Fish Standing Stock and Catch from Coral Reefs in Three Regions of the Philippines

Jean Asuncion T. Utzurrum,
Clarissa T. Reboton, and
Hilconida P. Calumpong
Silliman University – Institute of Environmental and Marine Sciences (SU-IEMS), Bantayan, 6200 Dumaguete City, Negros Oriental, Philippines

Coral reefs depicting ‘fair’ and ‘poor’ coral reef conditions were surveyed at each of three study sites in Regions V (Ticao I., Masbate), VII (Negros Oriental), and XI (Davao Oriental) in 2013 to compare fish standing stock and catch. Reef condition was determined using LIT while fish standing stock was measured using FVC. Fish catches were quantified by random monitoring at selected landing sites done by hired enumerators using Roving Creel Survey from April to December 2013. Results of this study showedpositive linear relationship between live hard coral cover with fish density and biomass but not species richness. No relationship was observed between reef rugosity and fish parameters. Overall, the site Chapel Pt. in Apo I., Negros Oriental was found to have the highest % coral cover (58.93 $\pm$ 7.21) and was the most rugose (1.45 $\pm$ 0.07) of all coral reefs assessed. As expected, this site also ranked the highest in terms of fish species richness (H’ = 7.54), fish density (n = 465 $\pm$ 67), fish biomass (3.84 $\pm$ 0.68 kg 500 m^{-2}), and catch per unit effort (CPUE) (3.41 $\pm$ 1.02 kg $manhr^{-1}$). Meanwhile, Bantayan Marine Sanctuary, also in Negros Oriental, had the lowest % coral cover (20 $\pm$ 9.86) and generally low CPUE (0.08 $\pm$ 0.04 to 1.04 $\pm$ 0.14 kg $manhr^{-1}$) but had high species richness (H’ = 6.26) and was moderately productive (1.83 $\pm$ 0.36 kg 500 m^{-2}). Baladingan reef in Monreal, Ticao I. was the least rugose and ranked amongst the lowest in terms of overall productivity (1.65 $\pm$ 0.68 kg 500 m^{-2}) despite having high fish diversity (H’ = 7.54) and generally high CPUE (0.75 to 1.38 $\pm$ 0.70 kg $manhr^{-1}$). Some of the commonly caught fishes recorded in catch data came from families that were not observed during FVC (e.g., Carangidae, Scombridae, Lutjanidae), making it difficult to infer direct relationships of coral reef condition and catch. These differences may be due to lack of FVC replicates that might show seasonal patterns and because fishing grounds were not necessarily adjacent to the LIT and FVC sites.

Keywords: coral reef fish; coral reef ecosystem goods and services; fish standing stock; fish catch; Ticao Island; Apo Island; Pujada Bay; Philippines

INTRODUCTION

The Philippines is considered to be a megadiverse country. Situated in the Coral Triangle, it has rich seascapes filled with diverse marine organisms that make up complex ecosystems. Coral reefs are perhaps the most productive of these ecosystems, providing critical habitat for spawning, breeding, nursery, and feeding areas of keystone species, *i.e.* herbivorous fishes and invertebrates (Moberg & Folke, 1999) and economic opportunities for fishing, tourism, and recreational activities. Reef-related fisheries have been estimated to contribute 15 to 30% of total fisheries production in the Philippines (Licuanan & Gomez, 2002; Aliño et. al., 2002) . However, the booming population growth of Filipinos has resulted to a rising demand in fish products, placing intense pressure on coastal resources with fishers sometimes resorting to destructive fishing methods, *i.e.* blast fishing and cyanide fishing. White, Vogt, and Arin (2000) have suggested that most coral reefs in the Philippines can no longer sustain fish catches although many papers will argue that fish yields can be increased with the establishment and proper management of marine reserves (Alcala, 1997; Alcala, Russ, & Maypa, 2002; Babcock *et al.*, 2010).

The benefits of marine reserves are best exemplified by the “spillover effect” or the net export of adults, and “recruitment effect,” which is the net export of juveniles. Recruitment patterns have been explored in species of anchovies and mackerels (Pauly & Navaluna, 1983) and groupers (Mamauag, Penolio, & Aliño, 2007) and are likely to be influenced by changes in monsoons and seasons. Spillover effect has been studied more extensively, especially in the world famous Apo I. Protected Landscape and Seascape (AIPLS) in Negros Oriental, Philippines, in researches on predatory fishes by Russ and Alcala (1996; 2010); Alcala *et al.* (2002); Russ, Alcala, and Maypa (2003); Russ, Alcala, Maypa, Calumpong, and White(2004); and Abesamis, Alcala, and Russ(2006a). The magnitude and scales of these fishery benefits may differ among various species (Gell & Roberts, 2003) and rely on several factors, *i.e.* effectiveness of protection (Alcala, Russ, Maypa, & Calumpong, 2005; Samoilys *et al.*, 2007), spatial gradients (Dorenbosch, Grol, Nagelkerken, & Van der Velde, 2005; Abesamis *et al.*, 2006b), and habitat complexity (Russ, Stockwell, & Alcala, 2005).

Fisheries in the Philippines provide major socio-economic benefits. However, declines have been reported in recent decades. Green *et al.* (2004) found that fish catches of hook-and-line gear in six provinces were <5% than catches in the 1940s and 1960s. In the early 1990s, a decline in catch landings by municipal fishers was recorded by Barut, Santos, and Garces (2004), suggesting increased resource depletion and stiff competition from commercial fishers. Hilborn *et al.* (2003) outlines other factors that can cause stock depletions, including climate, pollution, and the introduction of non-native species. Pollution has been linked with sedimentation which may inhibit coral growth and inconsequentially, degrade coral reef condition. This is because reef-building corals will not be able to perform their ecological function and the entire reef framework will likely collapse (Rogers, 1990), resulting in reduced habitat complexity or rugosity of the reef and downtrends in overall fish productivity.

This paper examines the relationships of coral reef condition with the services and goods it provides as inferred from fish biomass estimates and fish catch data collected from six coral reefs in three regions of the Philippines:Region V (Ticao I., Masbate), VII (Negros Oriental), and XI (Davao Oriental). Coral reefs assessed as 'fair' were expected to provide better services (*e.g.*fish production expressed as fish density and biomass) and goods (*e.g.* fish catch) compared to those assessed as 'poor'.

STUDY SITES

Transect Sites for Coral Condition and Fish Standing Stock

Two sites in each region were selected based on coral reef condition (e.g. 'fair' and 'poor') inferred from baseline data (Fig. 1). Baseline information used were from Reboton and Candido (2014) for Region V sites, Calumpong, Estacion, Lepiten, and Acedo (1997) for Region VII, and Alcala, Bucol, Maypa, Luchavez, and Padin (2012) for Region XI.

The sites in Region V are located on the eastern seaboard of Ticao I., which is one of three major islands in the province of Masbate. Site V-1 is the coral reef in Sitio Baladingan situated in Brgy. Famosa, Monreal

(12.62996°N - 12.6308°N, 123.70267°E – 123.70165°E). Site V-2 is located in Brgy. Tacdugan, San Jacinto located to the south across the opening of a shallow bay (12.61577° N – 12.61529°N, 123.71575°E – 123.71714°E). Site V-1 was assessed 'poor' while site V-2 was assessed as 'fair'in 2009 (Reboton & Candido, 2014). Both reefs were generally characterized by patchy coral communities in sandy areas(Calumpong *et al.*, 2014). According to accounts from locals, illegal fishing activities (e.g. blast fishing, compressor diving) also occur in the area. At the time of this study, no protective measures were in place for both sites. However, public consultation and demarcation of a proposed sanctuary in Sitio Baladingan was conducted by Silliman University – Institute of Environmental and Marine Sciences in early 2014 through a project funded by the United Board for Christian Higher Education in Asia. There are fishing communities on the island and this study appears to be the first to monitor fish catches landed in Famosa. No benchmark data and fisheries data were available for Tacdugan.

In Region VII, the two sites surveyed are located in Negros Oriental. These are the Bantayan Marine Sanctuary (BMS) in Dumaguete City (Site VII-3) and Chapel Pt. at Apo I. in the municipality of Dauin (Site VII-4). Site VII-3 is a 1.2-ha patchy reef flat interspersed with seagrass and sandy areas, located on the east coast of this province (9.33006° N – 9.33049° N, 123.31294° E – 123.31206° E). It lies close to the mouth of Tañon Strait, where a bottleneck effect tends to create a strong north to south current that exits into the Bohol Sea during the period of November to January and in the opposite direction from June to August (Han *et al.*; 2009). It was established in June 2012 and has since been actively managed by the local and city government through the Bantay Dagat, which consists of deputized fish/sea wardens. However, the areas outside the BMS are subjected to an array of activities, including swimming, water sports (*e.g.* jet skiing, skim boarding), gleaning, and fishing. Additionally, the coastline in Bantayan is generally exposed to pollution from picnickers, coastal households, and from a nearby creek. The reefs in Bantayan were assessed as 'poor' by Calumpong *et al.* (1997). On the other hand, Site VII-4 (9.07717° N - 9.07622° N, 123.26641° E – 123.26623° E) is located in the Apo I. Protected Landscape and Seascape (AIPLS)which has been protected since 1994 under a Protected Area Management Board (PAMB). Chapel Pt. is a dive site with extensive reef flat (≥ 50 m) found on the western front of the island, directly facing the community area and is subject to disturbances caused by snorkelers, SCUBA divers, and boat traffic. The AIPLS was strongly influenced by mainstream currents from the north (Abesamis *et al.*, 2006a) and fishing activities are limited by monsoonal changes (Russ *et al.*, 2004). The reefs in AIPLS were assessed as 'good' by Calumpong *et al.* (1997) and have remained as such despite having been exposed to extreme natural phenomena, which included three El Niño events (in 1997, 1998, 2010) and typhoons Sendong (in 2011) and Pablo (in 2012).

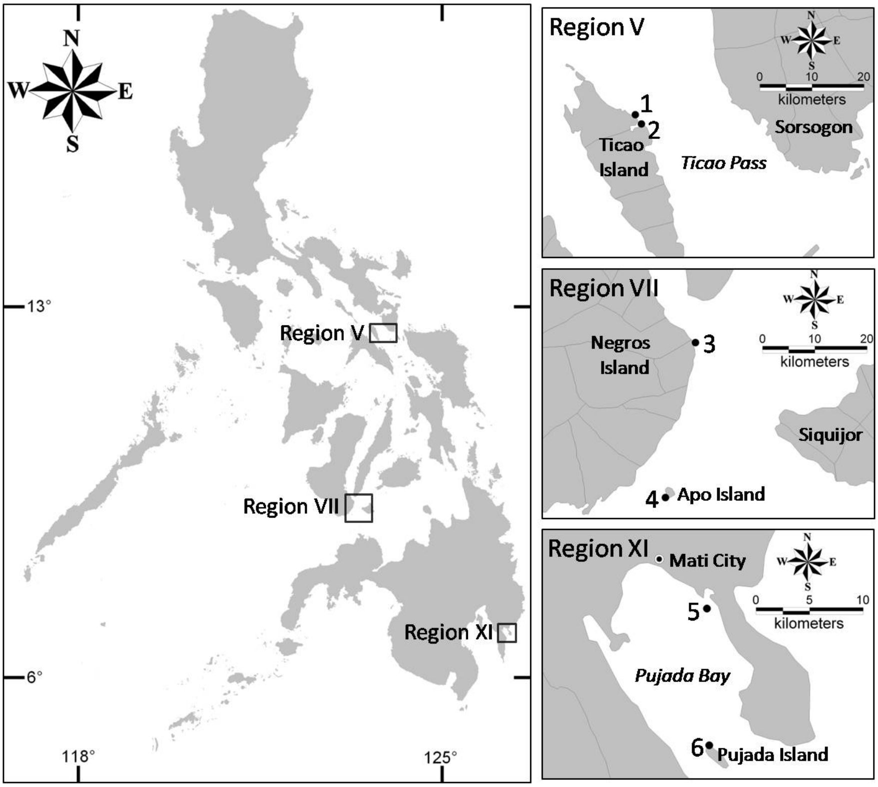

Fig. 1. Maps showing survey sites in Region V (Masbate): 1 - Baladingan, 2 - Tacdugan; Region VII (Negros Oriental): 3 – Bantayan Marine Sanctuary, 4 - Chapel Pt., Apo I.; Region XI (Davao Oriental): 5 - Guang-guang, and 6 - Pujada I.

Sites in Region XI are within the Pujada Bay Protected Seascape (PBPS) (6.80111° N – 6.90694° N, 126.15222° E – 126.32583° E), which is nestled in the southeastern portion of Mindanao, approximately 157 km from east-southeast of Davao City (Jimenez & Eballe, 2002). The bay encompasses an area of 21,200 ha and was declared as a protected seascape in 1994 under Presidential Proclamation No. 431, thereby placing it under the muti-sectoral management of its own PAMB. Site XI-5 is part of Sitio Guang-guang in Brgy. Dahican (6.91408° N – 6.91279° N, 126.25706° E – 126.25694° E) which made 'poor' coral reef condition (Alcala *et al*., 2012). It is located in the inner portion of the PBPS whileSite XI-6, Pujada I. (6.79690° N – 6.79641° N, 126.25823° E – 126.26016° E) with 'fair' coral reef condition (Alcala *et al*., 2012) is found near the mouth of the PBPS. Both survey sites are characterized by fringing coral reefs. In Guang-guang, the reef area begins after a seagrass bed at ~3 m depth and gradually slopes to ~13 m depth whereas the reef area in Pujada I. reached ~20 m depth, with corals most abundant at 3-7 m and slopes occurring at 6-10 m. Although both sites are within a protected area only Site XI-6 is a designated no-take marine reserve.

Sites for Fish Catch Monitoring

Fish catch monitoring was conducted in Brgy. Famosa for site V-1, Brgy. Bantayan for Site VII-3, Apo I. for Site VII-4, Brgy. Dahican for Site XI-5, and Brgy. Tamisan for Site XI-6 since it has local jurisdiction over Pujada I.

MATERIALS AND METHODS

Characterization and selection of sites were ascertained using manta tow technique. For measuring coral reef parameters, five 20-m transects were set parallel to the shoreline at 7-10 m depth at each site. Benthic cover was obtained using the line-intercept transect (LIT) method described in English, Wilkinson, and Baker (1997). Identification of coral species was done following Veron and Pichon (1976; 1980; 1982); Veron, Pichon, and Wijsman-Best (1977); Veron and Wallace (1984); Wallace (1999); Veron (2000); and Fabricius and Alderslade (2001). Coral reef condition was determined using the four categories of hard coral cover (Gomez, 1991), quality reef indices (Gomez, Alino, Yap, & Licuanan, 1994; Manthachitra, 1994), and indices of dominance and diversity (Odum, 1971). To determine rugosity, the Chain Method of Hill and Wilkinson (2004) was modified such that the chain was laid on the upper contour of the reef within the 20 m transect used for LIT. Rugosity was calculated as the length of chain used per 20 m transect and rugosity index was used to signify architectural complexity of the reef (Alvarez-Filip,Dulvy, Gill, Cote, & Watkinson, 2009). Thus, a perfectly flat surface would have a rugosity index of 1 while more complex surfaces would show larger values.

Reef productivity was determined from three 50-m transects that were laid along the LIT transects at each site. All fish encountered within 5 m on both the left and right sides of the transect line were identified and counted. Their total length was estimated following fish visual census (FVC) method modified from English *et al.* (1997). Identification of fishes was done using the field guide by Allen, Steene, Humann, and Deloach (2003) and Fishbase (Froese& Pauly, 2014).

Fish catch at landing sites was monitored using the Roving Creel Method as described in Maypa, Russ, Alcala, & Calumpong (2002). Local enumerators were trained to monitor fish catch for eight fishing days (two days per lunar cycle). Catch per unit effort (CPUE) and income per unit effort (IPUE) values were derived from the catch data. Identification of commercially important fishes was based on fish families reported as targeted in the baseline reports used.

RESULTS

Fish Standing Stock

Species Richness. Statistical Sites VII-4 and V-1 exhibited the highest indices of diversity (H' = 7.54), followed by VII-3 (H' = 6.26) and XI-6 (H' = 5.34) while V-2 and XI-5 ranked lowest with H' values of 4.42 and 3.65, respectively (Table 1). Herbivorous damselfishes (Pomacentridae) were the most diverse in all sites. Wrasses (Labridae) were also highly diverse at all sites except XI-5. Overall, commercially important fishes were more diverse at VII-4 (n = 38), BMS (n = 34), and XI-6 (n = 26).

Fish Density. Fish densities were highest at VII-4 and V-1 (Fig. 2A). Pomacentrids were the most dominant fish in all sites. Surgeonfishes (Acanthuridae) and butterflyfishes (Chaetodontidae) were the next two most abundant fishes at VII-4 while in V-1, wrasses and schooling cardinalfishes (Apogonidae) ranked second and third in abundance. Labrids also consistently ranked among the most abundant fish families observed except at VII-4 and XI-5. Site XI-5, which ranked low in species richness, ranked third in mean total density; however, this site had the lowest density of target fishes, with pomacentrids dominating fish abundance. Conversely, mean total density was lowest at XI-6 but 27% of this were target fishes, having the highest concentration of target fishes across all sites.Overall, there were remarkable downtrends in mean total densities of fishes observed in this study when compared to benchmark data from 2009 (Region V sites), 1997 (Region VII sites), and 2011 (Region XI sites). The most drastic of these declines appeared to be those at VII-3 and VII-4 while XI-6 showed less radical reductions (Fig. 2B). On a positive note, sites V1 and XI-5 were both reported as having low fish densities (Alcala *et al.*, 2012; Reboton & Candido, 2014) but were found to show uptrends in this study. No benchmark data were available for site V-2.

Fish Biomass. Biomass estimates for both total fish and target fishes were highest at VII-4 (Fig. 2C). Site VII-3 ranked second in overall productivity although biomass of target fishes ranked third after XI-6, which recorded the highest percentage of target fish biomass (52%). V-1 ranked third in overall biomass but was among the sites with low productivity of target fishes whileV-2 and XI-5 both ranked poorly in total productivity and biomass of target fishes. When compared to the above-mentioned benchmark data, downtrends were clearly visible for all sites except V-1 which showed slight improvement (Fig. 2D). Although total density of fishes at XI-5 had increased, this study found that density and biomass of target fishes at that site were reduced.

Fish Catch

A total of five landing sites were monitored during this study: Brgy. Famosa in Region V, Brgy. Bantayan and Apo I. in Region VII, and Brgys. Dahican and Tamisan in Region XI. Data collection was heavily reliant on the availability of catch enumerators; thus, the number of survey days were not the same across the sites. Hook-and-line gear appeared to be the preferred gear in Regions V and VII, next to fishing net. In Region XI, net was favored by fishers in Dahican while most fishers in Tamisan used speargun. Fisheries in Apo I. showed exceptionally high CPUE and IPUE values when compared to other sites. A summary of fisheries data can be found in Table 2.

In Famosa, fish landings were recorded for a total of 46 days across seven months (June – December). Most catches were fished in the coastal waters of Famosa and Tacdugan, and predominantly consisted of reef and

Table 1 Summary of coral reef and fish parameters in the three regions surveyed expressed in values ± S.E. Legend: C = Simpson's Dominance Index; H' = Shannon's Diversity Index; V-1 = Baladingan; V-2 = Tacdugan; VII-3 = Bantayan Marine Sanctuary; VII-4 = Chapel Pt., Apo I.; XI-5 = Guang-guang; XI-6 = Pujada I. Categories of coral reef condition is based on benchmark data collected in 2009 (Region V), 1997 (Region VII), and 2011 (Region XI).

Site	Coral Reef Condition			Reef Fish Productivity				
	Category	Coral Cover (%)	Rugosity	No. of Spp.	C	H'	Mean Density (per 500 m^{-2})	Mean Biomass (kg 500 m^{-2})
V-1	Poor	33.35 ± 3.31	1.18 ± 0.02	52	10.65	7.54	462 ± 44	1.65 ± 0.69
V-2	Fair	32.70 ± 6.17	1.25 ± 0.06	47	5.17	4.42	288 ± 51	1.28 ± 0.29
VII-3	Poor	20.00 ± 9.86	1.27 ± 0.09	70	3.97	6.26	371 ± 43	1.83 ± 0.37
VII-4	Fair	58.93 ± 7.21	1.45 ± 0.07	75	4.37	7.54	465 ± 67	3.84 ± 0.68
XI-5	Poor	42.05 ± 3.40	1.40 ± 0.07	43	4.01	3.65	377 ± 38	0.98 ± 0.25
XI-6	Fair	40.22 ± 6.23	1.37 ± 0.02	59	1.45	5.34	253 ± 17	1.42 ± 0.22

reef-associated fishes. Tuna and mackerel (Scombridae) were observed in almost all gear throughout the sampling period and recorded a total yield of 148.67 kg. Ten other target fish families were recorded but most had total yields of ≤3.00 kg except for one instance of a 40.00kg catch of anchovies in November. Scombrids were not encountered during the FVC survey in June while other target fish families (*e.g.* Nemipteridae, Serranidae, Sphyraenidae) were recorded in both FVC and fish catch data. Hook-and-line gear was the common gear used, observed 36 times in all seven months, and showed highest values for CPUE. Other gears observed were net, speargun, and compressor diving. IPUE was highest for speargun, but this is based on just one fishing trip.

Catches were monitored in Bantayan for a total of 58 days for nine months (April – December). Fishing net and hook-and-line gears were the most commonly used gears observed in all months, although the latter appears to be the preferred gear by fishers who fish in the southward adjacent waters of Brgy. Piapi. CPUE values were highest for hook-and-line, followed by fishing net. Other gears observed in this area were fish pot, fish trap, and crab pot. Similarly, IPUE was highest for hook-and-line followed by net. Majority of catches from both these dominant gears were tunas and mackerels (Scombridae), with total landed catch reaching 316.85 kg during the survey period. Jackfishes (Carangidae) and emperors (Lethrinidae) were also commonly caught throughout this period with total catch weights of 74.75 kg and 64.20 kg, respectively. Pelagic species of needlefish (Belonidae) also contributed to overall yield (61.10 kg) despite being recorded from September to December only.

Fish catch in Apo I. was monitored by two dive wardens for 18 days in four months (April – June, and September). It was unclear if no fishing occurred at all in August, October, and November or if the lack of data was due to the conflicting schedules of the dive wardens who often moonlighted as tourist dive guides. Hook-and-line was the only gear noted during these months. From April to June, most fishers used fishing grounds on the west to northwest of the AIPLS (Katipanan, Largahan, and Coconut Pt.) where majority of their catch were large Carangidae (>50.00 cm). This is consistent with Maypa (2012) which found carangids to be most abundant in this area. Catches reported for September were relatively smaller Acanthuridae (35-40 cm) fished in the northeastern grounds of Cogon Pt.

In Dahican and Tamisan, a site co-operator was assigned to monitor fish catch landings at both sites for at least eight days a month. However, catch data from Tamisan was recorded for a total of six days only over a three-month period (June - August) while monitoring in Dahican totaled 41 days over six months (May – October). The cause of shorter monitoring period in Tamisan is unknown. All fishes landed at Tamisan were purportedly caught from Pujada I., which is a no-take marine reserve (NTMR) within the PBPS. Speargun was the most common gear used as observed in all three months and showed higher CPUE and IPUE values. Other gears observed were fishing net and troll line known as 'subid' but this was encountered only once. On the other hand, fishes landed in Dahican were caught from coastal waters, including Sitio Guang-guang. Net fishing was the main gear used by fishermen at this site, noted in all six months of monitoring and had higher CPUE and IPUE values. Speargun fishing was also noted but this was only encountered twice during this period. Catch composition in Tamisan was more diverse when compared to those landed in Dahican, and included both targeted and non-targeted fish families. However, more commercially valuable fish were abundant in Dahican, with catches pirmarily composed of rabbitfishes (Siganidae), goatfishes (Mullidae), and snappers (Lutjanidae) that ranged in sizes from small (<10 cm), medium (11-15 cm), and large (>15 cm).

Overall, there were clear differences between species recorded in FVC data and those observed in catch data. A total of 18 families were identified although not all were targeted at each site: Acanthuridae (surgeonfishes), Balistidae (triggerfishes), Belonidae (needlefishes), Caesionidae (fusiliers), Carangidae (jackfishes), Engraulidae (anchovies), Haemulidae (grunts), Kyphosidae (chubs), Labridae (wrasses), Lethrinidae (emperors), Lutjanidae (snappers), Mullidae (goatfishes), Nemipteridae (breams), Scaridae (parrotfishes), Scombridae (tunas and mackerels), Serranidae (groupers), Siganidae (rabbitfishes), and Sphyraenidae (barracudas). Scombrids were absent from all FVC data but figured prominently in catch data from Baladingan (June – December) and Bantayan (April – December), with total weights reaching up to 148.67 kg and 316.85 kg, respectively. Similarly, carangids were noticeably absent in the FVC data collected in October 2013 at VII-3 and VII-4 but catch data show that carangids were landed in Apo I between the months of April to June and in Bantayan from May to December, respectively, thus contributing 308.30 kg and 74.75 kg in

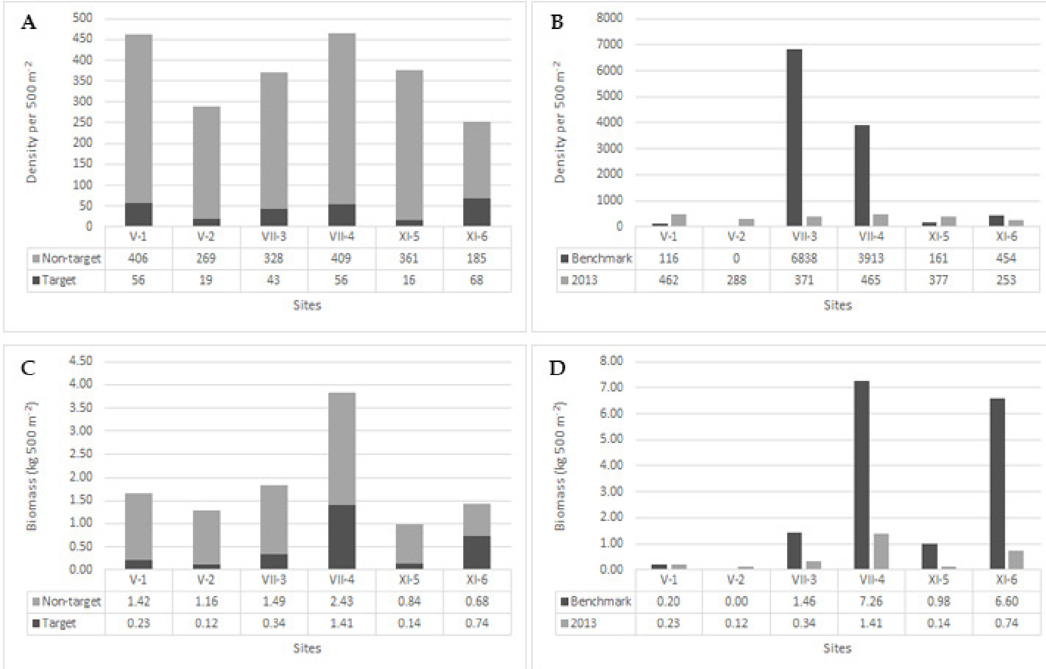

Fig. 2. Mean densities and biomass values of all fishes (non-target and target) sampled at sites in this study are shown in A, C. In B, mean total densities are compared with total densities from benchmark data. Total productivity of target fishes is compared with the same from benchmark data in D. Legend: V-1 = Baladingan; V-2 = Tacdugan; VII-3 = BMS; VII-4 = Chapel Pt., Apo I.; XI-5 = Guang-guang; XI-6 = Pujada I.

Table 2 Summary of fish catch data with corresponding mean CPUE (kg manhr^{-1} ± S.E.) and mean IPUE (Php manhr^{-1} ± S.E.) values in sites studied. Legend: BAL = Baladingan; APO = Apo I.; BAN = Brgy. Bantayan; DAH = Brgy. Dahican; TAM = Brgy. Tamisan; N = sample size; MP = average man power; FTP = average fishing time per trip (hr); HL = hook and line; * = no data.

Site	Gear	No. of Months Observed	N	MP	FTP	CPUE	IPUE
BAL	compressor	1	1	1	4.00	0.75	75.00
	HL	7	36	1	4.23 ± 0.16	1.38 ± 0.70	84.47 ± 34.54
	Net	3	5	1	2.78 ± 0.40	1.13 ± 0.41	86.74 ± 19.82
	speargun	1	4	1	2.25 ± 0.48	1.25 ± 0.92	114.06 ± 95.35
APO	HL	4	40	1	4.82 ± 1.41	3.41 ± 1.02	392.39 ± 122.55
BAN	crab pot	3	5	1	5.00	0.30 ± 0.12	18.80 ± 9.71
	fish pot	6	12	1	33.28 ± 9.79	0.08 ± 0.04	1.78 ± 1.03
	fish trap	2	4	1	9.00 ± 3.00	0.14 ± 0.01	0.00*
	HL	9	127	1	3.33 ± 0.13	1.04 ± 0.14	129.92 ± 24.47
	Net	9	64	1	10.65 ± 0.61	0.68 ± 0.44	70.63 ± 52.59
DAH	Net	6	159	1.7	8.69 ± 0.29	1.61 ± 0.86	96.72 ± 55.41
	speargun	2	2	1	4.00	0.33 ± 0.03	44.25 ± 2.25
TAM	Net	1	1	1	4.00	2.14	177.14
	speargun	3	6	1	7.50 ± 2.02	1.09 ± 0.31	81.24 ± 30.53
	"subid"	1	1	1	2.00	9.75	1,462.50

total weight of catches. Lutjanids were absent in FVC data from both Region XI sites yet appeared in catch data once at Tamisan and were the second most commonly landed fishes at Dahican, contributing 468.95 kg in total weight over the course of six months (May – October). Lethrinids were not encountered at VII-3 during FVC but were consistently landed from April to December in Bantayan. Serranids were scarcely recorded in both FVC and catch data for most sites, with the exception of catch data from Bantayan which shows these fishes were landed from May to December although weighing much less (17 kg total weight) than other predatory fishes landed. Siganids dominated fish catches in Dahican, supplying up to 1,180.25 kg of total weight in just six months (May – October) but this family does not appear on FVC data for XI-5.

Relationship of Coral Reef Parameters and Fish Productivity Parameters

Areas with high coral cover and rugosity index generally support higher total densities, biomass, and number of species of fish (Table 1), except in Region XI sites where only fish density was found to be correlated with coral cover and rugosity. Fish biomass and number of species appeared to be higher in XI-6, where coral cover was lower and rugosity was less complex. Fish parameters also had low values in V-2 which had a higher rugosity index.

Results of regression analysis (Fig. 3) revealed a significant positive relationship between live hard coral (LHC) cover and fish density (r^2=0.222, p=0.048) as well as LHC cover and fish biomass (r^2=0.330, p=0.013). However, no relationship was seen when reef rugosity was tested with fish density (r^2=0.003, p=0.836) and fish biomass (r^2=0.215, p=0.053). Likewise, the number of fish species did not show a relationship with both LHC cover (r^2=0.42, p=0.414) and reef rugosity (r^2=0.021, p=0.570).

DISCUSSION

Not all coral reefs assessed as 'fair' showed high productivity. Conventional assessments of coral reefs use percentage of coral cover as a basis for determining coral reef condition (Hill & Wilkinson, 2004). However, fish assemblages are also known to be influenced by the complexity of the reef structure than the mere presence or absence of coral species

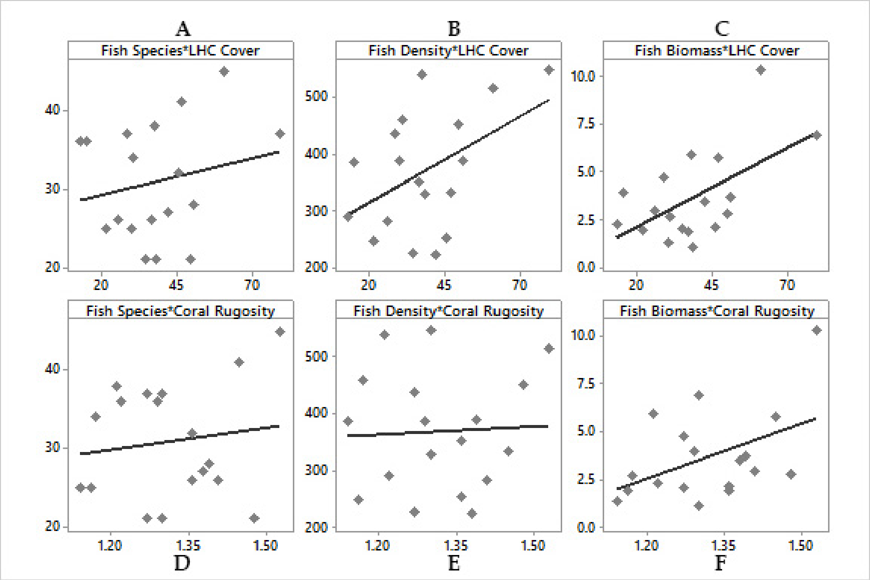

Fig. 3. Scatterplot showing positive linear relationships between fish density and biomass with live hard coral cover (B, C) and no relationship with rugosity (E, F). Number of species also did not show any relationship with LHC cover and rugosity (A, D).

(Stockwell *et al.*, 2009). Russ *et al.* (2005) found fish biomass outside of the AIPLS marine reserve to have increased relative to improved habitat complexity. In the Bahamas, increased habitat complexity was found to reduce mortality of fish recruits and increase abundance of both recruits and adults (Almany, 2004). In this study, the three sites with the highest coral cover and rugosity were VII-4, XI-5, and XI-6. Both VII-4 and XI-6 were assessed as 'fair', and while the latter ranked the lowest in total fish density, it showed higher density and biomass of targeted fish families than other sites surveyed. On the other hand, XI-5 had the lowest total fish biomass despite ranking third in total fish density. This means that the fishes were small which may be an indication of high fishing pressure.

The observed differences between sites might also be attributed to the protective status of some sites. Of the six sites surveyed, four were in protected areas: VII-3 in BMS, VII-4 in AIPLS, XI-5 and XI-6 in PBPS. However, only BMS and Pujada I. (Site XI-6) were designated as no-take marine reserves (NTMRs) while VII-4 and XI-5 are subject to fishing and recreational activities regulated by their respective governing PAMBs.

The effective implementation of NTMRs would significantly impact ecosystem condition by reducing fishing mortality of fishes. This has been examined in various studies, including an age-structured population model of the thumbprint emperor *Lethrinus harak* in Guam, Micronesia which showed that fish parameters (*e.g.* spawner biomass, total abundance, and sex ratio) remained stable over time if existing protective measures were maintained (Taylor, McIlwain, & Kerr,2012). Additionally, a study of fish biomass of targeted species inside the AIPLS marine reserve was shown by Alcala *et al.* (2005) to have strong positive relationship with the number of years the reserve was protected. Taking this into account, one would expect areas that have been protected longer to exhibit better coral reef condition and higher productivity. It should come as no surprise then that sitesVII-4, XI-5 and XI-6 ranked favorably in terms of coral reef condition and in certain fish parameters.

Trophic roles are also an interesting aspect of ecosystem services. Pomacentrids were the most abundant encountered in FVC surveys at all sites. Labrids were also observed at all sites and were among the top three most abundant fish families in Region V sites, VII-3 and XI-6. Pomacentrids are generally herbivorous fish that prevent overgrazing of turf algae on coral reefs by defending their feeding territory against other predators (Hixon & Brostoff, 1983). Turf algae are also a primary source of productivity on coral reefs and often host a diverse range of invertebrates, *i.e.* benthic crustaceans, making pomacentrids a keystone species for maintaining the integrity of microhabitats within the reef ecosystem and act as a bridge between producers and secondary consumers. For instance, harpacticoid copepods from algal turf were found to be most abundant in the gut contents of the wrasses *Thalassoma lunare, Halichoeres melanurus,* and *Stethojulis strigiventer* in the Great Barrier Reef (Kramer, Bellwood, & Bellwood, 2013). Large predatory reef fish, *i.e.* groupers (Serranidae), emperors (Lethrinidae), and snappers (Lutjanidae), were recorded in FVC surveys in only a few sites and in small numbers (<10 individuals) while jackfishes (Carangidae) were not encountered at all. It would be easy to assume that the coral reefs surveyed in this study are fished down as posited in the 'shifting baselines' paradigm by Pauly *et al.* (1998) – that is, overfishing of top predatory species will have cataclysmic cascading effects on lower trophic level species. However, carangids, lethrinids, and lutjanids contributed to most of fish catches landed especially in Regions VII and XI. It might be possible that these large predatory fishes were not observed because of the timing of the FVC surveys, which were conducted once at each site and at variable times of the year for different regions. Species composition may show slight changes within sites when sampled at different times of the day, let alone during different seasons and monsoons. After all, monsoonal changes have been known to influence recruitment patterns of Philippine serranids (Mamauag *et al.*, 2007), clupeids and scombrids (Pauly & Navaluna, 1983), as well as pomacentrids, labrids, chaetodontids, and acanthurids (Abesamis & Russ, 2005). One other possibility is that fishers are not necessarily fishing adjacent to the FVC sites. Catch data from the landing site in Dahican notes multiple fishing grounds within the PBPS but their exact locations and proximity to the FVC site in Sitio Guang-guang (Site XI-5) are unknown. Other evidence to explain this discrepancy points to siganids (rabbitfishes), locally called 'danggit', which contributed up to 1,180.25 kg of total catches landed in Dahican within a six-month period (May – October) but which were not encountered in the FVC survey conducted in XI-5 in late May. In the Philippines, this fish resource is commonly caught in seagrass beds by a range of gears as recorded in works by Calumpong *et al.* (1997; 2014) and Fabinyi (2007). It may then be supposed that siganid catches landed in Dahican were possibly caught in seagrass beds closer to shore rather than in coral reefs.

CONCLUSION AND RECOMMENDATIONS

The results of this study show strong positive relationships between fish density and biomass with LHC cover but not with reef rugosity. However, these results are still largely preliminary and long-term temporal monitoring of the sites may reveal otherwise. Regardless, coral reefs remain to be a significant resource for municipal fisheries and should be monitored vigilantly to ensure food security for future Filipino generations. Sustainable fish stocks are not only reliant on well-regulated fisheries but more so on the effective protection of coral reefs which fishes inhabit.

ACKNOWLEDGMENTS

This study is part of a three-year project entitled, STEWaRDS: Science Towards Environmental Well-being and Resource Development For Society In A Changing Climate, funded by the Commission on Higher Education

(CHED) through the Philippine Higher Education Research Network (PHERNet). This would not have been possible without the permission of Chief Local Executives of the municipalities of Monreal (Masbate) and Dauin (Negros Oriental), the cities of Dumaguete and Mati,and the specific barangays and sitios, to conduct this study in their areas of jurisdiction. Moreover, we are grateful for the cooperation of our Higher Education Institution partners, namely the Masbate School of Fisheries, Cebu Technological University, and Davao Oriental State College of Science and Technology, and our local enumerators Jerol Almiñana, Zacharias Generoso, Wilmer Pascobello, and Medel Tabañera. We also extend our thanks to all our dive guides, field assistants, and boat crews.

REFERENCES

Abesamis, R. A., & Russ, G. R. (2005). Density-dependent spillover from a marine reserve: Llong-term evidence. *Ecological applications*, *15*(5), 1798-1812.

Abesamis, R. A., Alcala, A. C., & Russ, G. R. (2006a). How much does the fishery at Apo Island benefit from spillover of adult fish from the adjacent marine reserve? *Fishery Bulletin*, *104*, 360-375.

Abesamis, R. A., Russ, G. R., & Alcala, A. C. (2006b). Gradients of abundance of fish across no-take marine reserve boundaries: evidence from Philippine coral reefs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *16*(4), 349-371.

Alcala, A.C. (1997). Roles of community-based fisheries management and marine reserves in coastal fisheries. *Silliman Journal*,*38* (3 & 4), 159 – 168.

Alcala, A.C., Bucol, A. A., Maypa, J. L. P., Luchavez, J. A., & Padin, J. I. M. (2012). Baseline information on the coral reef fish community and fishery resources. In Silliman University - Integrated Coastal Resource Management Project. (2012). *Final Report: Establishment of Baseline Data and Implementation of Research Projects and Technical Mentoring to ICRM Centers of Regions V, VII, & XI*. ICRMP of the Department of Environment and Natural Resources.

Alcala, A.C.,Russ, G.R.,& Maypa, A.P. (2002). Evidence for fishery enhancement effects of marine reserves in central Philippines. *UPV Journal of Natural Sciences, 7* (1 & 2), 1-5.

Alcala, A. C., Russ, G. R., Maypa, A. P., & Calumpong, H. P. (2005). A long-term, spatially replicated experimental test of the effect of marine reserves on local fish yields. *Canadian Journal of Fisheries and Aquatic Sciences*, *62*(1), 98-108.

Aliño, P.M, Miclat, E.F.B., Nañola, C.L. Jr., Roa-Quiaoit, H.A.& Campos, R.T. (Eds.). (2002). *Atlas of Philippine Coral Reefs.* Philippine Coral ReefInformation (Philreefs). Quezon City, Philippines: Goodwill Trading.

Allen, G., Steene, R., Humann, P., & Deloach, N. (2003). *Reef fish identification. Tropical Pacific.* Jacksonville: New World Publications.

Almany, G. R. (2004). Does increased habitat complexity reduce predation and competition in coral reef fish assemblages? *Oikos*, *106*(2), 275-284.

Alvarez-Filip, L., Dulvy, N.K., Gill, J.A., Cote, I.M., & Watkinson, A.R. (2009). Flattening of Caribbean coral reefs: Region-wide declines in architectural complexity. *Proceedings of the Royal Society B 276*(pp.3019-3025).

Babcock, R. C., Shears, N. T., Alcala, A. C., Barrett, N. S., Edgar, G. J., Lafferty, K. D., McClanahan, T. R.,& Russ, G. R. (2010). Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proceedings of the National Academy of Sciences*, *107*(43), 18256-18261.

Barut, N. C., Santos, M. D.,& Garces, L. R. (2004). Overview of Philippine marine fisheries. In DA-BFAR (Department of Agriculture – Bureau of Fisheries and Aquatic Resources). *In turbulent seas: The status of Philippine marine fisheries*(p.378). Coastal Resource Management Project of the Department of Environment and Natural Resources, Cebu City, Philippines.

Calumpong, H. P., Estacion, J. S., Cadiz, P. L., Reboton, C. T., Lucañas, J. R., Utzurrum, J. A. T., Sienes, P. M. Q., Bonsato, D. B., Pepito, A. R.,& Balaquit, R. C. (2014). *STEWARDS: Science Towards Environmental Well-being and Resource Development for Society in a Changing Climate (Terminal Report).*

Calumpong, H. P., Estacion, J. S., Lepiten, M. V., & Acedo, C. E. (Eds.). (1997). *Status of the Coastal Resources of the Negros Oriental Learning Site (Manjuyod to Dauin). Vol. 1.* Dumaguete City, Philippines: Silliman University Marine Laboratory and the Center of Excellence in Coastal Resources Management.

Dorenbosch, M., Grol, M. G., Nagelkerken, I., & Van der Velde, G. (2005). Distribution of coral reef fishes along a coral reef-seagrass gradient: Edge effects and habitat segregation. *Marine Ecology Progress Series*, *299*, 277-288.

English, S.A., Wilkinson, C.R., & Baker, V.J. (Eds.). (1997). *Survey manual for tropical marine resources* (2nd ed.) Townsville, Australia: Australian Institute of Marine Science.

Fabinyi, M. (2007). Illegal fishing and masculinity in the Philippines:A look at the Calamianes Islands in Palawan. *Philippine Studies*, 509-529.

Fabricius, K. K., & Alderslade, P. P. (2001). *Soft corals and sea fans: A comprehensive guide to the tropical shallow water genera of the central-west Pacific, the Indian Ocean and the Red Sea*. Australian Institute of Marine Science (AIMS).

Froese, R., & Pauly, D. (Eds.). (2014). FishBase. World Wide Web electronic publication. www. Fishbase.org.

Gell, F. R., & Roberts, C. M. (2003). Benefits beyond boundaries: The fishery effects of marine reserves. *Trends in Ecology & Evolution*, *18*(9), 448-455.

Gomez, E. D. (1991). Coral reef ecosystems and resources of the Philippines. *Philippine Technology Journal (Philippines)*.

Gomez, E. D., Alino, P. M., Yap, H. T., & Licuanan, W. Y. (1994). A review of the status of Philippine reefs. *Marine Pollution Bulletin*, *29*(1), 62-68.

Green, S. J., Flores, J. O., Dizon-Corrales, J. Q., Martinez, R. T., Nuñal, D. R. M., Armada, N. B. & White, A. T. (2004). *The fisheries of Central Visayas, Philippines: Status and trends.* Coastal Resource Management Project of the Department of Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources of the Department of Agriculture, Cebu City, Philippines.

Han, W., Moore, A. M., Levin, J., Zhang, B., Arango, H. G., Curchitser, E., Di Lorenzo, E., Gordon, A.L., & Lin, J. (2009). Seasonal surface ocean circulation and dynamics in the Philippine Archipelago region during 2004–2008. *Dynamics of Atmospheres and Oceans*, *47*(1), 114-137.

Hilborn, R., Branch, T.A., Ernst, B., Magnusson, A., Minte-Vera, C.V., Scheuerell, M.D., &Valero, J.L. (2003). State of the world's fisheries. *Annual Review of Environment and Resources*,*28*(15),1–15.

Hill, J., & Wilkinson, C. L. I. V. E. (2004). Methods for ecological monitoring of coral reefs. *Australian Institute of Marine Science, Townsville*, *117*.

Hixon, M. A., & Brostoff, W. N. (1983). Damselfish as keystone species in reverse: Intermediate disturbance and diversity of reef algae. *Science (Washington)*, *220*(4596), 511-513.

Jimenez, L., & Eballe, A. C.(2002). Pujada Bay. InP.M. Aliño, E.F.B. Miclat, C.L. Nañola, Jr., H.A. Roa-Quiaoit, & R.T. Campos (Eds.),*Atlas of Philippine Coral Reefs*(pp. 100-102). Philippine Coral Reef Information (Philreefs). Quezon City, Philippines: Goodwill.

Kramer, M. J., Bellwood, O., & Bellwood, D. R. (2013). The trophic importance of algal turfs for coral reef fishes: The crustacean link. *Coral Reefs*, *32*(2), 575-583.

Licuanan, W. Y., & Gomez, E. D. (2002). Philippine coral reefs: Status and the role of the academe to improve their management. *Proceedings of the Ninth International Coral Reef Symposium, Bali, 2* (pp. 835-840).

Manthachitra, V. (1994, May). Indices assessing the status of coral-reef assemblage: Formulated from benthic lifeform transect data. *Proceedings, Third ASEAN-Australia Symposium on Living Coastal Resources*, *2*(pp. 41-50).

Mamauag, S., Penolio, L., & Aliño, P. (2007). Deriving recruitment and spawning patterns from a survey of juvenile grouper (Pisces: Serranidae) occurrences in the Philippines. *Science Diliman*, *13*(1).

Maypa, A.P. (2012). *Mechanisms by which marine protected areas enhance fisheries benefits in neighboring areas* (Ph.D. Dissertation). University of Hawai'i at Mānoa. ProQuest Information and Learning registered under the United States Copyright Office. 147.p.

Maypa, A. P., Russ, G. R., Alcala, A. C., & Calumpong, H. P. (2002). Long-term trends in yield and catch rates of the coral reef fishery at Apo Island, central Philippines. *Marine and Freshwater Research*, *53*(2), 207-213.

Moberg, F., & Folke, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological Economics*, *29*(2), 215-233.

Odum, E.P. (1971). *Fundamentals of ecology*(3rded.).Philadelphia, USA: W.B. Saunders.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. (1998). Fishing down marine food webs. *Science*, *279*(5352), 860-863.

Pauly, D., & Navaluna, N. A. (1983). Monsoon-induced seasonality in the recruitment of Philippine fishes. *FAO Fisheries Report (FAO).*

Reboton, C.T.,& Candido, A. (2014). Assessment on the coral and reef fish communities in Ticao Island, Masbate. *Ecology Environment & Conservation 19 (Special Issue on Coastal Resource Management),33-43.*

Rogers, C. S. (1990). Responses of coral reefs and reef organisms to sedimentation. *Marine Ecology Progress Series. Oldendorf*, *62*(1), 185-202.

Russ, G. R., & Alcala, A. C. (1996). Marine reserves: Rates and patterns of recovery and decline of large predatory fish. *Ecological Applications*, 947-961.

Russ, G. R., & Alcala, A. C. (2010). Decadal-scale rebuilding of predator biomass in Philippine marine reserves. *Oecologia*, *163*(4), 1103-1106.

Russ, G. R., Alcala, A. C., & Maypa, A. P. (2003). Spillover from marine reserves: The case of Naso vlamingii at Apo Island, the Philippines. *Marine Ecology Progress Series*, *264*, 15-20.

Russ, G. R., Alcala, A. C., Maypa, A. P., Calumpong, H. P., & White, A. T. (2004). Marine reserve benefits local fisheries. *Ecological Applications*, *14*(2), 597-606.

Russ, G. R., Stockwell, B., & Alcala, A. C. (2005). Inferring versus measuring rates of recovery in no-take marine reserves. *Marine Ecology Progress Series*, *292*, 1-12.

Samoilys, M. A., Martin-Smith, K. M., Giles, B. G., Cabrera, B., Anticamara, J. A., Brunio, E. O., & Vincent, A. C. (2007). Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. *Biological Conservation*, *136*(4), 584-601.

Stockwell, B., Jadloc, C. R. L., Abesamis, R. A., Alcala, A. C., & Russ, G. R. (2009). Trophic and benthic responses to no-take marine reserve protection in the Philippines. *Marine Ecology Progress Series*, *389*, 1-15.

Taylor, B. M., McIlwain, J. L., & Kerr, A. M. (2012). Marine reserves and reproductive biomass: A case study of a heavily targeted reef fish. *PloS one*, *7*(6), e39599.

Veron, J. E. N. (2000). Corals of the World, vol. 1–3. *Australian Institute of Marine Science, Townsville.*

Veron, J.E.N.,& Wallace, C.C. (1984). *Scleractinia of Eastern Australia. Part V. Family Acroporidae. Australian Institute of Marine Science Monograph Series, 6,* 482. Canberra:Australian National University Press.

Veron, J.E.N. & Pichon, M. (1976). *Scleractinia of Eastern Australia. Part I. Families Thanmasteriidae, Astrocoeniidae, Pocilloporidae. Australian Institute of Marine Science Monograph Series,1,* 86. Canberra: Australian Government Publishing Service.

Veron, J.E.N. & Pichon, M. (1980). *Scleractinia of Eastern Australia. Part III. Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae, Dendrophylliidae. Australian Institute of Marine Science Monograph Series,. Vol. 4,* 422.Canberra: Australian National University Press.

Veron, J.E.N. & Pichon, M. (1982). *Scleractinia of Eastern Australia. Part IV. Family Poritidae. Australian Institute of Marine Science Monograph Series, 5, 159.* Canberra: Australian National University Press.

Veron, J.E.N., Pichon, M.,& Wijsman-Best, M. (1977). *Scleractinia of Eastern Australia. Part II. Families Faviidae, Trachyphyllidae. Australian Institute of*

Marine Science Monograph Series, 3, 233.Canberra: Australian Government Publishing Service.

Wallace, C. C. (1999). *Staghorn corals of the world: A revision of the coral genus Acropora. Collingwood.* Victoria: CSIRO Publishing.

White, A. T., Vogt, H. P., & Arin, T. (2000). Philippine coral reefs under threat: The economic losses caused by reef destruction. *Marine Pollution Bulletin*, *40*(7), 598-605.