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National Patterns of Philippine Reef Fish Diversity and Its Implications on the Current Municipal-Level Management

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ABSTRACT

Recent national-level assessments of Philippine reef fish diversity have been mainly based on species richness surveys, but generally do not account for reef fish abundance and biomass—metrics that better describe fish community assemblages. Given that the Philippines is considered a major biodiversity hotspot and is heavily reliant on coastal resources, there is a great need to quantify the current status of its reef fish diversity using standardized methods. Here, standardized Underwater Visual Census (UVC) belt transect sampling methods were used to quantify current levels of reef fish species richness, relative abundance, and relative biomass throughout the Philippines. Results showed that most surveyed municipalities were still species-rich (22.2 ± 0.8 reef fish species per 100 m^2), but appeared depleted in terms of reef fish abundance and biomass. Partitioning analysis revealed significant differences in reef fish species richness patterns across municipalities, suggesting the presence of a few restricted-range and rare species per site. However, partitioning analysis accounting for

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relative abundance showed that reef fish diversity was generally homogenous across study sites, suggesting the dominance of a few highly-abundant species. SIMPER analysis revealed that Philippine reefs were generally dominated by small and medium-bodied species, rather than large-bodied species—the latter of which are especially vulnerable to fishing due to certain life history traits (e.g., late age at maturity and slow growth rate) and commercial exploitation. While current municipal-level management may be sufficient for restricted-range fish species, large-scale conservation efforts (i.e., in the form of collaborative marine reserve networks) are needed for wide-range and large-bodied species that are not confined to politically-defined municipal boundaries. In addition, long-term and nationwide efforts to systematically monitor Philippine reef diversity are needed to provide up-to-date knowledge of the status of Philippine reef diversity that will help support science-based reef management and recovery efforts throughout the country.

Keywords: Conservation, coastal management, marine reserves, Philippine reefs, reef fisheries

LAYMAN'S ABSTRACT

Recent national-level assessments of Philippine reef fish diversity are mainly based on the number of species present, but generally do not account for the abundance and biomass of these species—metrics that better describe the fish community composition. Understanding the current status of reef fish in the Philippines is important, considering that the country is a marine biodiversity hotspot, and is greatly reliant on marine resources for food and livelihood.

To address this, we conducted underwater reef fish surveys throughout the country, recording fish abundance and size using standardized methods. We found that most surveyed municipalities still held a high number of species, but appeared depleted in terms of reef fish abundance and biomass. Further analysis suggested that most municipalities were home to some restricted-range and rare species, but were dominated by a few highly-abundant species. Furthermore, Philippine reefs were generally dominated by small- and medium-bodied species, rather than large-bodied species. Large-bodied fish are especially vulnerable to fishing due to their high commercial value, which makes them desirable fisheries targets. In addition, certain

characteristics, such as slow growth and low reproductive rate, also add to the vulnerability of large-bodied species.

Although current municipal-level management may be sufficient for restricted-range fish species, large-scale conservation efforts are needed for wide-range and large-bodied species that traverse large areas, often across politically-defined municipal boundaries. An example of large-scale conservation efforts would be creating networks of "marine reserves," which are areas of protected sea where fishing and other exploitative activities are not allowed. In addition, long-term and nationwide efforts to systematically monitor Philippine reef diversity are needed to provide up-to-date knowledge on the status of Philippine reef diversity. This knowledge is key in helping support science-based reef management and recovery efforts throughout the country.

INTRODUCTION

The Philippines, an archipelagic nation located in the Coral Triangle of the Indo-Pacific region, is considered to be one of the global centres of marine fish diversity (Carpenter and Springer 2005). The country is also a known biodiversity hotspot—a place that is rapidly losing biodiversity in a short amount of time due to extensive habitat destruction and exploitation (Licuanan and Gomez 2000; Roberts and others 2002; Possingham and Wilson 2005; Allen 2008). Over the past two decades, pressure from overexploitation and destructive human activities have contributed to the degradation of Philippine reefs and the deterioration of coastal resources (Gomez and others 1994; Gomez 1997; White and Vogt 2000; Nanola and others 2006; Briones 2007). Declines in coastal resource production, particularly in the fisheries sector, is a matter of concern for the Filipino people, since many Filipinos rely heavily on fisheries products for both food and livelihood (Gjertsen 2005; BFAR 2012). Therefore, it is important to ask what is left of reef fish diversity in the Philippines, considering the country's growing population and the potential increase in demands for fisheries-related products that may follow.

Most recent national or regional analyses of reef fish diversity in the Philippines have been based on species presence or absence data obtained through a variety of sources, including Underwater Visual Census (UVC) assessments, museum collections, published literature, and expert opinion (Carpenter and Springer 2005; Allen 2008; Nañola Jr. and others 2011). These studies used presence-absence data from various sources to create species distribution maps that allow assessments of biodiversity patterns over large areas, and pinpoint hotspots of conservation importance. Other assessments have used vulnerability scores (often put together by experts based on information on species population trends, distribution, life history, ecology, threats, and existing conservation measures) (Comeros-Raynal and others 2011) or local ecological knowledge (Lavides and others 2009) to map areas at risk of potential species loss. While useful, these assessments do not account for fish abundance and biomass—metrics that are needed in estimating potential fisheries production or yield, the effectiveness of management schemes (e.g., Marine Reserve [MR] enforcement), and describing fish community assemblages in greater detail than species presence-absence data. To date, only a few studies have presented estimates of reef fish diversity in the Philippines that account for not only species richness, but also species relative abundance and biomass (Go and others in press; Nanola and others 2006). However, many of these publications, generally included only a few sites in the country (Allen 2002; Stockwell and others 2009; Anticamara and others 2010), were limited to a few commercial species (Alcala 1988; Russ and Alcala 2004; Russ and others 2005), or were mainly focused on studying the effectiveness of select no-take Marine Reserves (MRs). Thus, there is still a great need to quantify the current status of reef fish diversity in representative sites throughout the Philippines by gathering reef fish diversity data that not only reflects estimates of species richness, but also show the relative abundance and biomass of reef fish species. Collecting such data is vital in providing up-to-date knowledge for science-based decision making and marine resource management in the country (Walton and others 2014).

In the Philippines, marine resource management began with a centralized, top-down, and use-oriented structure (Alcala and Russ 2006). Such early Philippine policies encouraged greater use of natural resources, which lead to depletion and habitat degradation. With the top-down approach, management responsibility often fell upon the central government, or government bureaucracies centred around large cities such as Manila and Cebu (Pomeroy and Carlos 1997; Alcala and Russ 2006). Unfortunately, in the case of the Philippines, this top-down approach to management was mostly ineffective, as the governing bodies were unable to properly manage resource exploitation and the expansion of fisheries (which included destructive and illegal fishing methods) in the country (Alcala and Russ 2006). However, in recent times, the responsibilities and power to establish marine resource policy in the Philippines has since shifted towards community-based co-management, which involves the municipal LGUs and, more importantly, the primary resource users themselves—the local fishers and coastal communities. A number of well-enforced MRs built on community co-management and collaboration have been documented in the Philippines, although these have only covered specific localities throughout the country (White and Courtney 2002; Alcala and Russ 2006;

Arceo and others 2008; Cabral and others 2014). Resource co-management tends to have better continuity over human generations, particularly if the local communities enforcing these policies are convinced of its effectiveness and have a strong desire to participate (Alcala and Russ 2006). Conversely, a lack of belief and participation in the management system could easily lead to non-compliance and resistance (Oracion and others 2005). There is generally a lack of standards in managing MRs among Philippine municipal governments, and the quality of management can vary with the skills and interests of local officials (White and Courtney 2002). Inconsistencies in enforcement may be limiting the effectiveness of marine resource policies across the country, and need to be addressed, especially with the turnover of jurisdictions with every change in local government administration after elections.

Current national policy devolves biodiversity conservation and management effort in the Philippines to the municipal level. For example, the Local Government Code (LGC) of 1991 provided municipal Local Government Units (LGUs) with authority to carry-out specific functions, including the establishment of policies regarding the conservation and management of natural resources, such as the establishment of reserves and protected areas (Philippine Government 1991). In addition, the Republic of the Philippines Fisheries Code Republic Act (RA) 8550 states that all Philippine municipalities must allocate about 15% of its municipal waters (i.e., coastal waters from foreshore to 15 km away from the coasts) as MRs (Department of Agriculture 1998). However, while the number of well-enforced MRs has increased over the years (Maypa and others 2012), recent estimates suggest that only about 1% of Philippine coral reef areas are well-protected (White and others 2014), and 90% of the 1,000+ MRs currently existing in the Philippines are small or < $1 km^2$ (Weeks and others 2010). Despite the pressing need to improve coastal resource management in the country (Weeks and others 2014), the current status of Philippine reef fish biodiversity remains largely unmeasured, except for surrogate data from a few sites, or select (usually commercial) families and species (Russ and Alcala 2004; Russ and others 2005; Stockwell and others 2009).

The main goal of this paper is to present the results of a recent and systematic assessment of Philippine reef fish diversity, accounting for reef fish species richness, relative abundance, and relative biomass across representative sites throughout the country. In addition, this paper will explore patterns of reef fish diversity and dominance across the Philippines. It is not within the scope of this paper to quantify the effects of municipal-level management on Philippine reef fish diversity, but rather to discuss how diversity patterns revealed in the study are potentially related to the existing municipal-level "devolution of power" of marine resource management in the country to date. Therefore, much of the analysis in this paper on Philippine reef fish biodiversity patterns will be conducted at the municipal level (e.g., comparing biodiversity between and across municipalities). Specifically, the paper seeks to answer the following questions: (1) What is the general picture of reef fish biodiversity throughout the Philippines to date, based on different biodiversity metrics (e.g., species richness, evenness, abundance, and biomass)?; (2) How does reef fish biodiversity vary across Philippine municipalities based on these metrics?; (3) What patterns can be observed in reef fish assemblages throughout the country?; and (4) What types of fish species dominate Philippine coral reefs to date?

METHODS

Study site selection and survey methods

Using Google Earth satellite images, we selected sites that most likely had coral reefs close to shore. In addition, study sites were selected to represent the Philippines' three major island groups (e.g., Luzon, Visayas, and Mindanao) and the six marine biogeographic regions proposed by Aliño and Gomez (1994), while accounting for budget and logistical constraints such as travel time, costs, issues of site accessibility, traveling with lots of equipment, and safety. Surveyed reef sites within each municipality included areas inside and outside MRs (where MR boundary demarcation was clearly established), and were often referred by local fishers, boatmen, or Local Government Unit (LGU) officers, whom we asked to direct us to reef areas where we could record as much of the local fish diversity as possible. Due to budget and logistical limitations, the number of surveyed transects varied per municipality and biogeographic region (Appendix 1).

To quantify Philippine reef fish diversity, standardized Underwater Visual Census (UVC) belt transects surveys were conducted throughout the Philippines. A total of 420 belt transects, belonging to 119 reef sites, forty-nine municipalities, and six Philippine marine biogeographic regions were surveyed from March 2012 to June 2014 (approximately two-year period), spanning north to south of the Philippines (Figure 1). The UVC belt transect method used is an established non-destructive reef fish survey method, for quantifying reef fish species diversity (Brock 1982; Samoilys 1997; Samoilys and Carlos 2000).

To conduct UVC surveys, a diver (J. Anticamara) swam along a 20 x 5 m transect and recorded all size (cm) and abundance estimates of non-cryptic reef fish species with a minimum length of 1 cm encountered within the transect boundaries.

Typically, a minimum length of 10-11 cm is recommended to avoid errors in length and abundance estimates (Bellwood and Alcala 1988). However, we initially observed that many of our survey sites were dominated by small-bodied species and individuals, so setting the minimum length of our methods to 10 cm would exclude a significant portion of the reef fish community. Therefore, we decided to include all reef fish species down to a minimum length of 1 cm, to appropriately represent the true status of reef fish diversity throughout our survey sites. The estimated length of recorded individual fish species was later converted into weight using Length-Weight (LW) relationships available in FishBase (Froese and Pauly 2014). In cases where the LW relationship of a particular fish species was not

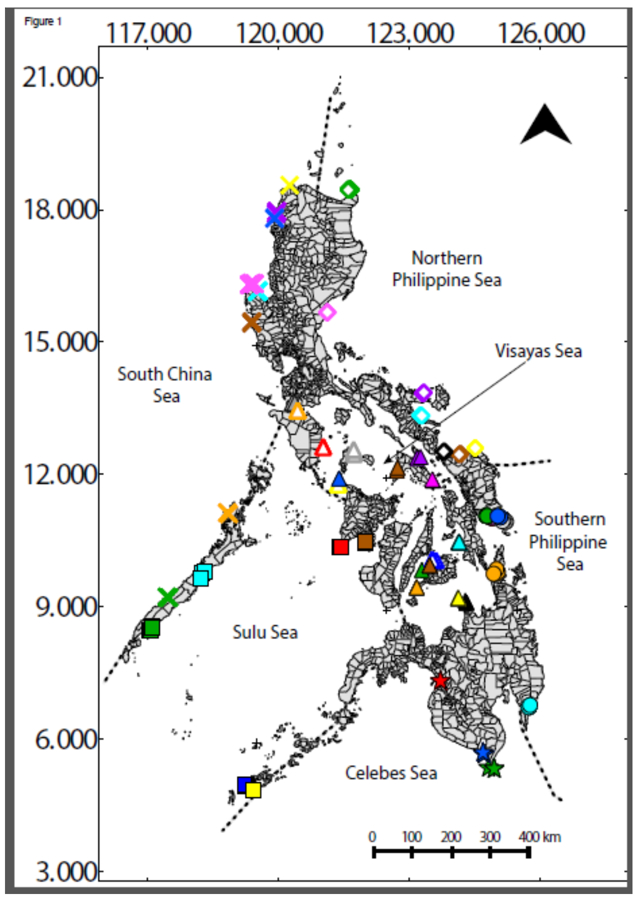

Figure 1. Map of surveyed reef sites throughout the Philippines. The broken lines represent demarcations of the Philippine marine biogeographic regions as proposed by Aliño and Gomez (1994). The number of transects and municipalities surveyed per biogeographic region can be found in Appendix 1.

available in FishBase, the LW of the congener or family member of similar shape and maximum total length was used (Anticamara and others 2010).

All surveyed transects were conducted at depths ranging from 3–6 m to capture as much fish diversity as possible at a manageable depth, since reef fish diversity and abundance are often high at this depth range relative to other depth ranges (Friedlander and Parrish 1998; Friedlander and others 2003).

To avoid variation due to surveyor's error, we only analyzed UVC survey data obtained by one of the authors (J. Anticamara), who has had nearly twenty years of experience conducting underwater surveys in Philippine coral reefs (Samoilys and others 2007; Anticamara 2009; Anticamara and others 2010). All surveys were conducted during daylight hours, and each transect was surveyed for approximately 20 minutes. Our choice of transect dimensions (20 x 5 m), number of transect replicates (3-4 transect replicates per reef site, or 8–10 transects per municipality) and total surveyed reef area per site (300–400 m^2total reef area per site, or 800–1,000 m^2 per municipality) is comparable to UVC methods used in other studies quantifying reef fish diversity (Brock 1982; Friedlander and Parrish 1998; Tissot and others 2004; Nakamura and Tsuchiya 2008; Shibuno and others 2008; Honda and others 2013).

The UVC belt transect method underestimates the abundance of cryptic reef fish species (e.g., Blennies, Gobies, Dottybacks, and Eels) and nocturnal species (e.g., Sweepers, Soldierfishes, and Priacanthids), since such species may remain hidden from census divers (Willis 2001). On the other hand, highly-mobile species may be overestimated, due to their conspicuous movements in the diver's field of vision (Smith 1988). To address these limitations, we conducted UVC surveys at slow swim speeds of about 5 m^2 min^{-1} (or roughly 20 min per 100 m^2 transect), which improves counting accuracy, search efficiency (Samoilys and Carlos 2000), and avoids scaring away skittish fish, while taking care not to double-count individuals that re-enter the transect area. In addition, photographs of all encountered reef fish species were taken for identification verification using a number of references (Allen and others 2003; Kuiter and Debelius 2006; Froese and Pauly 2014).

Data analysis

First, to present the adequacy of our current sampling effort in capturing Philippine reef fish diversity, we constructed Species Accumulation Curves (SACs) for each of the six sampled biogeographic regions. A SAC is a graph of recorded number of species as a function of sampling effort and allows for the estimation of the total number of species in a given area per increased sampling unit (Colwell and others 2004). Initially, the SAC rises steeply as common and abundant species are recorded, then more slowly as rare species are recorded (Ugland and others 2003).

To examine general patterns of reef fish diversity across the Philippines, histograms of reef fish species richness, abundance, and biomass per municipality were constructed. Then, to examine potential differences in reef fish diversity between municipalities across the country, bar plots showing mean (and standard errors SE) species richness, abundance, and biomass per municipality were also produced. Examining spatial trends at the municipal level coincides with the paper's objectives to discuss our research findings in relation to the current municipal-level policy of Philippine coastal management.

To explore patterns of reef fish assemblages throughout the country, non-metric Multidimensional Scaling (MDS) analysis was performed to help visualize potential grouping-by-similarity of reef fish assemblages at various spatial scales, namely: transects, reef sites, municipalities, or marine biogeographic regions. MDS analysis uses a constructed Bray-Curtis similarity matrix to visually map the similarities of the 420 sampled transects—i.e., transects that are more similar are plotted closer-together, while transects that are dissimilar are plotted further apart. For example, if transects from a given biogeographic region grouped more closely-together than with transects from other biogeographic regions, this would suggest that reef fish assemblages in that biogeographic region are distinct from the other biogeographic regions. Similarly, if transects from a given municipality grouped more closely together than with transects from other municipalities, this would suggest that reef fish assemblages in sampled transects within that municipality are similar and are distinct from transects sampled from the other municipalities. MDS analysis would therefore allow us to determine if transects grouped at certain spatial scales or did not show any clear grouping at all. MDS analysis was performed separately for reef fish assemblage similarity based on reef fish abundance and biomass data.

To further examine reef-fish assemblages at multiple spatial scales, additive diversity partitioning was performed. In additive diversity partitioning, total diversity (γ) is the sum of the mean local diversity or the mean diversity within samples or transects ($\bar{\alpha}$), and the diversity between samples (β) at various defined scales (e.g., between transects, reef sites, municipalities, or biogeographic regions). In an unbalanced, hierarchal sampling design, such as in our case, each sample level can be represented as hierarchal spatial scales (Veech and others 2002). Specifically, in this study, $\bar{\alpha}$ represents mean within-transect reef fish diversity, $\beta 1$ represents between-transect diversity, β2 represents between-reef site diversity, β3 represents between-municipality diversity, β4 represents between-biogeographic region diversity, and γ represents the estimated total Philippine reef fish diversity based on all our samples, as summarized in the following equations:

$$\beta 1_{transects} = \bar{D}_{sites} - \bar{\alpha}_{transects} \quad (1)$$

$$\beta 2_{sites} = \bar{D}_{municipalities} - \bar{D}_{sites} \quad (2)$$

$$\beta 3_{municipalities} = \bar{D}_{biogeographic} - \bar{D}_{municipalities} \quad (3)$$

$$\beta 4_{biogeographic} = \gamma - \bar{D}_{biogeographic} \quad (4)$$

where $\bar{D}$ is the mean diversity for each hierarchal spatial scale. Estimated total Philippine diversity (γ) based on all our samples can be expressed as:

$$\gamma = \alpha + \beta 1 + \beta 2 + \beta 3 + \beta 4 \bullet \quad (5)$$

Therefore, diversity partitioning can be used to determine the proportional contributions (percentage) of each level of $\bar{\alpha}$ and β-diversity to γ-diversity, wherein total diversity γ = 100% (Lande 1996). However, the interpretation of $\bar{\alpha}$ and β varies depending on the particular diversity index used. The general equation for $\bar{\alpha}$ is presented below:

$$\bar{\alpha} = \sum_{t=1}^{n_i} D_{ij} q_{ij} \quad (6)$$

Based on the above equation, the sample weight q_{ij} is the proportion of the total number of individuals found in each sample *j*, and sampling level *i*. In addition, $\bar{\alpha}$ can be calculated using different diversity indices D_{ij}. When partitioning is based on 0
species richness index, D_{ij} is the number of species in transect *j*, at sampling level *i*. When partitioning is based on Shannon's Diversity index, $D_{ij} = 1 - \sum p_{ijk} ln p_{ijk}$, where p_{ijk} is the proportional abundance of species *k* in transect *j*. Similarly, when partitioning is based on Simpson's Diversity index, $D_{ij} = 1 - \sum p_{ijk}^2$ (Crist and others 2003).

PARTITION v2 freeware (Veech and Crist 2007) was used to run additive diversity partitioning analysis, and to test for significant differences between our data (e.g., "observed diversity") and randomly-generated null models (e.g., "expected diversity") (Veech and Crist 2007). Null models were generated based on 999 individual-based randomizations. A significant difference between the observed data portioning and randomized data partitioning means that the observed hierarchical patterns of diversity are real and unlikely to be produced by a randomized assignment of species to samples at various defined scales.

Finally, to examine dominance patterns in reef fish assemblages, a Similarity Percentage (SIMPER) analysis was run separately for reef fish species abundance and biomass. SIMPER determines the contributions of each reef fish species to the pair-wise Bray-Curtis similarities of all surveyed transects within each municipality. The species with the highest contributions are usually the most abundant or have the highest total biomass and therefore are generally the most dominant species. Both MDS and SIMPER analyses were run using Primer v6 (Clarke and Gorley 2006). The body sizes (maximum total length (max TL)) of the top five dominant reef fish species for all municipalities was obtained from FishBase and categorized as small-bodied (max TL $\leq$ 10 cm), medium-bodied (max TL = 10.1 - 30 cm), and large-bodied (max TL > 30.1 cm).

RESULTS

Overall, we identified a total of 375 non-cryptic reef fish species, belonging to forty-eight families, across the 420 transects that we surveyed throughout the entire Philippines. Species accumulation curves per biogeographic region showed increasing number of species with every additional transect (Figure 2). However, the rate of increase in the number of species per additional transect started to plateau or visibly slow-down at around 20-30 transects per biogeographic region, at which point over 100 reef fish species had been recorded. This suggests that most common or dominant species in each biogeographic region have been recorded
0 after surveying about 20–30 100 m^2 transects, and additional species detected by surveying more transects may be rare or cryptic species.

Patterns in the frequency distribution of transects with respect to mean reef fish species richness (22.2 ± 0.8 species), abundance (387.7 ± 66.1 fish), and biomass (2.5 ± 0.3 kg) differed. Transects were normally distributed in terms of species richness (Figure 3a). On the other hand, transects were skewed to the left in terms of both abundance and biomass, indicating that most transects had abundance and biomass values way below the mean for both metrics (Figure 3d-e).

Bar plots on mean species richness, abundance, and biomass per municipality showed generally lower variation in species richness within and among municipalities, but higher variation in terms of both abundance and biomass (Figure 4). Most municipalities (61% of forty-nine municipalities) had high species richness (i.e., "high" defined as having values within or above the range values of the mean ± SE across all municipalities, and "low" defined as having values below it). On the other hand, most municipalities had low abundance (63%) and biomass (59%).

MDS analysis of the Bray-Curtis Similarity in reef fish species assemblages with respect to species relative abundance or relative biomass did not show clear grouping of surveyed transects according to either biogeographic regions or municipalities (Appendix 2). However, some transects from the same municipality tended to group together, indicating within-municipal similarity of reef fish assemblages, at least for those municipalities.

Additive partition of reef fish diversity in terms of species richness and species evenness (e.g., Shannon's diversity and Simpson's diversity) showed different spatial patterns of Philippine reef fish biodiversity. In terms of species richness, observed β1 and β2-diversity did not significantly differ from the expected null model, while observed β3 and β4-diversity were significantly higher than the expected

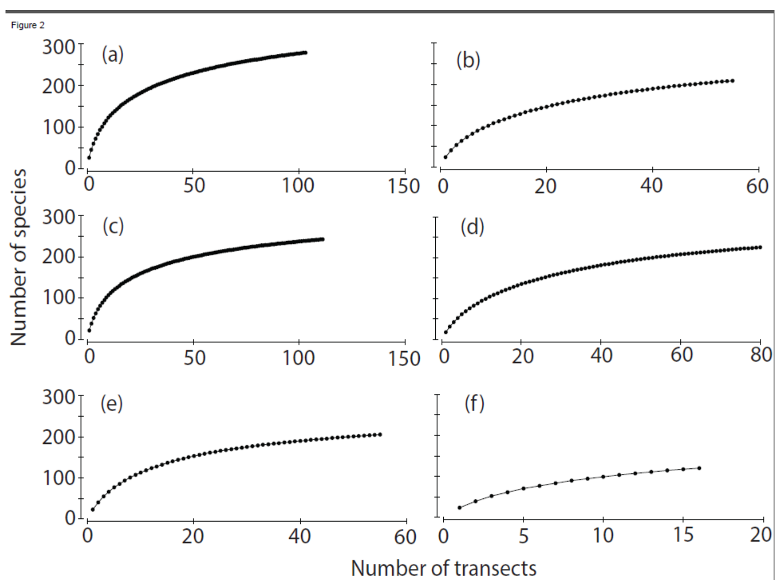

Figure 2. Species Accumulation Curves (SACs) per biogeographic region, for the Visayas Sea (a), Northern Philippine Sea (b), Sulu Sea (c), Southern Philippine Sea (d), South China Sea (e), and Celebes Sea (f). SAC curves show the cumulative number of fish species found in every additional transect based on 1,000 permutations of transect ordering.

null model. Furthermore, most of species richness γ-diversity was accounted for by β3 (37.7%) and β4 (41.8%). In contrast, $\bar{\alpha}$ accounted for much of Shannon's (50.0%) and Simpson's (81.13%) γ-diversity.

Dominance analysis using SIMPER indicated that each municipality generally had different sets of top five dominant species in terms of species' relative abundance (Appendix 3a) and biomass (Appendix 3b). The top five dominant species within each municipality generally accounted for about 73.7 ± 1.6% of the total abundance

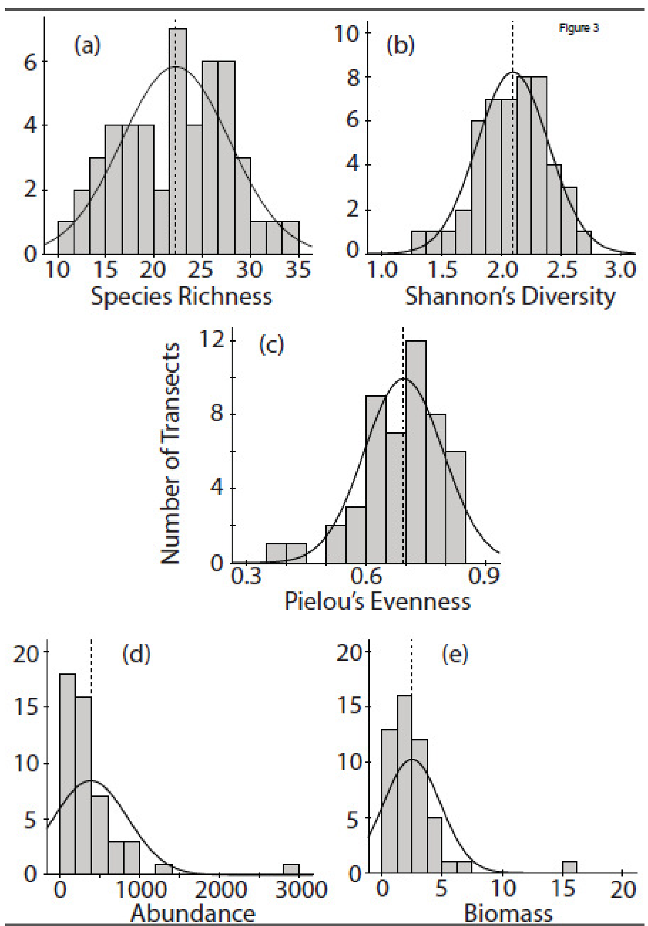

Figure 3. Histograms showing per-transect frequency distributions for reef fish species richness (a), Shannon's diversity (b), Pielou's evenness (c), abundance (d), and biomass (e). The broken line on each graph represents the mean value per transect for that respective metric.

and 65.6 ± 2.0% of the total biomass. Of the 375 reef fish species recorded in our study, only 66 and 68 species comprised the top five dominant species in terms of abundance and biomass for all municipalities, respectively. Certain reef fish families tended to dominate the top five species per municipality. For example, of the 66 species included in the dominant species listed for all municipalities based on

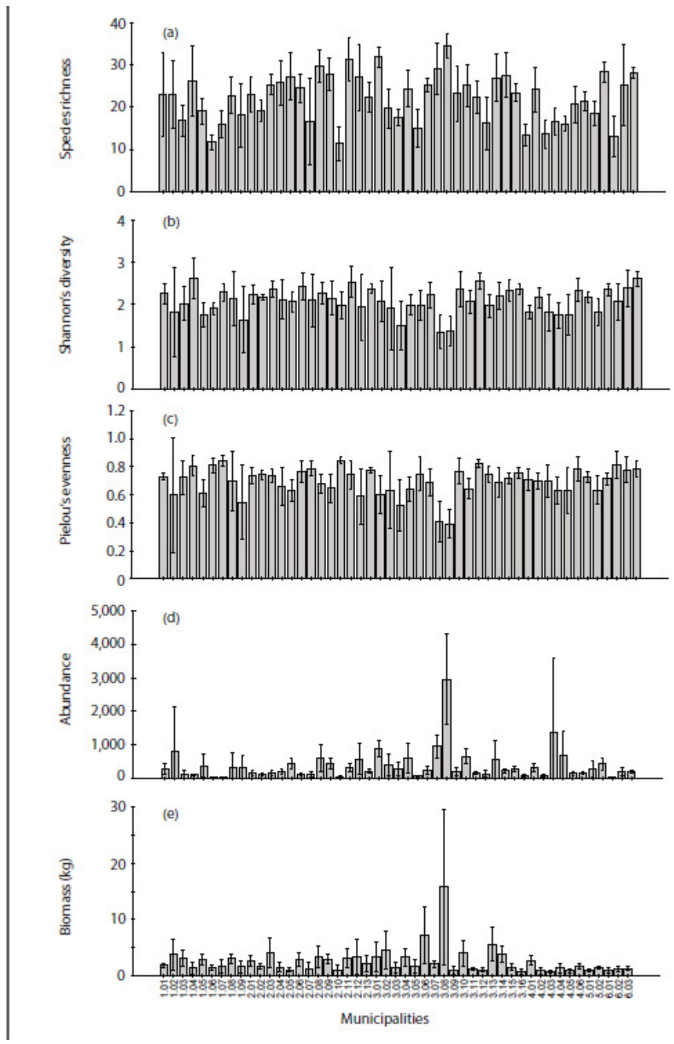

Figure 4. Bar plots showing per-municipality mean ± SE bars for reef fish species richness (a), Shannon's diversity (b), Pielou's evenness (c), abundance (d), and biomass (e), arranged by biogeographic region, and from north to south of the Philippines. Municipality codes can be found in Appendix 1.

abundance, 58% were Damselfishes and 13% were Wrasses. In terms of biomass, 18% of the 68 top five dominant species were Wrasses, 16% were Damselfishes, and 13% were Butterflyfishes. Furthermore, many of these dominant species in terms of both abundance and biomass were small to medium-bodied species. In terms of abundance, small-bodied, medium-bodied, and large-bodied species made up 36%, 58%, and 6% of the top five dominant species, respectively. In terms of biomass, small-bodied, medium-bodied, and large-bodied species made up 9%, 57%, and 34% of the top five dominant species, respectively. However, most of the medium to large-bodied species that appeared as top five dominant in terms of biomass were mainly omnivores, herbivores, and corallivores, suggesting the decline of most large-bodied carnivorous reef fish species throughout the Philippines.

DISCUSSION

Overall, results from this research show that many coral reef areas throughout the Philippines are still highly diverse, only if reef fish species richness is used as the sole measure of biodiversity. However, while still considerably species-rich (i.e., most municipalities having at least 21-23 species per 100 m^2), many areas throughout the Philippines appear to be exhibiting signs of depletion in terms of fish abundance and biomass, and in fact, previous studies have described the depletion of species richness as well (Lavides and others 2009; Nañola Jr. and others 2011). Diversity partitioning analysis revealed that Philippine reef fish assemblages can be characterized as having high variations in species richness across municipalities, but generally low species evenness (e.g., Shannon's and Simpson's diversity indices). Differences in species richness rather than evenness best explained differences in reef fish assemblages between municipalities, suggesting the presence of restricted-range species (i.e., species found in only a few of the surveyed municipalities) in each municipality (Go and others in press). On the other hand, Shannon's and Simpson's diversity were best explained by within-transect diversity, suggesting that most surveyed reefs were dominated by a few, highly-abundant reef fish species. Further investigation of dominance patterns via SIMPER analysis revealed that most surveyed reef sites were dominated by abundant small and medium-bodied reef fish species. However, there was also a general rarity of large-bodied species throughout most Philippine reefs—a finding which suggests overexploitation due to fishing, considering that large-bodied, high trophic-level species are particularly targeted by fisheries (Pauly and others 1998), and are especially vulnerable to fishing due to particular life history traits (Abesamis and others 2014). These findings suggest that the current "municipality-by-municipality" policy to biodiversity conservation in the Philippines may be affecting reef fish assemblages throughout the country (but see qualified discussions and elaborations of this point below).

Although previous work accounting for Philippine reef fish abundance, biomass, and functional diversity has been done (Carpenter and others 1981; Russ and Alcala 1998a; Russ and Alcala 1998b; Nanola and others 2006), to date, the most common measure of reef fish diversity in the Philippines is species richness (Allen 2002; Carpenter and Springer 2005; Allen 2008; Nañola Jr. and others 2011). Species richness or species presence-absence data is useful in estimating species range, restriction or expansion of range, and potential local extirpation (Lavides and others 2009; Nañola Jr. and others 2011). However, results of the current study show that species richness alone is not always a good indicator of reef fish diversity status in the country. For example, while reef fish species richness remains high in most places throughout the Philippines, examination of the other metrics reveals that most places in the country actually have low reef fish abundance and biomass. Indeed, other studies have also found that reef fish species richness may exhibit less-obvious changes than reef fish species abundance, in response to disturbances such as exploitation and habitat degradation (Alcala 1988; Harmelin and others 1995; Jones and others 2004)—human-induced disturbances that are common in many coastal areas of the Philippines. Therefore, the effects of such disturbances on reef fish assemblages may be underestimated, if only species richness is taken into account. Many species still exist, but most in very low population size or abundance throughout the sampled municipalities.

Patterns of Philippine Reef Fish Diversity: Restricted-range Species and the Dominance of a Few Highly-abundant Species

Results of additive partitioning analysis suggest two main findings regarding spatial patterns of reef fish assemblages throughout the country: (1) the presence of restricted-range species influences the differences in species richness between municipalities; and (2) only a few, abundant species tend to dominate reef fish assemblages throughout the country, and greatly influence species evenness. With regards to our first finding—additive diversity partitioning analysis showed that between-municipality ($\beta3$) and between-biogeographic region ($\beta4$) diversity species richness was significantly greater than that predicted by the null models, and also accounted for a relatively large portion of γ-diversity. This means that differences in reef fish species richness between municipalities and between biogeographic regions may reflect real variations in species richness at these spatial scales

(Belmaker and others 2008). The high contribution of β3-diversity to γ-diversity in terms of species richness indicates that the presence of restricted-range and rare species may account for the difference in species richness between municipalities (Rodríguez-Zaragoza and others 2011). Indeed, many of the reef fish species included in our study exhibited restricted ranges (Go and others in press). However, we suspect that the restricted ranges of many of these species is not due to evolutionary or ecological factors, considering the nationwide distributions of most of these species based on previous records (Carpenter and Springer 2005; Nañola Jr. and others 2011; Froese and Pauly 2014), but rather due to the high rates of exploitation and reef degradation in the Philippines to date.

With regards to our second finding of diversity partitioning analysis—it is possible to infer that most surveyed areas were dominated by a few, highly-abundant species, because $\bar{\alpha}$-diversity accounted for much of Shannon's and Simpsons' γ-diversity, but not for species richness' γ-diversity (Rodríguez-Zaragoza and others 2011). High $\bar{\alpha}$-diversity when accounting for species relative abundance (e.g., evenness metrics like Shannon's and Simpson's indices) can be interpreted as homogeneity of species assemblages across surveyed transects, because the very high abundance of a few species common to all sites overwhelms the small amounts of between-site (β) variation contributed by the non-abundant species (Rodríguez-Zaragoza and others 2011). These findings suggest that surveyed reef fish assemblages per municipality are generally characterized by high species richness, but low evenness (Rodríguez-Zaragoza and others 2011). The differences in observed patterns from diversity partitioning analysis between species richness and evenness again highlights the importance of measuring biodiversity using different metrics (Gering and others 2003).

Dominance Patterns in Philippine Reef Fish Assemblages: The Abundance of Small and Medium-bodied Species

Analysis of reef fish species assemblages based on Bray-Curtis SIMPER showed that most of the dominant species in surveyed reefs were small and medium-bodied species such as Wrasses, Damselfishes, and Butterflyfishes, in terms of abundance. Although some large-bodied species were among the top five dominant species in terms of biomass, this does not necessarily mean that these species are abundant in Philippine reefs—indeed, large-bodied reef fish species such as Emperors, Groupers, Jacks, Snappers, and Sweetlips were rarely dominant in terms of abundance across all surveyed reefs. This may be due to the fact that: (1) larger maximum body size—along with other life history traits such as slower growth rate, longer lifespan, later age at maturity, and lower rates of natural mortality—has been associated with increased vulnerability to fishing (Abesamis and others 2014); and (2) large-bodied fish species are especially targeted by fishers for their higher commercial value than small-bodied species (Russ and Alcala 1996; Pauly and others 1998). Shifts in fish assemblages from dominance of larger-bodied species and individuals towards dominance of smaller-bodied species and individuals have been documented in the past, following high levels of exploitation (Greenstreet and Hall 1996; Bianchi and others 2000; Rogers and Ellis 2000; Levin and others 2006). Thus, high exploitation rates in the Philippines, accompanying increasing demands for fish production and a growing human and fishing population, may be threatening most commercially-important, large-bodied reef fish species in the country.

The exploitation-induced depletion of large-bodied reef fish species may have negative implications on Philippine fisheries production and the food security of many Filipinos, who are largely-dependent on fish products as a dietary protein source, and actually prefer to consume large-bodied fish species (BFAR 2012). However, formal assessments on the threatened status of many reef fish species in the Philippines are limited by the lack of available species abundance and distribution data in the past and recent years. This makes assessment criteria commonly used by internationally-recognized conservation organizations like the IUCN (such as population decline and range contraction) difficult to apply for many reef fish species in the Philippines. As a result, many Philippine reef fish species remain under-assessed or totally unassessed (Go and others in press; IUCN 2014)—an issue that should be addressed by conservation and management efforts in the country.

Caveats and Limitations

The main caveat of the current study is that the number of surveyed transects varied across municipalities and biogeographic regions. This could lead to under-representation of reef fish diversity for biogeographic regions that had a disproportionally fewer number of surveyed transects than the other surveyed regions (e.g., Celebes Sea, in our study). Nañola Jr. and others (2011), who presented reef fish species richness patterns across Philippine marine biogeographic regions, showed with SACs that the number of species recorded per additional transect surveyed increased rapidly until about 40 to 50 transects per biogeographic region, after which the addition of new species recorded per additional transect slowed down. This suggests that around 40 to 50 surveyed transects are required to account for most of the common or abundant species in each biogeographic region. Based on this estimate, reef fish diversity in the Celebes Sea biogeographic region is under-represented in our study.

However, based on our own SACs and data, our sampling effort adequately captured reef fish diversity for all biogeographic regions, as all of our SACs per biogeographic region approached asymptotic patterns. In addition, we surveyed reef sites and municipalities that were geographically far apart, and selected sites referred by local fishers, boatmen, or LGU officers to capture as much representative reef fish biodiversity per municipality and per biogeographic region as possible. However, despite these efforts to survey as much reef fish diversity as possible, none of our SACs approached the 350–500 reef fish species recorded per biogeographic region at 40-50 transects reported by Nañola Jr and others (2011), even after we re-ran the SAC construction using Jackknife 2 estimators —e.g., the estimator used by Nañola Jr. and others (2011), which is based on species presence-absence data (Smith and Pontius 2006). This may suggest a general depletion of reef fish diversity throughout the Philippines (Lavides and others 2009; Nañola Jr. and others 2011), considering that Nañola Jr. and others (2011) included reef fish survey data from 1991 to 2008.

To account for the differences in the number of transects per municipality and biogeographic region when conducting diversity partitioning analysis, we used an unbalanced sampling design in PARTITION v2 (Veech and Crist 2007). Unbalanced sampling in diversity partitioning has been used in previous studies on reef fish diversity patterns as well, where sampling effort was not uniform across study areas (Rodríguez-Zaragoza and Arias-Gonzalez 2008; Francisco-Ramos and Arias-González 2013).

Implications for Management

The observed patterns in reef fish assemblages throughout the country may be affected by the municipal-level organization of coastal management in the Philippines today. For example, significant differences in diversity metrics (particularly abundance and biomass) between municipalities, as well as the presence of restricted-range species in each municipality, may be potentially due to the variations in management effectiveness (e.g., MR enforcement) between these municipalities (although this is not tested in the current study). The positive effect of well-enforced MRs on local fish diversity has been documented in previous studies (Russ and Alcala 1999; Walmsley and White 2003; Samoilys and others

2007; Maypa and others 2012; Bergseth and others 2013), and it is highly possible that surveyed municipalities that exhibited high diversity metrics were also those municipalities that had well-enforced MRs. However, quantifying the effects of varied management on reef fish diversity across municipalities is difficult given available datasets, since only 14 of the 49 municipalities included in our study had MRs with available enforcement ratings on the recently established Philippine Marine Protected Area Network (Cabral and others 2014). In addition, management effectiveness may be linked to the interest and support of stakeholders. For example, the distribution of MRs in the Philippines is concentrated in the Visayas region (Weeks and others 2010)—a region where academic institutions and non-government organizations (NGOs) continue to support MR establishment (Pollnac and others 2001), and where the first efforts of Philippine MR establishment began (Alcala and Russ 2006). While much has been done to quantify the extent of MR establishment and enforcement throughout the country (Weeks and others 2010; Maypa and others 2012), the effectiveness in terms of biological indicators (e.g., reef fish species abundance, biomass, and fish yield) of most Philippine MR's is still largely unknown. Maypa and others (2012) presented the most recent analysis of Philippine MR effectiveness on coral reef health, but only included a few (n = 56) MRs from the Visayas region that had available biophysical data. Thus, there is still a great need to monitor biological indicators of MR effectiveness throughout the Philippines.

To date, the Coral Triangle Marine Protected Area System (CTMPAS), created by the Coral Triangle Initiative (CTI) in 2009, hopes to achieve well-managed MPAs throughout the six coral triangle countries by integrating the aforementioned ecological, social, and governance factors through a consistent and science-based system of MR establishment (Walton and others 2014). However, there is still a great need to improve the enforcement, monitoring, socioeconomic accountability, governance, and financial support of many MRs in the Philippines (White and others 2014). In addition, facilitating collaboration and communication between multiple stakeholders, increasing local capacity to manage MRs, and developing learning networks across MR managers are invaluable in achieving successful MR enforcement (Weeks and others 2014). Finally, it is important to account for ecological factors in MR design, such as adequate habitat representation, protection of critical areas used in a species' different life history stages (e.g., spawning grounds, nurseries), ensuring connectivity between protected habitats, accounting for resilience or vulnerability to climate change, and minimizing local anthropogenic threats (e.g., land-based runoff and siltation) (Green and others 2014). For example, while current small-scale municipal-level management may be sufficient for restricted-ranged species, implementing large-scale (e.g., across networks of MRs rather than at select, individual MRs) and long-term management and monitoring of reef fish diversity would help refine and adjust marine biodiversity conservation strategies for the country, effectively manage species that traverse large spatial units beyond municipal boundaries (e.g., large-bodied species such as Groupers, Snappers, Sharks, and Whales, etc.), and ensure proper connectivity of reef fish diversity throughout the country (Kramer and Chapman 1999; Beets and others 2003; Lowry and others 2009; Matias and others 2013; Green and others 2014).

Results from this research provide the most recent analysis on the current status of reef fish diversity throughout the Philippines using a standardized or systematic survey strategy. The results and conclusions from this research suggest that there is a great need to fully enforce the current marine biodiversity conservation policies of the Philippines, to conduct national coral reef assessments that are systematic, scientifically-sound, well-organized (Licuanan and Aliño 2014), and to mitigate reef degradation and the depletion of valuable marine biodiversity resources. By ensuring that 15% of Philippine municipal waters receive effective protection from further overexploitation and destructive fishing (e.g., dynamite fishing and the use of poison), the remaining reef areas of the Philippines will have some chance of recovery, which will allow them to continue to provide benefits to Philippine fisheries and food security, and maintain the high levels of diversity in the country (Russ and others 2004; Russ and others 2005; Anticamara and others 2010).

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Appendix 1
All surveyed municipalities, with corresponding codes and biogeographic regions

Municipality Code	Municipality	Number of Transects	Biogeographic Region
1.01	Pagudpod	2	South China Sea
1.02	Burgos	2	South China Sea
1.03	Curimao	6	South China Sea
1.04	Sinait	4	South China Sea
1.05	Bolinao	19	South China Sea
1.06	Alaminos	25	South China Sea
1.07	Masinloc	11	South China Sea
1.08	El Nido	5	South China Sea
1.09	Quezon	6	South China Sea
	Total	**80**	**South China Sea**
2.01	Sta. Ana	18	North East Philippine Sea
2.02	Baler	8	North East Philippine Sea
2.03	Caramoan	8	North East Philippine Sea
2.04	Tabaco	7	North East Philippine Sea
2.05	Lavesarez	4	North East Philippine Sea
2.06	Catarman	6	North East Philippine Sea
2.07	Laoang	4	North East Philippine Sea
	Total	**61**	**North East Philippine Sea**
3.01	Mabini	17	Visayas Sea
3.02	Puerto Galera	9	Visayas Sea
3.03	Bongabong	5	Visayas Sea
3.04	Romblon	6	Visayas Sea
3.05	San Fernando	5	Visayas Sea
3.06	Mandaon	6	Visayas Sea
3.07	Cataingan	6	Visayas Sea
3.08	Malay	3	Visayas Sea
3.09	Buruanga	6	Visayas Sea
3.10	Inopacan	11	Visayas Sea
3.11	Getafe	5	Visayas Sea
3.12	Tubigon	6	Visayas Sea
3.13	Calape	2	Visayas Sea
3.14	Panglao	6	Visayas Sea
3.15	Mambajao	5	Visayas Sea
3.16	Mahinog	5	Visayas Sea
	Total	**97**	**Visayas Sea**

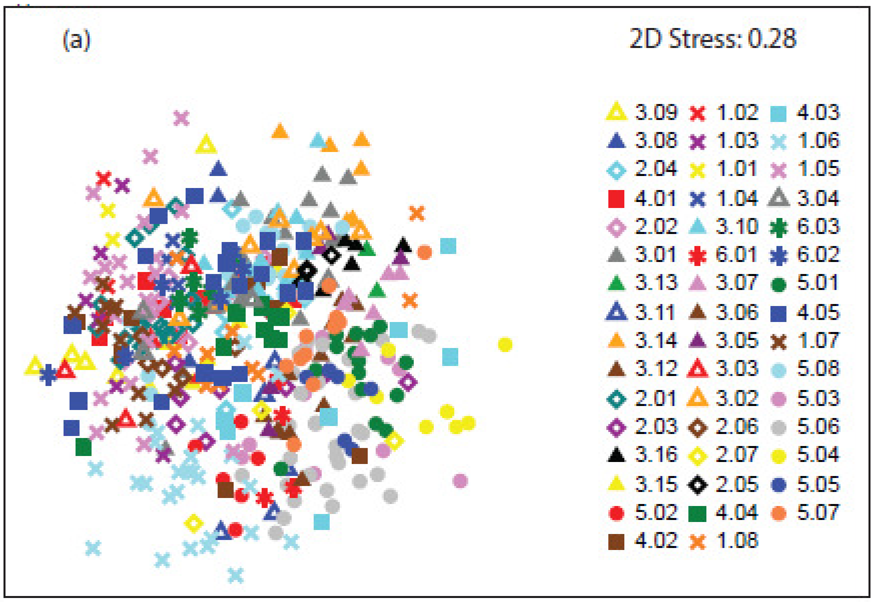
Appendix 1

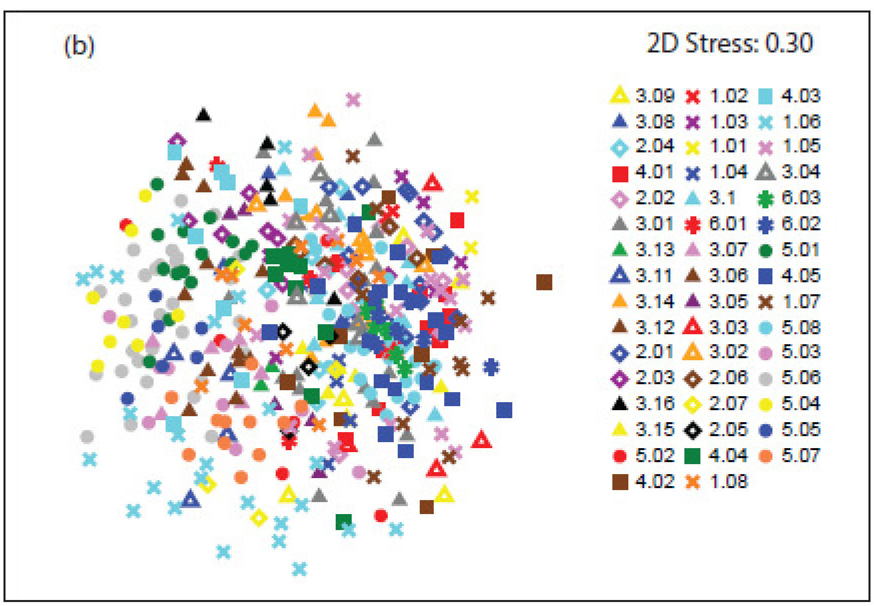
All surveyed municipalities, with corresponding codes and biogeographic regions (cont'n.)

Municipality Code	Municipality	Number of Transects	Biogeographic Region
4.01	Anini-y	10	Sulu Sea
4.02	Nueva Valencia	8	Sulu Sea
4.03	Puerto Princesa	8	Sulu Sea
4.04	Bataraza	10	Sulu Sea
4.05	Bongao	14	Sulu Sea
4.06	Simunul	5	Sulu Sea
	Total	**55**	**Sulu Sea**
5.01	Lawaan	16	Southern Philippine Sea
5.02	Balangiga	6	Southern Philippine Sea
5.03	Giporlos	10	Southern Philippine Sea
5.04	Quinapondan	8	Southern Philippine Sea
5.05	Salcedo	6	Southern Philippine Sea
5.06	Guiuan	31	Southern Philippine Sea
5.07	Surigao	11	Southern Philippine Sea
5.08	Mati	23	Southern Philippine Sea
	Total	**111**	**Southern Philippine Sea**
6.01	Parang	4	Celebes Sea
6.02	Glan	6	Celebes Sea
6.03	Sarangani	6	Celebes Sea
	Total	**16**	**Celebes Sea**

Appendix 2

MDS plots of Bray-Curtis similarity among municipalities
in terms of species abundance (a) and species biomass (b).
Transects with the same shape denote transects from withinthe same
biogeographic region. Municipality codes can be found in Appendix 1





Appendix 3A

Table showing the top 5 dominant species in terms of abundance, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others")

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
1.01	*Thalassoma amblycephalum*	34.48	Labridae	16.0	medium
Similarity: 39.7	*Chromis margaritifer*	34.48	Pomacentridae	9.0	small
Top 5: 93.1	*Pomacentrus bankanensis*	17.24	Pomacentridae	9.0	small
Others: 6.9	*Chaetodon kleinii*	3.45	Chaetodontidae	15.0	medium
	Centropyge vroliki	3.45	Pomacanthidae	12.0	medium
1.02	*Ctenochaetus striatus*	20.33	Acanthuridae	26.0	medium
Similarity: 15.0	*Chromis margaritifer*	16.26	Pomacentridae	9.0	small
Top 5: 70.7	*Thalassoma amblycephalum*	16.26	Labridae	16.0	medium
Others: 29.3	*Plectroglyphidodon dickii*	9.76	Pomacentridae	11.0	medium
	Chromis vanderbilti	8.13	Pomacentridae	4.5	small
1.03	*Pomacentrus philippinus*	25.09	Pomacentridae	10.0	small
Similarity: 16.9	*Ctenochaetus striatus*	17.89	Acanthuridae	26.0	medium
Top 5: 66.02	*Thalassoma hardwicke*	9.16	Labridae	20.0	medium
Others: 33.98	*Neoglyphidodon nigroris*	8.19	Pomacentridae	13.0	medium
	Ctenochaetus cyanocheilus	5.69	Acanthuridae	13.7	medium
1.04	*Plectroglyphidodon lacrymatus*	28.91	Pomacentridae	10.0	small
Similarity: 40.1	*Pomacentrus philippinus*	17.56	Pomacentridae	10.0	small
Top 5: 78.9	*Chromis margaritifer*	13.19	Pomacentridae	9.0	small
Others: 21.1	*Pomacentrus lepidogenys*	10.59	Pomacentridae	9.0	small
	Neoglyphidodon nigroris	8.62	Pomacentridae	13.0	medium
1.05	*Chromis margaritifer*	25.38	Pomacentridae	9.0	small
Similarity: 12.1	*Thalassoma hardwicke*	12.72	Labridae	20.0	medium
Top 5: 64.3	*Plectroglyphidodon lacrymatus*	10.20	Pomacentridae	10.0	small
Others: 35.7	*Ctenochaetus striatus*	9.35	Acanthuridae	26.0	medium
	Coris batuensis	6.61	Labridae	17.0	medium
1.06	*Pomacentrus chrysurus*	22.66	Pomacentridae	9.0	small
Similarity: 12.6	*Neoglyphidodon melas*	18.94	Pomacentridae	18.0	medium
Top 5: 60.2	*Plectroglyphidodon lacrymatus*	8.01	Pomacentridae	10.0	small
Others: 39.8	*Macropharyngodon meleagris*	5.98	Labridae	15.0	medium
	Stethojulis trilineata	4.64	Labridae	15.0	medium

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
1.07	*Ctenochaetus striatus*	37.47	Acanthuridae	26.0	medium
Similarity: 27.8	*Chromis margaritifer*	15.63	Pomacentridae	9.0	small
Top 5: 80.4	*Thalassoma hardwicke*	14.48	Labridae	20.0	medium
Others: 19.6	*Stegastes fasciolatus*	6.63	Pomacentridae	15.0	medium
	Plectroglyphidodon dickii	6.15	Pomacentridae	11.0	medium
1.08	*Plectroglyphidodon lacrymatus*	49.18	Pomacentridae	10.0	small
Similarity: 19.4	*Abudefduf sexfasciatus*	7.94	Pomacentridae	16.0	medium
Top 5: 78.1	*Hemiglyphidodon plagiometopon*	7.38	Pomacentridae	18.0	medium
Others: 21.9	*Thalassoma lunare*	6.85	Labridae	25.0	medium
	Labroides dimidiatus	6.78	Labridae	11.5	medium
1.09	*Plectroglyphidodon lacrymatus*	35.52	Pomacentridae	10.0	small
Similarity: 12.0	*Neoglyphidodon nigroris*	30.56	Pomacentridae	13.0	medium
Top 5: 81.5	*Amblyglyphidodon curacao*	7.14	Pomacentridae	11.0	medium
Others: 18.5	*Apogon griffini*	4.21	Apogonidae	13.5	medium
	Thalassoma lunare	4.08	Pomacentridae	25.0	medium
2.01	*Ctenochaetus striatus*	43.81	Acanthuridae	26.0	medium
Similarity: 22.0	*Chrysiptera rex*	6.12	Pomacentridae	7.0	small
Top 5: 66.1	*Plectroglyphidodon lacrymatus*	5.98	Pomacentridae	10.0	small
Others: 33.9	*Zanclus cornutus*	5.96	Zanclidae	23.0	medium
	Pomacentrus coelestis	4.23	Pomacentridae	9.0	small
2.02	*Ctenochaetus striatus*	23.65	Acanthuridae	26.0	medium
Similarity: 39.3	*Chrysiptera rex*	21.73	Pomacentridae	7.0	small
Top 5: 83.8	*Plectroglyphidodon lacrymatus*	19.81	Pomacentridae	10.0	small
Others: 16.2	*Pomacentrus lepidogenys*	14.23	Pomacentridae	9.0	small
	Pomacentrus bankanensis	4.35	Pomacentridae	9.0	small
2.03	*Abudefduf sexfasciatus*	14.18	Pomacentridae	16.0	medium
Similarity: 21.1	*Chaetodon octofasciatus*	13.87	Chaetodontidae	12.0	medium
Top 5: 56.0	*Pomacentrus bankanensis*	13.27	Pomacentridae	9.0	small
Others: 44.0	*Chrysiptera rex*	7.93	Pomacentridae	7.0	small
	Amblyglyphidodon curacao	6.74	Pomacentridae	11.0	medium

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
2.04	*Pomacentrus moluccensis*	21.31	Pomacentridae	9.0	small
Similarity: 23.1	*Pomacentrus lepidogenys*	18.72	Pomacentridae	9.0	small
Top 5: 68.8	*Amblyglyphidodon curacao*	13.84	Pomacentridae	11.0	medium
Others: 31.2	*Pomacentrus bankanensis*	9.04	Pomacentridae	9.0	small
	Plectroglyphidodon lacrymatus	5.85	Pomacentridae	10.0	small
2.05	*Chromis atripectoralis*	66.22	Pomacentridae	12.0	medium
Similarity: 55.5	*Pomacentrus lepidogenys*	6.48	Pomacentridae	9.0	small
Top 5: 87.9	*Pomacentrus moluccensis*	5.68	Pomacentridae	9.0	small
Others: 12.1	*Amblyglyphidodon curacao*	5.40	Pomacentridae	11.0	medium
	Neoglyphidodon nigroris	4.08	Pomacentridae	13.0	medium
2.06	*Chrysiptera rex*	25.25	Pomacentridae	7.0	small
Similarity: 36.9	*Pomacentrus lepidogenys*	24.04	Pomacentridae	9.0	small
Top 5: 78.3	*Pomacentrus bankanensis*	12.58	Pomacentridae	9.0	small
Others: 21.7	*Thalassoma hardwicke*	8.28	Labridae	20.0	medium
	Ctenochaetus striatus	8.15	Acanthuridae	26.0	medium
2.07	*Pomacentrus simsiang*	25.64	Pomacentridae	7.0	small
Similarity: 11.3	*Thalassoma hardwicke*	13.85	Labridae	20.0	medium
Top 5: 68.1	*Pomacentrus opisthostigma*	10.85	Pomacentridae	6.5	small
Others: 31.9	*Labrichthys unilineatus*	10.04	Labridae	17.5	medium
	Neoglyphidodon nigroris	7.72	Pomacentridae	13.0	medium
2.08	*Scarus rivulatus*	23.48	Scaridae	40.0	large
Similarity: 19.5	*Pomacentrus alexanderae*	14.93	Pomacentridae	9.0	small
Top 5: 67.0	*Pomacentrus moluccensis*	12.52	Pomacentridae	9.0	small
Others: 33.0	*Amblyglyphidodon curacao*	11.23	Pomacentridae	11.0	medium
	Pomacentrus simsiang	4.87	Pomacentridae	7.0	small
2.09	Pomacentrus chrysurus	71.09	Pomacentridae	9.0	small
Similarity: 42.0	*Chrysiptera rex*	9.73	Pomacentridae	7.0	small
Top 5: 89.2	*Thalassoma hardwicke*	3.11	Pomacentridae	20.0	medium
Others: 10.8	*Scolopsis lineatus*	2.72	Nemipteridae	23.0	medium
	Naso unicornis	2.59	Acanthuridae	70.0	large

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
2.10	*Pomacentrus chrysurus*	40.35	Pomacentridae	9.0	small
Similarity: 16.9	*Scarus rivulatus*	11.85	Scaridae	40.0	large
Top 5: 77.1	*Chrysiptera rex*	9.11	Pomacentridae	7.0	small
Others: 22.9	*Pomacentrus moluccensis*	8.20	Pomacentridae	9.0	small
	Pomacentrus alexanderae	7.58	Pomacentridae	9.0	small
2.11	*Chromis ternatensis*	34.07	Pomacentridae	10.0	small
Similarity: 24.7	*Chrysiptera cyanea*	17.41	Pomacentridae	8.5	small
Top 5: 77.7	*Pomacentrus burroughi*	9.89	Pomacentridae	8.5	small
Others: 22.3	*Pomacentrus alexanderae*	8.93	Pomacentridae	9.0	small
	Hemiglyphidodon plagiometopon	7.39	Pomacentridae	18.0	medium
2.12	*Pomacentrus moluccensis*	16.84	Pomacentridae	9.0	small
Similarity: 28.8	*Scarus rivulatus*	16.61	Scaridae	40.0	large
Top 5: 62.5	*Amblyglyphidodon curacao*	14.49	Pomacentridae	11.0	medium
Others: 37.5	*Chromis ternatensis*	7.75	Pomacentridae	10.0	small
	Dischistodus prosopotaenia	6.80	Pomacentridae	17.0	medium
2.13	*Pomacentrus coelestis*	15.08	Pomacentridae	9.0	small
Similarity: 17.4	*Scarus rivulatus*	11.61	Scaridae	40.0	large
Top 5: 53.1	*Pomacentrus chrysurus*	11.03	Pomacentridae	9.0	small
Others: 46.9	*Pomacentrus moluccensis*	8.29	Pomacentridae	9.0	small
	Pomacentrus burroughi	7.07	Pomacentridae	8.5	small
3.01	*Pseudanthias huchti*	22.52	Serranidae	12.0	medium
Similarity: 19.1	*Pomacentrus moluccensis*	21.86	Pomacentridae	9.0	small
Top 5: 59.6	*Pomacentrus brachialis*	6.05	Pomacentridae	8.0	small
Others: 40.4	*Chromis viridis*	4.94	Pomacentridae	8.0	small
	Centropyge vroliki	4.26	Pomacentridae	12.0	medium
3.02	*Acanthochromis polyacanthus*	39.84	Acanthuridae	14.0	medium
Similarity: 23.0	*Pomacentrus moluccensis*	14.6	Pomacentridae	9.0	small
Top 5: 67.5	*Chaetodon kleinii*	4.71	Chaetodontidae	15.0	medium
Others: 32.5	*Amblyglyphidodon curacao*	4.63	Pomacentridae	11.0	medium
	Chaetodon lunulatus	3.71	Chaetodontidae	14.0	medium

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.03	*Centropyge vroliki*	30.32	Pomacanthidae	12.0	medium
Similarity: 20.3	*Pomacentrus bankanensis*	26.1	Pomacentridae	9.0	small
Top 5: 91.4	*Thalassoma hardwicke*	25.7	Labridae	20.0	medium
Others: 8.6	*Plectroglyphidodon lacrymatus*	5.24	Pomacentridae	10.0	small
	Pomacentrus coelestis	4.06	Pomacentridae	9.0	small
3.04	*Ctenochaetus striatus*	18.01	Acanthuridae	26.0	medium
Similarity: 21.0	*Pomacentrus moluccensis*	13.27	Pomacentridae	9.0	small
Top 5: 53.3	*Dascyllus trimaculatus*	9.85	Pomacentridae	11.0	medium
Others: 46.7	*Centropyge vroliki*	6.36	Pomacanthidae	12.0	medium
	Pomacentrus lepidogenys	5.76	Pomacentridae	9.0	small
3.05	*Pomacentrus moluccensis*	55.51	Pomacentridae	9.0	small
Similarity: 18.1	*Pomacentrus bankanensis*	9.45	Pomacentridae	9.0	small
Top 5: 80.6	*Pomacentrus brachialis*	5.30	Pomacentridae	8.0	small
Others: 19.4	*Abudefduf vaigiensis*	5.19	Pomacentridae	20.0	medium
	Pomacentrus chrysurus	5.12	Pomacentridae	9.0	small
3.06	*Thalassoma lunare*	28.15	Labridae	25.0	medium
Similarity: 46.8	*Pomacentrus chrysurus*	18.45	Pomacentridae	9.0	small
Top 5: 78.2	*Scarus rivulatus*	15.27	Scaridae	40.0	large
Others: 21.8	*Pomacentrus simsiang*	11.61	Pomacentridae	7.0	small
	Dascyllus trimaculatus	4.77	Pomacentridae	11.0	medium
3.07	*Pomacentrus moluccensis*	43.24	Pomacentridae	9.0	small
Similarity: 32.6	*Pomacentrus chrysurus*	14.21	Pomacentridae	9.0	small
Top 5: 76.1	*Amblygliphidodon ternatensis*	6.82	Pomacentridae	10.0	small
Others: 23.9	*Neoglyphidodon melas*	6.68	Pomacentridae	18.0	medium
	Amblyglyphidodon curacao	5.18	Pomacentridae	11.0	medium
3.08	*Chaetodon kleinii*	54.25	Chaetodontidae	15.0	medium
Similarity: 26.2	*Plectroglyphidodon lacrymatus*	20.13	Pomacentridae	10.0	small
Top 5: 94.2	*Dascyllus trimaculatus*	13.29	Pomacentridae	11.0	medium
Others: 5.8	*Scarus rivulatus*	4.51	Scaridae	40.0	large
	Dascyllus reticulatus	2.04	Pomacentridae	9.0	small

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.09	*Pomacentrus coelestis*	58.18	Pomacentridae	9.0	small
Similarity: 19.4	*Pomacentrus bankanensis*	12.49	Pomacentridae	9.0	small
Top 5: 87.0	*Chrysiptera cyanea*	9.24	Pomacentridae	8.5	small
Others: 13.0	*Centropyge vroliki*	4.20	Pomacanthidae	12.0	medium
	Ctenochaetus striatus	2.94	Acanthuridae	26.0	medium
3.10	*Plectroglyphidodon lacrymatus*	27.83	Pomacentridae	10.0	small
Similarity: 27.2	*Pomacentrus moluccensis*	24.62	Pomacentridae	9.0	small
Top 5: 75.2	*Amblyglyphidodon curacao*	13.03	Pomacentridae	11.0	medium
Others: 24.8	*Zebrasoma scopas*	4.99	Zanclidae	20.0	medium
	Ctenochaetus striatus	4.77	Acanthuridae	26.0	medium
3.11	*Thalassoma lunare*	30.08	Labridae	25.0	medium
Similarity: 26.0	*Pomacentrus chrysurus*	19.54	Pomacentridae	9.0	small
Top 5: 75.5	*Pomacentrus simsiang*	12.87	Pomacentridae	7.0	small
Others: 24.5	*Plectroglyphidodon lacrymatus*	6.94	Pomacentridae	10.0	small
	Chromis ternatensis	6.07	Pomacentridae	10.0	small
3.12	*Pomacentrus moluccensis*	34.66	Pomacentridae	9.0	small
Similarity: 35.0	*Pomacentrus burroughi*	24.03	Pomacentridae	8.5	small
Top 5: 74.3	*Chromis ternatensis*	5.36	Pomacentridae	10.0	small
Others: 25.7	*Sphaeramia nematoptera*	5.23	Apogonidae	8.5	small
	Chaetodon octofasciatus	5.03	Chaetodontidae	12.0	medium
3.13	*Dascyllus aruanus*	41.73	Pomacentridae	10.0	small
Similarity: 14.5	*Pomacentrus moluccensis*	28.78	Pomacentridae	9.0	small
Top 5: 82.8	*Pomacentrus alexanderae*	5.76	Pomacentridae	9.0	small
Others: 17.2	*Amphiprion clarkii*	3.60	Pomacentridae	15.0	medium
	Amblyglyphidodon curacao	2.88	Pomacentridae	11.0	medium
3.14	*Pomacentrus moluccensis*	34.64	Pomacentridae	9.0	small
Similarity: 19.6	*Pseudanthias tuka*	14.82	Serranidae	12.0	medium
Top 5: 83.2	*Pseudanthias huchti*	13.63	Serranidae	12.0	medium
Others: 16.8	*Caesio caerulaurea*	12.67	Caesionidae	35.0	large
	Pomacentrus alexanderae	7.47	Pomacentridae	9.0	small

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Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.15	*Scarus rivulatus*	29.36	Scaridae	40.0	large
Similarity: 33.2	*Chromis weberi*	17.67	Pomacentridae	13.5	medium
Top 5: 68.9	*Dascyllus trimaculatus*	11.68	Pomacentridae	11.0	medium
Others: 31.1	*Plectroglyphidodon lacrymatus*	5.20	Pomacentridae	10.0	small
	Centropyge vroliki	5.03	Pomacanthidae	12.0	medium
3.16	*Pomacentrus moluccensis*	42.01	Pomacentridae	9.0	small
Similarity: 33.9	*Caesio caerulaurea*	23.14	Caesionidae	35.0	large
Top 5: 90.7	*Amblyglyphidodon curacao*	22.6	Pomacentridae	11.0	medium
Others: 9.3	*Pomacentrus brachialis*	1.83	Pomacentridae	8.0	small
	Neoglyphidodon nigroris	1.14	Pomacentridae	13.0	medium
4.01	*Abudefduf vaigiensis*	14.50	Pomacentridae	20.0	medium
Similarity: 25.7	*Plectroglyphidodon lacrymatus*	14.04	Pomacentridae	10.0	small
Top 5: 61.4	*Ctenochaetus striatus*	12.55	Acanthuridae	26.0	medium
Others: 38.6	*Pomacentrus vaiuli*	10.93	Pomacentridae	10.0	small
	Thalassoma hardwicke	9.34	Labridae	20.0	medium
4.02	*Plectroglyphidodon lacrymatus*	37.35	Pomacentridae	10.0	small
Similarity: 14.12	*Halichoeres hortulanus*	8.30	Labridae	27.0	medium
Top 5: 62.7	*Pomacentrus moluccensis*	6.69	Pomacentridae	9.0	small
Others: 37.3	*Pomacentrus coelestis*	5.62	Pomacentridae	9.0	small
	Thalassoma lunare	4.71	Labridae	25.0	medium
4.03	*Pomacentrus simsiang*	18.08	Pomacentridae	7.0	small
Similarity: 11.3	*Plectroglyphidodon lacrymatus*	8.57	Pomacentridae	10.0	small
Top 5: 49.5	*Dascyllus reticulatus*	8.2	Pomacentridae	9.0	small
Others: 50.5	*Dischistodus prosopotaenia*	7.62	Pomacentridae	17.0	medium
	Apogon griffini	7.0	Apogonidae	13.5	medium
4.04	*Pomacentrus moluccensis*	26.72	Pomacentridae	9.0	small
Similarity: 34.3	*Pomacentrus adelus*	21.94	Pomacentridae	8.5	small
Top 5: 71.5	*Plectroglyphidodon lacrymatus*	14.4	Pomacentridae	10.0	small
Others: 28.5	*Thalassoma hardwicke*	4.22	Labridae	20.0	medium
	Amblyglyphidodon curacao	4.2	Pomacentridae	11.0	medium

Appendix 3A

Table showing the top 5 dominant species in terms of abundance, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
4.05	*Pomacentrus moluccensis*	26.79	Pomacentridae	9.0	small
Similarity: 20.2	*Chromis margaritifer*	9.98	Pomacentridae	9.0	small
Top 5: 62.8	*Pomacentrus simsiang*	9.74	Pomacentridae	7.0	small
Others: 37.2	*Dascyllus reticulatus*	8.21	Pomacentridae	9.0	small
	Ctenochaetus striatus	8.06	Acanthuridae	26.0	medium
4.06	*Cirrhilabrus cyanopleura*	53.02	Labridae	15.0	medium
Similarity: 22.7	*Pomacentrus lepidogenys*	11.76	Pomacentridae	9.0	small
Top 5: 83.9	*Scolopsis bilineatus*	7.79	Nemipteridae	23.0	medium
Others: 16.1	*Ctenochaetus striatus*	6.7	Acanthuridae	26.0	medium
	Thalassoma lunare	4.65	Labridae	25.0	medium
5.01	*Pomacentrus moluccensis*	52.49	Pomacentridae	9.0	small
Similarity: 27.0	*Pomacentrus chrysurus*	10.42	Pomacentridae	9.0	small
Top 5: 86.4	*Amblyglyphidodon curacao*	10.34	Pomacentridae	11.0	medium
Others: 13.6	*Chromis viridis*	8.1	Pomacentridae	8.0	small
	Neoglyphidodon nigroris	5.02	Pomacentridae	13.0	medium
5.02	*Acanthochromis polyacanthus*	40.12	Pomacentridae	14.0	medium
Similarity: 29.9	*Pomacentrus moluccensis*	18.8	Pomacentridae	9.0	small
Top 5: 74.3	*Pomacentrus lepidogenys*	7.24	Pomacentridae	9.0	small
Others: 25.7	*Plectroglyphidodon lacrymatus*	4.17	Pomacentridae	10.0	small
	Ctenochaetus striatus	4	Acanthuridae	26.0	medium
6.01	*Thalassoma lunare*	24.91	Labridae	25.0	medium
Similarity: 29.2	*Scarus rivulatus*	20.96	Scaridae	40.0	large
Top 5: 78.5	*Chlorurus sordidus*	17.74	Pomacentridae	40.0	large
Others: 21.5	*Halichoeres melanurus*	7.55	Labridae	12.0	medium
	Chaetodon octofasciatus	7.37	Chaetodontidae	12.0	medium
6.02	*Dascyllus reticulatus*	20.63	Pomacentridae	9.0	small
Similarity: 24.7	*Plectroglyphidodon lacrymatus*	17.27	Pomacentridae	10.0	small
Top 5: 67.1	*Ctenochaetus striatus*	12.58	Acanthuridae	26.0	medium
Others: 32.9	*Plectroglyphidodon dickii*	9.35	Pomacentridae	11.0	medium
	Pomacentrus moluccensis	7.25	Pomacentridae	9.0	small
6.03	*Pomacentrus lepidogenys*	19.13	Pomacentridae	9.0	small
Similarity: 34.3	*Acanthochromis polyacanthus*	15.01	Pomacentridae	14.0	medium
Top 5: 65.2	*Ctenochaetus striatus*	12.12	Acanthuridae	26.0	medium
Others: 34.8	*Plectroglyphidodon lacrymatus*	11.63	Pomacentridae	10.0	small
	Centropyge vroliki	7.28	Pomacanthidae	12.0	medium

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others")

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
1.01	*Zanclus cornutus*	38.46	Zanclidae	23	medium
Similarity:20.7	*Chaetodon ornatissimus*	25.62	Chaetodontidae	20	medium
Top 5: 94.5	*Chaetodon kleinii*	25.52	Chaetodontidae	15	medium
Others: 5.5	*Sufflamen chrysopterus*	2.79	Balistidae	30	medium
	Centropyge vroliki	2.14	Pomacanthidae	12	medium
1.02	*Ctenochaetus striatus*	28.29	Acanthuridae	26	medium
Similarity: 37.4	*Chlorurus sordidus*	20.20	Scaridae	40	large
Top 5: 85.4	*Cheilinus chlorourus*	13.92	Labridae	45	large
Others: 14.6	*Zanclus cornutus*	11.70	Zanclidae	23	medium
	Chaetodon kleinii	11.31	Chaetodontidae	15	medium
1.03	*Halichoeres hortulanus*	28.41	Labridae	27	medium
Similarity: 17.9	*Ctenochaetus striatus*	23.04	Acanthuridae	26	medium
Top 5: 75.4	*Parupeneus multifasciatus*	10.23	Mullidae	35	large
Others: 24.6	*Thalassoma hardwicke*	8.50	Labridae	20	medium
	Chlorurus sordidus	5.18	Scaridae	40	large
1.04	*Epinephelus merra*	16.80	Serranidae	31	large
Similarity: 28.6	*Thalassoma lunare*	14.72	Labridae	25	medium
Top 5: 59.9	*Plectroglyphidodon lacrymatus*	10.28	Pomacentridae	10	small
Others: 40.1	*Halichoeres melanurus*	9.33	Labridae	12	medium
	Labracinus cyclophthalmus	8.72	Pseudochromidae	20	medium
1.05	*Ctenochaetus striatus*	34.43	Acanthuridae	26	medium
Similarity: 12.2	*Thalassoma hardwicke*	24.79	Labridae	20	medium
Top 5: 72.8	*Plectroglyphidodon lacrymatus*	6.04	Pomacentridae	10	small
Others: 27.2	*Thalassoma lunare*	4.09	Labridae	25	medium
	Lutjanus decussatus	3.45	Lutjanidae	35	large
1.06	*Dischistodus prosopotaenia*	23.73	Pomacentridae	17	medium
Similarity: 9.6	*Neoglyphidodon melas*	21.73	Pomacentridae	18	medium
Top 5: 69.2	*Dascyllus trimaculatus*	10.46	Pomacentridae	11	medium
Others: 30.8	*Choerodon anchorago*	7.41	Labridae	38	large
	Plectroglyphidodon lacrymatus	5.86	Pomacentridae	10	small

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
1.07	*Ctenochaetus striatus*	38.67	Acanthuridae	26	medium
Similarity: 13.3	*Thalassoma hardwicke*	11.74	Labridae	20	medium
Top 5: 72.3	*Balistapus undulatus*	10.28	Balistidae	30	medium
Others: 27.7	*Epinephelus merra*	5.94	Serranidae	31	large
	Stegastes fasciolatus	5.69	Pomacentridae	15	medium
1.08	*Thalassoma lunare*	19.78	Labridae	25	medium
Similarity: 17.5	*Ctenochaetus striatus*	19.51	Acanthuridae	26	medium
Top 5: 70.5	*Scolopsis margaritifer*	12.77	Nemipteridae	28	medium
Others: 29.5	*Arothron nigropunctatus*	9.73	Tetraodontidae	33	large
	Thalassoma hardwicke	8.75	Labridae	20	medium
1.09	*Lutjanus decussatus*	10.22	Lutjanidae	35	large
Similarity: 9.2	*Dischistodus prosopotaenia*	9.35	Pomacentridae	17	medium
Top 5: 44.1	*Plectroglyphidodon lacrymatus*	8.86	Pomacentridae	10	small
Others: 55.9	*Cheilinus chlorourus*	8.18	Labridae	45	large
	Neoglyphidodon nigroris	7.49	Pomacentridae	13	medium
2.01	*Ctenochaetus striatus*	42.90	Acanthuridae	26	medium
Similarity: 17.5	*Zanclus cornutus*	13.85	Zanclidae	23	medium
Top 5: 71.7	*Chaetodon vagabundus*	7.50	Chaetodontidae	23	medium
Others: 28.3	*Halichoeres hortulanus*	4.40	Labridae	27	medium
	Thalassoma hardwicke	3.07	Labridae	20	medium
2.02	*Ctenochaetus striatus*	46.36	Acanthuridae	26	medium
Similarity: 23.0	*Chlorurus sordidus*	13.45	Scaridae	40	large
Top 5: 76.7	*Parupeneus multifasciatus*	5.99	Mullidae	35	large
Others: 23.3	*Hemigymnus fasciatus*	5.61	Labridae	80	large
	Plectroglyphidodon lacrymatus	5.31	Pomacentridae	10	small
2.03	*Chlorurus sordidus*	24.39	Scaridae	40	large
Similarity: 16.5	*Scarus flavipectoralis*	23.29	Scaridae	40	large
Top 5: 70.1	*Lutjanus decussatus*	10.55	Lutjanidae	35	large
Others: 29.9	*Ctenochaetus striatus*	6.29	Chaetodontidae	26	medium
	Zanclus cornutus	5.58	Zanclidae	23	medium

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
2.04	*Lutjanus decussatus*	15.06	Lutjanidae	35	large
Similarity: 17.0	*Zanclus cornutus*	13.37	Zanclidae	23	medium
Top 5: 57.5	*Ctenochaetus striatus*	12.83	Acanthuridae	26	medium
Others: 42.5	*Halichoeres hortulanus*	10.30	Labridae	27	medium
	Scolopsis bilineatus	5.94	Nemipteridae	23	medium
2.05	*Zanclus cornutus*	17.01	Zanclidae	23	medium
Similarity: 25.8	*Chaetodon lunulatus*	7.48	Chaetodontidae	14	medium
Top 5: 42.6	*Hemigymnus fasciatus*	6.71	Labridae	80	large
Others: 57.4	*Chaetodontoplus mesoleucus*	6.09	Pomacanthidae	18	medium
	Labrichthys unilineatus	5.27	Labridae	17.5	medium
2.06	*Ctenochaetus striatus*	38.67	Acanthuridae	26	medium
Similarity: 18.7	*Thalassoma hardwicke*	13.10	Labridae	20	medium
Top 5: 77.6	*Chlorurus sordidus*	11.99	Scaridae	40	large
Others: 22.4	*Lutjanus decussatus*	8.58	Lutjanidae	35	large
	Chaetodon citrinellus	5.27	Chaetodontidae	13	medium
2.07	*Choerodon anchorago*	31.69	Labridae	38	large
Similarity: 12.3	*Thalassoma hardwicke*	24.77	Labridae	20	medium
Top 5: 80.0	*Pomacentrus simsiang*	10.24	Pomacentridae	7	small
Others: 20.0	*Siganus unimaculatus*	7.52	Siganidae	20	medium
	Amblyglyphidodon curacao	5.33	Pomacentridae	11	medium
2.08	*Scarus rivulatus*	24.38	Scaridae	40	large
Similarity: 17.6	*Chlorurus sordidus*	20.28	Scaridae	40	large
Top 5: 63.3	*Lutjanus decussatus*	10.05	Lutjanidae	35	large
Others: 36.7	*Hemigymnus melapterus*	4.73	Labridae	90	large
	Chaetodon octofasciatus	3.89	Chaetodontidae	12	medium
2.09	*Thalassoma hardwicke*	24.86	Labridae	20	medium
Similarity: 12.3	*Lutjanus decussatus*	12.78	Lutjanidae	35	large
Top 5: 68.1	*Cheilinus chlorourus*	10.75	Lutjanidae	45	large
Others: 31.9	*Pomacentrus chrysurus*	10.59	Pomacentridae	9	small
	Scolopsis lineatus	9.14	Nemipteridae	23	medium

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
2.10	*Scarus rivulatus*	24.85	Scaridae	40	large
Similarity: 15.6	Choerodon anchorago	18.49	Labridae	38	large
Top 5: 67.3	*Thalassoma hardwicke*	13.17	Labridae	20	medium
Others: 32.7	*Halichoeres melanurus*	6.91	Labridae	12	medium
	Coris batuensis	3.88	Labridae	17	medium
2.11	*Hemiglyphidodon plagiometopon*	27.14	Labridae	18	medium
Similarity: 20.4	*Chaetodontoplus mesoleucus*	15.78	Pomacanthidae	18	medium
Top 5: 72.5	*Scarus rivulatus*	14.19	Scaridae	40	large
Others: 27.5	*Hemigymnus melapterus*	8.20	Labridae	90	large
	Chaetodon octofasciatus	7.15	Chaetodontidae	12	medium
2.12	*Scarus rivulatus*	27.12	Scaridae	40	large
Similarity: 28.4	*Dischistodus prosopotaenia*	22.69	Pomacentridae	17	medium
Top 5: 70.9	*Lutjanus decussatus*	8.91	Lutjanidae	35	large
Others: 29.1	*Halichoeres chloropterus*	6.90	Labridae	19	medium
	Choerodon anchorago	5.24	Labridae	38	large
2.13	*Scarus rivulatus*	32.13	Scaridae	40	large
Similarity: 15.2	*Hemigymnus melapterus*	10.07	Labridae	90	large
Top 5: 61.5	*Choerodon anchorago*	8.92	Labridae	38	large
Others: 38.5	*Scolopsis bilineatus*	5.19	Nemipteridae	23	medium
	Hemiglyphidodon plagiometopon	5.17	Labridae	18	medium
3.01	*Thalassoma lunare*	9.07	Labridae	25	medium
Similarity: 13.2	*Chaetodon baronessa*	7.44	Chaetodontidae	16	medium
Top 5: 63.6	*Zebrasoma scopas*	7.17	Zanclidae	20	medium
Others: 36.4	*Pomacentrus moluccensis*	6.40	Pomacentridae	9	small
	Chaetodon kleinii	6.31	Chaetodontidae	15	medium
3.02	*Chaetodon lunulatus*	22.15	Chaetodontidae	14	medium
Similarity: 19.8	*Chaetodon baronessa*	8.29	Chaetodontidae	16	medium
Top 5: 50.6	*Ctenochaetus striatus*	7.24	Acanthuridae	26	medium
Others: 49.4	*Halichoeres hortulanus*	6.84	Labridae	27	medium
	Thalassoma lunare	6.03	Labridae	25	medium

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % (“Similarity”), the total contributory % of the top 5 dominant species for each municipality (“Top 5”), and the total contributory % of all other species not included in the top 5 (“Others”) (cont’n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.03	*Thalassoma hardwicke*	54.44	Labridae	20	medium
Similarity: 11.7	*Centropyge vroliki*	17.48	Pomacanthidae	12	medium
Top 5: 94.0	*Pomacentrus bankanensis*	11.98	Pomacentridae	9	small
Others: 6.0	*Halichoeres hortulanus*	8.18	Labridae	27	medium
	Bodianus mesothorax	1.94	Labridae	25	medium
3.04	*Ctenochaetus striatus*	17.56	Chaetodontidae	26	medium
Similarity: 18.7	*Thalassoma lunare*	12.39	Lutjanidae	25	medium
Top 5: 55.2	*Chaetodon vagabundus*	10.3	Chaetodontidae	23	medium
Others: 45.8	*Parupeneus multifasciatus*	8.37	Mullidae	35	large
	Zebrasoma scopas	6.60	Acanthuridae	20	medium
3.05	*Thalassoma lunare*	14.11	Scaridae	25	medium
Similarity: 9.9	*Chaetodon baronessa*	8.90	Chaetodontidae	16	medium
Top 5: 46.9	*Plectorhinchus vittatus*	8.56	Haemulidae	72	large
Others: 53.1	*Halichoeres melanurus*	8.48	Labridae	12	medium
	Neoglyphidodon nigroris	6.84	Pomacentridae	13	medium
3.06	*Thalassoma lunare*	53.96	Labridae	25	medium
Similarity: 40.6	*Scolopsis bilineatus*	18.61	Nemipteridae	23	medium
Top 5: 85.9	*Cephalopholis boenak*	5.70	Serranidae	30	medium
Others: 14.1	*Halichoeres melanurus*	3.91	Labridae	12	medium
	Scarus rivulatus	3.70	Scaridae	40	large
3.07	*Labracinus cyclophthalmus*	25.50	Pseudochromidae	20	medium
Similarity: 19.9	*Thalassoma hardwicke*	8.02	Labridae	20	medium
Top 5: 53.7	*Chaetodontoplus mesoleucus*	7.95	Chaetodontidae	18	medium
Others: 46.3	*Halichoeres chloropterus*	6.59	Labridae	19	medium
	Thalassoma lunare	5.64	Labridae	25	medium
3.08	*Chaetodon kleinii*	21.83	Chaetodontidae	15	medium
Similarity: 11.3	*Plectroglyphidodon lacrymatus*	13.36	Chaetodontidae	10	small
Top 5: 64.3	*Dascyllus trimaculatus*	11.14	Chaetodontidae	11	medium
Others: 35.7	*Scarus rivulatus*	10.27	Scaridae	40	large
	Dascyllus reticulatus	7.73	Chaetodontidae	9	small

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.09	*Centropyge vroliki*	17.0	Pomacanthidae	12	medium
Similarity: 11.2	*Thalassoma lunare*	13.44	Labridae	25	medium
Top 5: 63.7	*Chaetodon kleinii*	12.92	Chaetodontidae	15	medium
Others: 36.3	*Dascyllus trimaculatus*	10.52	Pomacentridae	11	medium
	Pomacentrus bankanensis	9.84	Pomacentridae	9	small
3.10	*Balistapus undulatus*	30.72	Balistidae	30	medium
Similarity: 25.5	*Ctenochaetus striatus*	11.77	Chaetodontidae	26	medium
Top 5: 67.5	*Chaetodon baronessa*	9.09	Chaetodontidae	16	medium
Others: 32.5	*Chaetodon lunulatus*	8.32	Chaetodontidae	14	medium
	Zebrasoma scopas	7.59	Acanthuridae	20	medium
3.11	*Thalassoma lunare*	40.76	Labridae	25	medium
Similarity: 16.8	*Halichoeres chloropterus*	13.99	Labridae	19	medium
Top 5: 85.3	*Halichoeres melanurus*	13.64	Labridae	12	medium
Others: 14.7	*Pomacentrus chrysurus*	8.68	Pomacentridae	9	small
	Pomacentrus simsiang	8.23	Pomacentridae	7	small
3.12	*Neoglyphidodon melas*	22.17	Pomacentridae	18	medium
Similarity: 19.1	*Chlorurus sordidus*	14.38	Scaridae	40	large
Top 5: 57.4	*Scarus quoyi*	8.25	Scaridae	40	large
Others: 42.6	*Scarus dimidiatus*	6.36	Scaridae	40	large
	Chaetodontoplus mesoleucus	6.21	Pomacanthidae	18	medium
3.13	*Thalassoma lunare*	29.49	Labridae	25	medium
Similarity: 43.1	*Parupeneus multifasciatus*	10.86	Mullidae	35	large
Top 5: 66.7	*Scolopsis bilineatus*	9.96	Nemipteridae	23	medium
Others: 33.3	*Chaetodon baronessa*	8.56	Chaetodontidae	16	medium
	Centropyge vroliki	7.81	Pomacanthidae	12	medium
3.14	*Thalassoma hardwicke*	17.82	Labridae	20	medium
Similarity: 13.4	*Scarus niger*	9.63	Scaridae	40	large
Top 5: 48.7	*Acanthurus lineatus*	7.72	Acanthuridae	38	large
Others: 51.3	*Chlorurus sordidus*	7.51	Scaridae	40	large
	Melichthys vidua	6.06	Balistidae	40	large

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
3.15	*Ctenochaetus striatus*	27.04	Acanthuridae	26	medium
Similarity: 24.2	*Chaetodon kleinii*	13.11	Chaetodontidae	15	medium
Top 5: 63.5	*Thalassoma lunare*	10.32	Labridae	25	medium
Others: 36.5	*Dascyllus trimaculatus*	6.74	Pomacentridae	11	medium
	Scarus rivulatus	6.31	Scaridae	40	large
3.16	*Pygoplites diacanthus*	20.12	Pomacanthidae	25	medium
Similarity: 13.1	*Chlorurus bleekeri*	13.20	Scaridae	49	large
Top 5: 63.5	*Chlorurus sordidus*	12.29	Scaridae	40	large
Others: 36.5	*Platax boersii*	10.82	Ephippidae	40	large
	Hemigymnus fasciatus	7.05	Labridae	80	large
4.01	*Ctenochaetus striatus*	35.59	Acanthuridae	26	medium
Similarity: 19.9	*Acanthurus lineatus*	13.87	Acanthuridae	38	large
Top 5: 67.3	*Thalassoma hardwicke*	10.03	Labridae	20	medium
Others: 32.7	*Parupeneus multifasciatus*	4.61	Mullidae	35	large
	Chaetodon vagabundus	3.25	Chaetodontidae	23	medium
4.02	*Acanthurus lineatus*	22.18	Acanthuridae	38	large
Similarity:14.6	*Ctenochaetus striatus*	12.58	Acanthuridae	26	medium
Top 5: 61.6	*Epinephelus merra*	10.70	Serranidae	31	large
Others: 38.4	*Halichoeres hortulanus*	8.09	Labridae	27	medium
	Chaetodon baronessa	8.02	Chaetodontidae	16	medium
4.03	*Plectorhinchus chaetodonoides*	12.89	Haemulidae	72	large
Similarity:13.0	*Hemiglyphidodon plagiometopon*	9.65	Pomacentridae	18	medium
Top 5: 44.3	*Dischistodus prosopotaenia*	7.69	Pomacentridae	17	medium
Others: 55.7	*Acanthurus auranticavus*	7.38	Acanthuridae	35	large
	Pentapodus bifasciatus	6.72	Nemipteridae	18	medium
4.04	*Ctenochaetus striatus*	15.95	Acanthuridae	26	medium
Similarity:18.0	*Thalassoma hardwicke*	11.24	Labridae	20	medium
Top 5: 44.0	*Thalassoma lunare*	6.69	Labridae	25	medium
Others: 56.0	*Chlorurus sordidus*	5.87	Scaridae	40	large
	Lutjanus decussatus	4.29	Lutjanidae	35	large

Appendix 3B

Table showing the top 5 dominant species in terms of biomass, based on Bray-Curtis SIMPER analysis within municipalities, for each municipality, arranged from north to south of the Philippines. Names of each municipality and biogeographic region can be found in Appendix 1. Also shown are the average within-municipality similarity % ("Similarity"), the total contributory % of the top 5 dominant species for each municipality ("Top 5"), and the total contributory % of all other species not included in the top 5 ("Others") (cont'n.)

Municipality Code	Species	Contributory %	Family	Max TL (cm)	Body Size
4.05	*Ctenochaetus striatus*	30.01	Acanthuridae	26	medium
Similarity:13.1	*Chaetodon lunulatus*	12.9	Chaetodontidae	14	medium
Top 5: 59.1	*Zebrasoma scopas*	6.64	Acanthuridae	20	medium
Others: 40.9	*Balistapus undulatus*	5.85	Balistidae	30	medium
	Pomacentrus moluccensis	3.74	Pomacentridae	9	small
4.06	*Ctenochaetus striatus*	49.75	Acanthuridae	26	medium
Similarity:18.2	*Scolopsis bilineatus*	19.54	Nemipteridae	23	medium
Top 5: 89.0	*Chaetodon kleinii*	8.7	Chaetodontidae	15	medium
Others: 11.0	*Thalassoma lunare*	7.24	Labridae	25	medium
	Centropyge bicolor	3.72	Pomacanthidae	15	medium
5.01	*Pomacentrus chrysurus*	17.35	Pomacentridae	9	small
Similarity:15.7	*Pomacentrus moluccensis*	16.27	Pomacentridae	9	small
Top 5: 64.9	*Thalassoma lunare*	11.6	Labridae	25	medium
Others: 35.1	*Neoglyphidodon nigroris*	10.22	Pomacentridae	13	medium
	Chaetodon octofasciatus	9.49	Chaetodontidae	12	medium
5.02	*Balistapus undulatus*	15.29	Balistidae	30	medium
Similarity:20.9	*Ctenochaetus striatus*	12.64	Chaetodontidae	26	medium
Top 5: 43.7	*Thalassoma hardwicke*	6.5	Labridae	20	medium
Others: 56.3	*Parupeneus multifasciatus*	4.79	Mullidae	35	large
	Naso lituratus	4.52	Acanthuridae	46	large
6.01	*Chlorurus sordidus*	55.2	Scaridae	40	large
Similarity:28.7	*Thalassoma lunare*	22.12	Labridae	25	medium
Top 5: 95.6	*Ctenochaetus striatus*	11.16	Acanthuridae	26	medium
Others: 4.4	*Cephalopholis argus*	5	Serranidae	60	large
	Chaetodon octofasciatus	2.17	Chaetodontidae	12	medium
6.02	*Ctenochaetus striatus*	37.91	Acanthuridae	26	medium
Similarity:22.3	*Balistapus undulatus*	6.7	Balistidae	30	medium
Top 5: 60.4	*Thalassoma hardwicke*	5.67	Labridae	20	medium
Others: 39.6	*Plectroglyphidodon dickii*	5.38	Pomacentridae	11	medium
	Plectroglyphidodon lacrymatus	4.74	Pomacentridae	10	small
6.03	*Ctenochaetus striatus*	22.99	Acanthuridae	26	medium
Similarity: 29.0	*Balistapus undulatus*	12.09	Balistidae	30	medium
Top 5: 56.6	*Parupeneus multifasciatus*	8.28	Mullidae	35	large
Others: 43.4	*Zanclus cornutus*	7.16	Zanclidae	23	medium
	Thalassoma hardwicke	6.07	Labridae	20	medium