among pairwise comparison of fish habitats showing dissimilarities between outside creek and creek mouth (R value = 0.53) as well as outside creek and inner creek (R value = 0.72) but indistinguishable for creek mouth and inner creek (R value = -0.01). Furthermore, non-shared species (70%) showed greater proportion over shared species (30%) which result in reasonable distinction among stations (Table I). For non-shared species, highest number belonged

Table I. Fish families and species (arranged phylogenetically) with their abundance (count) in four trawlings per habitat, total abundance (count) in all 12 trawlings, fish total length, TL, (range in millimeters) and wet weight (range in grams).

Family	Species	Outside creek	Creek mouth	Inner creek	Total abundance	Length (mm)	Weight (g)
Muraenidae	*Gymnothorax albimarginatus* *	1	-	-	1	440	120
Ophichthidae	*Pisodonophis cancrivorus* *	-	1	-	1	65	2
Plotosidae	*Plotosus lineatus* *	-	-	4	4	158-174	32-42
Batrachoididae	*Batrachomoeus dubius* *	5	-	-	5	68-99	5-19
Antennariidae	*Phrynelox zebrinus* *	-	3	-	3	76-106	14-37
Syngnathidae	*Hippocampus kuda* +	-	2	1	3	63-97	2-5
Scorpaenidae	*Pterois antennata* *	-	1	-	1	92	2
	Scorpaenopsis neglecta *	1	-	-	1	77	11
Aploactinidae	*Paracentropogon longispinnis* *	3	-	-	3	49-64	2-4
Platycephalidae	*Onigocia pedimacula* ++	31	7	1	39	68-163	2-29
	Platycephalus indicus +	1	-	1	2	161-166	25
Ambassidae	*Ambassis urotaenia* *	-	-	1	1	45	1
Serranidae	*Epinephelus malabaricus* +	-	1	2	3	58-132	3-31
Sillaginidae	*Sillago aeolus* *	-	1	-	1	64	3
	S. sihama *	3	-	-	3	57-66	1-2
Leiognathidae	*Leiognathus blochii* ++	55	46	43	144	30-83	0.5-10
	L. equulus *	4	-	-	4	54-75	3-7
	L. fasciatus *	-	-	2	2	72-74	5-7
	Secutor indicus *	-	1	-	1	52	3
Lutjanidae	*Lutjanus fulvus* *	-	-	1	1	56	3
	L. johnii *	-	-	4	4	54-67	3-5
	L. russelii	1	-	1	2	66-99	4-12
Gerreidae	*Gerres abbreviatus* *	-	-	1	1	89	13
	G. oyena +	8	5	-	13	35-68	1-6
Haemulidae	*Pomadasys kaakan* +	-	23	20	43	87-134	10-34
Lethrinidae	*Lethrinus semicinctus* +	1	-	4	5	37-105	1-18
Nemipteridae	*Pentapodus nagasakiensis* +	5	1	-	6	56-65	3-4
Mullidae	*Upeneus tragula* ++	22	6	1	29	47-101	1-13
Terapontidae	*Pelates quadrilineatus* +	42	3	-	45	70-91	1.5-10
Labridae	*Coris picta* *	3	-	-	3	81-95	6-11
	Parajulis poecilepterus *	1	-	-	1	57	2
	Stethojulis strigiventer *	2	-	-	2	81-87	8
Callionymidae	*Callionymus octostigmatus* *	-	6	-	6	75-85	2-3
Eleotridae	*Butis butis* *	4	-	-	4	57-81	1-5
Gobiidae	*Acentrogobius caninus* *	1	-	-	1	97	10
	A. janthinopterus *	5	-	-	5	65-89	4-9
	A. nebolusos *	2	-	-	2	61-91	3-9
	Glossogobius celebius *	-	-	1	1	96	8
Scatophagidae	*Scatophagus argus* *	1	-	-	1	300	781
Bothidae	*Taeniopsetta ocellata* *	1	-	-	1	nd	nd
Paralichthyidae	*Pseudorhombus arsius* *	1	-	-	1	220	12
Soleidae	*Liachirus melanospilos* *	12	-	-	12	58-89	2-10
	Solea ovata *	1	-	-	1	55	2
Cynoglossidae	*Cynoglossus abbreviatus* ++	17	4	3	24	71-135	2-18
Triacanthidae	*Triacanthus biaculeatus* +	5	1	-	6	47-78	1-5
Ostraciidae	*Lactoria cornuta* *	-	1	-	1	23	2
Tetraodontidae	*Arothron immaculatus* +	-	2	8	10	91-107	25-38
	A. manilensis +	-	4	5	9	63-116	7-47
	A. reticularis *	-	-	1	1	nd	nd
	Chelonodon patoca +	-	4	10	14	52-98	4-25
	Total abundance (count)	239	121	115			
	Total species (mean±s.d)	13.3±2.6	9.0±4.2	8.0±4.1			
	Species diversity (mean±s.d)	2.0±0.2	1.7±0.3	1.6±0.4			
	Mean fish abundance (mean±s.d)	59.8±43.6	30.3±23.9	19.0±22.2			

Legend: * unique species; + species shared between 2 stations; ++ species shared by all stations; nd – no data

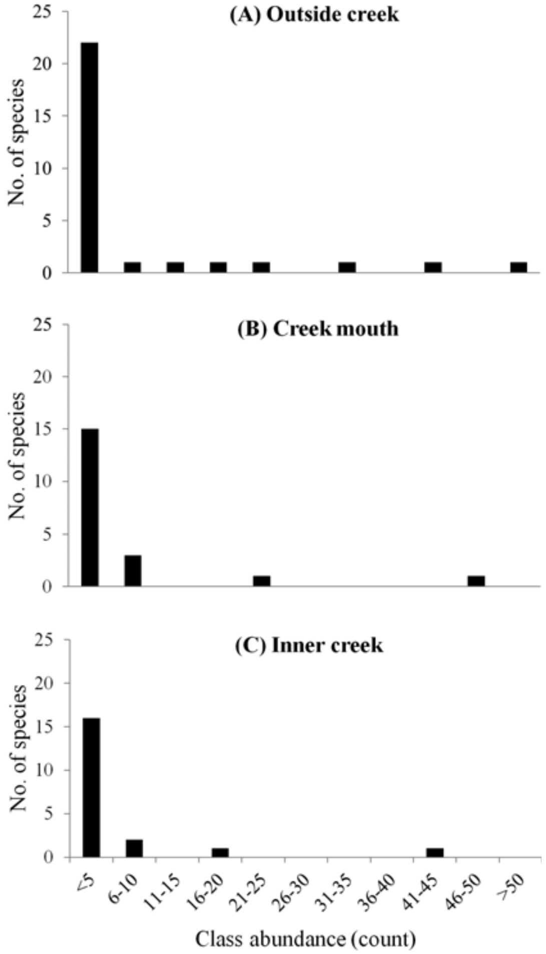

Fig. 3. Class abundance (count) and number of species for (A) outside creek; (B) creek mouth; and (C) inner creek.

to outside creek (18) followed by inner creek (8) and creek mouth (7) (Table I). Of these species, outside creek has 39% species represented by single individual, 71% for creek mouth and 63% for inner creek. For shared species, all stations shared only 4 species: *Leiognathus blochii, Onigocia pedimacula, Upeneus tragula* and *Cynoglossus abbreviatus.* Outside creek and creek mouth shared only 4 species: *Pelates quadrilineatus, Gerres oyena, Triacanthus biaculeatus* and *Pentapodus nagasakiensis.* Outside creek and inner creek shared only 3 species: *Lethrinus semicinctus, Lutjanus russelii* and *Platycephalus indicus*. Lastly, creek mouth and inner creek shared only 5 species: *Chelonodon patoca, Arothron immaculatus, Arothron manilensis, Hippocampus kuda* and *Epinephelus malabaricus*. ABC curve analysis revealed a noticeable increase of disturbances in which outside creek showed a lesser disturbance, creek mouth being moderately disturbed and inner creek being grossly disturbed (Fig. 5).

4. Discussion

The fish assemblage in Sibunag creek exhibited marked differences with that found in a larger and protected mangrove forest like those studies in Pagbilao, Northern Philippines (Pinto 1987; Rönnback *et al.* 1999). For instance, Pinto (1987), in Pagbilao rivers, registered 128 taxa while Rönnback *et al.* (1999), in Pagbilao mangroves, recorded 37 taxa. Both studies have recorded family Chandidae as the dominant group compared to family Leiognathidae for the present study. Furthermore, the species abundance was around 21 times larger in Pagbilao (e.g. Rönnback *et al.* 1999) than in Sibunag Creek. In Sikao creek, on an undisturbed, protected mangrove in Thailand, Tongnunui *et al.* (2002) harvested 135 taxa wherein fish abundance was 54 times larger than in the present study. Such finding substantially confirms that small, culture pond impacted mangrove creeks can accommodate a considerable lesser abundance of a lesser number of fish species when compared to larger and protected ones.

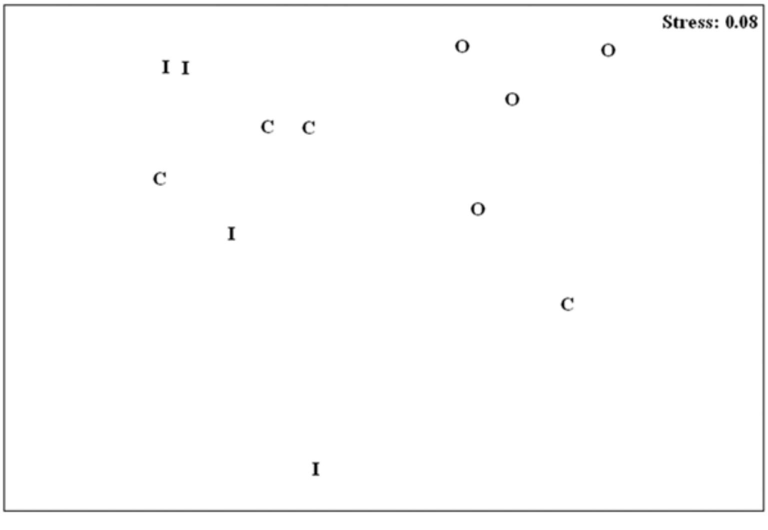

Fig. 4. Non-metric multidimensional scale (MDS) of fish communities among fish habitats using Bray-Curtis similarity index from a log (x+1) data transformed of species abundance. (O) outside creek, (C) creek mouth and (I) inner creek.

The differences in fish composition and abundance, spatial segregation of fish assemblages as well as the higher proportion of non-shared species over shared species among stations strongly suggest a degree of heterogeneity of fish assemblages in the mangrove creek. Despite the relatively homogenous water column (e.g. salinity and temperature), species overlapping in the creek was generally limited hence indicating a minimal interaction of fishes (e.g. Laroche *et al.* 1997). In fact, the most remarkable habitat heterogeneity was found between outside creek and both creek mouth and inner creek. Moreover, the higher variation of non-shared species between outside and even creek mouth, even at the closest proximity, creates an indication of habitat differences between creek system and adjacent coasts. Such heterogeneity can be explained by the presence of aquaculture ponds which probably exhibit a low capability to function as nursery and refuge area to adjacent coasts. The increasing level of disturbance from outside creek to inner creek as shown by ABC curve analysis is highly attributable to the presence of aquaculture farms which creates a remarkable ecological stress on fishes despite the variations in mangrove extent throughout the creek (i.e. richer mangroves in inner creek, lower in creek mouth and completely non-existent on several areas within the creek). Overutilization of mangroves has substantial negative influence on the ecological functioning of mangroves by reducing fish migration possibilities by limiting the shelter capacity inside and outside the creek, thereby affecting the premise of nursery and refuge habitat. Considerable concern arises from the fact that many of the species captured are represented by small number of fishes which may lead to specific extinction in this area. Exploitation of mangrove resources beyond threshold has strong negative consequences on the *status quo* of fish biodiversity and may eventually result in a collapse in fisheries production. Also noteworthy to consider is that most fishermen no longer dwell in this creek for fishing as abundance of highly commercial valued species is relatively low, hence, they fish largely in adjacent coast (J.B.R. Abrogueña, personal observation).

As we classified fish species according to their trophic group, ecological guild and life habits using a meta-analysis based on several literatures (Carpenter, Niem 1999a; 1999b; 2001a; 2001b; Chícharo *et al.* 2006; FishBase; Pinto 1987) we observed noticeable patterns which further enhance our understanding on fish assemblage structuring in the creek. For instance, in relation to trophic group (e.g. carnivorous, omnivorous and planktivorous; Chícharo *et al.* 2006; FishBase), a decreasing trend is observed for carnivorous species from outside to inner creek (55 to 41%) whereas carnivorous-omnivorous-planktivorous species (COP) remain generally stable between creek mouth and inner creek (32 to 35%). The occurrence of decreasing number of carnivorous species going to inner creek and evenness in the number of COP species may suggest limited prey availability and trophic interaction. In terms of ecological guild (e.g. marine, estuarine and riverine; Pinto 1987), the majority of the species present for each habitat were the representatives of the marine guild (65 to 77%), thus reflecting not only the absence of freshwater inputs but also a great dependence of these fish on mangroves. Regarding life habit (e.g. B-benthic, BP-benthopelagic and P-pelagic; Pinto 1987), the ratio of benthic and bentho-pelagic among habitat exhibited an inverse relationship with higher benthic species on outside creek but lesser for creek mouth and inner creek, i.e. outside creek (B21:BP6), creek mouth (B11:BP6) and inner creek (B9:BP12).

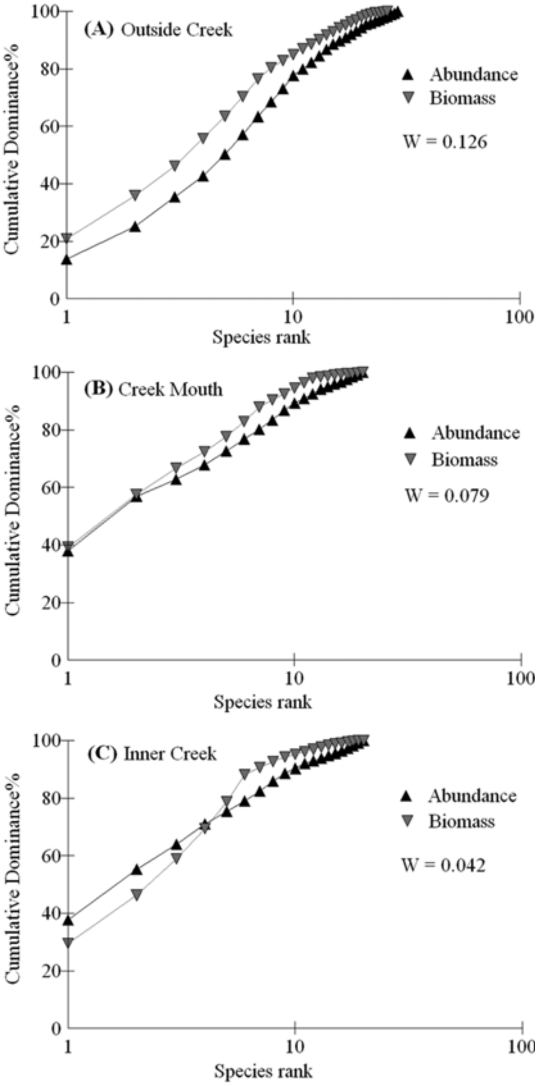

Fig. 5. Abundance/Biomass Comparison (ABC) plots for (A) outside creek; (B) creek mouth; and (C) inner creek. Abundance = black triangle, biomass = inverted gray triangle.

Overall, the present study provides a brief description of fish assemblage structure in the highly human-impacted Sibunag mangrove creek. We believe that the findings of the present study will reinforce studies with similar backgrounds and provide the basis on which larger scale studies may be built upon, even on legally regulated mangrove forests (e.g. Pagbilao mangroves; Gilbert, Jansssen 1998; Pinto 1987; Rönnback *et al.* 1999). Ultimately, the results presented herein provide proof of the need for mangrove rehabilitation efforts (as well as their fine-tuning) aiming to balance an acceptable relationship between human activities and robust mangrove functioning in the Philippines and elsewhere. A thorough enhancement of mangrove resources especially within the creek and the strict regulation of fishing activities and aquaculture pond operation that affects mangrove functioning should be encouraged and emphasized by conservation managers in order to reduce the level of stress and to regain gradually a robust ecosystem health in the creek which in turn could lead not only to an increase in fish biodiversity and fisheries production within mangroves but also the capacity mangrove creek to enhance productivity of adjacent coastal systems. Future works should focus on examining year-round spatial and temporal variability of fishes with an integration of hydrology and climatology as it would elevate not only empirical background of such type of system but also reinforce a solid basis of habitat connectivity necessary for fine-tuning the interplay between mangrove functioning and human activities.

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