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Effectiveness of locally managed Marine Protected Areas in the Visayas, Negros Oriental Province, Philippines

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ABSTRACT

No-take marine protected areas (MPAs) have been established as a management strategy to conserve biodiversity and sustain fisheries. When properly managed, such areas can maintain or increase reef productivity and also benefit surrounding areas, providing catch for fishermen. In the Philippines, most MPAs are usually small (<1 km^2) and locally managed, and most present poor levels of enforcement. Five locally managed MPAs located in Negros Oriental were studied in order to test the effectiveness of such MPAs. The objectives were to compare fish biomass, richness, abundance, diversity and evenness values between MPAs and adjacent fished sites and see how they varied between the different enforcement levels, sizes, and ages of these MPAs. Underwater visual census was carried out to record and measure fish from 76 indicator species inside and outside MPAs from September 2016 to February 2017. Data analysis showed that fish population parameter values were only higher inside certain MPAs when compared to fished areas. Two MPAs were found to be the most effective in the region, exhibiting greater species biomass, richness, density, diversity and evenness than non-MPAs. On the other hand, three MPAs were found to be ineffective, exhibiting similar fish population parameters than non-MPA sites. From the studied parameters, only enforcement level played a significant role in the effectiveness of these MPAs. Small and locally managed MPAs can benefit fish populations, but only when properly managed and enforced. Certain areas need further investments from the municipalities to be able to be effective and properly conserve fish populations.

Keywords: Marine Protected Areas, locally managed, effectiveness.

RESUMO

As áreas marinhas protegidas (AMPs) de proteção total foram estabelecidas como uma estratégia de gestão para conservar a biodiversidade e sustentar a pesca. Quando administradas adequadamente, tais áreas podem manter ou aumentar a produtividade dos recifes e beneficiar as áreas circundantes, proporcionando captura para os pescadores. Nas Filipinas, a maioria das AMPs são pequenas (<1 km^2), gerenciadas localmente, e a maioria apresentam níveis baixos de vigilância. Foram estudadas cinco AMPs localmente administradas em Negros Oriental para testar a eficácia destas. Os objetivos foram comparar a biomassa dos peixes, a riqueza, a abundância, a diversidade e a uniformidade entre AMPs e locais adjacentes abertos à pesca e ver como eles variavam entre os diferentes níveis de vigilância, tamanhos e idades das AMPs. Censos visuais subaquáticos foram realizados para registar e medir peixes de 76 espécies indicadoras dentro e fora das AMPs de Setembro de 2016 a Fevereiro de 2017. A análise de dados mostrou que os valores dos parâmetros estudados eram maiores apenas dentro de algumas AMPs. Duas AMPs foram consideradas eficazes na região, apresentando maior biomassa, riqueza, densidade e uniformidade de espécies. Por outro lado, três AMPs pareceram ser ineficazes, exibindo valores semelhantes aos das áreas de pesca. Dentre os parâmetros estudados, somente o nível de vigilância desempenhou um papel importante na eficácia dessas AMPs. Este tipo de AMPs podem beneficiar as populações de peixes, mas somente quando devidamente gerenciadas e vigiladas. Certas áreas precisam de mais investimentos dos municípios para serem eficazes e conservar populações de peixes.

Palavras-chave: Áreas marinhas protegidas, gerenciadas localmente, eficácia.

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1. INTRODUCTION

Located in the center of the coral triangle, the Philippines is home to one of the highest fish biodiversity in the world, and are therefore widely recognized as a priority in the marine conservation field (Cabral *et al.*, 2014, Carpenter and Springer, 2005, Spalding *et al.*, 2001). Over 1700 reef fish species are found in the Philippines, but overwhelming pressures from fisheries on marine resources are raising concerns as per the sustainability of local fisheries (Horigue *et al.*, 2012, White *et al.*, 2000). Reef fish are an important catch for fishers, and even though local communities highly depend on fish resources as a food source (Horigue *et al.*, 2012), most reef areas have been destroyed by human activities or overexploited by fisheries (Honda *et al.*, 2016, Nañola Jr. *et al.*, 2011).

In the last decades, Marine Protected Areas (MPAs) have been used as biodiversity conservation tools across the globe as they can in some cases increase richness, biomass, and density of fish in coral reefs through the effect of larval recruitment or adult spillover (Honda *et al.*, 2016, Muallil *et al.*, 2015, Abesamis *et al.*, 2006, Russ and Alcala, 1996). In the Philippines, some MPAs have been shown to be able to sustain small-scale fisheries when properly managed (Alcala and Russ, 2006, Indab and Suarez-Aspilla, 2004, Maliao *et al.*, 2004). More than 1600 MPAs exist in the Philippines, and most contain no-take areas surrounded by managed fishing areas (White *et al.*, 2014). However, only 30% of all MPAs in the Philippines are well managed, and considering that only 3.4% of coral reefs are protected within existing MPAs, only slightly more than 1% of the coral reef area is effectively managed and protected (White *et al.*, 2014).

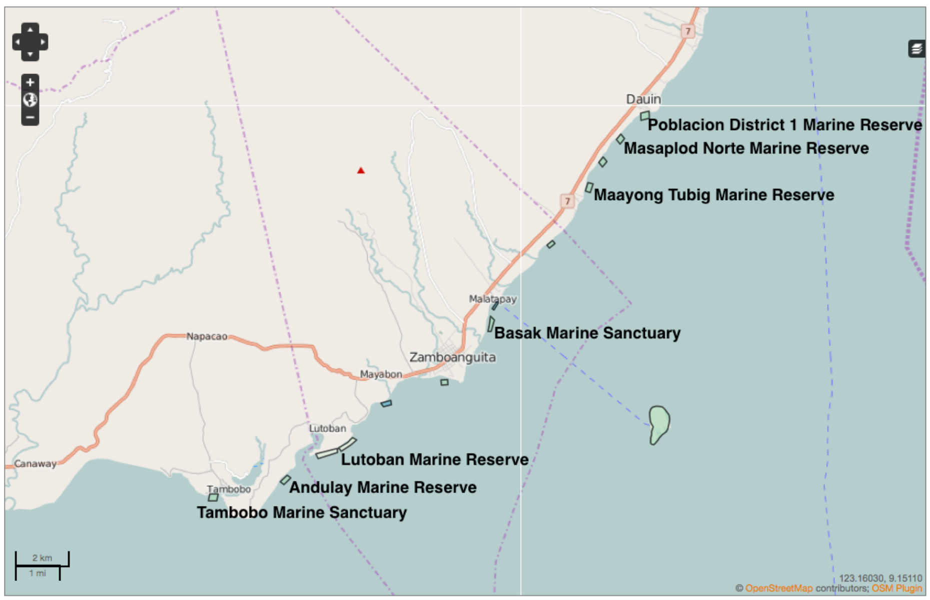
It is therefore important to study and understand the role and impact of locally established and managed MPAs on fish species parameters, and assess whether they really are useful and effective for the communities. Studies have focused on the effectiveness of MPAs all over the Philippines, but only few focused on the MPAs in Negros Oriental (Visayan region), especially in the municipalities of Siaton, Zamboanguita, and Dauin, with the exception of Apo Island's Marine Sanctuary. Apo Island's well-protected no-take reserve is one of the few reserves where several studies have been conducted in the last decade. Russ and Alcala (1996), Abesamis and Russ (2005), Abesamis *et al.* (2006) and Russ *et al.* (2015) all showed evidence of increased abundance and total size of target fish inside Apo's reserve compared to adjacent fishing areas, also correlated with time since protection, and consistent with a density-dependent home-range relocation of fish from no-take reserves to the surrounding areas.

Such studies are essential to the understanding of the effectiveness of locally managed MPAs, as they can be used as a guideline to improve the studied area and enhance the benefits of local fishermen who depend on marine resources. Since not all MPAs have the same enforcement and compliance levels and have their own specific parameters, by exploring five MPAs in the Philippines using underwater visual censuses, this report assesses the difference in fish parameters between the inside and the outside of five MPAs in order to measure MPA effectiveness across those three municipalities. The objectives are (1) to see if there's a difference in fish parameters (biomass, size, diversity and richness) of target and non-target species inside and outside MPAs; (2) to see if there's a difference in fish parameters between MPAs; (3) to see how enforcement, compliance, type of protection, distance between MPAs, distance to ports/villages and rivers and size and age of MPAs affect fish population parameters; (4) to see which families/species of fish are benefiting the most from the protected areas; and (5) to see whether there's a difference in coral and algae cover inside and outside MPAs. Results will provide insights of MPAs effectiveness, which are essential to assess future needs, adapt practices, and optimize the allocation of government and private resources to MPAs.

2. METHODS

This study was conducted in five locally managed Marine Protected Areas (LM-MPAs) and five open access sites used as controls, totalizing 10 sites on fringing reefs along the island of Negros, in the central Philippines (Visayas region): Dauin Poblacion District 1 Marine Sanctuary, Masaplod Norte Marine Reserve, Andulay Marine Reserve, Basak Marine Sanctuary, and Lutoban Marine Sanctuary. Poblacion District 1 Marine Reserve (Dauin MPA) was established in 2000 (17 years old), and has 9.2 hectares. Its enforcement is done by a *bantay dagat* (fish wardens) and has an enforcement rated "high." Masaplod Norte MPA was established in 1994 (23 years old) and has 6.1 hectares. Its enforcement is also done by a *bantay dagat* and has an enforcement rated "high." Andulay MPA was established in 1993 (24 years old) and has 6 hectares. Its enforcement is also done by a *bantay dagat* and has an enforcement rated "medium". Basak MPA was established in 2006 (11 years old) and has 7.8 hectares. Its enforcement is also done by a bantay dagat and has an enforcement rated "low". Lutoban South MPA was established in 2002 and has 10 hectares. However, this MPA never received formal enforcement and therefore has an enforcement rated as "none"; this MPA is considered a paper-MPA.

The MPAs are located in the municipalities of Zamboanguita, Siaton and Dauin, in the Province of Negros Oriental (Map 1). The LM-MPAs had relatively small sizes (6 to 10 hectares) and were managed by local communities. All control sites assigned were located 200 to 500 meters from their boundaries, in order to compare variables inside and outside MPAs (protected versus fished sites). When possible, control sites were located on the same stretches of continuous reef, and otherwise on a separate patch of reefs with similar characteristics. Habitats in the MPAs included coral reefs and commonly sea grass and/or mangroves inside or nearby.



Map 1: Map of existing MPAs in Zamboanguita, Siaton and Dauin, Negros Island, Philippines, with names of the proposed MPAs to be studied.

2.1. Underwater visual census

Underwater visual census (UVC) of fish indicator species was carried out using SCUBA diving on all sites as described by Hill and Wilkinson (2004), and following Reef Check's procedures. Surveys were performed at two stations per site (located at 5 and 10 meter depths), therefore two stations inside each MPA and two stations outside each fishing site. At each depth range, permanent transects were surveyed four times, resulting in 8 pseudo-replicates per site, and summing up to 40 psuedo-replicates for the 5 MPAs and 40 for the control areas, totalizing 80 fish surveys in total. Each survey was comprised of four 500 m^3 (20-m long by 5-m wide and 5-m high) belt transects

along a 100-m or two 50-m measuring tapes, each separated by 5-m from one another to ensure sample independence (Figure 1).

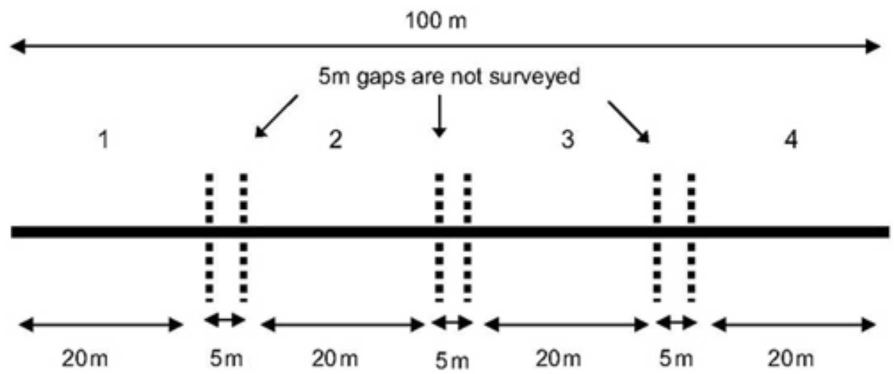


Figure 1: Division of the transect line (from Reef Check, http://www.reefcheck.org/ecoaction/monitoring-instruction/)

UVC were always conducted by at least two divers: after lying down the 100-m measuring tape, divers swam back to the beginning of the tape and waited 15 to 20 minutes before surveying to allow the fish to come back to the transect. Fish indicator species with more than 5 cm were recorded, and their total body length (TL) was estimated and classified in 10 cm intervals (0–10 cm, 10–20 cm, 20–30 cm, etc.). Divers also recorded data regarding water clarity during the surveys to ensure visibility was not influencing the results.

2.2. Benthic composition survey

The point intercept transect (PIT) method, as described by Hill and Wilkinson (2004) and used by Reef Check, was used to determine the benthic habitat composition along the same transects used in the fish UVC. Substrate types were recorded every 50 cm along the four 20 m belt transects (total of 160 points). Substrate types included silt/clay, sand, rubble, rock, trash, sponges, filamentous algae, macroalgae, soft corals, hard corals, and others (clams, corralimorphs, anemones, tunicates, sessile worms, zoanthids). For both macroalgae and hard corals, species or families were identified, and for hard corals only, growth form (branching, corymbose, digitate, tabulate, encrusting, foliose, laminar, massive, sub-massive, solitary) and colony health (healthy, partially bleached, fully bleached, dead coral) was assessed.

The main objective of the fish and benthic surveys were to monitor and compare fish richness, biomass and abundance and coral and algae coverage inside and outside LM-MPAs. All

dives were conducted from the shore, and surveys were performed starting September 2016 until February 2017.

2.3. Species recorded

Small-scale fisheries in the Philippines are becoming increasingly less selective in their target species, and coupled with aquarium fishing, also an important fishery in some areas of the Philippines (Muallil *et al*., 2015 and 2014), it is difficult to classify species as commercially important or not for a certain area. Furthermore, as no commercial operations are allowed to fish in municipal waters (within 15 kilometers of the shore, White and Salamanca, 2002), this study considered 76 species considered ecologically important for the reef health status and commercially important for local fishermen (Appendix 6.2.). The species belong to 22 fish families, being: parrotfish (Scaridae), surgeonfish (Acanthuridae), groupers (Serranidae), snappers (Lutjanidae), emperors (Lethrinidae), sweetlips (Haemulidae), goatfish (Mullidae), triggerfish (Balistidae), cardinalfish (Apogonidae), fusiliers (Caesionidae), butterflyfish (Chaetodontidae), batfish (Ephippidae), cornetfish (Fistulariidae), squirrelfish (Holocentridae), filefish (Monacanthidae), breams (Nemipteridae), boxfish (Ostraciidae), angelfish (Pomacanthidae), wrasses (Labridae), lionfish (Scorpaenidae), rabbitfish (Siganidae), and pufferfish (Tetraodontidae).

2.4. Data analysis

The length estimates of the target species were used to estimate fish biomass per cubic meters using the allometric length-weight equation (Bonhsack, 1988):

$$W = a\mathrm{TL}^b$$

Where W is the weight in grams, a and b are coefficients obtained either from the literature (Gumanao *et al.* 2016) or from FishBase (Froese and Pauly, 2016, Appendix 6.2.), and TL is the total length in centimeters. When length-weight relationships for a particular species were unknown, the available relationship of a closely related species was used. Fish biomass was assessed on 500 m^3 bases, by averaging the fish density of the four 20x5x5-m (500-m^3) segments of each transect. The species recorded were classified according to their functional group (scrapers, invertebrate specialists, corallivores, generalists, predators, and detritivores) and commercial status (targeted and non-targeted). Classification into functional groups and commercial status of all species was based on primary literature, when available, or FishBase (Froese and Pauly, 2016).

Benthic habitat for each site will be described as a percent cover of each substrate type, and calculated as follows (total number of points being 160): ([number of recorded points for each substrate type/total number of points]*100).

General linear mixed models (GLMM) were used, implemented under a Bayesian framework to test the effect of protection status (MPA versus non-MPAs) on the biomass and average size of commercially important species, and on the abundance, richness, diversity, and evenness of both commercially and ecologically important species on all MPAs and control sites. The models have a hierarchical structure, where the protection status was nested within the different sites sampled. For the abundance model, a Poisson error structure was used given the nature of the data, and for biomass, average length, richness, diversity and evenness, a Gaussian error structure was used. All models were compared using the Deviance information criterion (DIC) to benchmark models in which protection status was not included as a fixed effect. Markov-chain Monte-Carlo (MCMC) methods were used to sample the posterior distribution of effect sizes, which ran for 10^6 iterations and was sampled every 100 iterations (thinning=100) after burn-in (5x10^5). The effect size was considered significant when the value of 0 was not included in the 95% confidence interval of the estimated posterior distributions of parameters. Inverse gamma priors were used for variance components, and chain mixing was monitored by checking the effective sample sizes (ESS) for fixed and random factors.

Benthic cover between MPA and non-MPA sites were compared using two-way ANOVAs with sites as fixed factors. When differences between protected and non-protected sites were significant, tests were followed by Tukey's HSD contrasts test to identify where exactly the differences were. The same procedures were used to compare enforcement, MPA size and MPA age between the MPAs and the respective control sites.

3. RESULTS

3.1. Protection status of MPAs

Protection status affected target species's biomass and average total length, and both target and non-target species's abundance, richness, diversity, and evenness (Table 1) within each MPA. All

the models that included protection status as a fixed factor along with the sites had lower DICs than models excluding protection status (refer to DIC values on Table 1). When MPA enforcement level, MPA size and MPA age were included in the models, DIC values went up, and those variables were therefore excluded from the models for separate treatment.

Table 1: Deviance information criteria (DIC) for full models (including protection status as a predictor of the response variable) and reduced models (without protection as a predictor). The preferred models are the ones with a smaller DIC (in **bold**).

Response variable	Full model	Reduced model
Commercial species		
Biomass	**54448.63**	54513.08
Average total length	**22480.09**	22613.32
All species		
Richness	**1565.787**	1757.969
Abundance	**2397.836**	2398.602
Evenness	**-275.1222**	-227.8997

3.2. Mean fish biomass of commercially important species

In the present only three out of the five MPAs presented higher fish biomass than their control sites; one didn't present any significant differences with its control site; and one showed a lower biomass than in its control site. Masaplod Norte MPA is the area where the highest biomass was found, with 3.7 times the biomass of its control site, followed by Dauin MPA, which presented 1.6 times the biomass of its control site, and Basak MPA with 1.6 times. On the other hand, Andulay MPA presented more or less the same biomass than its control site, and Lutoban South MPA 0.7 times the biomass of its control area.

Biomass of commercially important species was significantly higher inside Dauin, Masaplod Norte, and Basak MPAs, and significantly lower inside Lutoban South MPA compared to their respective control sites (Table 2, Figure 2.1, Map 2). Indeed, Masaplod Norte had 846.7 g/500m^3 of fish, Dauin 570.6 g/500 m^3 and Basak had 378.6 g/500 m^3 of fish while their control sites only had 326, 368.7, and 244.5 g/500m^3, respectively. Lutoban South had 187.6 g/500m^3 while its control site had 265.3 g/500m^3. Biomass inside Andulay's MPA didn't present any significant difference with its control site (Table 2, Figure 21, Map 2), as it had 322.9 g/500m^{3}while its control site had 360.9. Significant biomass differences were found in regards of enforcement ($F_{4,3345}$ = 15.02, p = 3.6e-12),

MPA size ($F_{5,3345}$ = 14.34, p = 6.47e-14) and MPA age ($F_{5,3345}$ = 14.34, p = 6.47e-14). Biomass was significantly higher only for Masaplod Norte MPA (strong enforcement; Table 3, Figure 2.2). With regards of MPA size and age since protection, significant higher biomass was only found for Dauin (9.2 hectares, 17 years old) and Masaplod Norte MPAs (6.1 hectares, 23 years old) when compared to their control sites (Table 3, Figures 2.3 and 2.4).

Map 2: Mean biomass (in g/500m3) of commercially important species at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

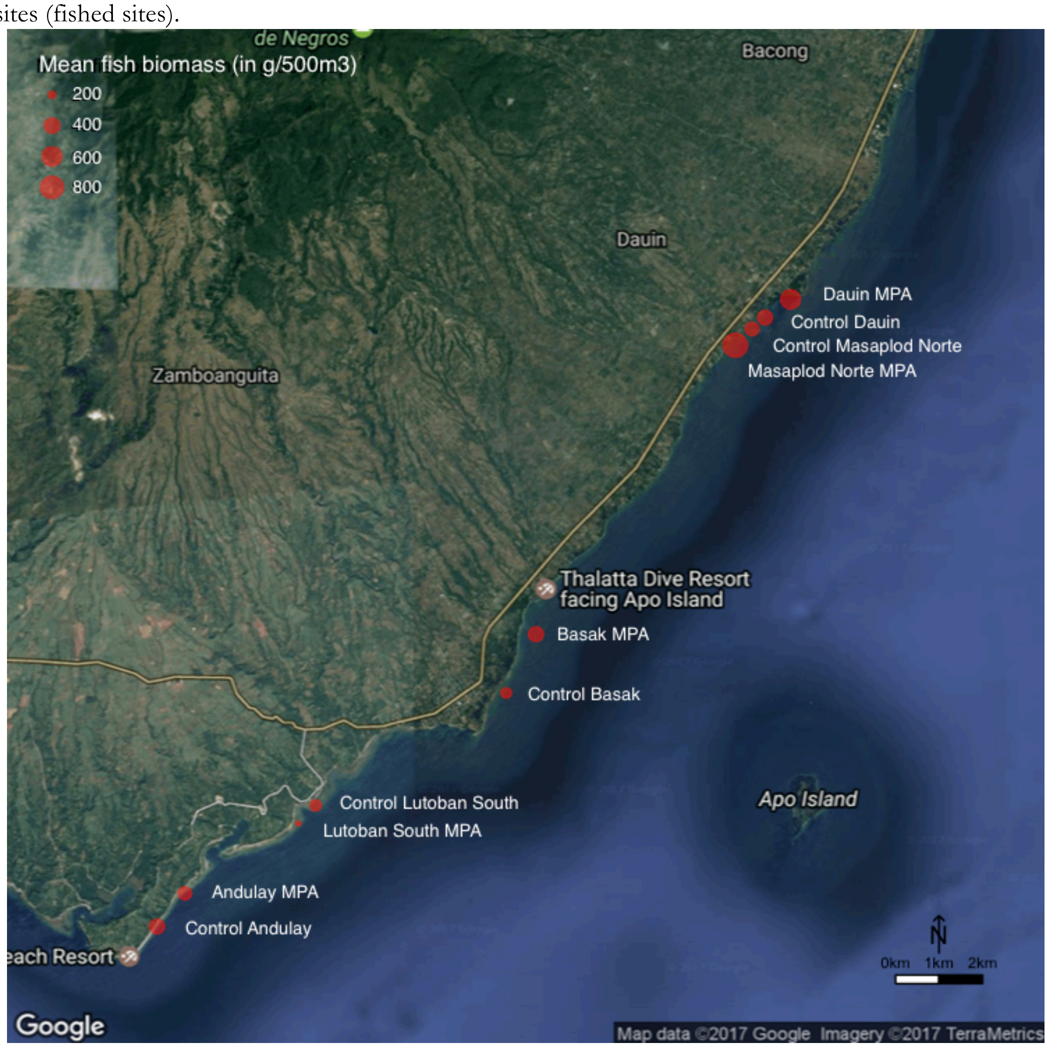


Table 2: Mixed models result for the biomass of commercially important species (in g/500m3) and the richness, abundance, and diversity of commercially and ecologically important species. The posterior means are given (Estimate), as well as the 95% credible interval (CI), the effective sample size (ESS) for the different variables and the interactions between the levels of the fixed factors, and the variance associated with the random factors of the models. The results of the interaction between **the** sites and the status are relative to benchmark levels (MPAs versus fished sites). The effects judged significant according to the 95% confidence interval (when it doesn't include 0) are highlighted in **bold**).

Effect	Estimate	95% CI		EES	pMCMC
Biomass of commercial species (Zone: Status)					
Andulay	37.94	-66.55	148.77	5000	0.0088
Basak	**-132.96**	**-243.61**	**-18.72**	**5000**	**0.01**
Dauin	**-197.06**	**-326.63**	**-71.64**	**5000**	**0.0044**
Lutoban South	**80.46**	**30.04**	**131.38**	**5000**	**0.0024**
Masaplod Norte	**-543.8**	**-718.6**	**-343.7**	**5000**	**<2e-04**
Random (Zone: Depth)	779	0.0004223	25010	5000	
Average total length (Zone: Status)					
Andulay	-0.2473	-1.0865	0.6203	5000	0.5536
Basak	**-1.6866**	**-2.7528**	**-0.6091**	**5000**	**0.0036**
Dauin	**-2.88**	**-3.928**	**-1.715**	**5190**	**<2e-04**
Lutoban South	0.6593	-0.2451	1.5085	5000	0.138
Masaplod Norte	**-6.195**	**-7.659**	**-4.784**	**5205**	**<2e-04**
Random (Zone: Depth)	1.867	0.1641	5.262	5000	
Abundance of all species (Zone: Status)					
Andulay	0.1218	-0.1587	0.3952	5000	0.388
Basak	**-0.604**	**-0.9271**	**-0.3018**	**4703**	**0.0004**
Dauin	**0.2012**	**-0.1119**	**0.5047**	**5000**	**0.2**
Lutoban South	**0.06436**	**0.2371**	**1.002**	**5000**	**0.0004**
Masaplod Norte	**-0.7057**	**-1.017**	**-0.3748**	**4755**	**<2e-04**
Random (Zone: Depth)	0.02209	0.0001473	0.07388	5000	
Richness of all species (Zone: Status)					
Andulay	-1.1024	-2.3952	0.2428	5000	0.112
Basak	**-2.329**	**-3.621**	**-0.938**	**5000**	**0.0008**
Dauin	**-4.694**	**-5.962**	**-3.477**	**5930**	**<2e-04**
Lutoban South	**-2.935**	**-4.144**	**-1.766**	**5000**	**<2e-04**
Masaplod Norte	**-9.469**	**-11.172**	**-7.852**	**5000**	**<2e-04**
Random (Zone: Depth)	1.709	0.0003739	8.792	5000	
Diversity of all species (Zone: Status)					
Andulay	-0.2705	-0.467	-0.0752	5000	0.0044
Basak	**-0.0315**	**-0.2002**	**0.1506**	**5000**	**0.7172**
Dauin	**-0.6189**	**-0.7926**	**-0.4593**	**5000**	**<2e-04**
Lutoban South	**-0.7998**	**-1.0234**	**-0.5847**	**5000**	**<2e-04**
Masaplod Norte	**-0.6696**	**-0.9104**	**-0.4295**	**5000**	**<2e-04**
Random (Zone: Depth)	0.03973	0.001964	0.1092	5000	
Evenness of all species (Zone: Status)					
Andulay	-0.080002	-0.146736	-0.004613	5000	0.0272
Basak	**0.10761**	**0.05327**	**0.15851**	**5000**	**0.0008**
Dauin	**-0.12564**	**-0.18777**	**-0.05823**	**5000**	**<2e-04**
Lutoban South	**-0.2308**	**-0.3316**	**-0.1242**	**5000**	**<2e-04**
Masaplod Norte	**-0.039**	**-0.12163**	**0.03995**	**5000**	**0.3412**
Random (Zone: Depth)	0.003113	0.000167	0.008777	5000	

Table 3. Biomass, average total length, abundance, richness, diversity and evenness of fish inside and outside MPAs. Comparison of fish biomass (in/500m3), average total length (in cm), abundance, richness, diversity (Shannon-Wiener diversity index) and evenness (Shannon evenness index) inside five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) and their corresponding control sites located along the southeastern coast of Negros Oriental, Philippines. The means refer to the means of the effect at each site and the adjusted p-values (p-adj) refer to Tukey's HSD contrasts following two-way ANOVAs. Significant p-values ($p < 0.05$) are marked in **bold**.

	Mean		p-adj (Tukey HSD)		
Effect/Location	**MPA**	**Control**	**Enforcement**	**MPA size**	**MPA age**
Biomass					
Andulay	322.9	360.9	1	0.7710588	0.7710588
Basak	378.6	244.5	0.9957117	0.1803292	0.1803292
Dauin	570.6	368.7	0.1936464	0.0107503	0.0107503
Lutoban South	187.6	265.3	0.9999767	0.9651385	0.9651385
Masaplod Norte	846.7	326	**0.0000001**	**0.0000097**	**0.0000097**
Average total length					
Andulay	14.46	14.2	1	**0.013946**	**0.013946**
Basak	15.27	13.59	0.7568149	**0.0024004**	**0.0024004**
Dauin	16.58	13.69	**0.0000275**	**0.0000002**	**0.0000002**
Lutoban South	13.07	13.51	1	0.2502486	0.2502486
Masaplod Norte	19.76	13.78	**0.0000001**	**0.0000001**	**0.0000001**
Abundance					
Andulay	39.56	53.09	1	1	1
Basak	52.66	29.53	**0.0295492**	0.0511642	0.0511642
Dauin	52.5	82.62	0.9999921	0.9993254	0.9993254
Lutoban South	26.81	72.22	0.075473	0.3911018	0.3911018
Masaplod Norte	95.62	52.84	**0.004474**	**0.0211286**	**0.0211286**
Richness					
Andulay	12.12	11	0.9973497	**0.0000444**	**0.0000444**
Basak	10.31	8	0.1736291	**0.0000002**	**0.0000002**
Dauin	16.12	11.44	**0.0000001**	**0.0000001**	**0.0000001**
Lutoban South	9.719	6.781	0.0102897	**0.0000001**	**0.0000001**
Masaplod Norte	19.19	9.71	**0.0000001**	**0.0000001**	**0.0000001**
Diversity					
Andulay	2.094	1.823	0.6193357	**0.0000733**	**0.0000733**
Basak	1.721	1.689	1	**0.0208604**	**0.0208604**
Dauin	2.409	1.79	**0.0000022**	**0.0000001**	**0.0000001**
Lutoban South	1.926	1.125	**0.0000001**	**0.0000001**	**0.0000001**
Masaplod Norte	2.338	1.669	**0.0000002**	**0.0000001**	**0.0000001**
Evenness					
Andulay	0.85	0.9011	0.9267661	0.1055273	0.1055273
Basak	0.7421	0.8495	0.482004	0.9937373	0.9937373
Dauin	0.8707	0.745	0.1813094	**0.0125468**	**0.0125468**
Lutoban South	0.8553	0.6242	**0.000002**	**0.0000097**	**0.0000097**
Masaplod Norte	0.7971	0.7584	0.9999993	0.4238696	0.4238696

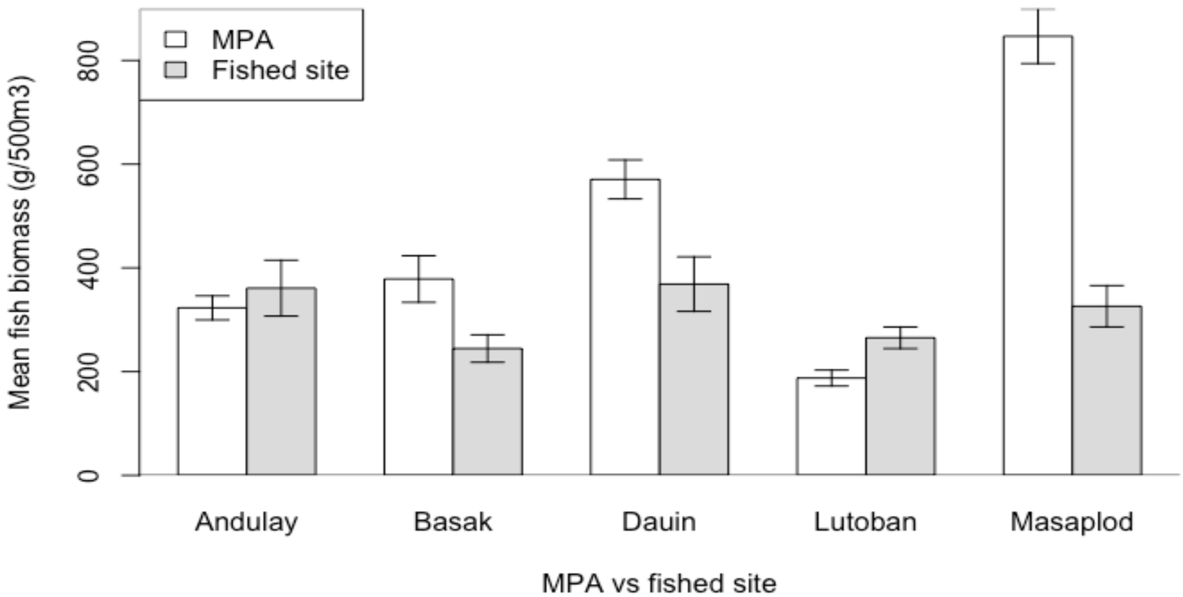


Figure 2.1: Mean biomass of commercially important species (in g/500m3) at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

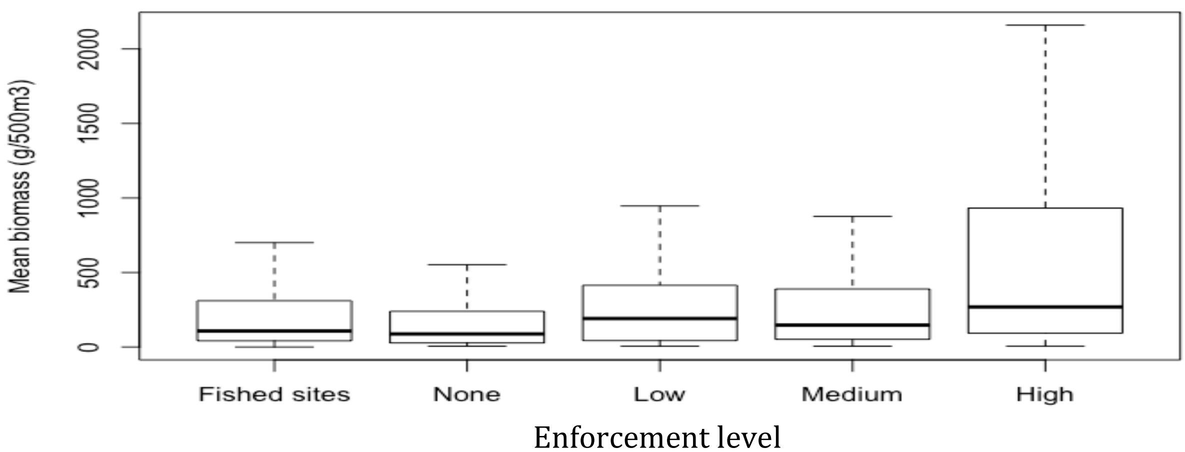


Figure 2.2: Mean biomass of commercially important species (in g/500m3) according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

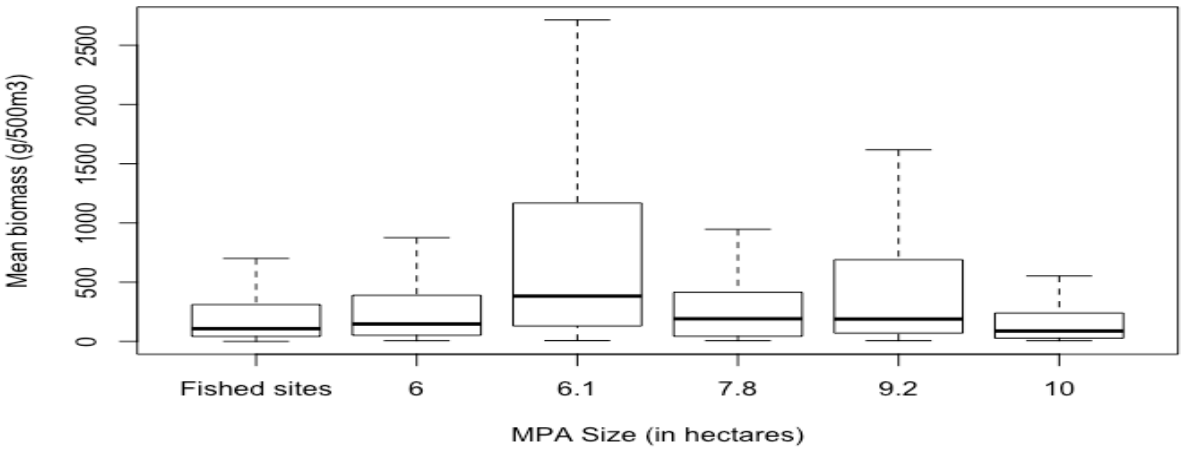


Figure 2.3: Mean biomass of commercially important species (in g/500m3) according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

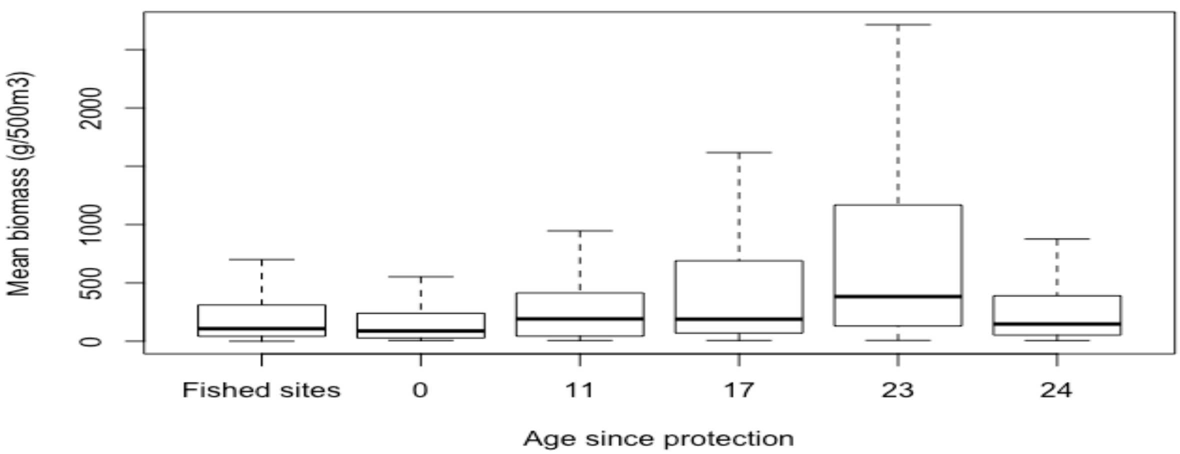


Figure 2.4: Mean biomass of commercially important species (in g/500m3) according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.3. Average total length of target species

Regarding the average total length of target species, three out of five MPAs presented significant higher averages than their control sites, while the other two showed no differences with their control sites. The biggest fish were found in Masaplod Norte MPA, where fish were on average 1.4 times bigger than in its control site, followed by Dauin MPA, where fish were 1.2 times bigger, and Basak MPA, where fish were 1.1 times bigger.

Average total length of commercially important species was significantly higher inside Masaplod Norte, Dauin, and Basak MPAs when compared to their respective control sites. No significant differences were found for Andulay and Lutoban South MPAs when compared to their control sites (Table 2, Figure 3.1). Significant average total length differences were found between MPAs and control sites in regards of enforcement ($F_{4, 3345}$ = 30.67, p=2e-16), MPA size ($F_{5, 3345}$ = 27.51, p=2e-16) and MPA age ($F_{5, 3345}$ = 27.51, p=2e-16). Enforcement level only caused a significant difference for Masaplod Norte (strong enforcement) and Dauin (strong enforcement) MPAs compared to their control sites (Table 3, Figure 3.2). With regards of MPA size and MPA age, significant differences were found in Masaplod Norte (6.1 hectares, 23 years old), Dauin (9.2 hectares, 17 years old) and Basak (7.8 hectares, 11 years old) MPAs when compared to their control sites (Table 3, Figures 3.3 and 3.4). No significant differences were found for Andulay and Lutoban South.

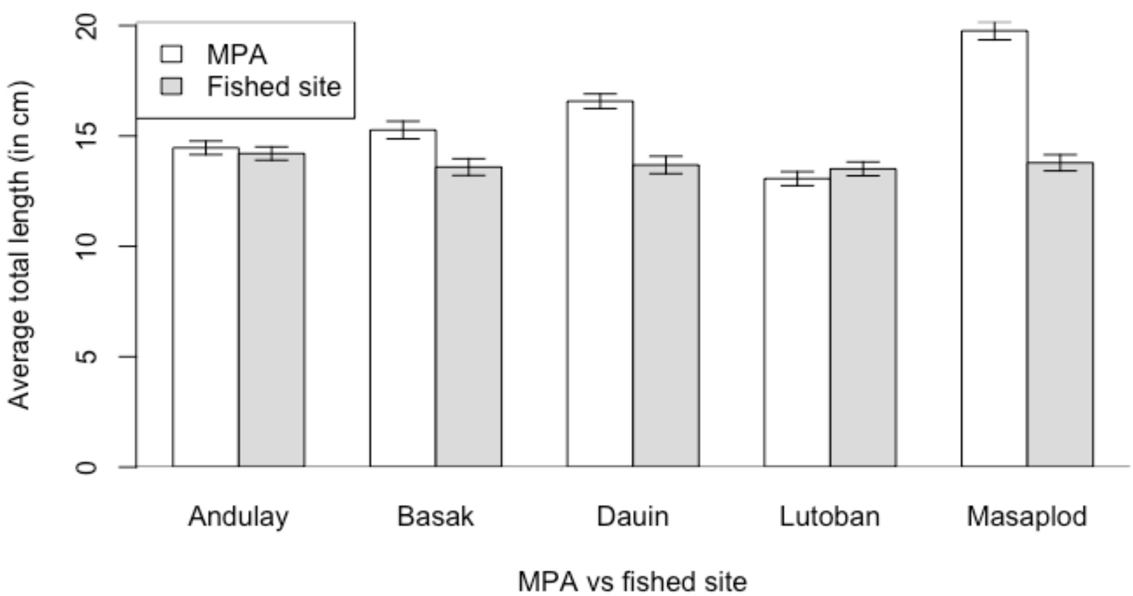


Figure 3.1: Average total length (in cm) of target species at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

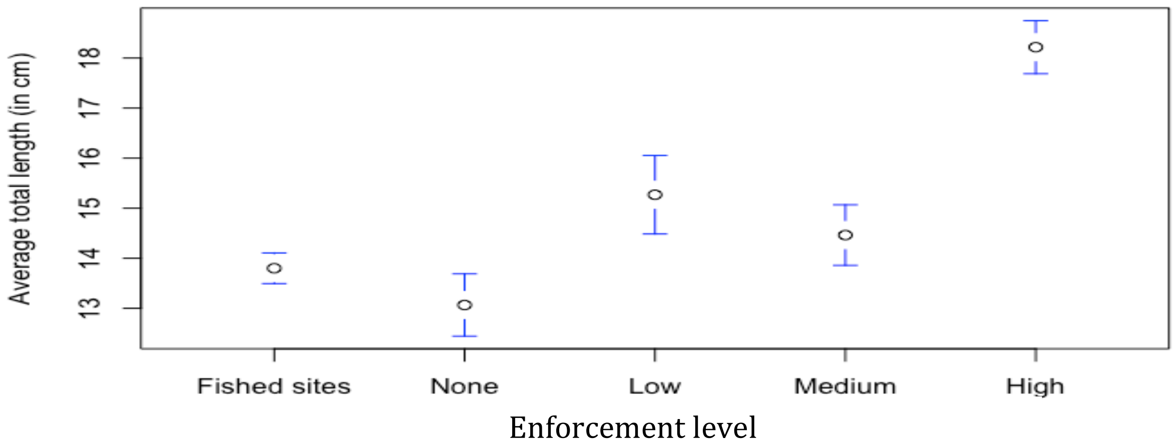


Figure 3.2: Average total length (in cm) of fish according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

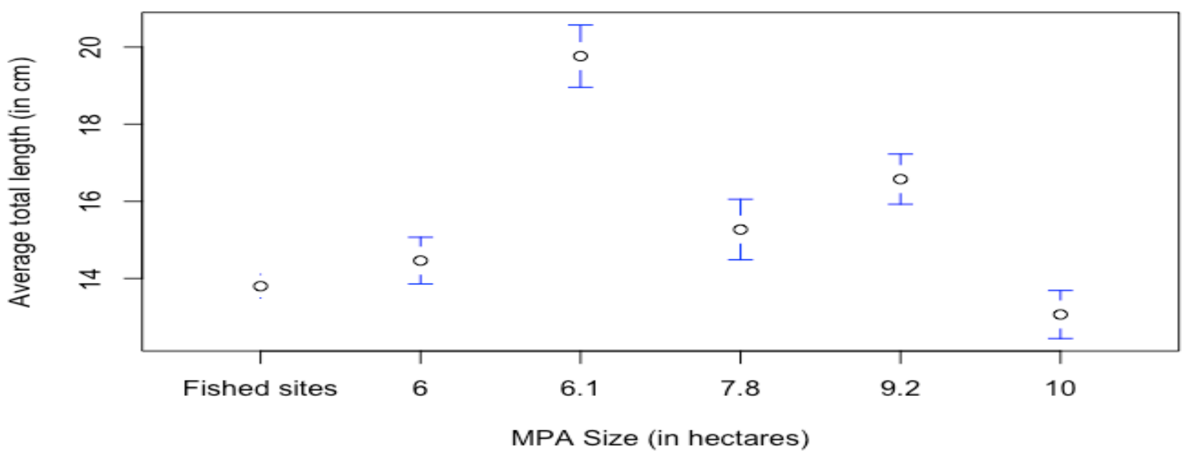


Figure 3.3: Average total length (in cm) of fish according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

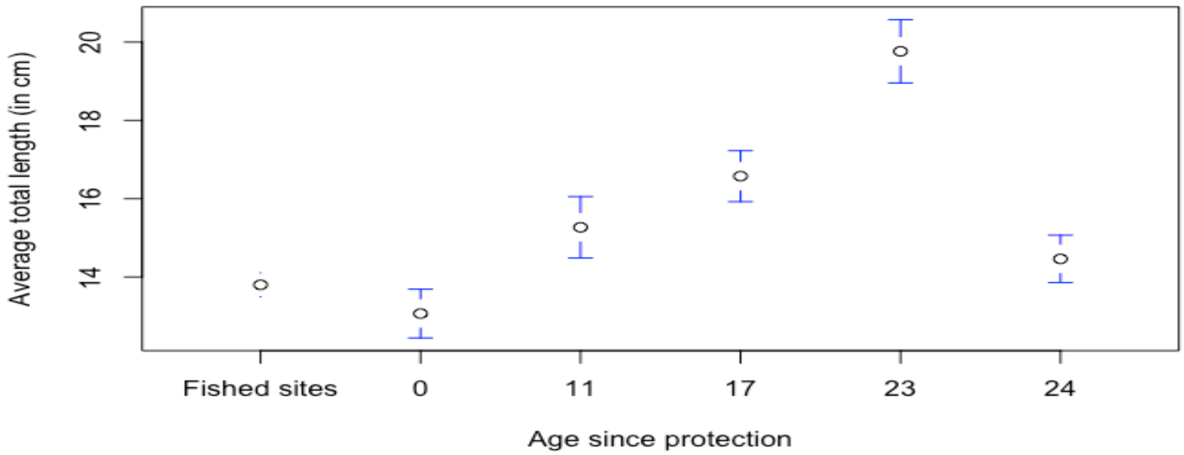


Figure 3.4: Average total length (in cm) of fish according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.4. Abundance of commercially and ecologically important species

Regarding abundance values for target and non-target species, only two out of five MPAs presented significant higher means compared to their respective control sites, while two didn't show any significant differences with their control sites and one presented a significant lower abundance than its control site. Masaplod Norte and Basak MPAs were the areas where the highest abundances were found, with 1.8 times the amount of fish than found in their control sites.

Abundance of all species was significantly higher inside Masaplod Norte and Basak MPA and significantly lower inside Lutoban South compared to their respective control sites (Table 2, Figure 4.1). No significant differences were found for Andulay and Dauin MPAs. Significant fish abundance differences were found between MPAs and control sites in regards of enforcement ($F_{4,309}$ = 8.252, p=2.46e-06), MPA size ($F_{5,309}$ = 9.617, p=1.53e-08) and MPA age ($F_{5,309}$ = 9.617, p=1.53e-08). Enforcement level only caused a significant difference for Basak (low enforcement) and Masaplod Norte MPAs (strong enforcement) compared to the fished sites (Table 3, Figure 4.2). No pattern was observed for fish abundance with regards to the size of the MPAs as the only significant difference found with the fished sites was for Masaplod Norte (6.1 hectares, Table 3, Figure 4.3). Age since protection followed exactly the same trend and the MPA sizes, with only significant differences found with Masaplod Norte MPA (Table 3, Figure 4.4).

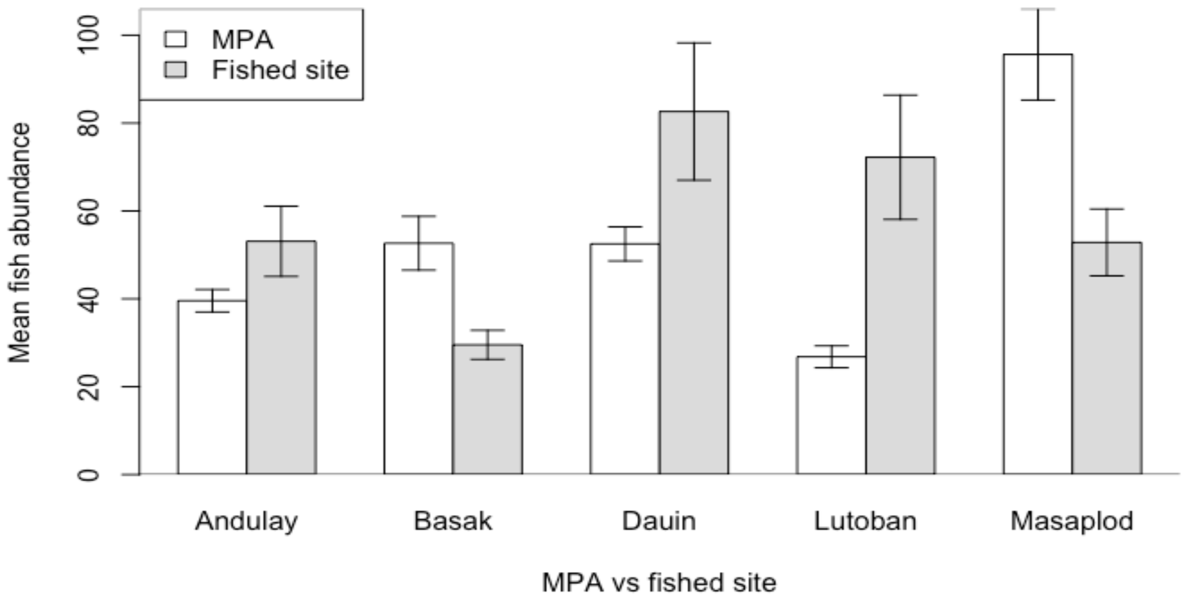


Figure 4.1: Mean abundance of commercially and ecologically important species at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

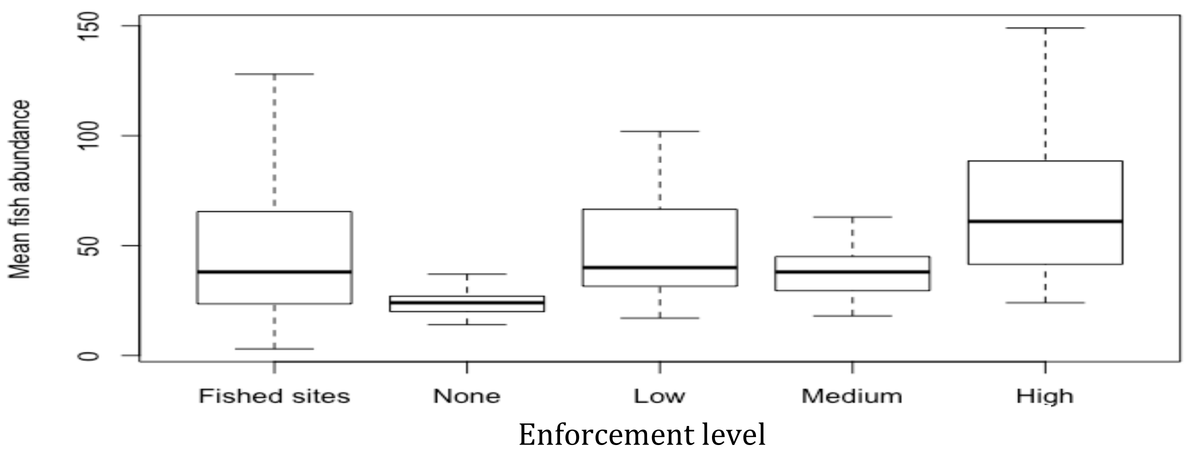


Figure 4.2: Mean abundance of commercially and ecologically important species according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

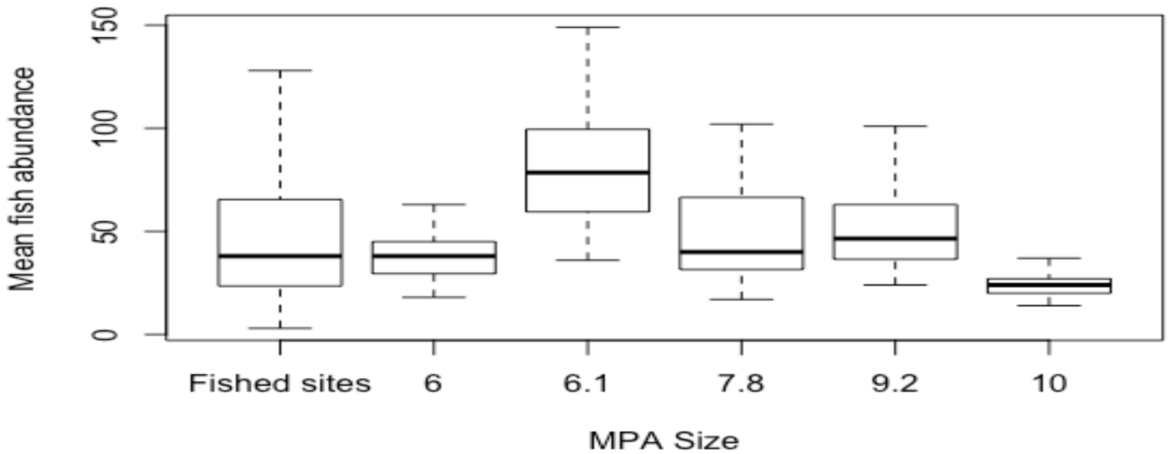


Figure 4.3: Mean abundance of commercially and ecologically important species according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

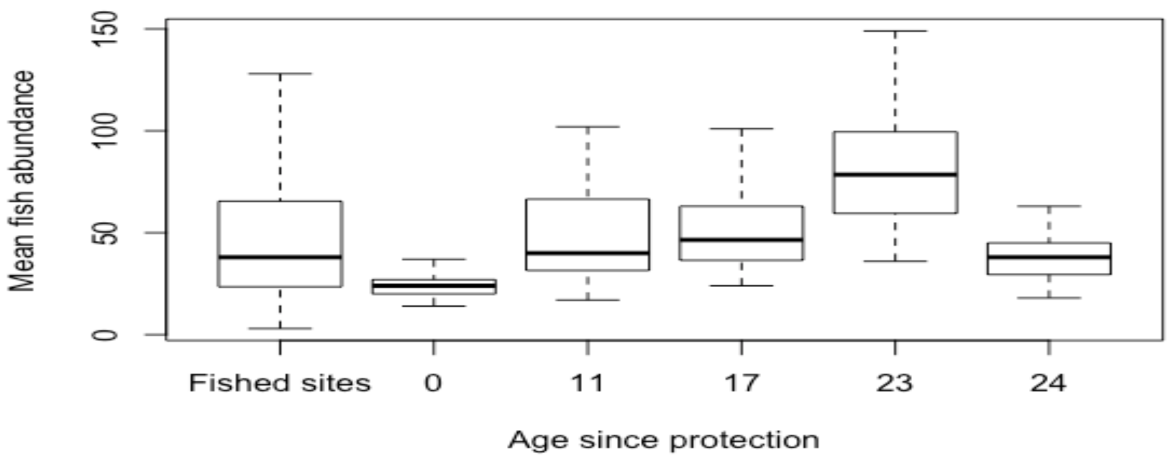


Figure 4.4: Mean abundance of commercially and ecologically important species according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.5. Richness of commercially and ecologically important species

As for the richness values of both target and non-target species, four out of five MPAs had significant higher means compared to their control sites, with only Andulay not presenting differences with its control site. By order, Masaplod Norte MPA had twice the number of species than its control site, while Dauin and Lutoban South had 1.4 times the number of species, and Basak 1.3 times.

Species richness values were significantly higher inside all but one MPA (Andulay) compared to their control sites, with the higher values found in Masaplod Norte and Dauin MPAs (Table 2, Figure 5.1). Significant species richness differences were found between MPAs and control sites in regards of enforcement ($F_{4,309}$ = 56.77, p=<2e-16), MPA size ($F_{5,309}$ = 49.96, p=<2e-16) and MPA age ($F_{5,309}$ = 49.96, p=<2e-16). MPA enforcement level had a positive impact on species richness for Dauin, Lutoban South and Masaplod Norte MPAs (high protection, no protection, and high protection, respectively) when compared to their control sites (Table 3, Figure 5.2). No significant differences were found for the low and medium levels of enforcement (Andulay and Basak MPAs). With regards of MPA size and age since protection, significant differences were found for all MPAs when compared to the control sites (Table 3, Figures 5.3 and 5.4).

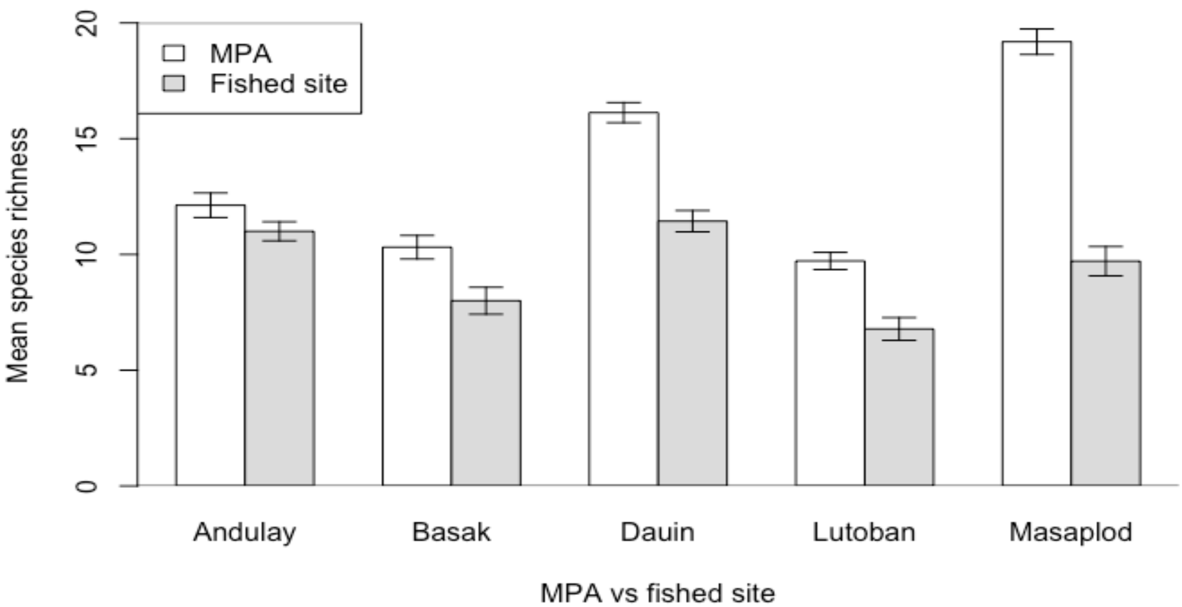


Figure 5.1: Mean richness of commercially and ecologically important species at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

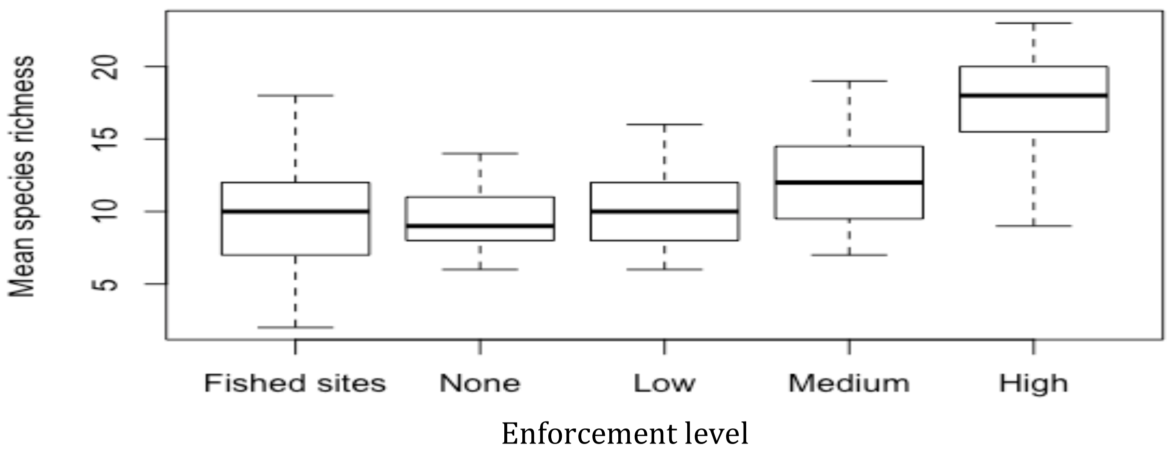


Figure 5.2: Mean richness of commercially and ecologically important species according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

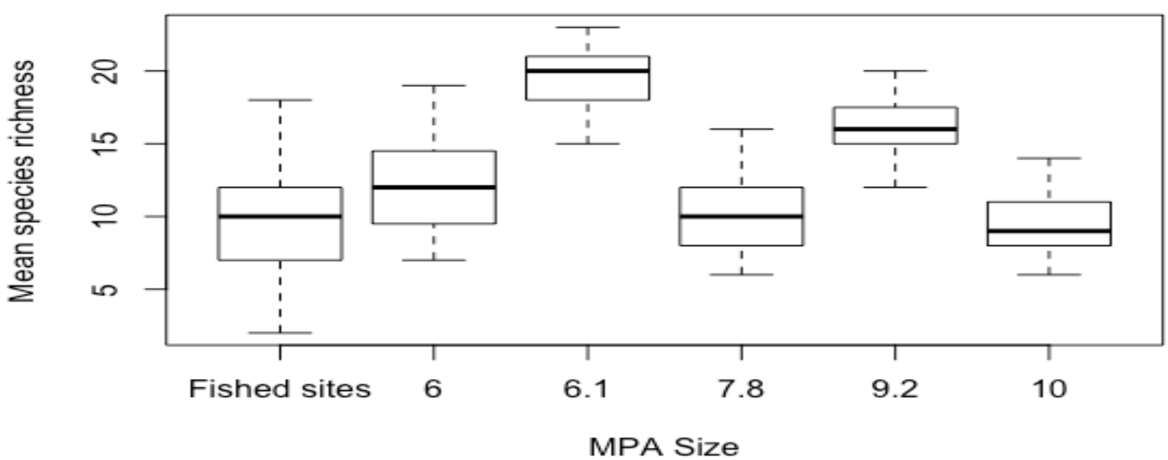


Figure 5.3: Mean richness of commercially and ecologically important species according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

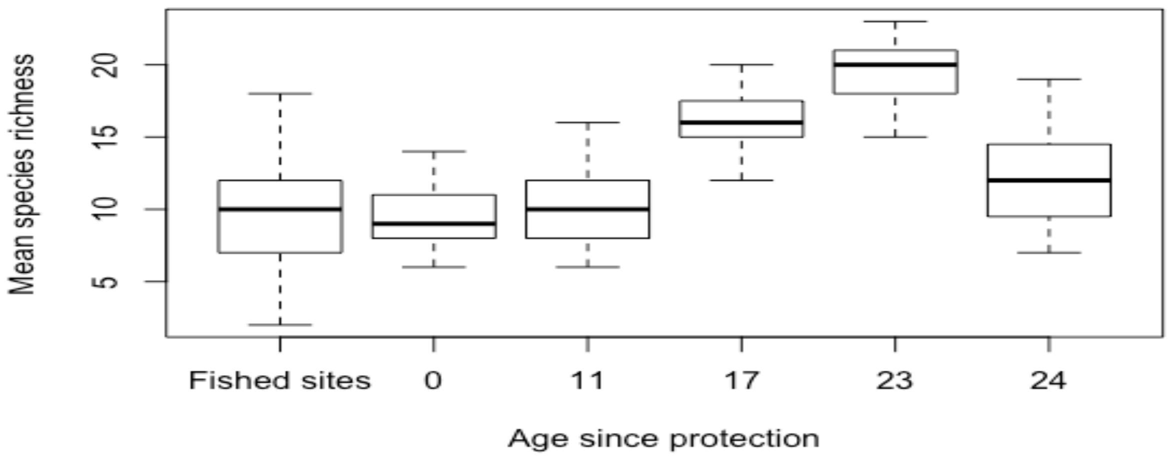


Figure 5.4: Mean richness of commercially and ecologically important species according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.6. Diversity of commercially and ecologically important species

Diversity of species was significantly higher inside all but one MPA (Andulay) compared to their control sites, with the highest values found for Dauin and Masaplod Norte MPAs (Table 2, Figure 6.1). Significant species diversity differences between MPAs and control sites were found in regards of enforcement ($F_{4,309}$ = 35.476, p=<2e-16), MPA size ($F_{5,309}$ = 28.40, p=<2e-16) and MPA age ($F_{5,309}$ = 28.40, p=<2e-16). Species diversity only presented significant differences for MPAs with no enforcement (Lutoban South) and MPAs with a strong enforcement (Dauin and Masaplod Norte), while no significant differences were found for low and medium levels of enforcement (Table 3, Figure 6.2). With regards of MPA size and age since protection, significant differences were found for all MPAs when compared to the control sites (Table 3, Figures 6.3 and 6.4).

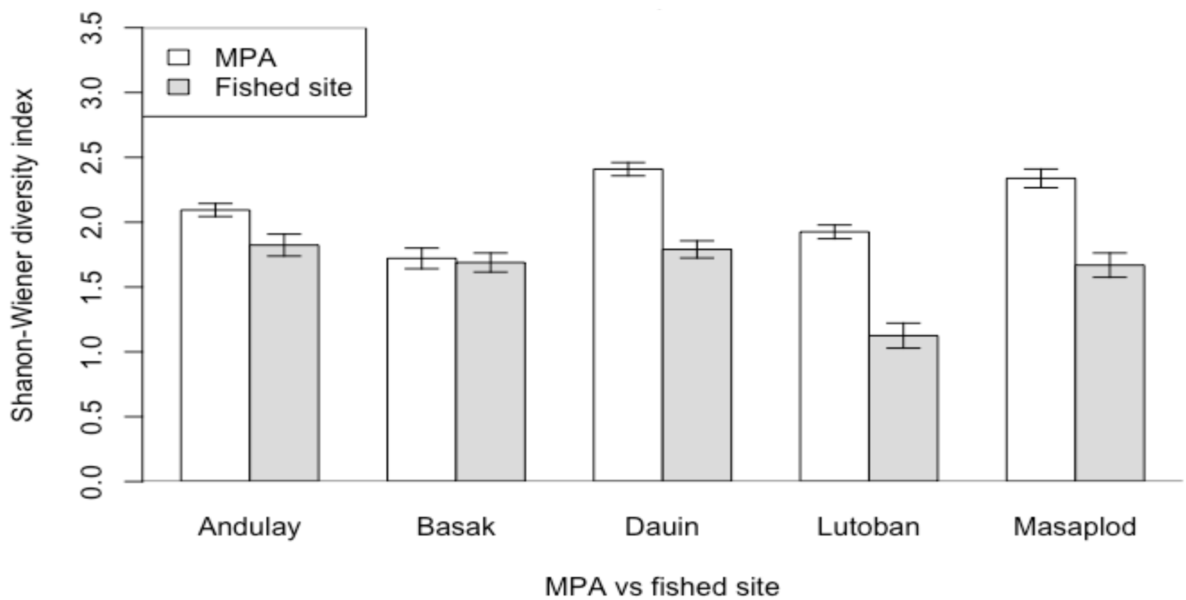


Figure 6.1: Shannon-Wiener diversity index at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

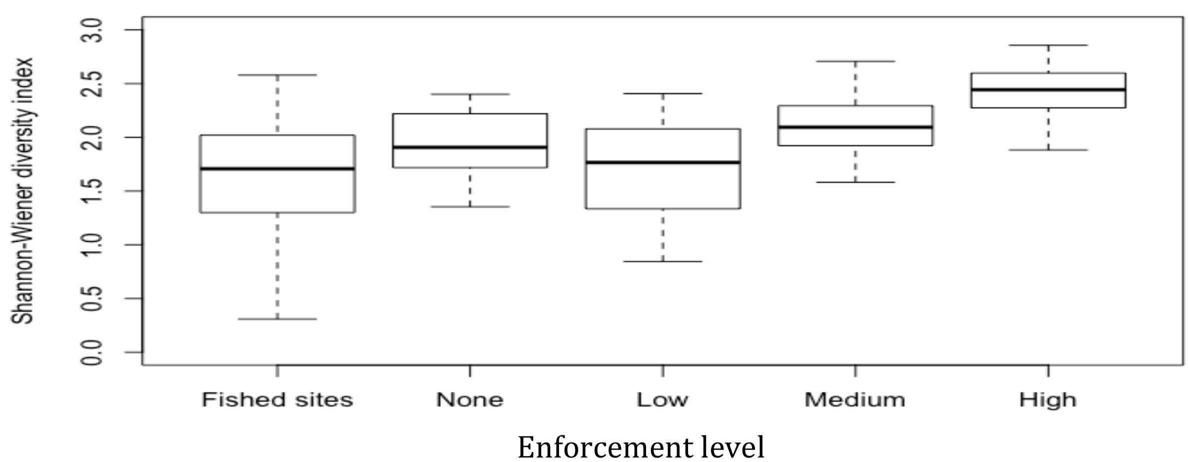


Figure 6.2: Shannon-Wiener diversity index according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

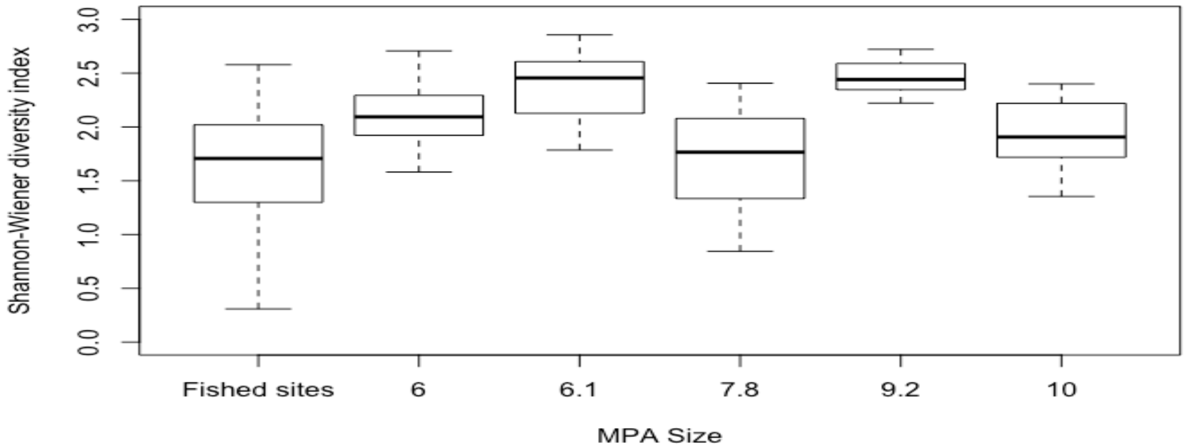


Figure 6.3: Shannon-Wiener diversity index according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

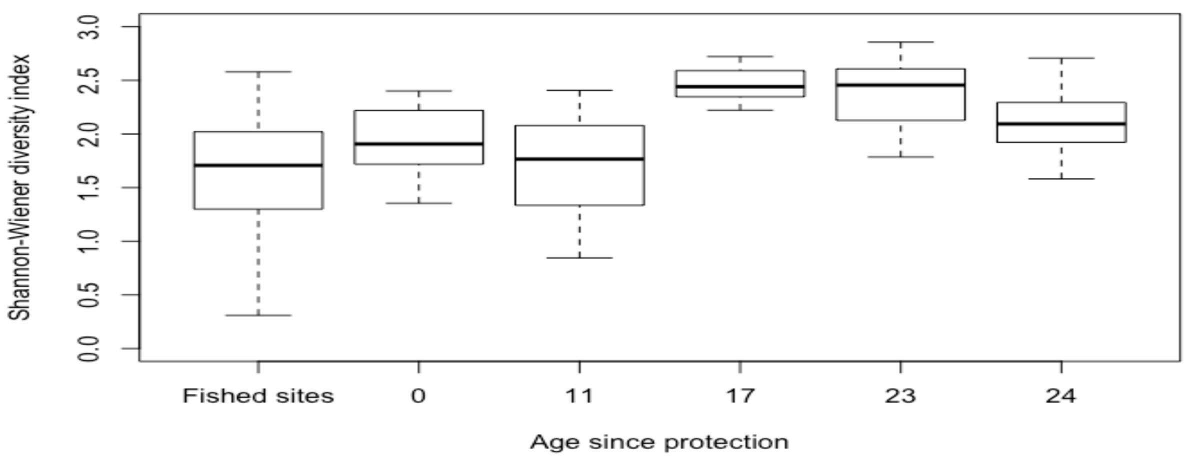


Figure 6.4: Shannon-Wiener diversity index according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.7. Evenness of commercially and ecologically important species

Evenness of species was significantly higher inside Dauin, Masaplod Norte, and Lutoban South MPA, and significantly lower inside Basak MPA when compared to their control sites. No significant differences were found between Andulay MPA and its control site (Table 2, Figure 7.1). Significant species evenness differences were found between MPAs and control sites in regards of enforcement ($F_{4,309}$ = 14.146, p=1.3e-10), MPA size ($F_{5,309}$ = 11.816, p=1.8e-10) and MPA age ($F_{5,309}$ = 11.816, p=1.8e-10). Regarding enforcement level, significant evenness differences were only found for the "no enforcement" level (Lutoban South MPA) when compared to control sites (Table 3, Figure 7.2). With regards of MPA size and age since protection, significant differences were only found for Dauin (9.2 hectares and 17 years old) and Lutoban South (10 hectares, 0 years old) when compared to their control sites (Table 3, Figures 7.3 and 7.4).

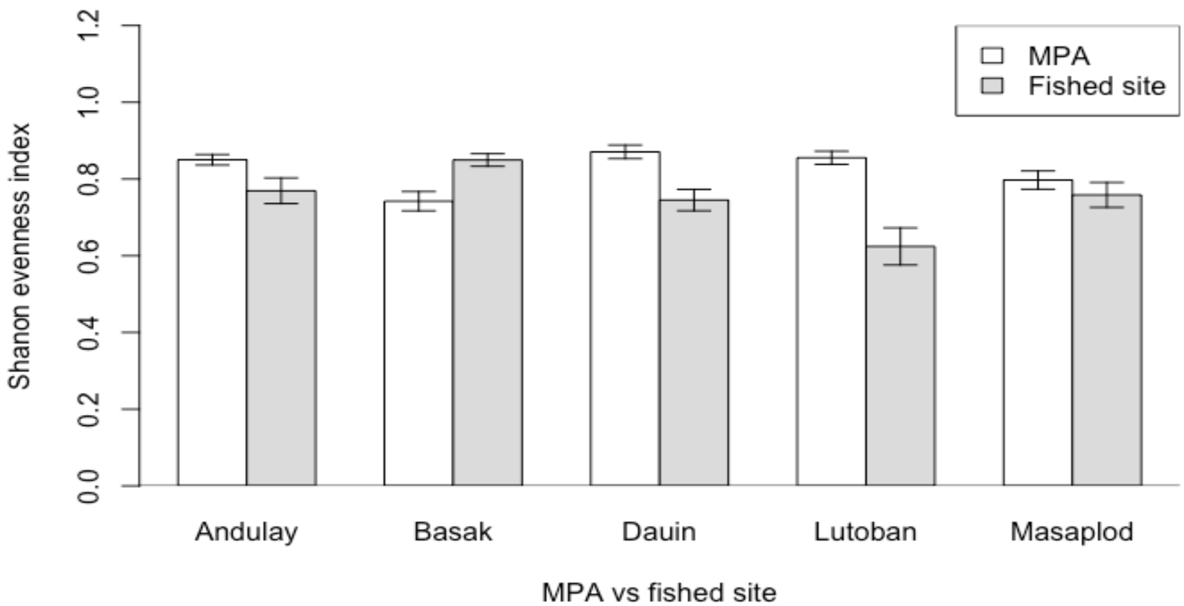


Figure 7.1: Shannon evenness index at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

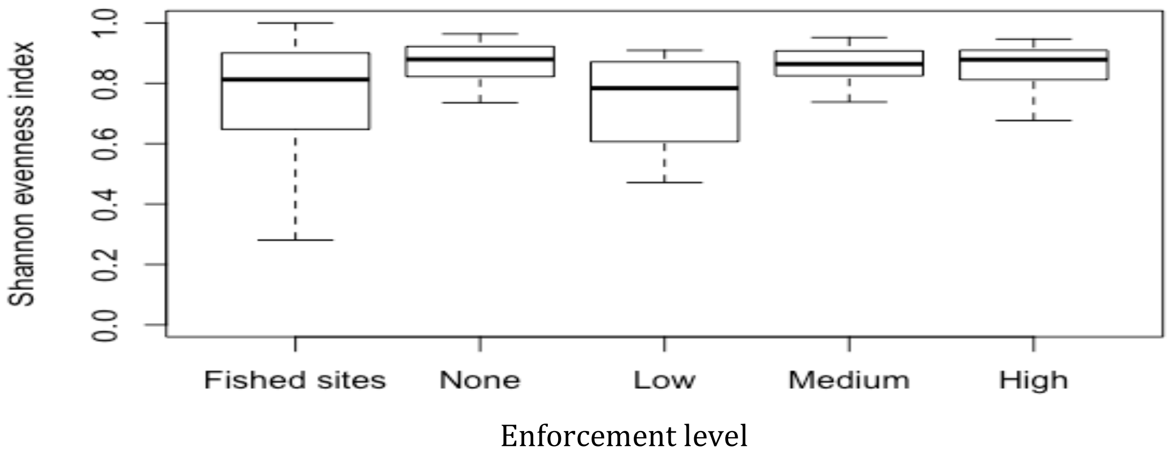


Figure 7.2: Shannon evenness index according to the enforcement level of five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and the corresponding control sites (fished sites).

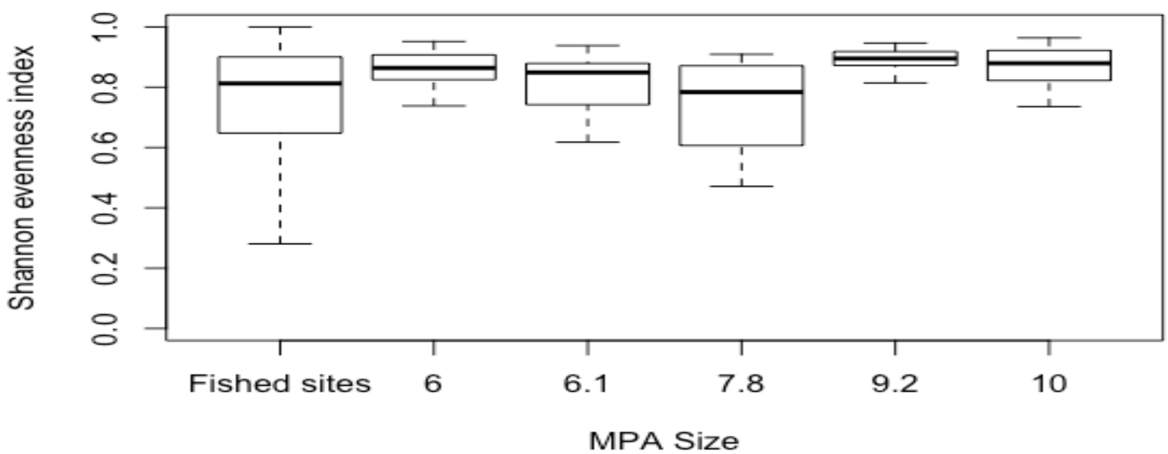


Figure 7.3: Shannon evenness index according to the size in hectares of the five MPAs (from smaller to bigger: Andulay, Masaplod Norte, Basak, Dauin, and Lutoban South) along the southeastern coast of Negros Oriental, in the Philippines, and in the control sites (fished sites).

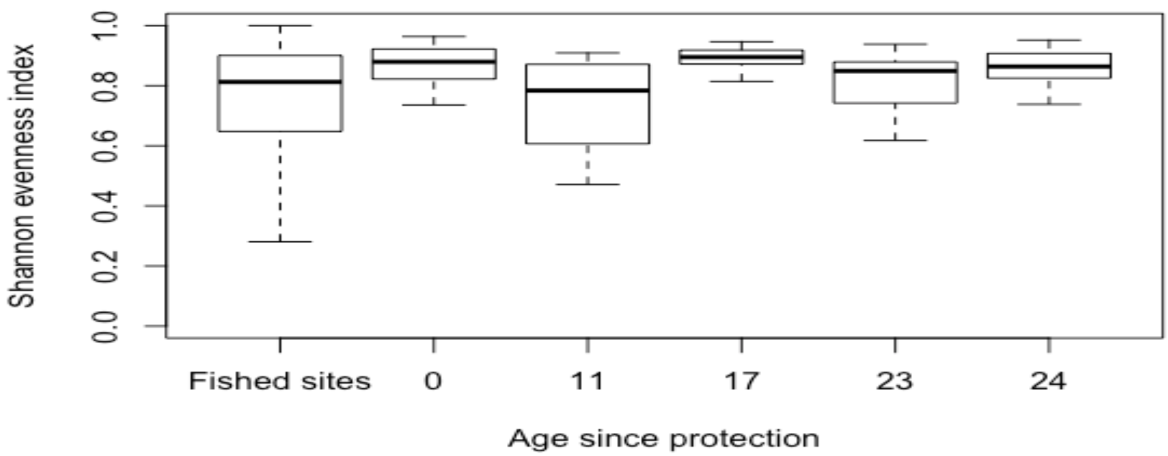


Figure 7.4: Shannon evenness index according to the age since protection of five MPAs (from younger to older: Lutoban South, Basak, Dauin, Masaplod Norte, Andulay) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

3.8. Trophic categories

Regarding trophic categories of commercially and ecologically important species, the five MPAs presented different mean abundances when compared to their control sites. Masaplod Norte had a significant higher abundance of corallivores than its control site (Figure 8.1), and a significant lower abundance of generalists and scrapers species. For the grazers, invertebrate specialists and predators, no significant difference was found. Dauin also presented a significant higher abundance of corallivores than its control site, and a lower abundance of generalists. No significant differences were found for the grazers, the invertebrates' specialists, the predators, and the scrapers. Inside Andulay MPA, a significant higher abundance of grazers was found when compared to its control site, and no significant differences were found for corallivores, generalists, invertebrates' specialists, predators, and scrapers species. In Lutoban South, a higher abundance of grazers was found, and a lower abundance of invertebrates specialists, when compared to its control site. No significant differences were found for corallivores, generalists, predators, and scrapers species. As for Basak, significant lower abundances of grazers and scrapers were found inside the MPA, and no significant differences for corallivores, generalists, invertebrates' specialists, and predator species.

Regarding biomass of trophic categories of commercially important species, few significant differences were found between the MPAs and their respective control sites. The only differences were found in Masaplod Norte MPA, where predator and scraper species had a significant higher biomass than in the control site (Figure 8.2). Regarding the other trophic categories, no significant

differences were found. That also applies to the trophic categories found in Dauin, Andulay, Lutoban South, and Basak MPAs, where no significant differences were found.

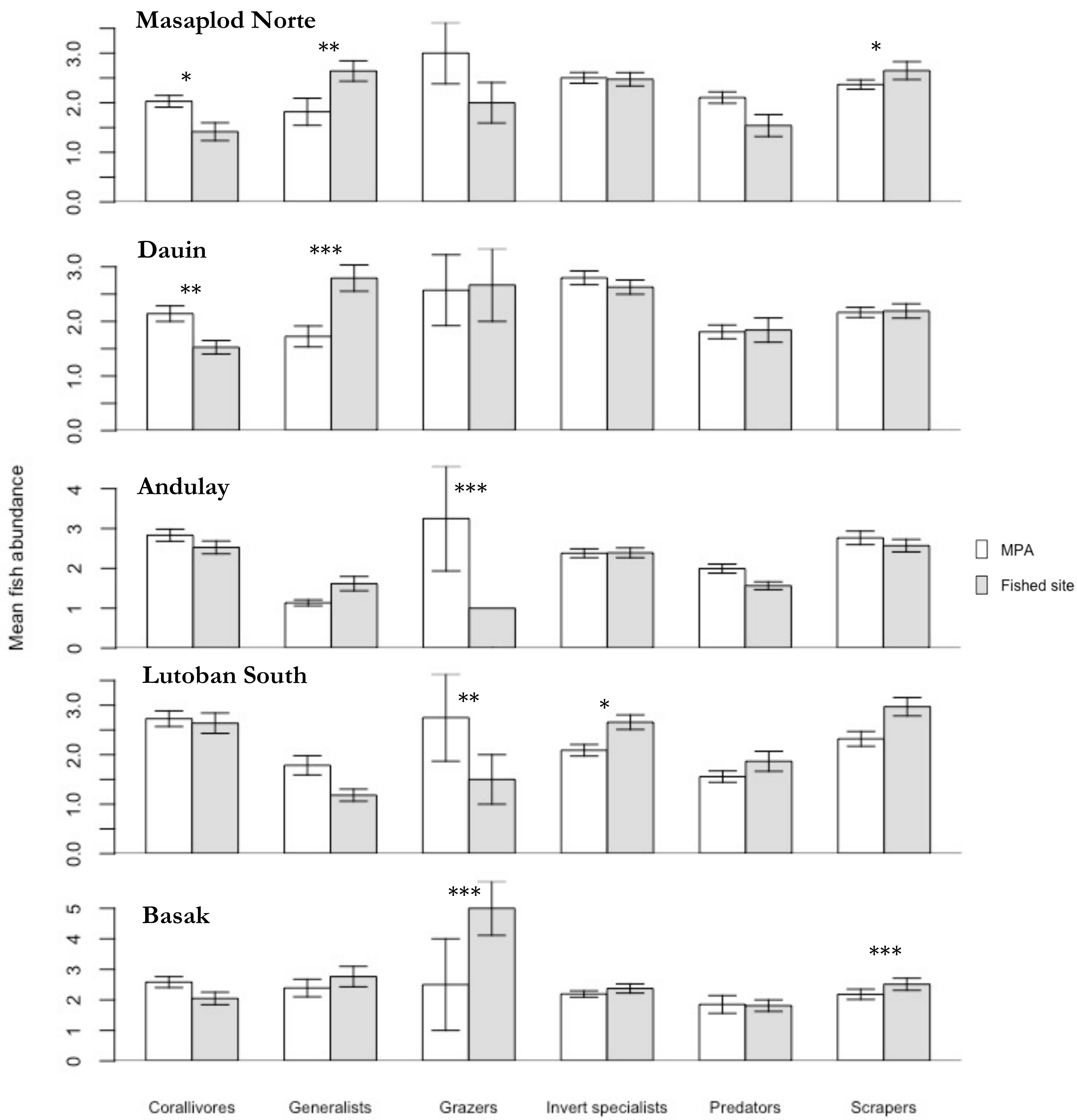


Figure 8.1: Mean abundance of commercially and ecologically important species according to their trophic level. Bar graphs represent the abundance of six functional categories of fish (corallivores, generalists, grazers, invertebrates specialists, predators, and scrapers) in MPAs and adjacent control sites at five locations (Masaplod Norte, Dauin, Andulay, Lutoban South and Basak) along the coast of Negros Oriental, Philippines. * Signals significant effects of protection status according to the 95% confidence interval (* indicates p-values below 0.05, ** indicates p-values below 0.001, and *** indicates p-values below 0.0001).

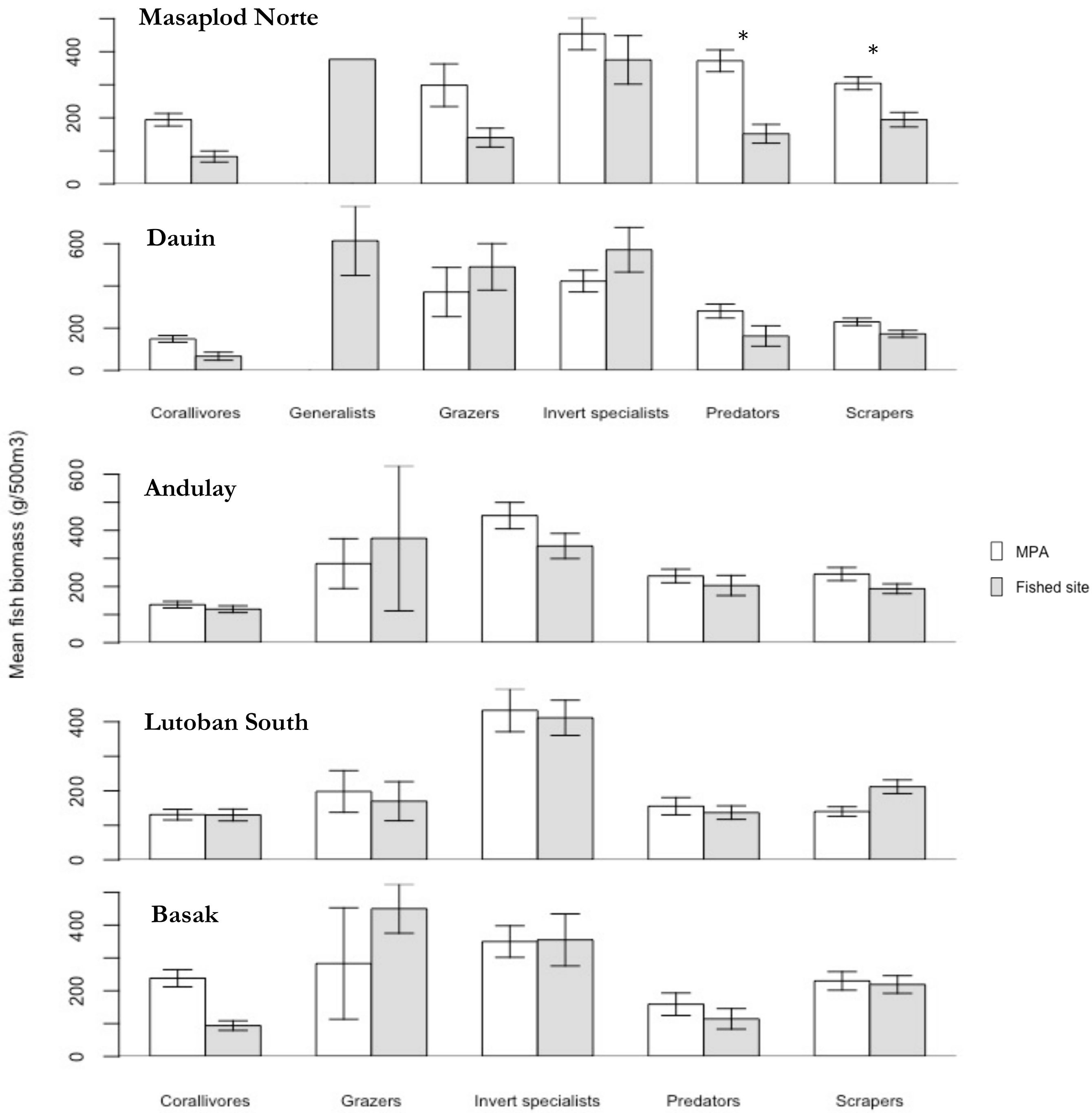


Figure 8.2: Mean biomass of commercially important species according to their trophic level. Bar graphs represent the biomass of six (only five categories for the last two locations) functional categories of fish (corallivores, generalists, grazers, invertebrates specialists, predators, and scrapers) in MPAs and adjacent control sites at five locations (Masaplod Norte, Dauin, Andulay, Lutoban South and Basak) along the coast of Negros Oriental, Philippines. * Signals significant effects of protection status according to the 95% confidence interval (* indicates p-values below 0.05, ** indicates p-values below 0.001, and *** indicates p-values below 0.0001).

3.9. Fish families

Few significant differences were found regarding the biomass of the different fish families between the MPAs and non-MPAs. The only significant differences found were for the Pomacentridae and Siganidae families: for the Pomacentridaes, biomass values were significantly lower inside Masaplod Norte (p-ajd <0.05), Dauin (p-ajd <0.05), and Andulay (p-ajd <0.001) MPAs compared to their respective control sites, and higher inside Basak MPA (p-ajd <0.05); and for the Siganidaes, the only difference found was a significant higher biomass inside Dauin MPA (p-ajd <0.05) compared to its control site.

3.10. Benthic cover

No significant differences were found between the mean hard coral coverage percentages inside MPAs (ranging from 12.81 to 32.925%) compared to control areas (ranging from 12.81 to 44.38%) ($F_{1,10}$ = 0.029, p=0.86773), but did show significant differences for certain locations ($F_{4,10}$ = 9.371, p=0.00194). There were no significant differences for Andulay, Basak, Masaplod Norte nor Dauin MPA compared to their control sites (p.adj>0.05; Table 4, Figure 9.1), but there was a significant difference between Lutoban South MPA and its control site (p. adj=0.0089338), where coral coverage was on average 3 times higher for the control site. Furthermore, the contrasts test showed that the control site for Lutoban South MPA had on average 3.5 times more coral coverage than Basak MPA (p=0.0057552) and 2.8 times more coral coverage than Masaplod Norte MPA (p=0.0289687). Regarding the other control sites, Lutoban South's control site had on average 2.5 times more coral coverage than Andulay's control site (p=0.0190074), 3.5 times more than Basak's control site (p=0.0057552), 4.2 times more than Masaplod Norte's control site (p=0.0034938) and 2.3 times more than Dauin's control site (p=0.0302209).

Similarly, no significant differences were found (p.ajd>0.05; Table 4, Figure 9.2) between the mean macroalgae coverage percentages inside MPAs (ranging from 1.25 to 5.024%) compared to

control areas (ranging from 12.81 to 44.38%) ($F_{1,10}$ = 3.187, p=0.1045), but did show significant differences between macroalgae coverage among locations ($F_{4,10}$ = 4.435, p=0.00128). Andulay's control site had on average 20 times more macroalgae coverage than Masaplod Norte's control site (p=0.0240777), and 10 times more than Dauin's control site (p=0.0400413) and Basak MPA (p=0.024215).

Table 4: Benthic cover in MPAs and control sites. Comparisons of the percentage cover of scleractinian coral and macroalgae in MPAs and adjacent control sites at five locations (Andulay, Lutoban South, Basak, Masaplod Norte, and Dauin) along the southeastern coast of Negros Oriental, Philippines. The p-values refer to comparisons following two-way ANOVAs. Significant p-values (p <0.05) are marked in **bold**.

	Percentage cover (mean)		
Location	MPA	Control area	p-adj (Tukey HSD)
Hard coral			
Andulay	27.57	17.81	0.7738509
Lutoban South	14.69	44.38	**0.0089338**
Basak	12.81	12.81	1
Masaplod Norte	19.52	10.62	0.843708
Dauin	32.92	19.69	0.4537089
Macroalgae			
Andulay	2.826	12.5	0.0775545
Lutoban South	4.375	1.875	0.9999627
Basak	1.25	0	0.9944027
Masaplod Norte	5.024	0.625	0.7415123
Dauin	2.822	1.25	0.9997650

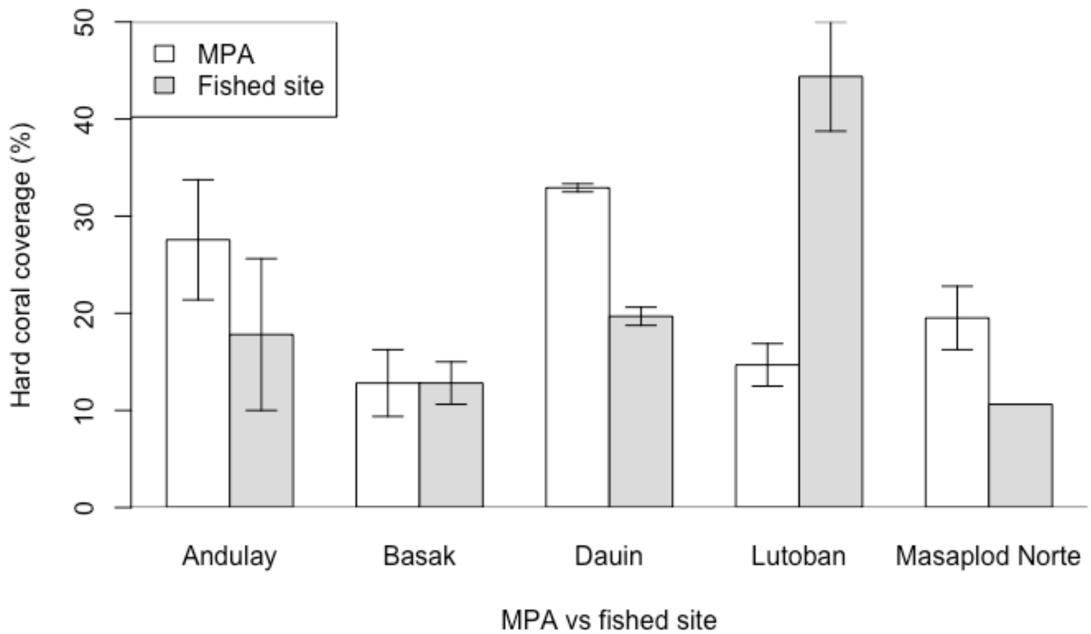


Figure 28: Hard coral cover (in %, mean±SE) at five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

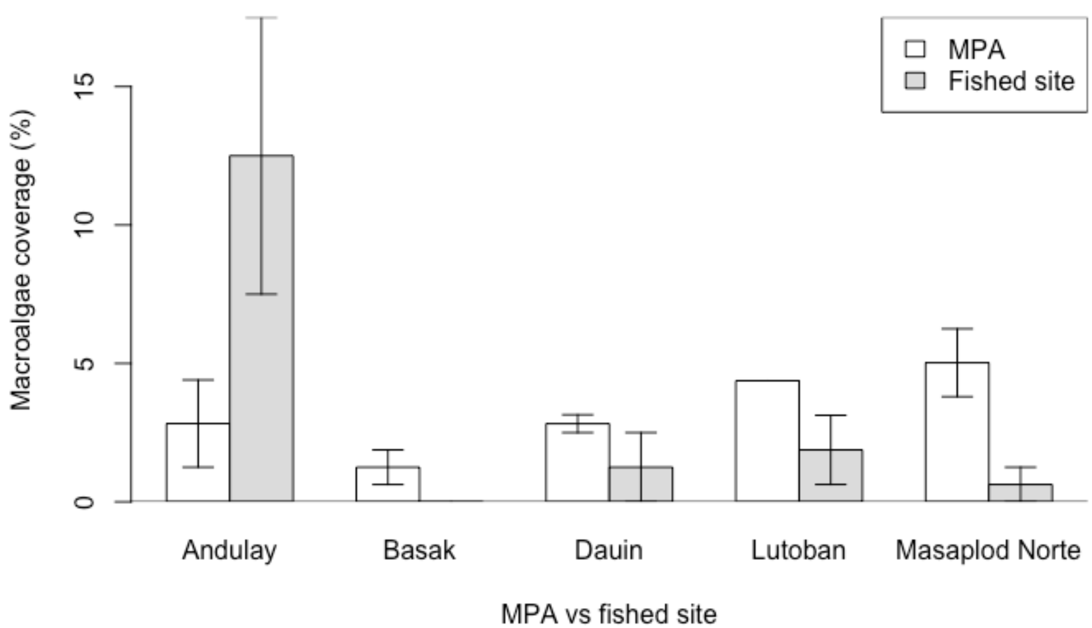


Figure 29: Macroalgae cover (in %, mean±SE) at the five MPAs (Andulay, Basak, Dauin, Lutoban South and Masaplod Norte) along the southeastern coast of Negros Oriental, in the Philippines, and their corresponding control sites (fished sites).

4. DISCUSSION

MPAs have been used across the globe to increase biomass, abundance, richness, diversity and evenness of fish species as a means to counter overfishing and reef disturbance effects (Honda *et al.*, 2016, Muallil *et al.*, 2015, Abesamis *et al.*, 2006, Russ and Alcala, 1996). In this study, despite the small size of the studied MPAs (<than 1 km^2), the protection conferred by the combination of these was found to positively affect the before-mentioned fish population parameters. Indeed, combined biomass of target species was 1.6 times higher inside MPAs than in fished sites, richness of all species was 1.4 times higher, diversity was 1.3 times higher, evenness was 1.1 times higher and abundance (target and non-target) was almost the same inside and outside MPAs. These results indicate that even small MPAs can effectively conserve fish communities, as already shown by Muallil et al. (2015), Russ *et al.* (2015) and Honda *et al.* (2016). Models were significant for protection status as a predictor of higher biomass for MPA sites compared to unprotected sites, but the fact that MPA size and time since protection (factors though to increase the studied fish population parameters according to several studies, such as Gaines *et al.*, 2010, Edgar *et al.*, 2014) increased the DIC values of the models and therefore didn't help explain the fish population parameters fluctuations indicate that those factors could be affecting fish populations in a particular way. In other words, when population parameters were combined and compared according to their status (MPA or non-MPA), there was a significant difference between the two levels, but when comparing them to the different sizes and ages, no significant differences appeared, meaning that not always bigger and older MPAs presented higher parameter values than smaller or younger MPAs in this study. In such cases, it is therefore important not to assess MPA effectiveness by combining fish population parameters from several different MPAs into one global unit, as it could be misleading. Indeed, differences between MPAs can be considerable, even when located nearby from one another. In order to properly understand the differences in fish parameters between the inside and the outside of the MPAs, these should be examined separately, as single units, and then compared.

Among the five studied protected areas, Masaplod Norte and Dauin MPAs stood out with the highest biomass and the bigger fish (of target species), and also the highest abundance and

richness (of both target and non-target species). According to the study of Edgar *et al.* (2014), the bigger the MPA the bigger the positive impact on fish population parameters. However, Masaplod Norte is the second smallest studied MPA (by 0.1 hectares) but still has the highest values found in all sites. Age is also an important factor affecting fish population parameters, but Andulay, the older MPA among the five studied, has lower values of biomass, size, richness, abundance and diversity of fish than Masaplod Norte, a younger MPA. Size-wise, they only differ by 0.1 hectares, and age-wise by one year, so the results obtained lead to think that the factor responsible for the significant differences between these two MPAs is the enforcement level. Indeed, Andulay has an enforcement qualified as medium while Masaplod Norte has an enforcement qualified as strong. Enforcement level has been shown to play the most crucial role in effectively protecting fish populations inside MPAs (Di Franco *et al.*, 2016, Gill *et al.*, 2017). As long as the protected area presents all vital aspects needed by the different species in question, enforcement level can have a bigger impact than the size or the age of the MPA. Furthermore, Dauin MPA is the second-biggest MPA of this study and the third older, and still had higher parameter values than bigger (Lutoban South) and older (Andulay) MPAs, underlying the previous stated assumption that enforcement level seems to play a more important role than size or age in MPA effectiveness in this part of the Philippines. Indeed, Gill *et al.* (2017) mentioned in their study, "MPA effectiveness (…) is generally greatest in MPAs that have adequate staff and budget", which means MPAs that are well enforced.

Lutoban South MPA is the good example of what is called a paper-MPA, as no enforcement whatsoever was observed there. Even if small, it is the biggest MPA (10 hectares) in this study and is 10 years old, which is the age and size other studies have mentioned as already being adequate to enhance and protect fish biodiversity (Edgar *et al.*, 2014, Bonaldo *et al.*, 2017). However, regarding fish population parameters, Lutoban South had the lowest biomass, abundance, and size of all studied sites, including the values found in fished sites. Means of hard coral and macroalgae coverage being similar to the other MPAs, the only factor in this study that could explain such differences is the lack of enforcement. Indeed, as no forms of authorities were found to be watching over that MPA, several types of fishing gears were found and fishermen were seen fishing inside the MPA at many occasions without constraint (personal observations). Furthermore, the lower values found in the MPA compared to the non-MPA site could be the result of Lutoban South having the status of MPA, which would lead fishermen to think there are more and bigger fish in that area than in others, leading them to favor that area for fishing over sites with no MPA status. As a result of the heavy

overfishing, having an area with an MPA status but no enforcement whatsoever leads to a faster resource depletion by local fishermen, which is the complete opposite result expected from an MPA. On another note, Lutoban South MPA's control site (Lutoban Pier), presented considerably high hard coral coverage means rising to almost 50%, which was the highest coral coverage found in this study. Considering it is an open-access site, but with biomass and abundance values similar as the ones found in certain MPAs, if this site were to be turned into an MPA with an effective enforcement, it could become a promising site to effectively conserve fish communities as the corals in that area seem to be thriving more than in the other areas. Either the corals there recovered faster from the Sendong typhoon from 2011, either that zone benefits from natural protection from the storms. Either way, it could also benefit the fish communities if protected.

Andulay MPA never presented significant differences with its control site for any of the fish population parameters considered in this study. Even though it had a "bantay dagat" (surveillance officer) with an enforcement considered as medium; is the oldest MPA in this study and is the second larger, almost every parameter values were lower than the ones found in all other MPAs, except one (Lutoban South MPA). Hard coral and macroalgae cover also didn't present significant differences between Andulay and its control site, so those variables can't explain the lack of differences. One possible explanation for this particular case is that Andulay's control site (located in Antulang) is close to what used to be Antulang's Dive Hub MPA, as mentioned in Bos's study in 2011. Even though that MPA doesn't further exist, the potential positive impacts it had on neighboring areas in the past could be responsible for the lack of differences observed between the protected and the unprotected site. On the other hand, another and more plausible explanation for the lack of differences is that both areas might not have fully recovered from typhoon Sendong that hit the coast in 2011. Indeed, Bucol (2014) indicated that the typhoon caused a coral-algae phase-shift in both areas after the reef was destroyed and algae overgrew the remaining corals, as he reported 37 and 53% of algae colonization and 2.25 and 3.33% hard coral coverage in Antulang and Andulay sites, respectively. In the present study, macroalgae coverage was only 2.8 and 12.5% and hard coral 27.6 and 17.8%, respectively. Regarding biomass and abundance values, he reported 70.6kg/500m^2 and 597 fish/500m^2 in Antulang, and 9.83kg/500m^2 and 361.7 fish/500m^2 in Andulay, while in this study values found were 0.36kg/500m^3 for biomass and 53.09 fish/500m^3 for abundance in Antulang and 0.32kg/500m^3 and 39.56 fish/500m^3 in Andulay. Regarding benthic cover, the reef seems to have recovered from the coral-algae phase-shift as macroalgae values are

lower and hard coral values are higher, but fish biomass and abundance seem to have decreased considerably in both locations. While an increase in coral coverage should have been accompanied by an increase in fish abundance and biomass, overfishing in or around the areas could be an explanation for the lower values found. For the case of Andulay's MPA, either medium enforcement level was not enough to cause a positive impact on fish population parameters or to protect them from human threats or natural impacts, or fish relocated in other areas after the Sendong typhoon in 2011 and haven't repopulated the area yet, which would explain the lower values found. Indeed, after severe storms, Walsh (1983) showed that resident reef fish communities could abandon the impacted area and relocate to calmer and more protected zones.

Basak MPA, unlike the other studied MPAs, was the only area with a patchy reef instead of a continuous fringing reef. Therefore, it presented less coral habitat and sandier areas, which can host less fish than reefs with more habitat complexity. However, some fish parameters such as biomass, total size, abundance and richness were higher than in Andulay and Lutoban South MPAs. Knowing that the enforcement of this MPA was "on and off" due to political issues and different points of view from the municipality mayors along the years and that therefore fishing activities took place during certain years since its creation (with the end of 2016 included, personal observations), the results show the potential of this site as an effective conservation area for fish, as even after fishing took place inside the MPA due to the lack of enforcement, parameter values remain relatively high.

Regarding fish families, no particular families were benefiting more than others from the protection of the MPAs, as the only cases where significant higher biomass values for specific genera were found were Basak MPA for damselfish (Pomacentridae) and Dauin MPA for rabbitfish (Siganidae).

There seems to be a clear difference of effectiveness in MPAs located in different municipalities, with the MPAs located in the municipality of Dauin (Masaplod Norte MPA and Dauin MPA) being more effective than the ones located in the municipalities of Zamboanguita (Basak and Lutoban South) and of Siaton (Andulay). When compared to previous studies, fish parameters such as biomass and abundance seem to have decreased for certain MPAs. As stated by Nañola *et al.* (2011), commercially and ecologically important species have been presenting and continue to present low abundances in MPAs of the Visayan region. In order to effectively conserve important species with MPAs, all MPAs in the region should implement the same enforcement,

surveillance, and fishing management strategies to be able to develop networks that could ensure high larval outputs to the fished sites and therefore properly act as fish reserves. As previously noted, MPAs need adequate staff and budgets to be effective (Gill *et al.*, 2017), especially when they don't meet the NEOLI criteria (no-take, enforced, old, large and isolated, Edgar *et al.*, 2014). As found in the study of Gill *et al.* (2017), small and inshore MPAs can still achieve ecological success if they have enough funds and staff to manage the area. But if not all neighboring municipalities have the same approaches regarding the management of their small MPAs and don't offer the same degree of protection to the different species, larval outputs from the better protected and more successful MPAs from one municipality cannot sustain fisheries for other regions as well. It is therefore crucial to increase protection in all MPAs in the region in order to effectively protect species from the effects of fishing. Even though some good practices are being followed in certain MPAs, the lack of funds, staff and facilities, the lack of education among the people and the lack of support from all interested parties (National Government, fisherman associations, NGOs, and so on) keep certain MPAs from being effectively managed, which furthermore fragments the expected success of the MPAs in the region. Even though the MPA field is globally rising, there is a lack in necessary capital investment for the MPAs to be effective. Indeed, there are few locally managed MPAs with enough staff and budget (Gill *et al.*, 2017), which means a high risk of diluting the effectiveness of the MPAs. The only way to boost MPA effectiveness is to offer real protection to the species and to do so, there must be a rise in budget and staff to properly demarcate and monitor the protected areas. Ideally, such small MPAs should be part of a large network of MPAs in order to offer real protection zones to the different fish species.

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6. APPENDIX

6.1. Appendix 1: Literature review

During this last century, the number of Marine Protected Areas has consistently and considerably increased worldwide, passing from 0,65% of the global ocean protected in 2006 to 3.4% in 2014. In 2010, the 10th Conference of Parties to the Convention on Biological Diversity (CBD) set Aichi Biodiversity Target 11 that aimed to protect "10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services" until 2020 through "effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures" (CBD, 2010, Boonzaier and Pauly, 2014, Spalding and Haze, 2016). Only 6 years later, in September 2016, the International Union for the Conservation of Nature (IUCN) World Conservation Congress approved a new target of protecting "at least 30% of each marine habitat in a network of highly protected MPAs and other effective area-based conservation measures" by 2030, "with the ultimate aim of creating a fully sustainable ocean, at least 30%of which has no extractive activities" (CBD, 2016).

With such an increase in the designation of protected areas, the evaluation of their performance has become a priority in the conservation field, and even more as not all MPAs have the same objectives and purposes. As defined by the IUCN, MPAs are a "*clearly defined geographical space, recognized, dedicated and managed, through legal or other active means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*" (Day *et al.*, 2012).

Scientists have been investigating MPAs effectiveness in protecting species since the 1980s, and evidence shows that Marine Sanctuaries and Marine Reserves can in some cases increase richness, density, and biomass of fish in coral reefs (Russ and Alcala, 1996, Abesamis *et al.*, 2006, Muallil *et al.*, 2015, Honda *et al.*, 2016). MPAs are an essential management strategy to mitigate several threats such as over-exploitation and habitat destruction, all of which affect the coastal and marine ecosystems and therefore the communities that deeply rely on those resources (Tupper *et al.*, 2015).

In the Philippines, MPAs can be either nationally or locally established, and four types exist: Marine Sanctuaries, which are no-take reserves where extractive activities are forbidden; Marine

Reserves, where extractive and non-extractive activities are allowed but regulated; Protected Landscapes and Seascapes, where protection may include non-marine resources; and Marine Parks, where uses are designated into multiple zones (Cabral *et al.*, 2014). More than 1800 MPAs exist in the Philippines, and most contain no-take areas surrounded by managed fishing areas (White *et al.*, 2014, Tupper *et al.*, 2015). No-take marine reserves have the objective to maintain or even enhance fisheries in the long-term, through the effect of larval recruitment or adult spillover to fished areas, preventing stock collapse (Abesamis *et al.*, 2006, Tupper *et al.*, 2015).

Most MPAs in the Philippines are locally established, which contributes to increased participation and acceptance by the stakeholders who depend on natural resources (Horigue *et al.*, 2012). Such MPAs have been shown to be effective tools to achieve conservation and sustainability of local small-scale fisheries (Alcala and Russ, 2006, Maliao *et al.*, 2004), even though most MPAs are small (<1 km^2) and are not always designed to be connected with others already existing (Weeks et al., 2010). In the small LM-MPAs of the Philippines, the expected positive effects have only been documented in effectively managed, enforced, and designed MPAs (Indab and Suarez-Aspilla, 2004), which considered biological and ecological information of the different species present (Honda *et al.*, 2016).

The Philippines is home to one of the highest fish biodiversity in the Coral Triangle and the world, and is therefore considered to be a global conservation priority (Spalding *et al.*, 2001, Cabral *et al.*, 2014). Reef fish are an important catch of local fisheries, and even though local communities highly depend on fish resources as a food source (Horigue *et al.*, 2012), most reef areas have been destroyed by human activities or overexploited by fisheries (Honda *et al.*, 2016). Less than a quarter (25%) of all MPAs in the Philippines are well managed (Tupper *et al.*, 2015), and considering that only 3.4% of coral reefs are protected within existing MPAs, only slightly more than 1% of the coral reef area is effectively managed and protected (White *et al.*, 2014).

Moreover, Weeks *et al.* (2010) argue that the current extent and distribution of MPAs do not adequately represent biodiversity as 85% of no-take areas are located in just 2 MPAs (Tubbataha Reef National Park and Apo Reef Natural Park) and more than 90% of MPAs are smaller than 1 km^2.

Nevertheless, community-based approaches to MPAs implementation can have considerable positive effects in the Philippines if distances between existing MPAs could ensure larval connectivity and provide opportunities to develop networks (Weeks *et al.*, 2010). It is therefore crucial to recognize that simply establishing MPAs is far from enough and that proper management and evaluation of MPAs is of critical importance to their success (Tupper *et al.*, 2015). Studying and understanding the role and impact of locally established and managed MPAs on species parameters allows assessing whether they really are useful and effective.

Muallil *et al.* (2015) studied the assemblages of seven commercially important coral reef fish families inside and outside LM-MPAs in 37 coastal municipalities in the Philippines. In their study, fish were overall more diverse inside than outside MPAs (based on Shannon-Wiener index of diversity), and reefs inside MPAs had a higher density of fish (average of four times more fish) than the reefs outside MPA boundaries. In terms of equitability, reefs inside and outside had comparative values, which was explained by fish communities being dominated only by a few species, even though big fish (with more than 25 cm in total length) were mostly recorded inside MPAs. Lastly, they found indications suggesting that the commercially important species still need an increase in protection to be effectively protected from the effects of fisheries inside MPAs.

The study showed evidence that some locally managed MPAs in the Philippines can be effective tools to conserve and protect commercially important coral reef fish, even when dealing with high-fishing pressure. However, they argue that the better condition of commercially important coral reef fish insides MPAs is due to the small home ranges of the fish, as all MPAs studies are small (less than 50 hectares). Results are encouraging, but more studies and long-term monitoring should be performed in order to see whether these small and locally managed MPAs could improve local fisheries.

Honda *et al.* (2016) studied the diel habitat-use patterns of target species of fish in a small LM-MPA (0.31km^2) located in the Northern part of Mindanao Island in southern Philippines. The area they studied contained both coral reef and seagrass beds, and using telemetry, they wanted to determine if even small MPAs are useful in the protection of the home range of certain species of commercially important fish belonging to the genera *Lutjanus* (snappers) *Lethrinus* (emperors) and *Siganus* (rabbithfish). Their findings showed that fish were found both inside and outside the boundaries of the MPA, and most species spent all of their time in the coral reef, while only some

utilized both the coral reef and the seagrass beds. More than one third of the tracked fish moved inside and outside of the MPA several times a day, but acoustic receivers deployed inside the MPA recorded 95.4% of detections. Overall, they concluded that the MPA in question, even though it has a small size, still protects the core of fish home ranges.

Indab and Suarez-Aspilla (2004) studied several aspects of community-based MPA in the Bohol Sea (Mindanao) as they were interested in the direction, status, and management issues from MPAs, which have considerably increased in numbers through the years. Being established and managed by local communities, governments, non-governmental organizations, academic institutions, and other legal institutions, Indab and Suarez-Aspilla were interested to see whether MPAs were effective and if not, which were the problems mentioned by the managers. Well-managed MPAs from the Bohol Sea seem to be effective due to the strong support from political leadership, networking with the concerned parties, and strong community involvement.

However, even though some of those good practices are being followed in less well-managed MPAs, several management issues cited by the MPA managers such as a lack of funds and facilities, a lack of education among the people and a lack of support from National Government Agencies/Non-Governmental Organizations keep certain MPAs from being effectively managed, so success appeared to be fragmented in the area.

Studies have focused on the effectiveness of MPAs all over the Philippines, but only few focused on the MPAs in the Negros Oriental Province of the Visayas. Historically, the Visayan region of the Philippines has been said to have the highest concentration of coral reef fish compared to any other area in the world (Nañola Jr. *et al.*, 2011), but recent underwater transect observations in the region indicate that the Visayan region has the lowest species richness in the Philippines (Nañola Jr. *et al.*, 2011). More precisely, according to Nañola Jr. *et al.*, 2011, the Visayan region has unusually low counts of commercially exploited species by fisheries and the aquarium trade, mostly due to overfishing and habitat destruction having a cumulative effect on the species richness of the region. MPA, coupled with fisheries management, are therefore key management tools to increase species richness at local scales to bring back biodiversity in the Visayas to its historical levels and studying the already present MPAs is a priority.

Apo Island's well protected no-take reserve is one of the few reserves were several studies have been conducted in the last decade. Russ and Alcala (1996) studied the spillover effect in Apo's reserve using underwater visual census monitoring of large predatory species of fish belonging to the genera *Serranidae*, *Lutjanidae*, *Lethrinide* and *Carangidae* over a period of ten years (1983 and 1993). They sampled the area each year, and observed a rise in mean density and species richness correlated with time since protection. After 9 to 11 years of protection, they observed a significantly higher density in the areas inside and closest to the reserve compared to areas further away, consistent with the theory of adult fish export from the reserve to the non-reserve areas.

Almost 10 years later, Abesamis and Russ (2005) studied the spillover to fishing sites of an adult fish in the same reserve (Apo Island's MPA), and especially the mechanisms behind the spillover effect, which were previously poorly understood. Studying the spillover from a planktivorous fish (*Naso vlamingii*) between 1983 and 2003, they showed that (as expected) the mean density of *N. vlamingii* increased threefold inside the MPA after 15–20 years of protection, with modal sizes increasing from 35 to 45 centimeters (total length) after 20 years of protection. They also found that modal size and density increased outside the MPA boundaries, but only close-by (200–300 meters), as they did not find an increase farther than 300–500 meters. Interestingly, they noticed that movements of adults across the MPA boundaries were rare, and since adults of that species display aggressive interactions among them (which was 3.7 times higher inside the MPA), density-dependent interactions were higher inside the reserve compared to outside. Larger individuals would therefore chase smaller ones outside the MPA when density reached its limit for the given ecosystem K-limit. That was further demonstrated by experimental fishing, where the further away they fished from the MPA, the smaller the size of the fish they caught.

In 2015, Russ and al. published another study of Apo Island's MPA, but this time presenting the long-term effects of the MPA on coral reef fish, as well as three other no take marine reserves locations in the Philippines. They studied the protection and habitat change effects of those areas on the densities and assemblage structures of fishery-targeted reef fish such as *Lethrinidae*, *Lutjanidae* and non-target fish such as *Pomacentridae*. Inside all the reserves and during all the studied years, target fish density was significantly higher than the non-MPA sites. Hard coral cover and non-target fish displayed a several changes of growth patterns over time, which couldn't be related with time since protection of the no-take zones.

However, density of non-target fish was explained by benthic habitat variables such as structural complexity and cover of dead substrate. Indeed, as target fish were considered predators of non-target, the population patterns of the latter depended on the predator-prey process, rather than on the effect of the no-take reserve. Such results help clarify the extent at which no take MPAs can have on different levels of the trophic chain for target and non-target species.

Stockwell *et al.* (2009) are one of the few that studied several MPAs in the Visayas, mostly in the municipalities of Zamboanguita, Siaton and Dauin. They were interested in coral reef resilience through the suppression of algal growth, controlled mainly by functionally important herbivorous fish, which would at the same time provide inferred evidence that MPAs protect species from harvest. Their study indicated a higher fish biomass and lower macroalgae cover inside LM-MPAs compared to adjacent sites outside MPA boundaries (fished sites). Overall, they indicated an 8 times higher biomass of herbivorous fish and 25 times lower macroalgae cover inside older reserves (8 to 11 years) than outside in fished sites. Total density and biomass of herbivorous fish inside reserves were positively related with the time since protection: they noted a rapid increase in density in the first 3 years since protection before tending to an asymptote at about 40 to 45 fish per $500m^2$ for the following years, and an exponential increase in biomass. Density and biomass increased by 9 and 15 times, respectively, in MPAs that was protected for a least 11 years.

On the other hand, density and biomass of herbivorous fish didn't show any trends at fished sites. Furthermore, they found that after only one year, herbivore biomass already started to be significantly different between protected and fished sites. More specifically, biomass was 1.4 times higher from 0.5 to 4 years since protection, 4.8 times higher after 4.5 to 7 years of protection, and 8.1 times higher after 8 to 11 years since protection. The families that increased the most in biomass were parrotfishes (Scaridae) and surgeonfishes (Acanthuridae), but population recovery rates were higher for parrotfishes than surgeonfishes. Youger MPAs (0.5 to 6 years) appeared to be dominated by parrotfishes, while older reserves (6 to 11 years) showed a more diverse herbivore composition, this time dominated by surgeonfishes. Regarding species richness, there wasn't a significant relationship with duration of protection; however, richness was higher inside MPAs than in fished sites.

In Siaton, since the establishment of the Dive Hub LM-MPA in Antulang's in 2007, Bos (2011) reported a continuous increase in fish biomass (37%) and density (10%) three years later in

2010. However, since then typhoons caused a lot of damage on the reef, and a more recent study showed that Dive Hub's and Andulay's LM-MPAs are now suffering from a coral-algal phase-shift after the severe damages caused by typhoon Sendong in 2011 (Bucol, 2014). Indeed, typhoons damage and destroy coral reefs, and in overfished areas or areas where grazers and herbivores are not present in sufficient abundance to control macroalgae growth, the reef would eventually become smothered and dominated by macroalgae, slowing the recovery of the reef (Bucol, 2014). In both Dive Hub's and Andulay's LM-MPAs, Bucol (2014) reported only 2.25% and 3.33% of coral cover and between 37 and 53% of algae colonization, respectively, dominated by *Bornetella oligospora*. Despite both reef's severed health, he reported a higher mean total biomass and density in the Dive Hub's MPA (70.6 kg/500m^2; 597 fish/500m^2) compared to Andulay's MPA (9.83 kg/500m^2; 361.7 fish/500m^2) for several families of target species.

Studies as the ones presented are crucial to the understanding of LM-MPAs functions and effects, and such should be undertaken regularly throughout time, especially after natural events such as typhoons that can severely damage and impact coral reefs and therefore fish populations depending on the reef.

6.1.1. References

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6.2. Appendix 2: List of indicator species used. "C" in status stands for "Commercial" and "N-C" for "Non-Commercial" species. References are for the "a" and "b" coefficients ("1" is for Gumanao *et al.*, 2016, and "2" is for FishBase accessed on the 5th and 6th of October 2016 (Froese and Pauly, 2016).

Species	Family	Functional group	Status	a coef.	b coef.	Reference
Acanthurus mata	Acanthuridae	Scrapers	C	0.0849	2.713	1
Acanthurus pyroferus	Acanthuridae	Scrapers	C	0.00179	3	2
Acanthurus thompsoni	Acanthuridae	Scrapers	C	0.01533	3	2
Ctenochaetus cyanocheilus	Acanthuridae	Scrapers	C	0.02239	2.97	2
Naso lituratus	Acanthuridae	Scrapers	C	0.0497	2.839	2
Naso unicornis	Acanthuridae	Scrapers	C	0.0314	3.037	1
Balistoides viridescens	Balistidae	Invert specialists	C	0.0696	2.929	1
Melichthys vidua	Balistidae	Invert specialists	C	0.0058	3.554	2
Odonus niger	Balistidae	Invert specialists	C	0.0438	2.91	1
Caesio caerularea	Caesionidae	Scrapers	C	0.0223	3.091	1
Pterocaesio tile	Caesionidae	Scrapers	C	0.013	3.268	1
Chaetodon ornatissimus	Chaetodontidae	Corallivores	C	0.02291	3.01	2
Chaetodon punctatofasciatus	Chaetodontidae	Corallivores	C	0.02291	3.01	2
Chaetodon rafflesi	Chaetodontidae	Corallivores	C	0.02291	3.01	2
Chaetodon speculum	Chaetodontidae	Corallivores	C	0.02512	2.97	2
Chaetodon triangulum	Chaetodontidae	Corallivores	C	0.02291	3.01	2
Chaetodon vagabundus	Chaetodontidae	Corallivores	C	0.01995	2.99	2
Forcipiger flavissimus	Chaetodontidae	Corallivores	C	0.01249	3	2
Heniochus singularius	Chaetodontidae	Generalist	C	0.03009	3	2
Plectorhinchus polytaenia	Haemulidae	Invert specialists	C	0.01259	3.01	2
Lethrinus harak	Lethrinidae	Invert specialists	C	0.0238	3.059	1
Lethrinus ornatus	Lethrinidae	Invert specialists	C	0.0293	3.067	1
Lutjanus biguttatus	Lutjanidae	Predators	C	0.01413	2.98	2
Lutjanus bohar	Lutjanidae	Predators	C	0.01259	3	2
Lutjanus decussatus	Lutjanidae	Predators	C	0.0421	2.887	1
Lutjanus gibbus	Lutjanidae	Predators	C	0.0296	3.047	1
Lutjanus monostigma	Lutjanidae	Predators	C	0.01349	2.96	2
Macolor macularis	Lutjanidae	Predators	C	0.01445	2.97	2
Centropyge tibicen	Pomacantidae	Scrapers	C	0.0601	2.692	2
Chaetodontoplus mesoleucus	Pomacantidae	Scrapers	C	0.0302	2.89	2
Pomacanthus imperator	Pomacantidae	Scrapers	C	0.0371	2.968	2
Pygoplites diacanthus	Pomacantidae	Scrapers	C	0.02762	3	2
Chlorurus bleekeri	Scaridae	Scrapers	C	0.0415	2.946	1
Chlorurus sordidus	Scaridae	Scrapers	C	0.0257	3.15	2
Scarus niger	Scaridae	Scrapers	C	0.0142	3.338	1
Scarus tricolor	Scaridae	Scrapers	C	0.0229	3.106	1
Cephalopholis argus	Serranidae	Predators	C	0.0186	2.987	2

6.2. Appendix 2: List of indicator species used (continued).

Cephalopholis boenak	Serranidae	Predators	C	0.01462	3.019	2
Epinephelus fasciatus	Serranidae	Predators	C	0.0229	2.877	2
Epinephelus fuscoguttatus	Serranidae	Predators	C	0.01335	3.057	2
Plectropomus areolatus	Serranidae	Predators	C	0.01096	3.05	2
Variola louti	Serranidae	Predators	C	0.01219	3.079	2
Siganus corallinus	Siganidae	Scrapers	C	0.00234	3.821	2
Siganus guttatus	Siganidae	Scrapers	C	0.0386	3.009	1
Siganus virgatus	Siganidae	Scrapers	C	0.0204	3.236	1
Sphyraena barracuda	Sphyraenidae	Predators	C	0.006170	3.011	2
Cheilodipterus quinquelineatus	Apogonidae	Predators	N-C	-	-	-
Platax pinnatus	Ephippidae	Scrapers	N-C	-	-	-
Fistularia commersonii	Fistulariidae	Predators	N-C	-	-	-
Myripristis botche	Holocentridae	Invert specialists	N-C	-	-	-
Bodianus dictynna	Labridae	Invert specialists	N-C	-	-	-
Cheilinus chlorourus	Labridae	Invert specialists	N-C	-	-	-
Cheilinus undulatus	Labridae	Invert specialists	N-C	-	-	-
Cirrhilabrus lubbocki	Labridae	Invert specialists	N-C	-	-	-
Coris gaimard	Labridae	Invert specialists	N-C	-	-	-
Halichoeres hortulanus	Labridae	Invert specialists	N-C	-	-	-
Halichoeres melanurus	Labridae	Invert specialists	N-C	-	-	-
Halichoeres scapularis	Labridae	Invert specialists	N-C	-	-	-
Labrichthys unileatus	Labridae	Invert specialists	N-C	-	-	-
Labroides dimidiatus	Labridae	Invert specialists	N-C	-	-	-
Macropharyngodon meleagris	Labridae	Invert specialists	N-C	-	-	-
Oxycheilinus digrammus	Labridae	Invert specialists	N-C	-	-	-
Pseudocheilinus hexataenia	Labridae	Invert specialists	N-C	-	-	-
Stethojulis interrupta	Labridae	Invert specialists	N-C	-	-	-
Thalassoma lunare	Labridae	Invert specialists	N-C	-	-	-
Amanses scopas	Monacanthidae	Invert specialists	N-C	-	-	-
Mulloidichthys flavolineatus	Mullidae	Invert specialists	N-C	-	-	-
Parupeneus barberinus	Mullidae	Invert specialists	N-C	-	-	-
Pentapodus aureofasciatus	Nemipteridae	Generalist	N-C	-	-	-
Scolopsis affinis	Nemipteridae	Generalist	N-C	-	-	-
Ostracion solorensis	Ostraciidae	Generalist	N-C	-	-	-
Pterois volitans	Scorpaenidae	Predators	N-C	-	-	-
Arothron nigropuncatus	Tetraodontidae	Predators	N-C	-	-	-
Canthigaster valentini	Tetraodontidae	Predators	N-C	-	-	-