Marine Biodiversity at the SEAFDEC/AQD Research Stations in Iloilo and Guimaras, Philippines

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Abstract

Species inventories were recently made in and around the research stations of the SEAFDEC Aquaculture Department to facilitate subsequent monitoring. AQD's Tigbauan Main Station (TMS, since 1973) faces the deep open waters of the Panay Gulf and Sulu Sea and is flanked by densely populated fishing villages operating nearshore fish corrals, gillnets, longlines, and beach seines. In 2013–2014, sampling at the sand-gravel intertidal and monitoring of the catch of the various gears showed at least 579 species from 213 families, including 252 species of fishes, 228 mollusks, 48 crustaceans, 12 cnidarians, 9 echinoderms, 16 seaweeds, sea turtles, and sea snakes inhabiting the nearshore areas off TMS. Any adverse effect of the TMS hatcheries and laboratories is difficult to discern on top of the continuous intense fishing and habitat disturbance. AQD's Igang Marine Station (IMS, since 1980) is in a cove under the rocky cliffs of southern Guimaras, behind several islands facing the Panay Gulf and Sulu Sea. IMS includes 40 ha of seagrass beds and sandflats around five rocky islets and two 6–12 m deep basins where broodstock and grow-out cages are moored. IMS is flanked by many fish corrals operated by fishers who live in villages in nearby coves. Fishers on outrigger boats also use gillnets and spears, and others glean for mollusks and echinoderms inside IMS. In 2011–2012, some 786 species in 261 families were collected or photographed at IMS, including 74 species of fishes, 40 crustaceans, 391 mollusks, 44 echinoderms, 87 cnidarians, 47 poriferans, 24 ascidians, and 12 bryozoans, and sea snakes living among 48 seaweeds and 4 seagrasses. Biodiversity at IMS seems high despite 35 years of operation of the fish cages and the continuous fishing, gleaning, and boating by the locals. Several species of filter-feeding invertebrates grew on the cage nets and platforms but were not found in the natural habitats. The cages provide additional attachment surfaces for many species; these biofoulants presumably reduce water flow into the cages but they also remove nutrients and particulate wastes and help maintain good water quality. Nevertheless, siltation is evident under the cliffs inside the cove, and the sandflats may be expanding over the seagrass beds. AQD's 16-ha Dumangas Brackishwater Station (DBS, since 1998) is flanked by freshwater Talaugis River, by hundreds of hectares of mangrove-derived fish ponds, and by Pulao Creek and an extensive mudflat with fringing mangroves at the northeastern end of Iloilo Strait. In 2009–2010, 16 ponds with water areas from 0.5 to 0.9 ha were sampled during harvest of the experimental crops. At least 90 species of non-crop fishes lived in the DBS ponds, along with 35 crustaceans, 60 mollusks, three echinoderms, two cnidarians, and a water snake. The snails *Cerithideopsilla* spp., *Cerithium coralium*, and *Batillaria* spp. were very abundant in the ponds. Almost all the same species in the ponds, plus many others, were found in the adjoining fringing mangroves with ~10 species of trees. The ponds serve as proxy for mangrove lagoons that harbor the young of migratory fishes as well as all life stages of resident species. Several non-crop species inside the IMS cages and the DBS ponds are harvested by the pond workers and contribute to nutrition and income. Aquaculture farms should be managed for high biodiversity to ensure sustainability. Ways are suggested for SEAFDEC/AQD to do so at its aquaculture research stations.

Keywords: species inventories, biodiversity, sustainability

Introduction

Marine resources and ecosystems must be adequately studied and known to be sustainably used. Such knowledge has been generally taken for granted or overlooked by aquaculture practitioners and even research institutions. Partly as a result of such historical oversight, aquaculture has been chastised both in the scientific literature and by the media for a wide range of environmental and social impacts, including (i) pollution (uneaten feeds, excreta, silt, pathogens, debris, nitrogen and phosphorus); (ii) the fish meal trap; (iii) loss of biodiversity; and (iv) poor people becoming poorer (Primavera, 1993; Phillips, 1995; Naylor *et al.,* 1998, 2000; Holmer *et al.,* 2002).

Loss of biodiversity due to aquaculture has been widely assumed but not much documented in the Philippines, except the reduction of the mangrove area from 418,000 ha to 117,000 ha as pond area increased from 73,000 ha to 261,000 ha between 1950 and 1995 (Bagarinao, 1998, 1999). Indeed, that species have been and are lost due to aquaculture? For many aquaculture areas, the baseline species composition in nearby natural aquatic habitats has not been studied, and the later (current) species composition has yet to be studied. To address such neglect even belatedly, species inventories were conducted at the three research stations of the SEAFDEC Aquaculture Department in Tigbauan and Dumangas, Iloilo, and in Igang, Guimaras.

Materials and Methods

Species inventory at Tigbauan Main Station

SEAFDEC/AQD's Tigbauan Main Station (TMS, since 1973) in Buyuan, Tigbauan, Iloilo, faces the deep open waters of the Panay Gulf and further to the west and south, the Sulu Sea (Figure 1) and is flanked by densely populated fishing villages. The TMS beach front is ~540 m long, with black sand and gravel, the high tide debris line ~5–10 m from the water line at lowest low tide, the beach slope ~30–40° (Figure 2). In 2013, the sand-gravel intertidal fronting TMS and eastward to Buyuan Creek was surveyed several times during daytime negative low tides and all attached species (e.g. seaweeds, sea anemones) and stranded species (e.g., seaweeds, opisthobranchs, jellyfish) were photographed and recorded, and the unfamiliar specimens preserved in formalin. Buried species were not included (not dug out). Empty but intact mollusk shells and echinoderm testa found at the beach were included and considered as those of Tigbauan resident species.

Figure 1. Google Earth view of the three aquaculture research stations of the SEAFDEC Aquaculture Department in Panay and Guimaras Islands in Central Philippines: TMS, Tigbauan Main Station; DBS, Dumangas Brackishwater Station; IMS, Igang Marine Station. Panay Gulf opens into the Sulu Sea to the west and south.

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Figure 2. SEAFDEC/AQD's Tigbauan Main Station. A. Aerial view circa 1996, showing the seawall jetties traversing the beach and the effluent pipes emptying onto the beach as creeks and puddles; B. Some of the hatcheries and two seawater reservoirs, circa 1996; C. View of the TMS beach and nearshore area in 2014. Visible in all three photos are the nearshore fish corrals, the current versions of which were sampled in 2013-2014.

In March–April 2013 and February–March 2014, the catch of two fish corrals (locally known as 'punot' and 'tangkop'), 3–4 gill nets ('pukot'), 2–3 beach seines ('sahid'), 1–2 longlines ('labay'), and a big fish basket ('bubo') operated nearshore off Buyuan village were monitored in the early morning and sometimes in the late afternoon when the catch was landed. All species landed were examined and photographed and specimens of the unwanted species were preserved in formalin. The species caught by fishing gears were wide-ranging but entered Tigbauan and TMS waters presumably in the course of foraging and migration.

Species inventory at Igang Marine Station

SEAFDEC/AQD's Igang Marine Station (IMS, since 1980) is in a cove surrounded by the rocky cliffs of southern Guimaras, behind several islands facing the Panay Gulf and the northern Sulu Sea (Figure 1). Cages for milkfish were set up at a marine cove in Igang about 1980 and a 50 ha marine cove with islets was reserved for SEAFDEC about 1986. IMS includes 40 ha of seagrass beds and sandflats around five rocky islets and two 6–12 m deep basins where broodstock and grow-out cages are moored (Figure 3). In 2003, the Igang Mariculture Park (IMP) was established to anchor commercial marine cages of private operators. IMS is flanked by many fish corrals operated by fishers who live in villages in nearby coves. Fishers on outrigger boats also use gill nets and spears inside IMS, and gleaners walk around the seagrass beds exposed during negative low tides. Motorized outrigger boats carrying IMS personnel and goods, and now also tourists, traverse the IMS habitats every day.

Figure.3. SEAFDEC/AQD's Igang Marine Station. A. Google Earth view taken in February 2015, showing the five rocky islets, the seagrass bed, the sandflat, coral bed, and the 6–12 m deep basins for broodstock cages near Islet 9, and growout cages near Islet 6; B. Aerial view looking south, circa 2000, showing the different habitats and the cage basins looking much the same as today. Both photos show some of the 50 or so fish corrals that local fishers operate within 200 m of IMS.

Several visits were made to IMS during the northeast monsoon months between September and June in 2010–2012 when the calm weather and the daytime negative low tides allowed field work around the station, particularly the intertidal around the five rocky islets and the connecting seagrass beds, sand flats, and silty coves. All attached marine plants and invertebrates and all species living among them were examined closely and photographed. Buried species were not dug out. All empty but intact mollusk shells and echinoderm testa found inside IMS were considered as those of resident species. The aquaculture platforms and nets were examined for attached species, and the fishes inside and outside the fish cages were recorded and photographed during harvest of farmed milkfish and seabass under AQD-approved projects. Whenever gillnetters, spear fishers, and gleaners were found operating inside IMS, their catch was also recorded and photographed.

Species inventory at Dumangas Brackishwater Station

SEAFDEC/AQD's 16-ha Dumangas Brackishwater Station (DBS, since 1998) is flanked west by the freshwater Talaugis River, north and south by hundreds of hectares of mangrove-derived fish ponds, and east by Pulao Creek and an extensive mudflat with fringing mangroves at the northern end of Iloilo Strait (Figure 1, Figure 4). The 16 DBS ponds (with water areas from 0.5 to 0.9 ha) are used in technology verification experiments and production runs (Baliao *et al.,* 1998; Coniza *et al.,* 2010; Jamerlan and Coloso, 2010; Madrones-Ladja *et al.,* 2012; Jamerlan *et al.,* 2014). In 2009–2010, all ponds were sampled during harvest of the experimental crops when the ponds were totally drained. Bycatch species were collected, identified, and enumerated fully.

Figure 4. SEAFDEC/AQD's Dumangas Brackishwater Station, Google Earth views taken 2014. A. DBS (in the white rectangle) lies in the midst of large tracts of fishponds derived from mangrove land, with Talauguis River at the west end and Pulao Creek to the northeast; B. The 16 experimental ponds (several subdivided for replicates), with the mangrove greenbelt at the east end.

DBS has a mangrove greenbelt (30 m wide x 180 m long) fronting, but separated by a high concrete dike from Pulao Creek, and subdivided into one large and six small compartments by concrete fences for a past experiment. The mangroves and mollusks in the DBS greenbelt were documented in October 2009. In addition, a local fisher was hired to set a tidal enclosure net ('pahubas') outside the DBS greenbelt in October 2010, and all the fishes and crustaceans that were caught were photographed and identified.

Identification of species

For identification of the commercially important fishes, crustaceans, and mollusks, the main reference was the six-volume FAO Species Identification Guide for Fishery Purposes, West Central Pacific (Carpenter and Niem, 1998a, 1998b; 1999a, 1999b; 2001a, 2001b). Other taxonomic references include Masuda *et al.* (1984), Kuiter (1992), Rainboth (1996), Kimura and Matsuura (2003), Matsuura and Kimura (2005), Yoshida *et al.* (2013) for fishes; Springsteen and Leobrera (1986), Okutani (2004), and Poppe (2008a, 2008b; 2010, 2011) for mollusks; Schoppe (2000) for echinoderms; Colin and Arneson (1995), Richmond (1997) for invertebrates; Trono (1997), Calumpong and Menez (1997) for seaweeds; and Primavera *et al.* (2004) for mangroves. Also useful were pictorial accounts of marine biodiversity in the Philippines and the South China Sea (Chou and Alino, 1996; Allen, 1998, 2000; White, 2001). Many species of sponges, bryozoans, and tunicates could not be identified to scientific names. Marine botanist Lawrence Liao identified the unfamiliar seaweeds, carcinologist Jose Christopher Mendoza identified the unfamiliar crabs, and ichthyologist Helen Larson provided advice with the unfamiliar gobies.

Results and Discussion

Biodiversity nearshore off Tigbauan Main Station

The TMS shore and the adjoining Buyuan shore (about 1 km long) is depauperate in intertidal flora and fauna, compared to Igang Marine Station and Dumangas Brackishwater Station. No seagrasses, no corals, no attached invertebrates, but seasonal seaweeds, and seasonal strandings of sea hares, jellyfishes, salps, and other pelagic invertebrates. This is mainly because the seabed off TMS is unconsolidated gravel and sand and provides limited and unstable habitat surfaces and crevices for flora and fauna. Also, the rough weather during the southwest monsoon overturns the seabed and disrupts life cycles. However, the intensive fishing during the northeast monsoon brings to shore so many species of fishes, cephalopods, and crustaceans. In 2013–2014, some 579 species from 213 families in major marine taxa were collected, photographed, and inventoried, including 252 species of fishes, 228 species of mollusks, and 48 species of crustaceans (Table 1). More species could be expected with continued sampling at other times of the year; if the infauna were included; if the microscopic species were sampled; and if the subtidal was surveyed underwater.

This study is the first documentation of the marine biodiversity off Tigbauan, Iloilo in southern Panay, Philippines. This southern coast has had many notable megafauna visitors, many of which have been documented by SEAFDEC FishWorld since 2000: five species of sea turtles (Bagarinao *et al.*, 2010; Bagarinao, 2011), the sunfish *Mola mola*, the whale shark

Table 1. Biodiversity in the nearshore areas fronting the Tigbauan Main Station, Iloilo, Philippines, 2013–2014.

Phylum	Class/Order	Families	Species	Representative species
Chordata	Selachei	3	3	*Rhincodon typus, Odontaspis ferox*
	Batoidei	2	3	*Mobula kuhli, Pteroplatytrygon violacea*
	Osteichthyes	80	246	*Carangoides spp., Lutjanus spp., Nemipterus* spp., *Upeneus spp., Arothron* spp., *Mola mola*
	Reptilia	2	7	*Chelonia mydas, Eretmochelys imbricata, Lepidochelys olivacea, Hydrophis* spp.
	Urochordata	2	3	*Thalia, Doliolum, Tethys*
	Ascidiacea	1	1	*Pyrosoma*
Crustaceans	Penaeidea	2	7	*Acetes* spp., *Penaeus* spp.
	Brachyura	13	28	*Portunus* spp., *Calappa* spp.
	Anomura	3	3	*Coenobita violascens*
	Palinura	1	3	*Panulirus versicolor, P. ornatus*
	Stomatopoda	1	1	*Harpiosquilla harpax*
	Thalassinidea	1	1	*Thalassina anomala*
	Cirripedia	4	4	*Balanus amphitrite, Tetraclita squamosal*
	Isopoda	1	1	*Ligia exotica*
Mollusks	Gastropoda	38	122	*Harpa major, Aplysia* spp., *Cypraea* spp.
	Bivalvia	23	96	*Placuna placenta, Alectryonella plicatula*
	Cephalopoda	6	10	*Octopus* spp., *Sepia* spp., *Photololigo* spp.
Cnidarians	Anthozoa	4	6	*Stichodactyla haddoni, Aiptasia diaphana*
	Scyphozoa	5	5	*Aurelia aurita, Cassiopea medusa*
	Hydrozoa	1	1	*Plumaria* sp.
Annelids	Polychaeta	2	2	*Marphysa* sp., *Eunice* sp.
Sipuncula		1	1	*Chloeosiphon aspergillus*
Echinoderms	Asteroidea	3	3	*Astropecten monacanthus*
	Echinoidea	3	3	*Astropyga radiate*
	Holothuroidea	1	1	*Opheodesoma serpentine*
	Ophiuroidea	2	2	*Ophionereis* sp., *Ophiactis* sp.
Plantae	Chlorophyceae	3	10	*Ulva=Enteromorpha* spp., *Acetabularia* sp.
	Phaeophyceae	4	5	*Dictyota ceylanica, Rosenvingea intricate*
	Rhodophyceae	1	1	*Hypnea spinella*
	All	**213**	**579**	

Rhincodon typus, the tiger shark *Galeocerdo cuvier*, and the dwarf sperm whale *Kogia sima* (Bagarinao, unpublished data). The fishing gears also brought in small deep-sea fishes: the lanternfish *Benthosema pterotum*, the barracudina *Lestidium*, and the snaggletooth *Astronesthes lucifer*. The lionfishes *Pterois* spp., the puffers *Arothron* spp., and the sea anemone *Stichodactyla haddoni* and its commensal *Amphiprion polymnus* were quite common nearshore off TMS.

Above all, the commercial fishes were very diverse in species, sizes, and value—sharks, rays, eels, sardines, mullets, needlefishes, groupers, snappers, threadfins, slipmouths, jacks, round scads, goatfishes, barracudas, mackerels, and the occasional sailfish *Istiophorus platypterus* and milkfish *Chanos chanos*. Cephalopods, crabs, and large shrimps made up a small part of the catch, but included many species. Moreover, the TMS and Buyuan beaches had a high complement of gastropod and bivalve shells, many of them intact and indicative of live animals nearshore.

The TMS tanks discharge large volumes of seawater laden with uneaten plankton, wasted feeds, as well as feces and other metabolites of the hatchery species (and rarely, bacteria and viruses from diseased stocks). This polluted sea water goes through a maze of drain pipes and canals onto the TMS beach. The AQD laboratories, restrooms, and housing complex also discharge large volumes of fresh water laden with various chemicals and sewage into drain canals that mostly open onto the beach as well. Seasonal blooms of the green seaweeds *Ulva=Enteromorpha* and *Chaetomorpha* occur at the TMS and Buyuan beaches during the calm water months, but these have been rapidly consumed by corresponding swarms of sea hares (*Aplysia* spp., *Bursatella leachii*, etc., collectively called by the local term 'kalamputay') that leave behind a huge volume of egg masses. Biological pollution by TMS is undeniable, but the current level of enrichment seems to be within carrying capacity, and adds to the food supply without diminishing the oxygen supply. It is fortunate that TMS is located on an open coast with relatively steep slope and strong tidal currents from the Panay Gulf and the Sulu Sea. The pollutants from TMS apparently are quickly diluted and broken down.

TMS broodstock tanks, plankton tanks, and hatcheries have increased over the years and have multiplied in seawater requirements. All this sea water passes through sand filters and is stripped of particulates including the larvae and juveniles of countless marine species. The sand filters are effective (except during the stormy months) and very few marine species (sea anemone *Aiptasia diaphana*, green seaweeds *Ulva* spp.) can be found in the drain canals inside TMS. Many species (barnacles, sponges, crabs, hydrozoans, even the black coral *Antipathes* sp., etc.) grow on the screens of the seawater intake pipes and have to be regularly removed.

Any adverse effect of the TMS hatcheries and laboratories is difficult to discern on top of the continuous intense fishing and habitat disturbance. So many nearshore species are harvested every day from the water column and from the bottom by various and numerous fishing gears. It is estimated that the resident fishers in Buyuan harvest from the 1 km coast an average of ~500 kg of fishery products every day during the northeast monsoon period (October–May), but a lot less during the southwest monsoon when the fish corrals can not operate. Such high level of extraction of fishes, shrimps, and cephalopods is detrimental to the marine ecosystem. Nearshore fishing gears use fine-mesh nets to catch the small sergested shrimps *Acetes* spp. ('hipon' or 'alamang') and anchovy *Stolephorus* spp. larvae ('lobolobo'), but they also catch large amounts of other small animals of no commercial value but of great ecological importance (e.g., as prey for complex food webs). Several species of small crabs as well as swarming sea hares were not eaten but thrown out of the water to prevent entanglement in fishing nets and interference in seining. Yet, the fisheries sector has not been sufficiently criticized or regulated for this wanton waste of biodiversity.

Biodiversity in the seagrass beds, rocky islets, and sandflat at Igang Marine Station

In 2011–2012, some 786 species in 261 families were collected or photographed at IMS, including 74 species of fishes, 40 crustaceans, 391 mollusks, 44 echinoderms, 87 cnidarians, 47 poriferans, and 24 ascidians (Table 2). Different species combinations were found in the varied habitats — seagrass beds, rocky bases of the islets, sand flats, silty-muddy inner cove, cage netting, and cage platforms (plastic drums floats, bamboo frames). Most invertebrates and seaweeds growing on the net cages and platforms were also found in the natural habitats, but some were not. IMS has a very different species composition than TMS although some species occurred in both stations. More benthic species occurred at IMS because of the protected cove environment, varied habitat types, and the stable substrates. Among the attached seaweeds, seagrasses, corals, sponges, sea squirts, and oysters lived a variety of mobile echinoderms, snails, jellyfish, small fishes, and sea snakes—in a colorful albeit often turbid aquatic forest only a few meters deep. Larger fishes come in with the high tides, and the sunfish *Mola mola*, the sea turtles *Chelonia mydas* and *Eretmochelys imbricata*, and the dugong *Dugong dugon* occasionally strayed into the IMS cove. Artificially reseeded giant clams *Tridacna gigas* have grown large in the IMS sandflat.

Table 2 includes only those that were readily seen when walking around the station during daytime low tides, and none of the microscopic species, nor the infauna, nor the subtidal coral terrace. Presumably missing in the inventory were the species that came into the station only during high tides, or at night, or during the southwest monsoon months between June and September. Certainly more species could be found at IMS if sampling is continued. The IMS species inventory adds information on the marine biodiversity in Guimaras, which has been studied in part by the University of the Philippines-Visayas. IMS has many of the same species photographed in the wild by Kuiter (1992), Colin and Arneson (1995), Allen (1998, 2000), and White (2001), but the IMS specimens did not look as clean and healthy.

Biological pollution by IMS —from fish excreta, uneaten feeds, and occasional diseases— is undeniable. The fish cages also probably impede water flow around the seagrass beds and sandflat and into the inner cove from Islet 5. The seagrass beds are heavily silted and turbid, the sandflat may have expanded, and the inner cove and cliff sides are deep in mud. Still, the IMS species count (Table 2) seems high despite 35 years of operation of the aquaculture

Table 2. Biodiversity in the seagrass beds, sandflats, and rocky islets at Igang Marine Station, Guimaras, Philippines, 2011–2012.

Phylum	Class	Families	Species	Representative species
Chordata	Osteichthyes	37	74	*Pterois* spp., *Canthigaster* spp., *Siganus* spp., *Apogon* spp., *Aeoliscus strigatus, Mola mola*
	Reptilia	2	3	*Chelonibia mydas, Eretmochelys imbricata, Hydrophis cyanocinctus*
	Mammalia	1	1	*Dugong dugon*
	Ascidiacea	7	24	*Oxycorynia fascicularis, Didemnum* spp.
Porifera	Demospongiae	25	47	*Spheciospongia vagabundus, Xestospongia exigua, Adocia viola, Theonella, Haliclona*
Cnidarians	Anthozoa	27	75	*Dendronephthya* spp., *Sarcophyton* spp., *Cerianthus* spp., *Heteractis crispa, Acropora* spp., *Goniopora* spp., *Fungia* spp.
	Scyphozoa	4	5	*Versuriga anadyomene; Cassiopea andromeda*
	Hydrozoa	5	7	*Millepora* spp., *Plumularia* sp.
Annelida	Polychaeta	6	7	*Sabella* spp., *Reteterrebella* sp.
Platyhelminthes	Turbellaria	1	2	*Pseudoceros* sp., *Pseudobiceros* sp.
Crustaceans	Penaeidea	1	2	*Penaeus semisulcatus*
	Stenopodidea	1	1	*Stenopus hispidus*
	Caridea	2	6	*Lysmata amboinensis, Alphaeus* spp.
	Brachyura	9	16	*Pilumnus vespertilio, Lissocarcinus orbicularis*
	Anomura	1	8	*Diogenes megistos, Calcinus laevimanus*
	Palinura	1	1	*Panulirus ornatus*
	Stomatopoda	1	1	*Nanosquilla* sp.
	Cirripedia	5	5	*Balanus amphitrite, Tetraclita squamosa*
Mollusca	Bivalvia	27	140	*Tridacna gigas, Malleus malleus, Atrina vexillum, Trachycardium rugosum*
	Gastropoda	50	244	*Conus* spp., *Cypraea* spp., *Cymatium* spp., *Nassarius* spp., *Cerithium* spp., *Morula* spp.
	Cephalopoda	2	5	*Octopus* spp., *Sepioteuthis lessoniana*
	Polyplacophora	1	2	*Acanthopleura spinosa, A. gemmata*
Echinodermata	Asteroidea	5	10	*Protoreaster nodosus, Culcita novaeguineae*
	Echinoidea	7	16	*Toxopneustes pileolus, Diadema setosum*
	Holothuroidea	2	10	*Pearsonothuria graeffei*
	Crinoidea	1	6	*Comanthus alternans*
	Ophiuroidea	1	2	*Ophiocoma scolopendrina*
Bryozoa		8	12	*Schizoporella serialis, Stylopoma, Zoobotryon*
Hemichordata	Enteropneusta	1	1	*Balanoglossus* sp.
Plantae	Chlorophyceae	8	23	*Caulerpa* spp., *Halimeda* spp., *Codium* spp., *Ulva=Enteromorpha* spp., *Neomeris vanbossae*
	Phaeophyceae	3	9	*Padina* spp., *Dictyota* spp., *Turbinaria* spp., *Sargassum* spp., *Colpomenia sinuosa*
	Rhodophyceae	6	16	*Gracilaria* spp., *Halymenia* spp., *Acanthophora* spp., *Amphiroa* spp., *Sporolithon* spp.
	Angiospermae	3	5	*Thalassia hemprichii, Enhalus acoroides, Halophila ovalis, Rhizophora mucronata*
	All	**261**	**786**	

cages, and despite continuous fishing and gleaning by the local villagers since long before IMS. But most species occurred in low densities, and many were found singly or just once. Some species occasionally or seasonally became abundant—e.g., the horned sea star *Protoreaster nodosus*, the black sea urchin *Diadema setosum*, and the edible sea urchin *Tripneustes gratilla* (which was avidly harvested). Such population explosions may have been responses to sea-grass and seaweed blooms due to nutrient enrichment from the cages, or just natural fluctuations.

Several species of sponges, barnacles, bryozoans, ascidians, and oysters not found in the natural habitats were found growing on the net cages and platforms as biofoulants. Cage structures evidently provided additional surfaces for settlement of seaweed spores and planktonic larvae of many invertebrates that otherwise could not find space or food in the adjoining natural habitats. Cage aquaculture adds structural substrate, food items, and refuge for a variety of species, and can enhance biodiversity in the marine habitats it occupies. Eggs and larvae of all sorts of organisms are always in the water ready to get into the cages and attach to the nets and supporting structures. Over time, these extraneous organisms grow, go through community succession, and interact with the farmed species in various ways. The seaweeds that grow on the cages absorb nitrogen and phosphorus from the fish feeds and wastes, and provide food for grazing snails and crabs. The biofoulant filter-feeding invertebrates remove the particulates (feeds, feces, plankton) from the cage. The older the cages, greater fouling is noted. The greater the biodiversity there is and the more effective the biological recycling, the less outward pollution is observed. The biofoulants impede water flow into the cages but they also help maintain good water quality. Before the nets are fouled, small fishes continually go in and out of the cages and partake of the feeds given to the crop species. Some of these fish stay and grow in the cages with the farm crop.

Cages that are kept in the water long enough often yield a wide variety of extraneous species, most of them small, many of them edible, many others ornamental, and all of them contributors to farm sustainability and ecosystem balance. Some of the extraneous fishes are harvested with the farmed fishes, and are in effect cage bycatch. Some bycatch are eaten by the cage workers, but many are too small or toxic and just left to die when nets are removed from the water. In addition, all attached species die when cages, floats, and associated structures are taken out of the water as part of farm management. This practice can be changed. For cage farms to contribute to biodiversity, extraneous species (if not big enough for eating) should not be left high and dry to die. Instead they can be thrown alive overboard or scraped off fresh and deposited onto denuded sandflats, seagrass beds, rocky shores, or mudflats, where they may reattach and survive.

On top of the biological pollution and siltation, gross carelessness by fishers, gleaners, and boatmen has seriously damaged the IMS habitats. Local fishers including IMS personnel walk on the seagrass beds during negative low tide to harvest edible bivalves, gastropods, and sea urchins. Seagrasses and seaweeds are trampled, corals and sponges are broken, sediment is dug up, rocks are turned over, and the resident flora and fauna displaced and driven to a marginal existence in turbid water. Every day, the IMS service boat and several tourist boats traverse the IMS seagrass beds, sandflat, and coral beds, causing further damage. Thirty-five years on, it is time for the IMS habitats to be rehabilitated or protected in some way.

Biodiversity in the ponds and mangroves at Dumangas Brackishwater Station

At least 312 species in 117 families were found at DBS, 210 species in the ponds plus 102 more in the mangrove greenbelt (Table 3). Some 90 species of fishes and 35 species of crustaceans lived in the ponds along with 60 mollusks, only 10 of these crop species and the others naturally seeded by the tides. Sixteen species of mangrove gobies and sleepers resided in the ponds. Three gobies often became very abundant: *Acentrogobius viganensis, Pseudogobius javanicus,* and *Mugilogobius cavifrons*, collectively called in the local dialect as 'dalodalo'. Two others were common: *Acentrogobius janthinopterus* and the almost transparent *Gobiopterus panayensis*. The 'bagtis' or *Glossogobius aureus* was not abundant but grew larger and was prized as food by the pond workers. Another mangrove resident, the larva-like priapiumfish *Neostethus amaricola* was found in some fish ponds in small schools. The pond bycatch also included juveniles of several species of commercial fishes (*Elops hawaiiensis, Eleutheronema tetradactylum*, mullets, jacks, slipmouths, mojarras), forage species (*Ambassis* spp.), and the large eels *Muraenesox cinereus* and *Pisodonophis cancrivorus*. The tilapia *Oreochromis mossambicus* and the mosquitofish *Gambusia affinis* were found in the ponds but not in the mangroves outside.

The DBS ponds also harbored 6 species of penaeid shrimps, 4 palaemonids, 6 portunid crabs, and 4 grapsids (Table 3). Only the smaller *Macrobrachium* species were found at DBS, and no *M. rosenbergii*. Some volume of *Varuna litterata* was obtained as bycatch from nearly all ponds, and a surprising crop of naturally seeded *Portunus pelagicus* was harvested from one pond. The small shrimp *Acetes erythraeus* and the mysid *Prosopodopsis orientalis* were sometimes very abundant in some ponds. Burrowing crabs like *Neosarmatium* spp. weaken earthen dikes. Many other small crabs (*Episesarma* spp., *Uca* spp., etc.) were common in the main canals and the mangrove greenbelt, but rare inside the ponds.

Mollusks in the DBS ponds included 38 species of bivalves and 22 species of gastropods (Table 3). The oysters *Saccostrea* spp. and *Crassostrea* spp. were a voluminous edible bycatch, and the snails *Cerithidea cingulata*, *Cerithium coralium*, and *Batillaria multiformis* were very abundant and considered pests. In the mangrove greenbelt were found several mollusks not found in the ponds. On both tree trunks and concrete walls clung the holed oyster *Enigmonia aenigmatica*, the coffee murex *Chicoreus capucinus*, the delicate *Cerithidea quadrata*, the black-blotched *Nerita planospira*, and the pulmonates *Cassidula mustelina*, *Onchidium* sp., and *Peronia* sp. On the leaves were glued the periwinkles *Littoraria* spp., and in the mud and on the roots crawled the orange bead snail *Sphaerassiminea minuta*.

Table 3. Biodiversity in the ponds and mangroves at Dumangas Brackishwater Station, Iloilo, Philippines, 2009–2010.

Phylum	Class/Order	Families	Species	Representative species
Chordata	Osteichthyes	43+7	90+34	*Elops hawaiiensis, Acentrogobius* spp., *Gobiopterus panayensis, Neostethus amaricola*
	Reptilia	1	1	*Cerberus rhynchops*
Crustacea	Penaeidea	2	7	*Penaeus* spp., *Metapeneus* spp., *Acetes erythraeus*
	Caridea	2	6	*Macrobrachium* spp., *Nematopalaemon tenuipes*
	Brachyura	3+1	10+16	*Thalamita crenata, Varuna litterata, Uca* spp.
	Anomura	1	3	*Clibanarius* spp.
	Stomatopoda	1	3	*Chloridopsis scorpio, Oratosquilla gravieri*
	Thalassinidea	1	1	*Thalassina anomala*
	Mysida	1	1	*Mesopodopsis orientalis*
	Cirripedia	3	4	*Balanus Amphitrite*
Mollusca	Bivalvia	14+5	38+31	*Crassostrea belcheri, Saccostrea cucculata, Enigmonia aenigmatica, Isognomon* spp.
	Gastropoda	7+6	22+21	*Cerithidea* spp., *Cerithium coralium, Telescopium telescopium, Littoraria* spp., *Chicoreus capucinus, Sphaerassiminea minuta, Nerita planospira*
Cnidaria	Scyphozoa	2	2	*Cassiopea medusa*
Annelidae	Polychaeta	2	3	*Capitella capitata*
Brachiopoda		1	1	*Lingula ungguis*
Echinodermata	Holothuroidea	1	1	*Holothuria coluber*
	Echinoidea	2	2	*Diadema setosum*
Plantae	Angiospermae	8	10	*Avicennia marina, Sonneratia alba, Rhizophora* spp.
	Chlorophyceae	1	3	*Enteromorpha=Ulva, Chaetomorpha*
	Rhodophyceae	2	2	*Gracilaria* spp., *Catenella caespitosa*
	All	**97+20**	**210+102**	

Thus, the DBS ponds and mangroves are still biodiverse systems, despite intended monoculture for many years and in contrast to the general perception that aquaculture causes loss of biodiversity. Herre and Mendoza (1929) recorded 40 species of fishes, 20 crustaceans, and several snakes and birds in milkfish ponds in the Philippines in the 1920s. Brackishwater ponds are evidently leaky, even the better ones like those at DBS, and the young of many mangrove animals find their way into ponds, survive, and grow despite net screens, liming, ammonium sulfate or teaseed treatment, and chlorination. Despite the absence of mangrove trees, and as long as tidal water flow is maintained, ponds act as proxy mangrove lagoons that harbor the young of migratory fishes as well as all life stages of resident species.

Several bycatch species were eaten or sold by the pond workers, but the small and abundant gobies were often used to feed crabs and carnivorous fishes stocked in the ponds. Indeed, ways should be developed to manage gate screens, water supply, soil preparation, and crop species to maintain a biologically diverse, balanced, healthy pond environment, produce an extra crop of bycatch species, and improve farm economics.

Conclusion and recommendations

As part of the implementation of the SEAFDEC-sponsored Regional Code of Conduct for Responsible Fisheries, greater conscious effort must be applied towards managing aquaculture farms for high biodiversity and low pollution. This study provides some of the biodiversity information needed to formulate strategies to keep the SEAFDEC/AQD research stations cum aquaculture farms full of life, non-destructive, and sustainable.

SEAFDEC/AQD does not know what biodiversity has been lost due to its aquaculture operations because there had been no species inventories done at its research stations before 2009. Now we have a good idea of the present biodiversity, and we have baseline species inventories as of 2008–2014 on which future monitoring can be compared. The main difficulty with biodiversity monitoring is the fact that TMS, IMS, and DBS, as well as other aquaculture farms, are sited in multi-use water bodies and the effect of aquaculture on biodiversity is difficult to discern over the effects of fisheries, boating, settlements, and other uses.

Next steps

1. Voucher specimens of the species from TMS, IMS, and DBS should be properly documented and deposited in the AQD Museum of Aquatic Biodiversity. If physical specimens can not be obtained, then at least good photographs.

2. A permanent exhibit of the marine biodiversity at TMS, IMS, and DBS should be set up at SEAFDEC FishWorld for the science and environment education of the Filipino (*Sambayanang Pilipino*)

3. The TMS, IMS, and DBS species inventories and photographs should be published as hardcopy books, digital books, and online databases. These books will serve three purposes:

    - For SEAFDEC/AQD to use in monitoring biodiversity at its aquaculture stations in the future;

- For farmers and government regulators (Bureau of Fisheries and Aquatic Resources) to use as species identification guides to baseline-survey and monitor other aquaculture sites in the Philippines (and Southeast Asia); and
- To add to the marine biodiversity literature for students, teachers, and researchers to use as general taxonomic guide for marine habitats in the Philippines (and Southeast Asia).

4. A training-workshop on biodiversity survey and species identification should be offered to BFAR and Department of Environment and Natural Resources (DENR) technicians assigned to environmental monitoring. The training should be done on site at TMS, IMS, and DBS.

5. Monitoring of biodiversity at TMS, IMS, and DBS should be continued as a regular program or standard operating procedure of AQD, with the Stations Heads as Head Monitors. The monitoring program should eventually include subtidal surveys, infaunal sampling, quantitative analysis, and other protocols not carried out in 2009–2014.

6. Institute strategic interventions to protect biodiversity at TMS, IMS, and DBS over the long term. Some strategic interventions are described below.

Protect the nearshore habitats off TMS: declare an MPA

More than the biological pollution caused by AQD effluents, the serious threat to nearshore habitats and biodiversity off TMS comes from the intensive collective fisheries off Buyuan. SEAFDEC/AQD cannot regulate fishing, but it can protect the nearshore habitats right in front of TMS, to prevent the operation of the beach seine, and allow seaweeds and benthic animals to settle and stabilize (before and after the monsoon waves and storms). Beach seines stir up the subtidal and intertidal sediment; overturn gravel where seaweeds grow and animals hide and feed; and catch the small animals and larvae concentrated by the waves and currents at the surf zone. Many of these small animals are left to die on the beach, and even when eaten are really a waste of marine life.

Although the effect of TMS on nearshore biodiversity is not noticeably adverse, AQD now has good opportunity to protect the habitat and possibly maintain or increase biodiversity. AQD can do the following:

- Request the Tigbauan local government unit (LGU) to designate the TMS intertidal and subtidal area (~500 m long, 20 m seaward of the jetties, within 10 m deep) as a marine protected area (MPA), not because it is high in biodiversity but so that it can be so;
- Construct and install large heavy rocks or concrete multi-faceted modules in this MPA to add topographic relief and stable habitat surfaces for shore animals and plants. The species that recruit and mature inside the MPA can serve as broodstock to seed the adjacent nearshore waters; and
- Monitor the biodiversity in the MPA over the years.

Rest and rehabilitate the IMS habitats: Build a road and bridge and discontinue boats

More than the biological pollution and siltation due to the IMS fish cages, gross carelessness by fishers, gleaners, and boatmen has seriously damaged the IMS habitats. In particular, every day over the last 35 years, the IMS service boat has traversed the seagrass beds, sandflat, and coral beds around the station. During low tides, the outriggers, hull, and propellers hit and break coral heads and sponges, entangle seaweeds and seagrasses, churn up the sediment, the damage obvious but undocumented. In recent years, several tourist boats a day traverse IMS to visit the fish broodstocks in cages. IMS guards have not been able to keep local boatmen, fishers, and gleaners off IMS, but AQD can otherwise manage the resources at IMS. AQD can discontinue the use of the IMS service boat and disallow the use of tourist boats in order to rehabilitate the damaged seagrass beds, sandflat, and coral terrace.

After 35 years, it is time to build a road and bridge to IMS from the main road going to Barangay Dolores. At the nearest road junction, the distance from the town road to Humaraon Cove is about 600 m (shorter than the feeder road going to Landasan Cove), and the bridge over Humaraon Cove to IMS would be about 500 m long. From Igang bridge, it is about 3 km to this proposed junction. Dolores is served by many public jeepneys to and from Jordan pier. Guimaras is now in a road-building mania and the provincial government might fund and build a feeder road leading to IMS. AQD can do the following:

- Lobby the Guimaras LGU to build a feeder road to Humaraon Cove (directly opposite IMS Islet 5) from the town road leading to Barangay Dolores. Make the case that this feeder road brings goods and services to the people in Humaraon; eliminates the dangers of boat travel and increases tourist visits to IMS and tourism income to Guimaras; eases the transport of harvested fish from the mariculture park to the Guimaras markets; and facilitates the transport of personnel and materials to and from IMS;
- Construct a wooden bridge from the feeder road over Humaraon Cove to the IMS house on Islet 5. This bridge can be like the one between Islets 6, 7, 8, and 9, and can use wooden planks from the mahogany trees in Tigbauan. Another bridge could be built over the sandflat from Islet 5 to Islet 9 where the lab and growout cages are located;
- Discontinue the use of the IMS service boat for routine transport (but standby for emergencies or urgencies). Arrange for a Dolores jeep to shuttle IMS personnel to and from Humaraon Cove;
- Disallow tourist boats from IMS but let tourists visit via the road and bridge. Manage the tourists and disallow food, drinks, and wastes at IMS; and
- Monitor the status of the IMS habitats over the years.

Green up DBS: Integrate BMP into SOP

SEAFDEC/AQD advocates responsible aquaculture and has done several experiments to develop various best management practices (BMP) for brackishwater ponds. However, these BMPs are hardly in evidence at DBS now. There is no trace of the muchtouted aquasilviculture, and none of the recommended effluent treatment through arrays of oysters, mussels, and seaweeds. To maintain credibility, as well as get good results, DBS should integrate BMPs into SOP in the ponds, and not just do them as a project. Since brackishwater ponds serve as proxy mangrove lagoons and nursery habitats for a variety of species, BMPs should be developed to allow ponds to be' leaky', maintain a biodiverse and healthy pond environment, and produce an extra crop of bycatch species.

AQD can institutionalize BMP-SOP for a greener DBS. The BMP-SOP can include the following:

- Use hatchery-reared postlarvae or juveniles or 'fry' (better nourished, no predators and competitors);
- Rear fry to a larger size in a nursery pond or tank before stocking in large ponds with tidal water supply (so the stocks have a head start over the extraneous species);
- Reconfigure the ponds such that influent water comes through the main canal from Pulao Creek, but the effluent water leaves through another main canal into Talauguis River (to minimize self-pollution);
- Plant and grow stands of *Avicennia* mangroves (with readily available seedlings), or arrays of oysters, mussels, and seaweeds in the main canals to remove particulates and nutrients from both the incoming tidal water and the effluents;
- Manage 1–2 large ponds at the east end for aquasilviculture with a clump of *Avicennia* mangroves at the center;
- Extend the mangrove greenbelt by planting *Avicennia* outside the concrete dike facing Pulao Creek and the mudflat to remove particulates from the influent water before it enters the main gate;
- Monitor, measure, and record the pond bycatch from all experiments and production runs. Such data should be analyzed for trends and economic value;
- Collect the bycatch and feed it to carnivorous farmed species to reduce feed costs and pollution. Bycatch may also be given away to pond workers; and
- The small gobies that are not to be collected should be released alive from ponds back into the mangroves and mudflats during draining and harvest (as a simple restocking scheme).

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