Incorporating Local Harvester Knowledge to Assess Vulnerability in the Aquarium Trade

Emily Malsack

Lancaster University

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A thesis submitted for the degree of MSc Environmental Science (by research)

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Lancaster Environment Centre, Lancaster University, United Kingdom

Supervisors

Dr. Jacob Phelps (Lancaster University)

Dr. Christina Hicks (Lancaster University)

Co-supervisor

Dr. Joanna Murray (CEFAS)

Lancaster, England

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Declaration

I herewith declare that this work has been originally produced by myself for the present thesis, and it has not been previously presented to obtain a degree in any form. Collaboration with other researchers, as well as publications or submissions for publication are properly acknowledged throughout the document.

Emily Malsack,
Lancaster, England, December 2017.

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Abstract

The aquarium fishery in Calatagan, Batangas is one of many that participate in the global enterprise. This study looked at the aquarium trade from a ground-scale and personal perspective. A mixed methods approach was used to incorporate both literature and fishers' knowledge to determine the sustainability of this particular fishery. Over 180 species of fish (97,635 individuals) were identified as being collected for the aquarium trade from 2013-July 2017 due to fishers' receipts. One species, the fire dartfish (*Nemateleotris magnifica),* comprised 41.3% of the total number of fish collected. Twenty of these species underwent a productivity susceptibility analysis (PSA) to determine their vulnerability to being locally overharvested using life history traits. Out of the twenty species selected for analysis, 18 were categorized as least vulnerable and two species, the zebra lionfish *(Dendrochirus zebra)* and palette surgeonfish *(Paracanthurus hepatus),* were categorized as moderately vulnerable. While the fish collected for the trade do not appear highly vulnerable, the aquarium fishers themselves seem to be. Aquarium fishers need to contend with monsoons, local conflicts, and even long distances in order to provide for their families. According to the fishers, the fire dartfish, the most heavily collected species, cannot be found anywhere in Calatagan and so they must travel to nearby islands such as Mindoro. In spite of using greater exertion to collect, 100% of aquarium fishers stated that they enjoy their job. However, 76.7% of fishers said they would discourage younger people from entering the aquarium trade, primarily because of the difficulty associated with it. The aquarium trade in Calatagan is a family enterprise. Fishers learn how to fish from family members both in Calatagan and other areas of the Philippines. Recruitment of younger fishers for the trade appears to be declining, as most fishers are over 40 years old. Therefore, the future of this livelihood is questionable. Results from this study not only have direct applications for local policy-makers, but also identify sizeable gaps in the aquarium trade at the global scale.

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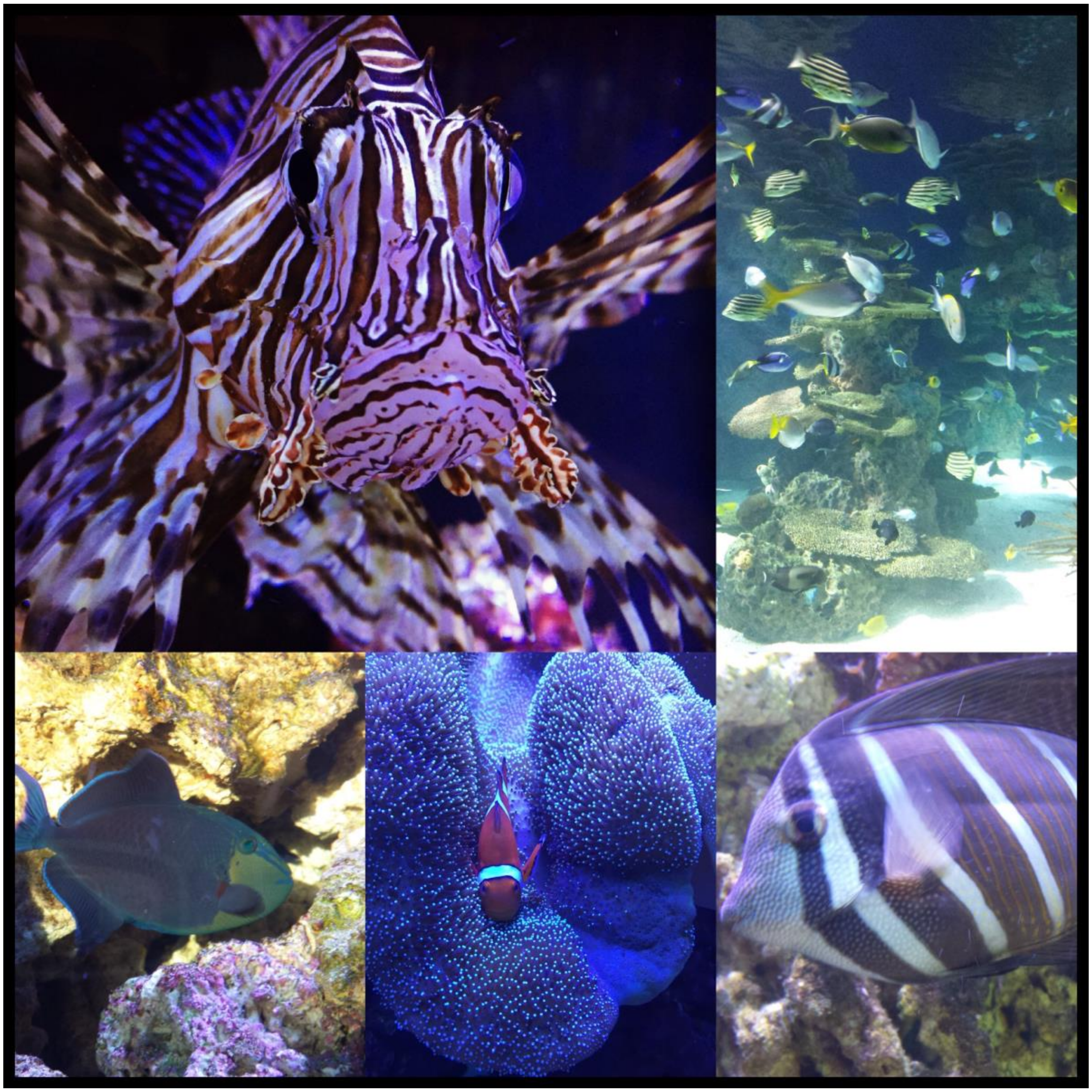
1 Introduction to the Aquarium Trade



Introduction

The international wildlife trade is comprised of numerous species of flora and fauna for a multitude of reasons including food, pets, medicine, fashion, display, household items, and industrial resins and extracts (TRAFFIC 2008). It is a multi-million dollar industry, with the vast majority of trade invested in fisheries and timber products (TRAFFIC 2008). While many studies have focused on wild-caught fisheries for food, the marine aquarium fish trade is less well known. The harvest and trade of marine fish for the aquarium trade is thought to have originated on a small scale in Sri Lanka in the 1930s (Wabnitz et al. 2003). In the 1950s, shortly after World War I, the trade expanded to other places such as Hawaii and the Philippines (Wood 2001). Approximately 99% of all imported marine fish and invertebrates are for hobbyists, while the other 1% is for public aquariums (Ochavillo et al. 2004).

The marine aquarium fish trade has expanded significantly within the last few decades. From 2000-2011 global exports of aquarium fish rose from $177.7 million to $364.9 million, then somewhat decreasing in 2014 to $347.5 million (Dey 2016). The trade operates in more than 125 countries, primarily throughout the tropics in Southeast Asia (Wabnitz et al. 2003; Dey 2016; Leal et al. 2016). Currently, the top exporting countries of the aquarium trade are the Philippines, Indonesia, Malaysia, Sri Lanka, and the Solomon Islands (Wabnitz et al. 2003; Rhyne et al. 2015; Leal et al. 2016). The top importing countries are the United States, the United Kingdom, Japan, the Netherlands, France, and Germany (Wabnitz et al. 2003; Rhyne et al. 2015; Leal et al. 2016). Although only a few aquarium species are harvested for other purposes, such as food fisheries, there are several other problems associated with the trade, making it controversial among conservationists (Best 2000; Friedlander 2001; Moore 2001; Best 2002; Inskipp 2003). Damaging harvest techniques such as sodium cyanide and quinaldine, over-harvesting of particular species, and poor handling and shipping protocols raise concern. In addition, unlike freshwater aquaria species, most marine aquaria species are harvested directly from the reef instead of mariculture (Andrews 1990; Dey 2016). On the other hand, the trade can provide jobs to poor, coastal communities and inspire a greater interest in coral reef conservation and education if managed sustainably (Wabnitz et al. 2003; Dey 2016).

In the Philippines, there were approximately 2,500 collectors for the aquarium trade in the 1990s, and more currently there are about 41 exporting companies of aquarium species (Wood 2001; BFAR 2010).

This review will consider existing knowledge on the marine fish species targeted for the trade; problems with current trade data used to monitor this trade, and the need for more bottom-up, species-level data collection. It then considers different methods for assessing species' vulnerability, including the use of local harvester knowledge, and the use of participatory mapping methods to understand local harvest patterns and how these are related to fishery sustainability. It focuses on the Philippine context, as a significant global exporter of wild fish for the aquarium trade (Wabnitz et al. 2003; Rhyne et al. 2015) and as the site of this study (Calatagan, Philippines).

Targeted Species

Based on the Global Marine Aquarium Database (GMAD), approximately 1800 species (30 million individuals) of tropical marine fish are traded annually; however, most species are within five or six families (Wabnitz et al. 2003; Thornhill 2012; Leal et al. 2016). Damselfish (Pomacentridae), wrasses (Labridae), gobies (Gobiidae), angelfish (Pomacanthidae), surgeonfish (Acanthuridae), and other fish such as butterflyfish (Chaetonidae) are the most commonly traded fish (Wabnitz et al. 2003; Rhyne et al. 2012; Rhyne et al. 2015). The most traded species both worldwide and from the Philippines are the blue-green chromis (*Chromis viridis),* sapphire devil (*Chrysiptera cyanea),* threespot dascyllus (*Dascyllus trimaculatus),* goldtail demoiselle *(Chrysiptera parasema)*, whitetail dascyllus (*Dascyllus aruanus),* and the clownfish (*Amphiprion ocellaris)* (Wabnitz et al. 2003; Rhyne et al. 2012; Rhyne et al. 2015). The trade is very selective and can produce high prices for rare species, species of a particular sex or size, and unusual color forms (Sadovy et al. 2001; Wood 2001; Sadovy and Vincent 2002).

Rabinowitz (1981) asserted that geographic range, habitat specificity, and local population size are attributes that can help classify different forms of rarity. A species with a wide geographic range and narrow habitat specificity is a different form of rarity than a species with a narrow geographic range and wide habitat specificity. For example, the International Union for Conservation of Nature (IUCN) Red List is widely recognized as the premier database for classifying species according to their risk of extinction (Rodrigues et al. 2006). The IUCN categorizes species based on criteria at the global level, rather than the national or local level. This means that a species may be listed as lower risk globally, but may in fact be critically endangered for a particular region. On the other hand, a species may be listed as vulnerable at the global level, but have stable populations at the regional or national level. As a result, studies performed at the regional or local level are also important when evaluating a species' vulnerability. Another point to consider regarding a species' IUCN status is the status itself. Some scientists involved in the wildlife trade believe that categorizing a species as vulnerable or endangered represents proof that a species is rare and therefore more valuable (Courchamp et al. 2006). Thus, labeling a species as vulnerable as a precaution may in fact make it more desirable and therefore more vulnerable to overexploitation (Courchamp et al. 2006). Thus the term 'rare' is dependent on multiple factors and manifests itself in different ways, thereby affecting species' vulnerability.

In order for the IUCN to classify a species into a particular risk category, there needs to be data to support that categorization. If there is limited data regarding a species' distribution and/or population status to perform an assessment, the species is labeled as data deficient (Mace et al. 2008; IUCN 2017). However, just because a species is data deficient does not mean that it is not threatened. There have been increasing studies on trying to re-evaluate both terrestrial and marine data deficient species' risks of extinction (Luiz et al. 2016). Because data deficient species often lack basic life history traits, it makes them harder to generate extinction risk models. This is especially true for marine species because they are significantly less well studied than terrestrial and freshwater species (Webb and Mindel 2015). In fact, there are twice as many marine species listed as data deficient than non-marine species (Webb and Mindel 2015). This is a prevalent issue with the tropical marine fish being traded for aquaria. Furthermore, marine species make up less than 10% of the 34,000 species protected under Convention on International Trade in Endangered Species (CITES) (McClenachan et al. 2012). CITES is an international treaty between governments that aims to protect endangered species of plants and animals from being over-traded, thereby promoting sustainable trade (CITES 2017). Problems associated with aquarium trade regulation in regards to CITES and other organizations will be discussed in depth in the following section.

Inaccurate Trade Data

Many species in wildlife trade are regulated internationally by CITES. However, the majority of marine fish species in the aquarium trade are not regulated by CITES. The humphead wrasse (*Cheilinus undulatus*), clarion angelfish (*Holacanthus clarionensis*), and pipefishes and seahorses (*Hippocampus spp.)* are the only aquarium species regulated by CITES under Appendix II (CITES 2017). Appendix II lists species that are not necessarily immediately threatened, but may become threatened if trade is not controlled (CITES 2017). As well as CITES, national governments often calculate statistics regarding the export and import of marine fish through customs or other trade officials (Wabnitz et al. 2003). However, there is oftentimes a discrepancy between traded numbers that are reported and actual exports due to differences in units recorded (kilograms vs. specimens) (Wood 2001; Rhyne et al. 2012). Exports and imports are generally registered through customs by weight or value rather than number of specimens, with import values remaining higher than export values because of the added costs of packing and shipping (Wood 2001; Rhyne et al. 2012). Only the work of Rhyne et al. (2012) has looked at shipment declarations and commercial invoices to try and determine the number of individuals and species traded. However, this was only performed for research purposes and this method is yet to be officially implemented. When weight is the unit registered, the weight includes packaging and water weight in addition to the weight of the fish, thus overestimating the volume of material (Wabnitz et al. 2003; Rhyne et al. 2012). Additionally, some operators either overestimate their quantities for insurance purposes, or underestimate their quantities to reduce tax and remain within the allowed individual quota (Green 2003; Monteiro-Neto et al. 2003). However, some countries, such as Singapore, the Maldives, the Solomon Islands, and Australia have established trade statistics for the number of specimens exported (Wood

2001; Green 2003). Australia even requires that catch data rather than export data is to be registered (Queensland Fisheries Management Authority 1999).

The United States Fish and Wildlife Services created the Law Enforcement Management Information Systems (LEMIS) in an attempt to examine shipments in order to quantify species-specific data according to CITES requirements (Rhyne et al. 2012). For non-CITES-listed species, trade data is often aggregated so that marine fish are combined with freshwater fish and even invertebrates under one code marine ornamental fishes (MATF) in the LEMIS database (Rhyne et al. 2012). Thus, data lacks volume, species diversity, and trade pathways (Smith et al. 2009). Further inaccuracy regarding the aquarium trade, originates from fish rejections. Fish may be rejected prior to exportation due to several reasons including fin or body damage, undersized or oversized, too thin or too fat, not ordered, or death (Militz et al. 2016). Damages may result from harvesting or handling techniques. Fish rejections often go unreported and so the actual number of fish being harvested for the aquarium trade is underestimated. Both the overharvesting of fish as well as rejection of fish by buyers are known problems in the Philippines (Marine Aquarium Council 2006).

Although there are several challenges to accessing and compiling accurate trade data, within the Philippines there is potentially a relatively simple source of improved, potentially species-specific trade data. In some places, such as Calatagan, fishers are given receipts after selling to a middleman or exporter, showing the quantity of each species sold, species' names, and prices per fish. Thus a collection of fishers' receipts could more accurately show how many of which species are being collected and sold for the aquarium trade at the local level. The aquarium trade is an international business; however, harvesting usually takes place within small fishing communities. Therefore, examining the trade from the bottom up will provide better indicators of species' populations relative to the numbers in which they are being traded. Additionally, studies can then begin to assess species' vulnerability and risk of extinction to help fill in some of the gaps that currently exist in CITES and the IUCN.

Defining and Assessing Vulnerability

Coral reefs have lower levels of net productivity and biomass compared to other marine ecosystems. This means that harvesting large amounts of fish could have significant impacts on coral reef productivity (Bellwood et al. 2004). Fishing can lead to degradation of benthos both directly through destructive techniques and indirectly by causing trophic cascades (Graham et al. 2011). Species from almost every trophic level are harvested for the aquarium trade, making monitoring extremely difficult (Andrews 1990; Wabnitz et al. 2003; Thornhill 2012). Furthermore, rare species' populations are challenging to assess because the probability of observing them in underwater surveys is low (Dee et al. 2014). Therefore, it is important to examine different species' vulnerability to being overharvested using proxies. Vulnerability can be defined in several ways and assessed via various methods at different scales.

There are multiple ways in which to consider or define vulnerability (Intergovernmental Panel on Climate Change 2001; Allison et al. 2009; Graham et al. 2011; Mamauag et al. 2013; Giakoumi et al. 2015). The definition of vulnerability which will be used in this study, states that vulnerability is the combination of productivity (function of a stock's life-history traits) and susceptibility (degree to which the fishery can negatively affect the stock) (Stobutzki et al. 2001; Patrick et al. 2009). Using these terms then, vulnerability will be defined as the potential for a stock to be reduced by fishing pressure, both directly and indirectly. Direct fishing pressure affects a stock because it physically removes fish from the environment, thus reducing the population level. Indirect fishing pressure may occur through accidental bycatch or habitat degradation. This definition of vulnerability is different from another common definition of vulnerability in that the focus does not rest merely on the productivity of the stock, but rather focuses on the relationship between both productivity and susceptibility (Musick 1999). The definition of vulnerability often used when evaluating a species' risk of extinction focuses on its productivity because it evaluates the probability that the species will recover from a declining population. In this study, however, a species or stock with low productivity would not necessarily be vulnerable to overfishing unless it was also susceptible to the fishery (Patrick et al. 2009).

The aquarium trade presents specific difficulties in regards to assessment and management. Conventional survey methods are difficult to implement in developing countries due to lack of funding, limited institutional capacity, and inadequacy of fishery survey methods to monitor multispecies aquarium fisheries (Fujita et al. 2014). Some species are exploited not only for the aquarium trade, but also other fisheries, making it nearly impossible to determine the aquarium trade's impact alone. In addition, coral reefs are highly threatened due to anthropogenic impacts and climate change. In fact, 88% of reefs in Southeast Asia are at medium to high risk from anthropogenic impacts (Burke et al. 2002). Therefore, it is important that the marine aquarium trade does not compound further pressure on these already vulnerable habitats. All of these factors makes establishing a baseline or reference condition for assessing stock status and informing management tricky. To further complicate the matter, most stock assessments rely on relationships between fish size and age. However, sizes and ages are often not recorded, and some marine fish present asymptomatic age-growth curves (Choat and Robertson 2002; Donaldson 2003). As juveniles are often the preferred targets due to distinctive coloration, ease of maintenance, and size-ratio with respect to tank size (Sadovy and Vincent 2002), they may also skew size and age distributions (Thornhill 2012).

Using the definition of vulnerability as stated above, a productivity susceptibility analysis (PSA) can be performed to estimate the productivity of a stock and its susceptibility to a fishery. The PSA was originally developed by Australia's Commonwealth Scientific Industrial Research Organization (CSIRO) to classify bycatch sustainability for the prawn industry (Patrick et al. 2009; Osio et al. 2015). The PSA uses life history traits that are often available from literature, FishBase database, and local fishers. FishBase is a global information system on fishes that provides a wide range of information on species' taxonomy, trophic ecology, biology, uses, and life history (Froese and Pauly 2017). Life history traits incorporated in the PSA include: population growth rate (r), maximum age, maximum size, von Bertalanffy growth coefficient (k), estimated natural mortality, measured fecundity, breeding strategy, recruitment pattern, age at maturity, and mean trophic level (Patrick et al. 2009). In addition to life history traits, the PSA also considers attributes that would influence susceptibility. These attributes include: management strategy, areal overlap, geographic concentration, vertical overlap, fishing rate relative to M, biomass of spawners, seasonal migrations, behavioral responses, morphology affecting capture, survival after capture and release, value of the fishery, and fishery impact to habitat (Patrick et al. 2009). Catch, effort, age, or size data is not needed for the PSA, although would be highly useful additions if available for the stock under assessment. However, this model is quite flexible in that traits can be added or removed for analysis in order to better reflect the fishery being assessed. For instance, other factors that could be considered in the analysis of the aquarium trade include a species' ability to change sex and its suitability for aquarium life (Roelofs and Silcock 2008).

While the PSA has several benefits, it also has its limitations (Fujita et al. 2014; Osio et al. 2015). The PSA is limited by the fact that the vulnerability score can only prioritize species and inform management as a precautionary measure, it does not produce specific sustainable catch or biomass levels for management to implement (Fujita et al. 2014). For example, species with moderate vulnerability scores could require species-specific quotas and further assessment while species with high vulnerability scores could be only lightly harvested or banned altogether (Fujita et al. 2014). Results could also be used in a precautionary manner to inform importers and consumers to make more informed purchase decisions. Because the PSA relies on a variety of data sources, it includes a data-quality index to incorporate uncertainty into the analysis. Data sources are given a score relating to their overall quality (Fujita et al. 2014). This controls for inflated vulnerability scores due to lack of data. When data is unavailable for a particular species or region, it is acceptable to use data from another species within the same genus or other areas where that species is found (Patrick et al. 2009; Fujita et al. 2014). It may also be given a value that results in the highest vulnerability score as a precaution (Patrick et al. 2009; Osio et al. 2015). Each option produces significantly different results and so it is necessary to justify how these differences affect vulnerability scores.

Assessing the vulnerability of fisheries at the national level has become increasingly popular (Allison et al. 2009). Some research has also been done to assess vulnerability at the coastal community level (Mamauag et al. 2013). For instance, Graham et al. (2011), looked at a species' combined risk of extinction and climate vulnerability at both the global and local level. Giakoumi et al. (2015) assessed vulnerability from an ecosystem-based analysis rather than a species' risk analysis. This study looked at how anthropogenic factors impact various ecosystem components based on food web interactions. Many of the methods for assessing vulnerability are semi-quantitative. Risk assessments have evaluated fisheries' impact on target and bycatch species (Stobutzki et al. 2001), ecosystem viability (Astles et al. 2006), and extinction risk of species (Mace et al. 2008). The PSA is more limited than truly quantitative methods like the Sustainability for Fishing Effects model; however, it is applicable to a greater variety of situations where data is limited (Osio et al. 2015). In addition, due to its flexibility, the PSA can incorporate local harvester knowledge, which is of great value at the community level. Before incorporating harvester knowledge, one must first attempt to understand who harvesters are as well as their motivations for participating in wildlife trade.

Harvester Motivations in Wildlife Trade

Understanding the aquarium fish trade requires an understanding of the social dynamics that shape harvest. However, studies on the motivations of harvesters in the wildlife trade, whether illegal or legal are few, due to the sensitive nature of the topic (Duffy et al. 2015). It is important to understand questions such as why and how harvesters participate in wildlife trade, particularly the illegal wildlife trade (IWT). Many actions in the wildlife trade are illegal and result in penalties such as prison; therefore it is rational to know why harvesters are willing to take the risk. It can also look at benefits harvesters receive from participation in the trade and why they do or do not have other less controversial jobs. All of this information can be used to help policy-makers implement appropriate laws promoting conservation and sustainability. While the aquarium fish trade in the Philippines is legal, it is still governed by rules. Therefore, it has many similarities to the IWT regarding motivation to participation. Many socio-economic factors influence peoples' participation in the wildlife trade including income, harvest opportunities, available livelihoods, and access to wildlife resources (Phelps et al. 2016). Harvester motivations include sustenance, money, the chance to add a rare animal to a collection, or eliminating a pest (TRAFFIC 2008). Harvesting may also be a result of cultural reasons such as the right to use their natural resources. TRAFFIC (2008) looked at a variety of species, both plants and animals, in the wildlife trade in south-east Asia and found that most harvesters surveyed listed the need for income as their primary motivation for harvest, with very few mentioning other reasons such as enjoyment, culture, and pest removal. However, this does not mean that other reasons are not important to some harvesters. TRAFFIC (2008) also reported that harvesting may be planned or opportunistic and occur among individuals as well as in groups.

According to South and Wyatt (2011), harvesters in the illegal wildlife trade may be classified into five different categories based on the frequency in which they partake in trading activities. Trading charities-collectors are involved due to their philosophical or religious ideas. Mutual societies are harvesters who depend on this work and have wealthy consumers who purchase exotic species from them. Business sideliners are those that are in the position to partake in illegal activities, may be in legal trade but take more than necessary to make additional profit. Criminal diversifiers are those harvesters that partake in organized crime to make large profits with little chance of being detected. Finally, there are opportunistic irregulars that occasionally catch an animal and take advantage by making a profit from it (South and Wyatt 2011). Similarly, Marshall et al. (2006) categorized harvesters as ‘safety net’, ‘gap-filling’, or ‘stepping stone’, and TRAFFIC (2008) stated that the IWT supports a variety of actors and provides differing benefits such as a regular source of income, supplementary income, or an advantageous business. Furthermore, Phelps et al. (2016) describes eight categories of harvesters that also explore non-monetary motivations such as enjoyment, bycatch, protest, and rule abuse of legal trades.

Illegal wildlife hunting has often been blamed on poverty because collection supplies harvesters with basic needs (Duffy et al. 2015). Wildlife trade is appealing to people, especially the poor, because it can be technically simple, cheap to participate, provide quick economic gains, and easy access to resources (Neumann and Hirsch 2000). However, it is important to note that wildlife trade may require specialized techniques or equipment. Furthermore, poverty is a dynamic concept and thus defining poverty, especially in a materialistic fashion, is difficult. Materialistic poverty may drive some people to harvest illegally, but trading can only continue if there is a demand for such products from wealthier consumers (Duffy et al. 2015). Poverty is not merely a lack of income, but also a lack of power or prestige (Duffy et al. 2015). A technical solution to reducing illegal hunting and therefore poverty is alternate livelihoods along with disincentives. However, alternative livelihoods oftentimes just become additional livelihoods, whereby harvesters' income increases but collection continues regardless (Roe et al. 2015).

Although harvesters generally receive a severely reduced income for their products compared to those higher up in the trade network, this does not mean that this money is not important to their overall household income (de Beer and McDermott 1996; Belcher and Kusters 2004). There is a high level of variability in which harvester households depend on wildlife trade for income. Where poverty was reduced, people still remained in the trade (TRAFFIC 2008). Therefore it is a mistake to conclude that additional sources of income alone will reduce the wildlife trade. In fact, the most common motivation mentioned for leaving the trade was the decline in species' availability (TRAFFIC 2008). This section discussed actors and their motivations in the IWT. The aquarium fish trade is legal; however, there are still issues of illegal fishing activities and what drives these activities. Aquarium fishers are known to use damaging harvest techniques such as cyanide fishing and hookah compressors, which are illegal in most countries (Halim 2002). Hookah compressors are air hoses attached to a compressor on the boat in which fisherman can breathe oxygen while diving to greater depths (Halim 2002). Oftentimes, these compressors are located near the boat's exhaust vent, leading fishers to inhale air polluted with harmful substances such as carbon monoxide (Halim 2002). This technique is frequently used in conjunction with cyanide. Sodium cyanide and other chemicals are used to stun fish to increase catchability. While the purpose of cyanide is to stun fish, it has additional consequences. Post-capture mortality rates are higher in fish caught with cyanide and may kill non-target species, including corals (Rubec 2001). Therefore, motivations and alternatives to the IWT are also applicable to fishers in the aquarium trade.

Fishers in the Philippines

Fishers (principally referring to harvesters of fish for food) are reported as the poorest of the nine basic sectors in the Philippines (Fishery and Aquaculture Country Profiles: Philippines 2014). Fisher households generally have lower levels of education, less access to basic necessities, and have larger families than the national average (Fishery and Aquaculture Country Profiles: Philippines 2014). Although small-scale fishing is usually associated with the poorest of all people, this has been questioned in several studies (Garaway 2005; Béné 2009; Martin et al. 2013). In one study carried out in the Philippines, Knudsen (2016) points out that while many fishers are poor, fishers who were poorer compared to other fishers were more likely to leave the fishery. Small-scale fishing can be viewed as a backup plan for some because it provides a consistent source of income that can supplement other livelihoods. Poorer fishers are often part-time and have other labor-intensive jobs, while full-time fishers are generally better off.

Poverty and limited alternative livelihoods are the two most popular reasons why small-scale fishers continue to fish in highly exploited habitats (Knudsen 2016). There are not many options besides fishing in the Philippines, particularly in remote rural coastal areas (Muallil et al. 2014). According to Mamauag et al. (2013), alternative livelihood options in the Philippines include seaweed farming, milkfish culture, sea cucumber culture, rice farming, coconut farming-related activities, and short-term labor work such as carpentry, construction, and public transportation services. Other opportunities, such as government livelihood and economic assistance programs are available at the community level in some areas of the Philippines (Muallil et al. 2014). The Department of Science and Technology together with state colleges and universities are developing ways to use and increase the value of raw materials available in local communities. The Department of Trade and Industry provides training for product development, packaging, and marketing. The Department of Agriculture is providing planting materials and livestock to small-scale farms. Furthermore, the Technical, Education and Skills Development Authority (TESDA) is providing skills training to local communities in order to boost employment opportunities. Despite some alternatives to fishing, fishers often vary on their willingness to leave the fishery but Muallil et al. (2014) speculates that younger fishermen are more likely to exit the fishery if provided with alternative livelihoods.

Knudsen (2016) showed that when asked to leave fisheries when other jobs of equal or greater pay are available, fishers often still prefer fishing. Fishing offers other non-economic benefits that appeal to fishers and is viewed as more rewarding than other jobs. Fishing is closely related to fishers' self-worth and identity (Knudsen 2016). It allows them to use their own skills to provide for their families in a close proximity to their community. Aquarium fishers tend to be individuals or small groups of people, often comprised of family members, therefore a cultural aspect may be necessary to consider (Wabnitz et al. 2003). Fishing may be passed down generations and thus could be an important factor in better understanding aquarium fishers. Another method that can easily be applied to understand fishers in the aquarium trade is to look at job satisfaction (Stevenson et al. 2011). Understanding if fishermen would encourage or discourage others to join the fishery, if they would leave the fishery for another job, or are satisfied with their current job, can all begin to paint a clearer picture of local harvesters (Stevenson et al. 2011). Furthermore, it may be beneficial to learn what they like and dislike the most about fishing in the aquarium trade. Perhaps, what they dislike most is that there are fewer fish to be caught, and therefore could lead to better management of the trade with more harvester support. As a result, including fishers' knowledge and opinions is essential when establishing management policies that affect them.

Using Local Fishers' Knowledge to Improve Scientific Knowledge

In the absence of information on trade dynamics and fish vulnerability, fishers themselves can be valuable sources of information. Participatory research approaches and traditional ecological knowledge can and should be integrated into formal scientific research. It is impossible for scientists to study every location of every species in the world (Drew 2005). By using local knowledge, however, they may be able to identify areas of concern or hope.

There are several reasons why fishers' knowledge has been continuously consulted in scientific studies. First, fishers' knowledge is thought to be more locally specific and current than scientific knowledge (Daw et al. 2011). Fishers' knowledge may also go back further in history than other data (Dulvy and Polunin 2004; O'Donnell et al. 2010; Lavides et al. 2016), particularly in coral reef fisheries (Johannes, 1998). Second, they may have a greater understanding of environmental linkages between multiple species and ecological processes (Drew 2005). Third, incorporating participants' knowledge is useful for capacity building and improving management policies (Daw et al. 2011). When locals are treated as partners in a research project, they may be more willing to share their knowledge and take pride in it (Drew 2005). Community involvement in management has been reported to have longer-lasting environmental policies due to more appropriate socio-cultural and environmental needs (Beierle 2002; Koontz and Thomas 2006; Newig 2007). It has also been shown to induce higher rates of compliance and reduce conflicts, while encouraging a sense of ownership (Yates and Schoeman 2013). Furthermore, previous studies have shown that respondents are often quite willing to participate in research studies because it allows them to express their opinions (Yates and Schoeman 2013). Building a rapport with participants prior to and concurrently with any exchange of knowledge is key for success.

However, as with all scientific research, there are potential problems and biases with incorporating participants' knowledge. One such problem lies in scientific and/or common names of fish (Saleem and Islam 2008). While scientific names are more accurate, even they are subject to change due to updated taxonomies. Additionally, most aquarium fishers are not familiar with scientific names. Common names also provide difficulties when describing species, especially regarding the aquarium trade. Oftentimes, common names used in the aquarium trade are not the same as the ones listed in ichthyological field guides (Michael 2001). The same species can also have multiple common names. For example, the palette surgeonfish (*Paracanthurus hepatus)* may also be called the common surgeon, blue hippo tang, Pacific blue tang, regal tang, flagtail surgeonfish, hepatus tang, and most recently 'Dory' (IUCN 2017). Furthermore, aquarium fishers may have local names for fish, which differ from both the names used in field guides as well as in the aquarium trade. Therefore, careful consideration should be given when discussing specific species with fishers and others involved in the aquarium trade to reduce confusion and identification errors.

Comparisons of fishers' knowledge and scientific knowledge can sometimes be contradictory, leading to the debate over the accuracy of fishers' knowledge (O'Donnell et al. 2010). There may be errors in interpretation by the researchers, participants, and translators (if necessary) (Huntington 2000). Therefore, it is critical for researchers to take ample time considering their meanings, and how to clearly express them to others. Multiple factors can affect participants' responses. A practical application of using fishers' knowledge is to help identify local depletions. In a study conducted by Lavides et al. (2016), fishers in the Philippines were asked to identify which species used to be harvested but no longer were and what a good day's catch was in past decades compared to the present. Lavides et al. (2016) also identified several biases associated with relying on fishers' memories. For example, older more experienced participants are more likely to report greater declines (Daw et al. 2011). Shifting baseline syndrome can also produce biases because younger participants may not know past population levels (generational amnesia) or individual participants may forget past abundances (personal amnesia) (Daw et al. 2011). In order to help control for this, data can be categorized according to age ranges or years of experience of participants (Drew 2005)).

Another way in which declines may be overestimated is due to deeper-water fish. Fishers may perceive a greater decline due to their limited ability to catch shallower fish populations. This is known as hyperdepletion and can also be applied to scientific knowledge of population declines. However, this problem has yet to be assessed (O'Donnell et al. 2010). Regardless of potential biases, fishers might be able to detect smaller-scale changes that other data may not reveal. It is important to note that the true or actual abundance of a resource cannot be fully determined by either scientific or local fishers' knowledge (Daw et al. 2011).

Identifying Spatially Important Areas for Fishers

Critical social dynamics relate not only to species identification, but also to the geographic dimensions of harvest. Conflicts over dwindling resources among different stakeholders can lead to debates concerning their management (Lowery and Morse 2013). Unsustainable trade is not only detrimental to wildlife biodiversity, but also local harvesters and communities themselves, as they may depend on these resources and be in competition for them (Ostrom 2008). The use of common pool resources involves interactions between humans and their environment. Common pool resources are resources that benefit groups of people, but may be diminished if each person uses them to pursue his or her own self-interest (Hardin 1968). Therefore, identifying a common pool resource as well as where it is found is crucial for effective management. Spatial mapping is beneficial in that it provides deeper understanding of a place and how a community uses it. It allows participants to identify areas of importance or value, and then explain why these areas are important, creating a more in-depth profile. In this way, participants are able to both indicate and explain the shape, extent, and intensity of mapped areas (Lowery and Morse 2013). Spatial mapping can be carried out both at the individual and group level (Lowery and Morse 2013). For this particular study, spatial mapping will be performed at the group level, thus enabling the sharing of opinions, location re-enforcement, and community bonding.

In order to make relevant management decisions, policy-makers need spatial information on what the resource boundaries are and who is and is not allowed to use it (Ostrom 2008). Forests and fisheries are two common pool resources of particular concern in the present (Ostrom 2008). Therefore, rules and regulations regarding their use need to align with the needs of their stakeholders while also protecting them from overharvest. Moreover, there is often a disjunction between de jure laws and de facto practices, which only fishers will be able to illuminate (Robbins 2000). However, data is often limited regarding the distribution of specific species and the intensity and distribution of fishing. Most catch statistics available from the appropriate government agencies rarely indicate the size and location of the area where the data apply (Licuanan and Gomez 2000). In order to better understand fisheries stock information, researchers have begun to use spatial mapping to include participants' knowledge of areas of importance. Participatory mapping as a research tool has been around for about 30 years (Chambers 2006). Maps are generated by local people's knowledge and can display people and their characteristics (social or census), resources (land, trees, water), and where people travel for services (mobility) (Chambers 2008). In the marine environment, participatory mapping has already recorded fishing ground locations and distributions of both habitats and species, including key spawning grounds (Moreno-baez et al. 2010).

Data derived from participatory mapping can inform marine spatial planning, which is becoming increasingly important to designate marine protected areas and other forms of marine resource management. Fishermen are one of the largest stakeholder groups that are likely to be negatively impacted by spatial boundaries in coastal communities. Therefore it is essential that they are consulted in the management planning process to identify places of importance to them. Fishers have some of the most intimate knowledge of marine habitats and are likely to be privy to trends or details that have been overlooked or are unknown, such as the local distribution of fish species. Fishers' extensive knowledge has become increasingly documented in fisheries studies (Thornton and Scheer 2012; Silvano and Valbo-Jorgensen 2008; Yates and Schoeman 2013). Stakeholder involvement has also been found to result in better quality and longer-lasting environmental policies due to more appropriate socio-cultural and environmental needs (Beierle 2002; Koontz and Thomas 2006; Newig 2007). It has been shown to induce higher rates of compliance and reduce conflicts, while encouraging a sense of ownership (Yates and Schoeman 2013). Furthermore, previous studies have shown that fishers are often quite willing to participate in spatial mapping because it allows them to express their opinions (Yates and Schoeman 2013).

In addition to identifying which areas are of importance to fishers, it is also necessary to find out why specific areas are important to them. Yates and Schoeman (2013) did not explore fishers' reasoning behind chosen areas, but suggested that it would be beneficial to expand and discover fishers' motivations and reasoning behind selections. For instance, they may prefer areas closer to home because they are less expensive to travel to allowing them to stay more connected with family and friends, or they may prefer certain areas because they are the best places to catch the highest quantity of fish or most expensive species. Furthermore, there may be different rules, both formal and informal, that may apply to the use of different areas. For instance, fishers may have their own social norms that they follow even though they are not established by the government, such as who fishes where and when. This information would be relevant to governmental and environmental trajectories to help ensure that the aquarium trade is sustainable.

Conclusion

The wildlife trade has been the focus of many studies over the years; however, few studies have focused on the aquarium fish trade. The trade lacks accurate quantitative data regarding the quantity of each species being collected and most species collected specifically in the Philippines are listed as data deficient according to IUCN. However, this does not mean that these species are not vulnerable to overexploitation. In addition, there is little to no information regarding local harvesters and their motivations to participate in the aquarium trade, only generalizations applicable to harvesters in other fisheries. While including fishers' knowledge in research has increased, it is still a relatively new concept. Past studies have focused merely on spatial areas of importance to harvesters, but not on why these areas are important or if these places have changed over time.

In 2014, Dr. Joanna Murray from Centre for Environment Fisheries and Aquaculture (CEFAS) began working together with a marine conservation NGO, Community Centred Conservation Philippines (C3) to consider strategies for building more sustainable harvest and trade regimes. They quickly realized that aquarium trade dynamics are poorly understood, limiting their ability to propose viable interventions. They then joined with Lancaster Environment Centre in recruiting research students to provide solid ground-level data to inform future conservation actions. This project has several goals that it aims to accomplish using a mixed methods approach:

1. To identify which marine fish species are being collected for the aquarium trade in Calatagan, Philippines.

2. To gain a better understanding of the socio-economic profiles of local fishers as well as what drives them to partake in the aquarium trade.
3. To incorporate knowledge of local fishers in order to assess the relative vulnerability of species to being overharvested along with recognizing important places of harvest.
4. To provide this data to the local community and government to inform future decision making regarding the marine aquarium trade.

2 Methods

Introduction

This chapter describes the highly participatory mixed methods approach that was used in this study. Fishers' receipts, a vulnerability assessment, focus groups, and personal interviews were incorporated to provide both quantitative and qualitative data pertaining to the aquarium trade in Calatagan, Batangas. The methods explained in this section were used to examine both the fish and fishers involved in this global trade at the local level. As a result, these methods are very site and study specific. This chapter will also provide justifications for why particular methods were chosen.

Ethical Considerations

This study was approved by the Faculty of Science and Technology Research Ethics Committee (FSTREC) at Lancaster University. Both the researchers and C3 Philippines had conducted personal interviews before and were familiar with the ethical implications and appropriate behavior. The voluntary nature of participation was stressed to respondents to ensure there was no pressure to participate. Consent was gained orally, using an introductory participant information sheet, which clearly informed the participants that by completing interviews they were providing consent for the use of the data for research. This was provided in hard copy and read to respondents, many of whom were illiterate. Along with participant confidentiality/anonymity and consent, several other aspects were also taken into consideration.

There are power imbalances throughout the trade network. Therefore, focus groups consisted entirely of fishers, maintaining trade-level equality. Researchers lived within the community for the duration of fieldwork, reducing their appearance as more distant and unfamiliar persons, making them more approachable and participation less uncomfortable. Because C3 is a non-governmental organization (NGO) focused on conservation, we had to be aware of how this might affect our relationships with the fishermen. It was prudent that the fishermen did not think we disapproved of their livelihood or have negative associations with NGOs that might affect their attitudes towards this research. The programme coordinator of C3 Philippines already had existing relationships with some of the fishermen in Calatagan prior to this study, which in fact led to a more positive introduction to the community. In addition, we as researchers, clarified that this study was for our university thesis and that the involvement of C3 was primarily for translation and logistics. Therefore, any perceived disadvantages of being associated with an NGO were mitigated.

Introductions to Aquarium Fishing Communities

C3 Philippines provided logistical as well as field support for this study. One staff member remained present throughout the duration of fieldwork and served as a translator as most of the fishers could speak little to no English. This staff member was employed by C3 for three years and serves as a programme officer, with previous experience in leading community projects in the Philippines. Therefore, the staff member was familiar with Filipino culture and language as well as a knowledge of proper research methodologies and protocols, making her a competent and invaluable research partner. C3 also made sure that we were properly introduced into the community and were granted all of the necessary permissions from the local government prior to the research being conducted. In the Philippines, there are different levels of government from the national level down to the barangay level. Therefore, it was necessary to meet and gain permissions from both the mayor and local government unit (LGU) of Calatagan as well as the barangay captains of Barangay Santa Ana and Barangay 1 prior to research conduction in May 2017. In addition, we met with the Calatagan police chief to notify him of our presence in the community. After the proper protocols were performed, we were introduced to some of the aquarium fishers in Barangay Santa Ana. Observations of both fish collection and fish packaging took place before interviews so that the fishermen could become used to us in a more relaxed setting. After meeting the majority of fishers in Santa Ana, we were introduced to the aquarium fishers in Barangay 1 where observations also took place prior to more formal research methods.

Methods

Study Site

The Philippines is the largest exporter of marine aquarium fish in the world. It is located within the Coral Triangle in the Indo-Pacific and thus a center of marine biodiversity. Calatagan, Batangas (13.8646° N, 120.6315° E) on the island of Luzon was the site of this study from May to July 2017 (Figure 1.1). Calatagan is a peninsula between the South China Sea and Balayan Bay. It is approximately three hours south of Manila and consists of 25 barangays (villages). Within Calatagan, there are two major barangays that take part in aquarium fish collection: Barangay Santa Ana and Barangay 1, which are approximately eight kilometers apart. Barangay 1, otherwise known as Poblacion Uno, is one of four barangays in Calatagan that were given the name of Poblacion (meaning town) and serve as commercial or industrial centers of the municipality (Province: Batangas 2016). The study site is also within a priority area for C3 Philippines, who have local contacts and partnerships in place that facilitated working with both the communities and the local government. Initial scoping in 2014 showed that both aquarium fishers and the local government were interested in participating in a study to better understand the aquarium trade in Calatagan. Both fish collection and fish packaging occur in these two barangays and so observations as well as other research methods were carried out there.

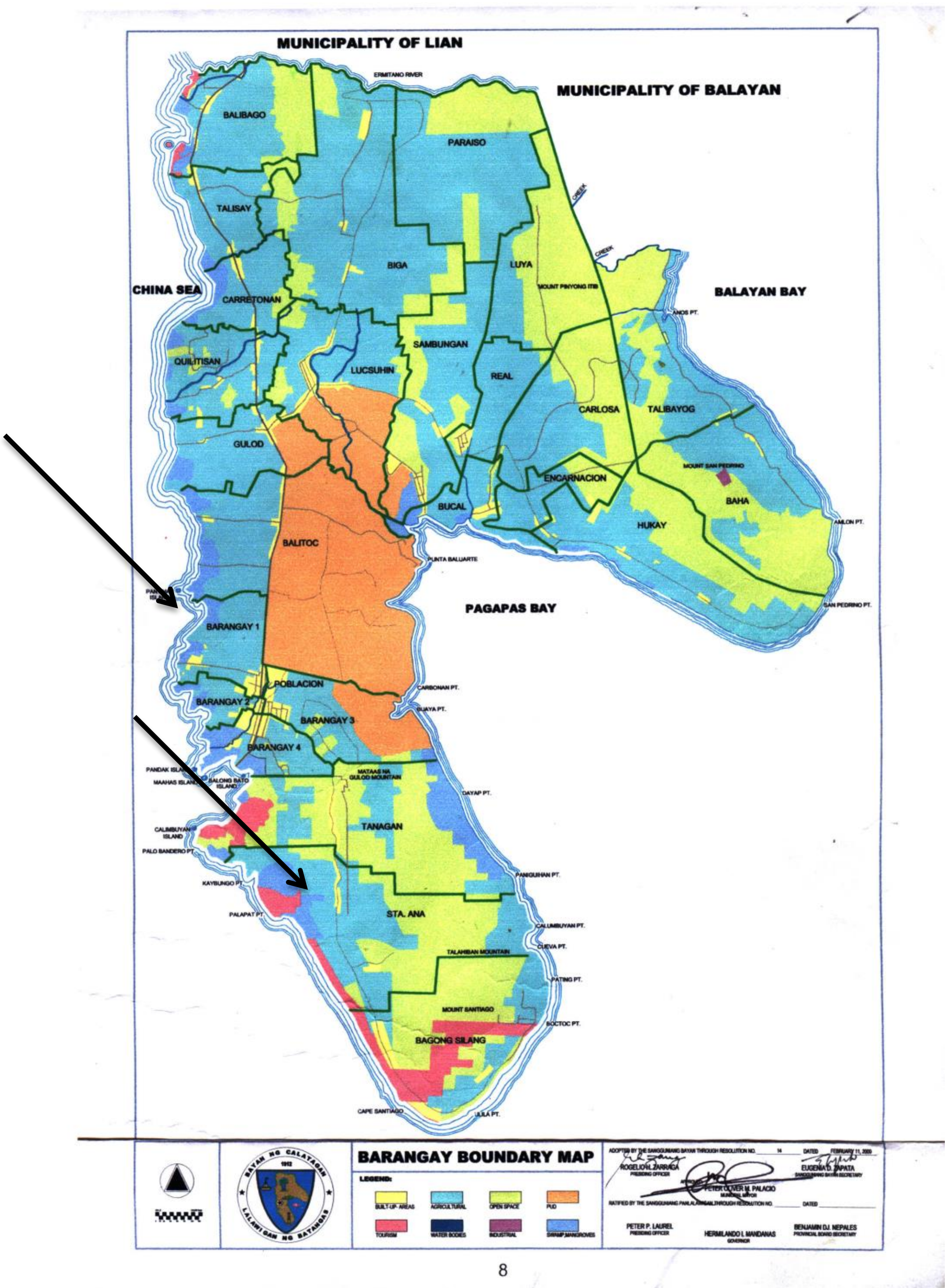


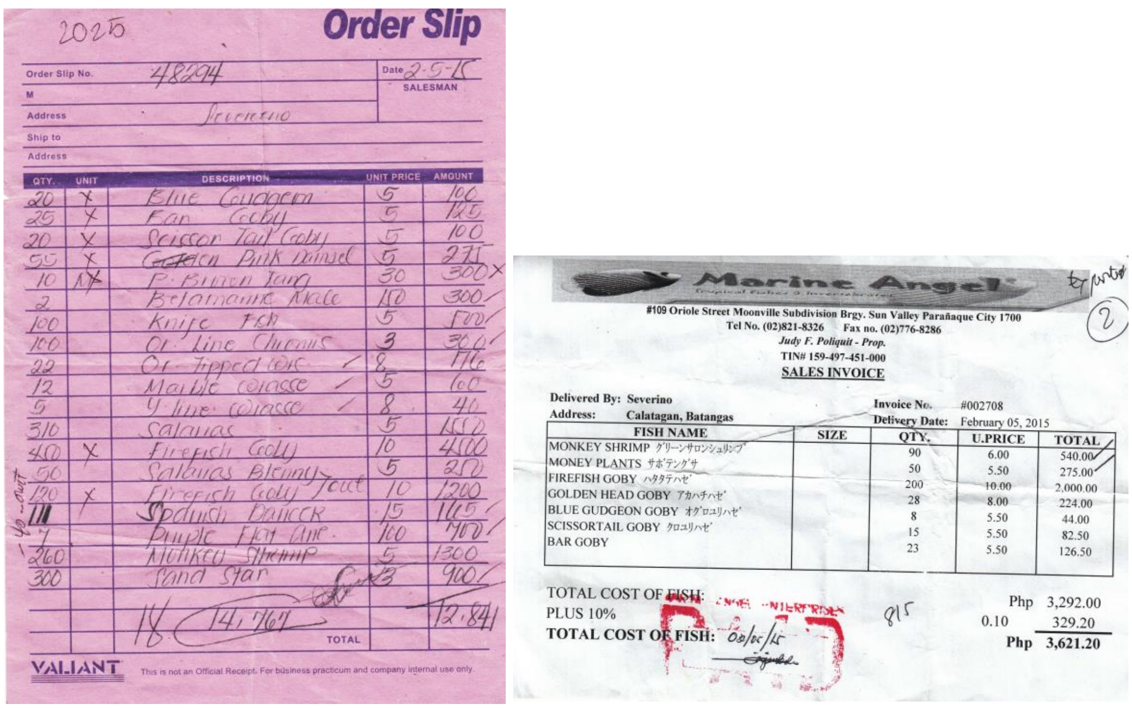
Figure 1.1 Barangay boundary map of Calatagan showing locations of Barangay 1 (top arrow) and Santa Ana (bottom arrow). Image designed by C2LK Internet Solutions Copyright © 2016 from <http://calatagan.gov.ph/clup-maps/>.

Receipt Collection

Receipts are given to byaheros (intermediaries) by exporters, after they transfer the fish to the exporters in Manila approximately once a week. Receipts are either hand-written or typed and show the common names of species, quantity, and price per fish transacted (Figure 1.2). It is necessary to note that several species of invertebrates are also collected for the aquarium fish trade in Calatagan and are therefore included on receipts; but were beyond the scope of this study.

In order to compile a historical species list of aquarium fish traded from the municipality of Calatagan, receipts were collected from byaheros. Receipts were collected opportunistically from 15 byaheros, which is the total number of byaheros in Calatagan. This was opportunistic, based on availability, as not all byaheros keep their receipts long term. A total of 255 receipts dating from 2013 to July 2017 were collected between May-July 2017 and data was entered into an Excel spreadsheet. Byaheros responsible for larger volumes of fish provided more receipts than those responsible for fewer fish. For example, some fishermen also serve as byaheros for themselves and so their receipts only represent the fish that they catch as individuals. The majority of fishers; however, give their fish to one of two main byaheros. These byaheros have more extensive receipts, which represent fish collected from many fishers in Calatagan. Therefore, the majority of receipts collected were from the two main byaheros, and thus represents the majority of species caught. Species' receipts showed the local common names of species and were identified using fish guides and discussions with key informants (Michael 2001; Allen et al. 2015). If fishers' identification contradicted accepted scientific taxonomy, scientific knowledge was given higher merit. In some cases, local names were similar or identical to a species' common name and were easy to identify, other names could only be determined by the fishers. Additionally, some fishers had different or multiple local names for the same species. For example, the jeweled blenny (*Salarias fasciatus)* was called salarias, salarias goby, salarias blenny, or paog depending on the fisher. Prior to discussions with fishers, as many names as possible were identified on receipts in order to streamline the process. A list of all names present on receipts was then prepared, including the ones with high certainty, and were then verified with the fishers using regional fish guides. Species with high certainty were verified quickly, while other species were initially difficult to identify with fish guides. In these instances, live individuals were examined during fish packaging and later confirmed by both the fishers and fish guides.

On some receipts, fish are categorized as ordinary/assorted (e.g., assorted wrasse, ordinary goby, etc.) When asked which species fall into these categories, fishers gave very different answers, making it impossible to determine. An exporter was then consulted to determine what these categories were comprised of. The exporter's response was that assorted/ordinary means that there are one or two different species that are either very rarely or commonly brought in and so they do not list the names on the receipts. Therefore, only fish families were recorded for these categories.


2025

Order Slip

Order Slip No. 48294 — Date 2-5-15

M

SALESMAN

Address Severino

Ship to

Address

QTY.	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
20	X	Blue Gudgeon	5	100
25	X	Fan Goby	5	125
20	X	Scissor Tail Goby	5	100
55	X	Golden Pink Damsel	5	275
10	NX	P. Brown Tang	30	300 X
2		Belamaine Male	150	300
100		Knife Fish	5	500
100		Or. Line Chromis	3	300
22		Or. Tipped Wrasse	8	176
12		Marble Wrasse	5	60
5		Y-line Wrasse	8	40
310		Salaguas	5	1550
40	X	Firefish Goby	10	400
50		Salaguas Blenny	5	250
120	X	Firefish Goby Toutt	10	1200
11		Spanish Dancer	15	165
7		Purple Flat Ane.	100	700
260		Monkey Shrimp	5	1300
300		Sand Star	3	900
		18 14,767		12,841
		TOTAL		

VALIANT — This is not an Official Receipt. For business practicum and company internal use only.

Marine Angel

#109 Oriole Street Moonville Subdivision Brgy. Sun Valley Parañaque City 1700

Tel No. (02)821-8326 Fax no. (02)776-8286

Judy F. Poliquit - Prop.

TIN# 159-497-451-000

SALES INVOICE

Delivered By: Severino — **Invoice No.** #002708

Address: Calatagan, Batangas — **Delivery Date:** February 05, 2015

FISH NAME	SIZE	QTY.	U.PRICE	TOTAL
MONKEY SHRIMP グリーンサロンシュリンプ		90	6.00	540.00
MONEY PLANTS サボテングサ		50	5.50	275.00
FIREFISH GOBY ハタタテハゼ		200	10.00	2,000.00
GOLDEN HEAD GOBY アカハチハゼ		28	8.00	224.00
BLUE GUDGEON GOBY オグロユリハゼ		8	5.50	44.00
SCISSORTAIL GOBY クロユリハゼ		15	5.50	82.50
BAR GOBY		23	5.50	126.50

TOTAL COST OF FISH: Php 3,292.00

PLUS 10% 0.10 329.20

TOTAL COST OF FISH: Php 3,621.20

Figure 1.2 Examples of a hand-written and typed receipt collected from byaheros.

Focus Group Discussions

Five focus group discussions (FGDs) of five to six fishers were conducted in May 2017. Fishers were notified in advance of an opportunity for them to express their opinions and knowledge of the aquarium trade in a group setting and so participation was entirely voluntary. Prior to each FGD, fishers were informed about the project objectives and given a Participant Information Sheet, and asked to give verbal consent. Preliminary discussions with fishers revealed that while all aquarium fishers live in Calatagan, not all aquarium fishers collect in Calatagan. A select portion of fishers from both barangays travels to nearby islands such as Mindoro (Figure 1.3). Therefore, fishers were divided into FGD groups based on the collection areas in the study scope; two FGDs were held with aquarium fishers collecting in Barangay Santa Ana, one with fishers collecting in Barangay 1, one with fishers collecting in Looc, Mindoro, and one with fishers collecting in Paluan, Mindoro. As a result, fishers collecting in Calatagan identified places in Calatagan, while fishers collecting in Mindoro identified places in Mindoro.

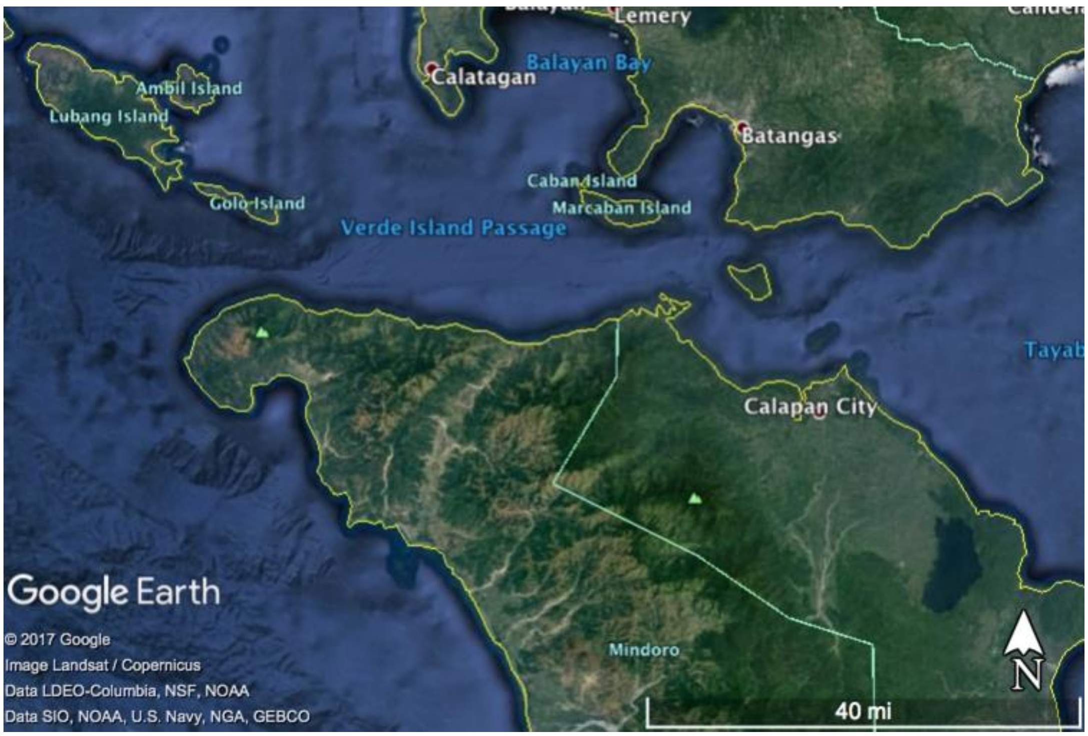


Figure 1.3 Google Earth image including the main study site (Calatagan) as well as all fish collection areas (Calatagan, Ambil Island, Lubang Island, Golo Island, and mainland Mindoro). Google Earth Pro 7.3.0.3832. Copyright © 2017. Batangas and Mindoro, Philippines from <http://www.earth.google.com>.

Focus groups were held at barangay halls in Santa Ana and Barangay 1 as well as fishers' houses in these two barangays, and lasted between 1-1.5 hours. As a group, fishers were asked to draw a map of the places where they collect aquarium fish on a large piece of paper. This form of participatory mapping is known as sketch mapping (Forrester and

Cinderby 2011). Sketch mapping was appropriate because most of the aquarium fishers have low literacy rates and so this simple method minimized their stress and encouraged their participation (see Evans et al. 2006; IFAD 2009). Furthermore, sketch mapping is a useful technique for getting a broad idea of land use and resource distribution. Maps of Calatagan and other nearby islands were printed out on large sheets of tarpaulin and used as references for the fishers to identify specific barangays as well as the general outline of islands and any other points of interest. They were then asked to identify places where they fish most often, places they are not allowed to fish, and any places that they used to fish but now cannot, due to rules or any other reasons. Photographs were taken of the drawn maps at the end of each FGD (Figure 1.4).

Figure 1.4 Sketch map of Calatagan drawn by aquarium fishers from one of the focus groups. Map size is approximately 56 x 35 cm and represents a land area of 43.24 square miles. Fish were used as a wrap-up activity, but were not part of any analysis.

After all of the FGDs were completed, GPS points were taken using a Garmin GPSMap 64s in Calatagan to help ground truth some exact locations based on the fishers' maps in (Figure 1.3). This was completed via a daylong boat trip in June 2017 with one of the more experienced fishers, who helped verify all places of importance identified in the FGDs, such as specific barangays where they are and are not allowed to fish and marine protected areas. GPS points were not taken in Mindoro and other islands due to lack of time and significant travel distance. Coordinates and fishing locations were then input into ArcGIS10.4© to display the data visually.

Interviews

After all of the focus groups were finished, interviews with fishers were conducted in June 2017 to collect fishers' socio-demographic information, involvement in the aquarium trade, participation in the trade, livelihoods, employment and income, and identify species for a vulnerability assessment. Demographics included age, gender, level of education, household size, barangay where they were born, and where they currently live. This was necessary to create a profile of who collectors were, noting any similarities or differences. Fishers' involvement in the trade looked at how and why they began working in the aquarium trade in order to understand their motivations for collection. Participation in the trade focused on how fishers collect (i.e. equipment, frequency) to see if aquarium fishing was a part-time or full-time job or if it varied according to season. The section on livelihoods addressed fishers' enjoyment in working in the aquarium trade, whether they would encourage/discourage others to enter the trade, and any other jobs they would do if they were not aquarium fishers. This too looked at motivations and, but also explored alternative livelihood options available to fishers. The final section regarding aquarium fishers focused on any additional activities that provided money/food for aquarium fishers' families in addition to fishing. These activities were then ranked in order of most important to household income and overall importance to the household. The purpose of this was to see how important aquarium fishing was to their families in comparison to other jobs. Finally, aquarium fishers were asked indirectly about their income and wealth, including about the financial situation of their household relative to their day-to-day costs as well as if they perceived themselves to be poor, rich, or average compared to others in their barangay. There is often an assumption in the general literature that fishing equals poverty (Panayotou 1982; Wright 1990; Cunningham 1993; Payne 2000), and these questions aimed to test this assumption by looking at wealth through the eyes of the fishers.

The final section of the interviews was used to gain a list of species from which a subset could be selected for a vulnerability assessment. Fishers were asked to identify a maximum of five species for each of the four categories provided: most commonly caught, most desirable to catch, easiest to catch, and species that were once commonly caught but now are rarely caught. These categories were selected because they were likely to include some of the most vulnerable species to overharvest, either due to collection or distribution in the wild. Species that are most commonly caught are those that are caught in larger quantities and so their populations are more likely to decline as a result (Andrews 1990; Moore and Best 2001; Thornhill 2012). Species that are most desirable to catch or are easiest to catch may be more vulnerable to overharvest if fishers preferentially target them over other species (Wood 1985; Tissot 1999; Wood 2001; Wabnitz et al. 2003; Stevenson et al. 2011). Lastly, species that were once commonly caught but now are rarely caught may indicate a population decline associated with the fishery (Wood 2001; Lavides et al. 2016). Fishers were also asked to explain why they chose each species for a particular category as well as their perceived population status.

Interviews were conducted in Tagalog by the C3 staff member and reported back to the researcher in English. Prior to each interview, fishers were informed about the project objectives and given a Participant Information Sheet, and asked to give verbal consent. Each of these interviews lasted approximately 30 minutes and took place at both the collection sites and fishers' houses in Santa Ana and Barangay 1, varying on their availability and comfort. Interviews were semi-structured and conducted with 45 out of a possible 46 fishers living in Calatagan: 18 fishing in Santa Ana, 15 fishing in Barangay 1, nine in Looc, Mindoro, and three in Paluan, Mindoro. There was one refusal and three interviews were not fully completed due to the fishers' hearing problems. Interviews were semi-structured to provide a standard format, while also allowing some flexibility to explore areas of interest for optimum data quality (Cohen and Crabtree 2006). An additional technique was used to discover fishers' motivations (Paudel et al. in prep.). Fishers were given nine cards, each with a different motivation for joining the aquarium trade, and told to choose as many as applied to them (Figure 1.5). Fishers were then asked to rank their selected motivations from highest to lowest. Motivations selected were derived from literature and informed by existing knowledge about wildlife traders across contexts (Neumann and Hirsch 2000; TRAFFIC 2008; Duffy et al. 2015; Phelps et al. 2016).

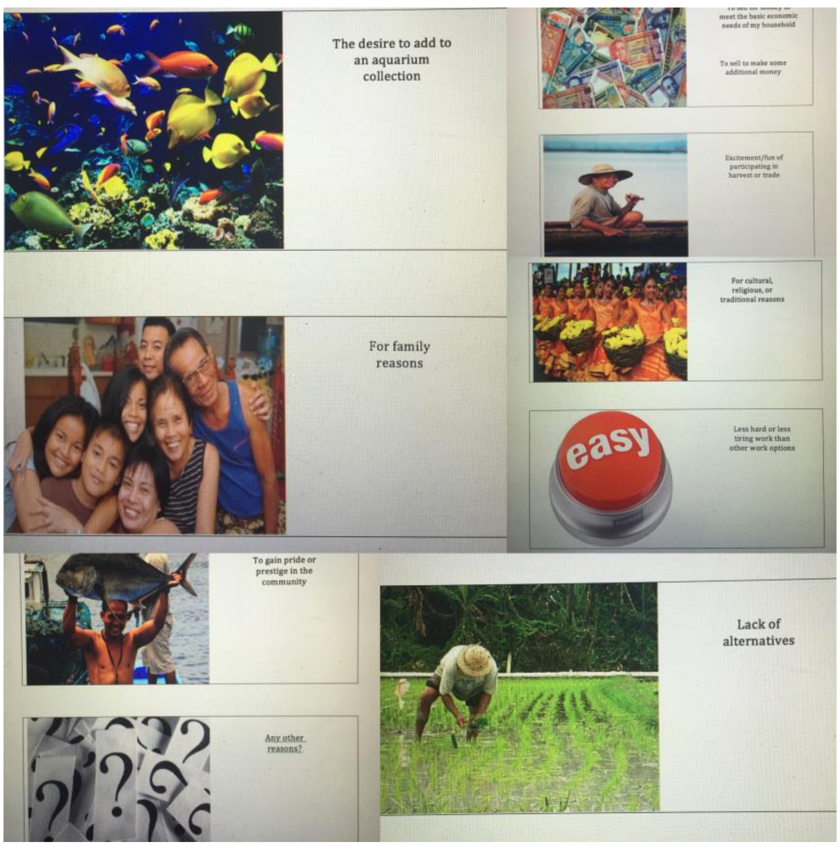


Figure 1.5 Nine motivation choice cards used in interviews: the desire to add to an aquarium collection, for family reasons, the desire to gain pride/prestige in the community, lack of alternatives, easy, for cultural/religious reasons, enjoyment, as a means of primary income, and any other reason.

Vulnerability Assessment

After all of the fisher interviews were conducted, the top five species for each category (most commonly caught, most desirable to catch, easiest to catch, and species that were once commonly caught but now are rarely caught), a total of 12 species, were selected for the assessment. Several species were in the top five for multiple categories and therefore eight additional species were chosen based on the frequency in which they were mentioned by fishers and appeared on receipts, to create a final list of twenty species (Table 1.1). This sub-sample of twenty species represented 25.6% of all species mentioned in fishers' interviews, and was a manageable number to gain information on from the fishers while avoiding respondent fatigue.

A further nine 30 minute interviews with key informants were conducted in July 2017 in the fishers' houses in order to explore local fishers' knowledge regarding species' behavior in relation to the fishery (i.e. susceptibility attributes, Table A1.2) for the vulnerability assessment. Three fishermen collecting in Santa Ana, Barangay 1, and Looc, Mindoro were selected based on availability and experience level. One younger fisher (approx. age 30), one middle aged fisher (approx. age 45), and one older fisher (age 60+) from each group were selected to reduce any bias associated with age. For example, one susceptibility attribute in the vulnerability assessment looked at the depth at which a species was collected. Presumably, a younger fisher would be able to dive down to deeper depths than an older fisher and thus the vertical overlap with the fishery would be greater than if only older fishers were consulted. Furthermore, the vulnerability assessment examined species distribution across the fishery and different fishers collect in different areas. Therefore, it was necessary to interview a range of fishers to obtain a more accurate picture of the collection area as a whole.

Table 1.1 List of 20 species selected for the PSA according to the number of categories and total number of mentions from fishers. Stars indicate if a species was in the top five for the corresponding category.

Scientific Name	Common Name	Most Commonly Caught	Most Desirable to Catch	Easiest to Catch	Rarely Caught	Number of Mentions
Salarias fasciatus	Jeweled blenny					33
Chromis viridis	Blue green chromis					34
Labroides dimidiatus	Bluestreak cleaner wrasse					45
Chaetodon auriga	Threadfin butterflyfish					22
Nemateleortis magnifica	Fire dartfish					29
Coris gaimard	Yellowtail coris					15
Chrysiptera rex	King demoiselle					22
Pomacanthus semicirculatus	Koran angelfish					21
Dendrochirus zebra	Zebra lionfish					17
Paracanthurus hepatus	Palette surgeonfish					13
Pomacanthus imperator	Emperor angelfish					12
Balistoides conspicillum	Clown triggerfish					5
Pomacanthus navarchus	Bluegirdled angelfish					4
Neoglyphidodon melas	Black damselfish					18
Acanthochromis polyacanthus	Spiny chromis					17
Valenciennea strigata	Blueband goby					15
Amphiprion ocellaris	False clownfish					12
Chrysiptera cyanea	Sapphire devil					10
Acanthurus japonicus	Japan surgeonfish					12
Ptereleotris evides	Blackfin dartfish					10

The vulnerability assessment used in this study is called a Productivity Susceptibility Analysis (PSA). The PSA was originally developed by Australia's Commonwealth Scientific Industrial Research Organization (CSIRO) to classify bycatch sustainability for the prawn industry (Patrick et al. 2009; Osio et al. 2015). The PSA calculates the exposure of a fishery to activity (susceptibility) and its effects, and how the fishery will react (productivity) (Hobday et al. 2007). Therefore, the PSA uses both productivity and susceptibility attributes as proxies for determining species' vulnerability (Table 1.2). This approach was chosen for this study for several reasons. First, vulnerability assessments are rarely done at such a small scale (Fujita et al. 2014), even though fish populations vary from reef to reef (Wood 2001). Second, the Philippines has a decentralized system of government, in which fisheries management is conducted by barangay captains and local government units (Fabinyi et al. 2015). And third, this study aimed to incorporate local fishers' knowledge. Aquarium fishing is their livelihood and so its continuation is important to them. A national or regional assessment would mean little to nothing to them. Therefore, the PSA was performed at the municipal scale in order to estimate the productivity of each species, as well as its susceptibility to the aquarium fishery in Calatagan.

The PSA uses life history traits that are often available from literature, FishBase (Froese and Pauly 2017), and local fishers. These attributes are predominantly based on primary literature (Alderhoven 1986; Gharaibeh and Hulings 1990; Sakai and Kohda 2001; Wood 2001; Wabnitz et al. 2003; Pitcher et al. 2007; Thornhill 2012; Donelson et al. 2014; Froese and Pauly 2017). In addition, PSA uses attributes that reflect how susceptible species are to a fishery. The majority of these attributes came from key informant interviews since they have knowledge of fishing patterns as well as fish behavior. Where information for a species was limited or unavailable, scores were based on other species within the same genus or family. An additional susceptibility attribute, aquarium suitability, which is unique to the aquarium fishery, was also included. This attribute looks at a species' durability, hardiness, and/or adaptability to life in captivity and is based on the work of Michael (2001). This attribute was added because even if a species survives capture, packaging, and transport, it still needs to survive in captivity in order for it to be a successful aquarium species. Different species vary on their ability to adjust to life in captivity and therefore may be more or less susceptible. A species may be frequently caught and traded, but may not survive well in captivity. Therefore, the collection of such a species could be discouraged to reduce vulnerability and increase sustainability.

Table 1.2 Definitions of productivity and susceptibility attributes as defined by Patrick et al. (2009) used in the PSA, and the additional aquarium suitability attribute as defined by Michael (2001).

Attribute	Input
Population growth rate (r)	Intrinsic rate of population growth or maximum population growth that would be expected to occur in a population under natural conditions (i.e., no fishing), and thus directly reflects stock productivity.
Maximum age	Maximum age is a direct indication of the natural mortality rate (M), where low levels of M are negatively correlated with high maximum ages (Hoenig 1983).
Maximum size	Maximum size is also correlated with productivity, with large fish tending to have lower levels of productivity (Roberts and Hawkins 1999), though this relationship tends to degrade at higher taxonomic levels.
von Bertalanffy growth coeffiecient (k)	The von Bertalanffy growth coefficient measures how rapidly a fish reaches its maximum size, where long-lived, low-productivity stocks tend to have low values of k (Froese and Binohlan 2000).
Estimated natural mortality	Natural mortality rate directly reflects population productivity, as stocks with high rates of natural mortality will require high levels of production in order to maintain population levels.
Measured fecundity	Fecundity (i.e., the number of eggs produced by a female for a given spawning event or period), and is measured at age of first maturity.
Breeding strategy	The breeding strategy of a stock provides an indication of the level of mortality that might be expected for the offspring in the first stages of life.
Recruitment pattern	This attribute is intended as a coarse index to distinguish stocks with sporadic recruitment patterns and high frequency of year-class failures from those with relatively steady recruitment.
Age at maturity	Age at maturity tends to be positively related with maximum age (tmax), as long-lived, lower productivity stocks will have higher ages at maturity relative to short-lived stocks.
Mean trophic level	The position of a stock within the larger fish community can be used to infer stock productivity, with lower-trophic-level stocks generally being more productive than higher-trophic-level stocks.
Areal overlap	Extent of geographic overlap between the known distribution of a stock and the distribution of the fishery
Geographic concentration	Extent to which the stock is concentrated into small areas.
Vertical overlap	Concerns the position of the stock within the water column (i.e., demersal or pelagic) relative to the fishing gear.
Seasonal migrations	Movement to or from the fishery area (i.e. spawning or feeding migrations) could affect the overlap between the stock and the fishery.

Attribute	Input
Schooling/Aggregation and other behavioral responses	Behavioral responses of both individual fish and the stock in response to fishing.
Morphology affecting capture	The ability of the fishing gear to capture fish based on their morphological characteristics (e.g., body shape, spiny versus soft rayed fins).
Desirability/Value of the fishery	This attribute assumes that highly valued fish stocks are more susceptible to overfishing or becoming overfished by recreational or commercial fishermen due to increased effort.
Management strategy	The susceptibility of a stock to overfishing may largely depend on the effectiveness of fishery management procedures used to control catch.
Fishing rate relative to M	Only applicable to stocks where estimates of both fishing mortality rates (F) and (M) are available.
Biomass of spawners (SSB) or other proxies	Analogous to fishing mortality rate, the extent to which fishing has depleted the biomass of a stock relative to expected unfished levels offers information on realized susceptibility.
Survival after capture and release	Fish survival after capture and release varies by species, region, and gear type or even market conditions, and thus can affect the susceptibility of the stock.
Fishery impact to EFH or habitat in general for nontargets	A fishery may have an indirect effect on a species via adverse impacts on habitat.
Aquarium suitability	This attribute gives an indication of the durability/hardiness/adaptability of fish to life in captivity.

Each productivity and susceptibility attribute is given a score from 1-3, indicating a low, medium, or high absolute value. Productivity attributes are scored from high (3) to low (1) while susceptibility attributes are scored from low (1) to high (3) (Appendix Tables 1.1-1.2). This is because a species with high productivity is likely to have a low vulnerability while a species with high susceptibility is likely to have a high vulnerability. The overall productivity and susceptibility score for a species is the average of all of their corresponding attributes (Fujita et al. 2014). A species' vulnerability score is then calculated as $\sqrt{(p-3)^2 + (s-1)^2}$ where p refers to productivity and s refers to susceptibility (Fujita et al. 2014).

A data quality index is also incorporated into the vulnerability assessment. The data quality index estimates the uncertainty in the vulnerability scores by ranking data from best data (high belief in score) to no data (high uncertainty in score) (Patrick et al 2009).

Each productivity and susceptibility attribute is then given a data quality score from 1-5, with 1 being the highest quality data and 5 being no data (Table 1.3).

Table 1.3. The five data quality scores and their descriptions for productivity and susceptibility attributes as defined by Patrick et al. (2009).

Data Quality Score	Description	Example
1	(Best Data) Information is based on collected data for the stock and area of interest that is established and substantial	Data rich stock assessment, published literature that uses multiple methods, etc.
2	(Adequate Data) Information with limited coverage and corroboration, or for some other reason deemed not as reliable as Tier 1 data	Limited temporal or spatial data, relatively old information, etc.
3	(Limited Data) Estimates with high variation and limited confidence and may be based on similar taxa or life history strategy	Similar genus or family, etc.
4	(Very limited Data) Expert opinion or based on general literature review from wide range of species, or outside of region	General data - not referenced
5	(No Data) No information to base score on - not included in the PSA, but included in the DQI score	

Table A1.1 Productivity attributes and their rankings.

Productivity Attribute	High (3)	Moderate (2)	Low (1)
r	> 0.5	0.16-0.5	< 0.16
Maximum age	< 10 years	10-30 years	> 30 years
Maximum size	< 60 cm	60-150 cm	> 150 cm
k	> 0.25	0.15-0.25	< 0.15
Estimated natural mortality	> 0.40	0.20-0.40	< 0.20
Fecundity	> 10e4	10e2-10e3	< 10e2
Breeding strategy	0	Between 1-3	≥ 4
Recruitment pattern	Highly frequent recruitment success (>75% of year classes are successful)	Moderately frequent recruitment success (between 10% and 75% of year classes are successful	Infrequent recruitment success (<10% of year classes are successful)
Age at	< 2 years	2-4 years	> 4 years

Productivity Attribute	High (3)	Moderate (2)	Low (1)
maturity			
Mean trophic level	< 2.5	Between 2.5 and 3.5	> 3.5

Table A1.2 Susceptibility attributes and their rankings.

Susceptibility Attribute	Low (1)	Moderate (2)	High (3)
Management strategy	Targeted stocks have catch limits and proactive accountability measures; non-target stocks are closely monitored	Targeted stocks have catch limits and reactive accountability measures	Targeted stocks do not have catch limits or accountability measures; non-target stocks are not closely monitored
Areal overlap	< 25% of stock occurs in the area fished	Between 25% and 50% of the stock occurs in the area fished	> 50% of stock occurs in the area fished
Geographic concentration	Stock is distributed in > 50% of its total range	Stock is distributed in 25% to 50% of its total range	Stock is distributed in < 25% of its total range
Vertical overlap	< 25% of stock occurs in the depths fished	Between 25% and 50% of the stock occurs in the depths fished	> 50% of stock occurs in the depths fished
Fishing rate relative to M	< 0.5	0.5-1.0	> 1
Biomass of spawners	B is > 40% of B0	B is between 25% and 40% of B0	B is < 25% of B0
Seasonal migrations	Seasonal migrations decrease overlap with the fishery	Seasonal migrations do not substantially affect the overlap with the fishery	Seasonal migrations increase overlap with the fishery
Schooling	Behavioral responses decrease the catchability of the gear	Behavioral responses do not substantially affect the catchability of the gear	Behavioral responses increase the cathcability of the gear
Morphology	Species shows low selectivity to the fishing gear	Species shows moderate selectivity to the fishing gear	Species shows high selectivity to the fishing gear
Survival after capture	Probability of survival > 67%	33% < probability of survival < 67%	Probability of survival < 33%
Value to fishery	0-10 Php	10-50 Php	> 50 Php
Habitat impact	Adverse effects absent, minimal or temporary	Adverse effects more than minimal or temporary but are mitigated	Adverse effects more than minimal or temporary and are not mitigated
Aquarium suitability	≥ 4.0	2.1-3.9	≤ 2.0

3 Species Collected for the Aquarium Fish Trade and Their Vulnerability to Local Overharvest in Calatagan

Pictures obtained from Froese and Pauly (2017).

Introduction

This chapter will explore species' richness and vulnerability of fish that are harvested for the marine aquarium trade by combining both scientific literature and fishers' knowledge in a mixed method approach. It is generally acknowledged that species across many trophic levels are collected (Andrews 1990; Wabnitz et al. 2003; Thornhill 2012), but that small-scale collection often focuses on only a few target species (Wood 2001). Different species may exhibit varying degrees of vulnerability due to both intrinsic and extrinsic factors and many of these factors will be identified and discussed in the following sections. While the data gathered in this study is site specific, it has broader applications for the aquarium trade at the global scale.

Results

Species Collected for the Aquarium Trade in Calatagan

In order to assess species' vulnerability to local overharvest, it is crucial to first determine which species are being collected. Aquarium fishers in Calatagan are instructed by their byaheros (intermediaries) how many of which species they are to collect in order to fulfill the order of the exporters. Therefore, fishers do not collect more than necessary. If excess fish are accidentally caught, the fishers immediately release the fish that they do not need back into the sea. Exporters provide guides (pictures) of particular species to the byaheros to pass on to the collectors to ensure the correct fish species are collected. In addition, older fishers teach younger fishers how to identify fish.

The quantities of receipts, species, and individual fish were totaled (Table 2.1). Fish belonging to 180 species, 95 genera, and 35 families were identified using fish identification guides and through discussions with fishers (Appendix Table 2.1). According to functional groups, 11.7% of species are herbivores, 40% are carnivores, 35.6% are omnivores, 9.4% are planktivores, and 3.3% are corallivores. Thus, species from many trophic levels are present. An additional 14 categories of fish were recorded on receipts but were unable to be identified to species level as they were only categorized as ordinary or assorted. Therefore, the quantities of ordinary/assorted squirrelfish, butterflyfish, scorpionfish, wrasse, tang, goatfish, boxfish, filefish, goby, pipefish, eel, snapper, pufferfish, and blenny were recorded, but it was impossible to clarify which particular species made up these categories. The FishBase database recognized 163 of these species as aquarium trade species, but 17 of the identified species were not listed as traded (Froese and Pauly 2017) (Table 2.2). Of the species recorded, the IUCN lists 108 species as least concern, 65 as not evaluated, four as data deficient, one as near threatened, and two as vulnerable (IUCN 2017) (see Appendix Table 2.1).

The sum of fish caught from all receipts was 97,635. The most frequently reported species was the fire dartfish (*Nemateleotris magnifica*), which consisted of 40,358 fish or 41.3% of the total (Figure 2.1). The second commonly caught fish was the jeweled blenny (*Salarias fasciatus*), which consisted of 11,939 fish or 12.2% of the total. The remaining 46.5% of fish consisted of the other 178 identified species and 14 unidentified categories. The top nine most caught species were also selected for the vulnerability assessment.

Table 2.1 All receipts broken down by year, quantity, and number of species and fish.

Year	Number of Receipts	Number of Species	Number of Fish
No Date	1	14	231
2013	1	18	249
2014	35	85	14,851
2015	12	67	5939
2016	53	124	20,540
2017	153	147	55,825

Table 2.2 List of species not recorded as aquarium trade species according to FishBase, but encountered in trade in Calatagan. Along with taxonomic classification, the table also displays each species' IUCN status, functional group, and known uses to humans (Froese and Pauly 2017).

Family	**Genus**	**Species**	**IUCN**	**Functional Group**	**Known Uses**
Pomacentridae	*Acanthochromis*	*polyacanthus*	NE	herbivore	none
Apogonidae	*Pristicon*	*trimaculatus*	NE	carnivore	none
Haemulidae	*Plectorhinchus*	*polytaenia*	NE	carnivore	commercial fisheries
Haemulidae	*Plectorhinchus*	*vittatus*	NE	carnivore	none
Chaetodontidae	*Chaetodon*	*lunulatus*	LC	corallivore	none
Pomacentridae	*Pomacentrus*	*auriventris*	NE	herbivore	none
Monacanthidae	*Aluterus*	*monoceros*	LC	omnivore	commercial fisheries
Congridae	*Heteroconger*	*taylori*	DD	planktivore	none
Serranidae	*Plectropomus*	*laevis*	VU	carnivore	commercial fisheries, gamefish
Balistidae	*Balistoides*	*viridescens*	NE	carnivore	commercial fisheries
Blennidae	*Cirripectes*	*quagga*	LC	herbivore	none
Tetradontidae	*Arothron*	*manilensis*	LC	carnivore	none
Caesionidae	*Pterocaesio*	*tile*	LC	planktivore	commercial fisheries, bait
Nemipteridae	*Pentapodus*	*emeryii*	LC	carnivore	subsistence fisheries
Monacanthidae	*Pervajor*	*janthinosoma*	LC	omnivore	none
Muraenidae	*Pseudechidna*	*brummeri*	NE	carnivore	none
Haemulidae	*Plectorhinchus*	*lessonii*	NE	carnivore	none

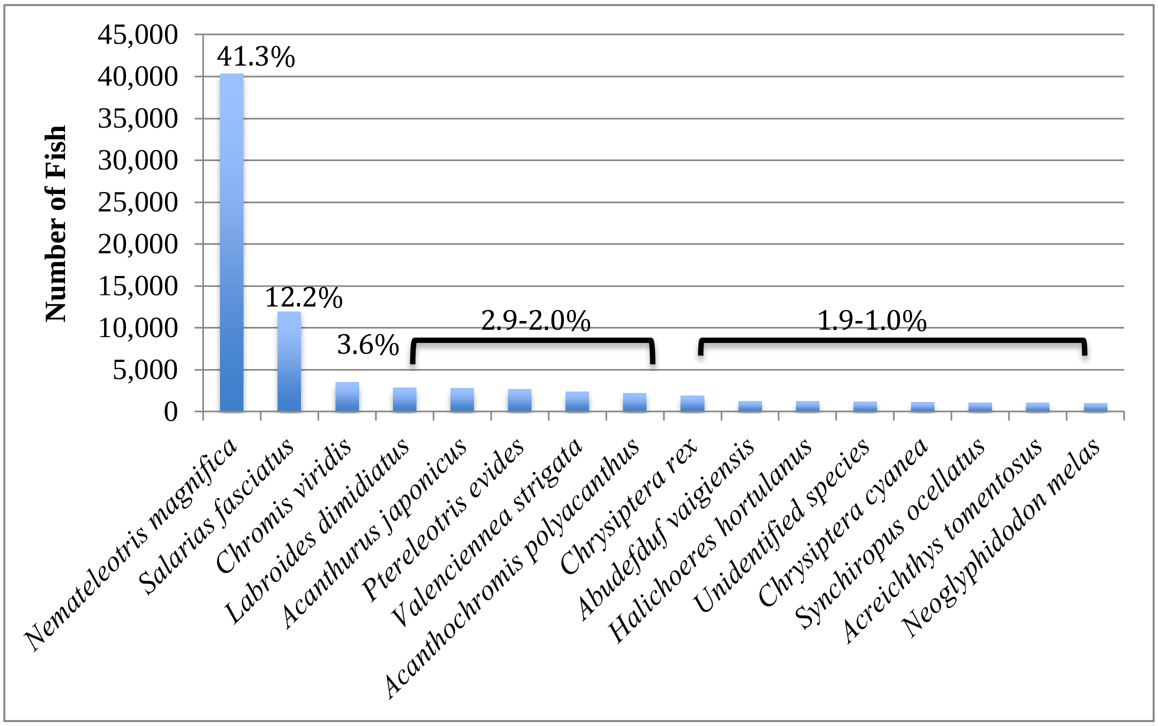


Figure 2.1 The distribution of the most caught species according to fishers' receipts (>100 individuals between 2013-2017), and what percent each species comprises the total number. The unidentified species category includes all fish that were unable to be identified to species level.

The number of new species added each month and year was calculated based on species' initial date of occurrence on receipts (Figure 2.2). The largest number of new species (42) occurred in March 2014. By July 2017, only one new species was added, suggesting that the species list is fairly complete. It is important to note that while 153 receipts (60% of total) were from 2017, only 31 new species (16.1%) appeared. During the three months of fieldwork, May-July 2017, only 14 new species (7.2%) were identified in addition to those identified on the receipts. In contrast, only 36 receipts were collected from 2013 to 2014, but 90 new species (46.6%) were identified.

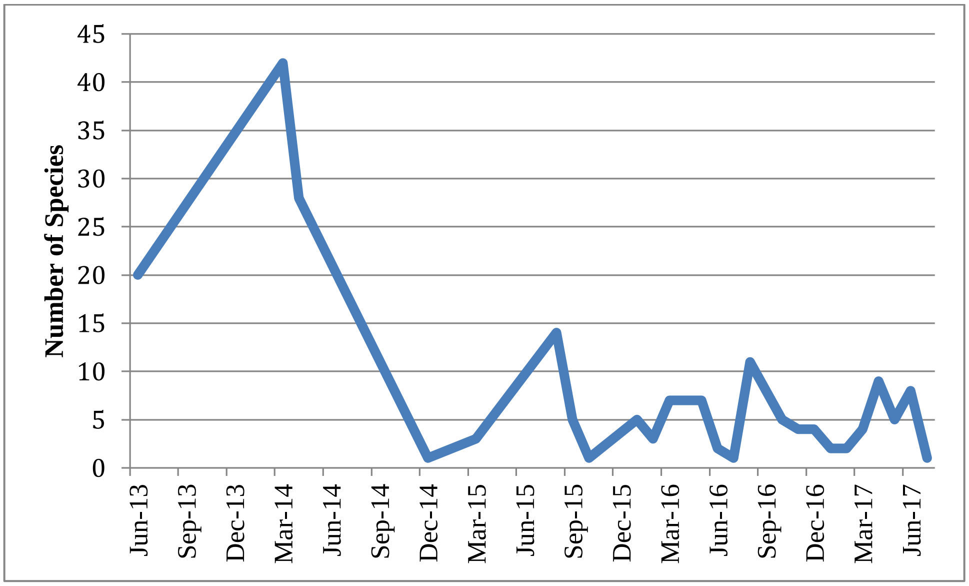


Figure 2.2 Species accumulation curve showing the number of new species added by month and year.

Price

Along with species' names and quantities, prices were also listed on fishers' receipts. The amount of money aquarium fishers receive per fish is highly variable. Fish prices can depend on species, size, quality, sex, age, and even exporter (Wood 2001; Wabnitz et al. 2003). An aquarium fisher in Calatagan only receives Php 1 ($0.02) for one striped eel catfish (*Plotosus lineatus).* In contrast, a fisher can receive Php 400-500 ($7.84-$9.80) for one emperor angelfish (*Pomacanthus imperator)*. Therefore, fish were categorized as low Php 1-10 ($0.02-$0.20), medium Php 11-50 ($0.22-$1.00), or high value Php 51+ ($1.02+) species based on the range of prices on receipts as well as discussions with aquarium fishers. Most of the species listed on receipts are low value (51.1%), 42% are medium value, and only 6.7% are high value (Table 2.3). A more in-depth price analysis was not conducted due to the complex nature and study scope.

Table 2.3 Number and percent of species categorized as low, medium, and high value species.

Species	Low value (Php 1-10)	Medium value (Php 11-50)	High value (Php 51+)
Number of species	92	76	12
Percentage of species	51.1%	42.2%	6.7%

Aquarium Trade Impacts on Species' Vulnerability

The purpose of the productivity susceptibility analysis (PSA) was to evaluate the vulnerability of a subset of species to overharvest. Vulnerability scores can be divided into three main categories: least vulnerable (<1.1) moderately vulnerable (1.1-1.5), and highly vulnerable (>1.5) (Patrick et al. 2009). Of the 20 species assessed, 18 were given scores in the range of low vulnerability (Table 2.3). The two species that were given scores in the range of moderate vulnerability were the zebra lionfish (*Dendrochirus zebra*) and palette surgeonfish (*Paracanthurus hepatus*).

Along with productivity, susceptibility, and vulnerability scores (Appendix Tables 2.2-2.3), each species was given data quality scores to indicate the certainty of the vulnerability scores based on available data (Appendix Tables 2.4-2.5). The data quality index proposes low quality data is >3.5, moderate is between 2.0-3.5, and high is <2.0 (Patrick et al. 2009). All data quality scores were in the moderate to high quality ranges (Table 2.4). Five species (*Chromis viridis, Labroides dimidiatus, Chaetodon auriga, Valenciennea strigata*, *Amphiprion ocellaris*) received high data quality scores for productivity, susceptibility, and vulnerability. The lowest data quality scores were for the productivity of the fire dartfish (*N. magnifica*) and the blackfin dartfish (*Ptereleotris evides*).

Table 2.4 Productivity, susceptibility, vulnerability, and data quality scores for the 20 species selected for PSA. Vulnerability category is based on the vulnerability score in the previous column.

Common Name	Productivity score (p)	Susceptibility score (s)	Vulnerability score (v)	Vulnerability Category	Data Quality (p)	Data Quality (s)	Data Quality (v)
Jeweled blenny	2.89	1.82	0.83	Low	2.2	1.92	2.06
Blue green chromis	2.6	1.73	0.83	Low	1.9	1.92	1.91
Bluestreak cleaner wrasse	2.7	1.73	0.79	Low	1.8	1.92	1.86
Threadfin butterflyfish	2.8	1.64	0.67	Low	1.8	1.92	1.86
Fire dartfish	2.71	1.64	0.70	Low	3.2	1.92	2.56
Yellowtail coris	2.4	1.45	0.75	Low	2.3	1.92	2.11
King demoiselle	2.6	1.73	0.83	Low	2.1	2.08	2.09
Koran angelfish	2.3	1.73	1.01	Low	2.2	1.92	2.06
Zebra lionfish	2.1	1.73	1.16	Moderate	2.2	1.92	2.06
Palette surgeonfish	2.7	2.09	1.13	Moderate	2.0	1.92	1.96
Emperor angelfish	2.3	1.64	0.95	Low	2.0	1.92	1.96
Clown triggerfish	2.3	1.82	1.08	Low	2.0	1.92	1.96
Bluegirdled angelfish	2.5	1.73	0.88	Low	2.0	1.92	1.96
Black damselfish	2.5	1.82	0.96	Low	2.1	1.92	2.01
Spiny chromis	2.5	1.82	0.96	Low	2.0	2.08	2.04
Blueband goby	2.7	1.82	0.87	Low	1.7	1.92	1.81
False clownfish	2.5	1.82	0.96	Low	1.7	1.92	1.81
Sapphire devil	2.6	1.82	0.91	Low	2.1	1.92	2.01
Japan surgeonfish	2.8	1.73	0.76	Low	2.3	1.92	2.11
Blackfin dartfish	2.57	1.73	0.85	Low	3.2	1.92	2.56

Discussion

Species Richness

According to Wood (2001), there is globally a high volume of trade in low value species such as gobies, damselfish, and wrasse and a low volume of high value species such as angelfish and clown triggerfish. High prices reflect desirability and the fact that these species are difficult to collect in large quantities due to their behavioral responses or the depth at which they are found (Wood 2001). In fact, while high prices may indicate a species that is rare and vulnerable to overharvest, this is not always true. Some species are simply perceived as rare because much of their population lives in deeper water so they may actually be more common than they appear (Allen 1981). Furthermore, it is widely acknowledged that species across many trophic levels are collected (Andrews 1990; Wabnitz et al. 2003; Thornhill 2012), but that small-scale collection often focuses on only a few target species (Aguilar 1992; Graham 1996; Division of Aquatic Resources unpublished data quoted in Tissot 1999, Wood 2001). The results of this study support these previous findings based on the mixed methods approach that was taken. Receipts, discussions with aquarium fishers, and existing scientific knowledge have contributed to obtaining an understanding of, not only the Calatagan fishery, but the aquarium trade as a whole.

Although 255 receipts is not the total number of receipts produced between 2013 and July 2017, it is still illustrative of the species caught for the aquarium fishery in Calatagan. Species saturation was essentially reached at the end of receipt collection. By the end of July 2017, only one new species was present on receipts. Furthermore, receipts were collected from all the byahero in the area, with most receipts from the largest actors. Observations of both the collection of fish as well as byahes (fish packaging days) support this conclusion. Other fish species are presumably collected; however, they must be collected rarely and most likely in smaller quantities.

In addition to the 180 species that were identified, there were 14 categories present on receipts in which species level identification was not possible. Together, these categories represented only 1190 individuals (1.2% of all species) listed on receipts. On some receipts, fish are categorized as ordinary/assorted (e.g., assorted wrasse, ordinary goby, etc.) Rhyne et al. (2012) also documented this type of categorization on sales invoices. According to one exporter, assorted/ordinary means that there are one or two different species that are either very rarely or commonly brought in and so they do not list the names on the receipts. While this categorization appears rather contradictory, it provides some insight into trade dynamics. Ordinary or assorted species are grouped together and each species is valued at the same price. Therefore, a species that is rarely caught for the trade does not necessarily equate to a higher price. Instead, a rare species can simply mean that it is rarely demanded by consumers and not rare in the wild, indicating a low market demand and therefore low cost. This leads back to a point in Chapter 1 that the definition of rare is ambiguous and relies on multiple factors (Rabinowitz 1981; Courchamp et al. 2006). However, these general categorizations complicate quantifying numbers of individual species being collected and should be taken into consideration when looking at gaps in the aquarium trade. Additionally, the receipts only list species that were bought by exporters, it does not include fish that were caught but died before reaching Manila. Receipts may therefore underestimate the actual quantity of caught species. One recommendation to reduce this issue is for fishers to use pro-forma daily log books in which they record the number of fish collected and mortality of fish as well as hours spent on collection and information on collection areas (Wood 2001; Saleem and Islam 2008).

Fisher's receipts were the primary means of creating a species list, although it was not without its problems. Receipts only show the local names of fish, which made establishing a robust taxonomic identification problematic. If aquarium fishers were given the more widely accepted common names, the identification process would have been easier. In spite of differing common names, the fishers were patient and proficient in species' identification. While the vast majority of species were fairly easy to identify, some were more difficult due to subtle differences between similar species leading to possible misidentifications. Aquarium fishers were excellent in distinguishing between species based only on pictures in books, but their knowledge regarding identification is purely visual. They are not aware of species' global distributions or minor taxonomic distinctions.

Fire Dartfish

Firefish are a key species in the aquarium fish trade in Calatagan. They were mentioned in three of the four categories in fisher interviews: most commonly caught (ranked 2nd), most desirable to catch (ranked 1st), and easiest to catch. Of the 97,635 fish documented from receipt collection, 40,358 (41.3%) of the fish belong to one species, the fire dartfish or fire goby (*Nemateleotris magnifica*). Therefore, it would be logical to assume that the firefish would be one of the most vulnerable species to overfishing at the local level. According to the PSA, the firefish was calculated to have a low vulnerability and there are a few reasons to account for this. Fishers are only able to dive to a limited depth to collect fish and firefish may be found at depths ranging from 6-70 meters (Froese and Pauly 2017). Second, not much is known about the reproduction of most species within the family Microdesmidae, including the fire dartfish and blackfin dartfish (*P. evides*), and therefore the PSA used similar taxonomic data as a proxy. As a result, a couple attributes for these two species could not be included in the PSA due to lack of data, although this was accounted for in the data quality score. This gap in data could partially explain why the fire dartfish received a low vulnerability score in this analysis, and should be considered when evaluating the legitimacy of this result. However, until 1986, firefish were classified as gobies and blennies (Brough 2015), which have known high rates of fecundity. Therefore, it would not be surprising if firefish do indeed have a high fecundity and are reproducing faster than they are being collected for the Calatagan fishery.

The fire dartfish may not currently be vulnerable to overharvest, but it is the most heavily fished of all species for the aquarium fishery in Calatagan. Price would be an obvious reason for it to be desirable to collect; however, price does not seem to be the driving factor as the fire dartfish falls under the low end of medium value species. Aquarium fishers stated that firefish are very hardy fish with low mortality rates, making it easier for them to transport from Mindoro to Calatagan to Manila. Additionally, they mentioned that the firefish is a popular aquarium fish that is in high demand from the exporters. The firefish also received the highest score according to the aquarium suitability index, meaning that they adjust well to captivity. Consumer demand is acknowledged as the driving force behind the aquarium trade as a whole (Wood 2001). Some species, such as cleaner wrasse and clownfish, are very popular with importers and so they are constantly in high demand (Wood 2001). Based on this study, it would appear as though the fire dartfish also falls into this category. Further support for this classification comes from a study that looked at shipment declarations and sales invoices of all marine aquarium fish species being imported into the United States within a one-year period (Rhyne et al. 2012). The fire dartfish was in the top 10 species. Therefore, consumer demand appears to be the leading factor behind collection of firefish and fishers are merely striving to meet this demand.

Species Vulnerability

Many traders argue that collecting fish for the aquarium trade has no negative impact on reef populations (Wabnitz et al. 2003). This is possible for fisheries that are smaller than the available fish population. Presently, the Calatagan aquarium fishery seems to fall into this category on a precautionary basis. Eighteen species selected for the PSA were calculated to be least vulnerable and two were calculated to be moderately vulnerable to overharvest in the Calatagan aquarium fishery. Many of the species assessed are smaller fish with high reproduction rates and therefore are able to reproduce faster than they are being caught. Most coral reef fish have wide distributions (Sale 1991) and all of the species in this analysis, with the exception of the fire dartfish, can be found throughout Calatagan and other nearby islands. In addition, many of these species can be found in both shallower and deeper depths. Fishers free dive to collect their fish and so are only able to swim down to approximately 15 m for a very short period of time. Populations found at lower depths are unlikely to be in danger of being overharvested.

There are some possible explanations for why the zebra lionfish (*D. zebra)* and palette surgeonfish (*P. hepatus)* scored slightly higher than the other species and may be more vulnerable to being locally overharvested. The zebra lionfish was mentioned in three out of the four categories in fishers' interviews: most commonly caught, most desirable to catch, and easiest to catch (ranked 4th). It had the highest mean trophic level of all species chosen for the PSA and also takes longer to reach sexual maturity. As a result, the overall productivity of this species was lower than the other species. On the other hand, the palette surgeonfish received the highest susceptibility score out of all the species. It was also mentioned in three of the four categories in fishers' interviews: most desirable to catch, easiest to catch, and once commonly caught but now rarely caught (ranked 3rd). Based on key informant interviews, the palette surgeonfish can be caught in groups, making it easier to collect multiple fish at a time. Fishers also mentioned that it has a higher chance of mortality when being accidentally caught. Both of these factors combined with the high price attached to it, resulted in a higher susceptibility score.

Aquarium Suitability

Despite the fact that most species received lower vulnerability scores, it does not mean that they are unsusceptible to negative impacts from the aquarium trade. Aquarium suitability is a unique attribute of aquarium fisheries that was specifically incorporated in this study for the PSA. The trade relies on fish remaining alive throughout collection, transportation, and in captivity. No party involved, fish or human, benefits from mortalities. Of the 20 species selected for the PSA, 14 species received high aquarium suitability scores, three received moderate scores, and two received low scores. The bluestreak cleaner wrasse (*Labroides dimidiatus)* and blueband goby (*Valenciennea strigata)* were the 3rd and 6th most caught species according to receipts; however, aquarists are advised not to keep them. Both are difficult to feed, and often starve to death (Michael 2001). The bluestreak cleaner wrasse grooms other fish for parasites and mucous and so is desirable in an aquarium for this very reason (Michael 2001). However, it needs a large population of fish to be able to groom and in most cases it is not able to do so in captivity (Michael 2001). In the wild, *Labroides dimidiatus* is typically more abundant in areas with fewer predators, greater numbers of sedentary fish, fewer fish aggregating in large schools, and areas of higher species richness (Arnal et al. 2002). One study revealed that the removal of *Labroides dimidiatus* from a coral reef led to a decrease in fish diversity whereas the addition of *Labroides dimidiatus* led to an increase in fish diversity (Bshary 2003). Therefore, it raises the question if such species are suitable for the aquarium trade or if they should instead be left on the reef to provide crucial ecosystem services to greater fish populations.

Implications from Species Vulnerability

Vulnerability categories based on the PSA can be used to direct management decisions. Because this analysis was performed at the local scale, the aquarium fishery of Calatagan, the results can only be applied to this particular fishery. This approach was selected because it is rarely done, fisheries management is highly decentralized in the Philippines, and fishers are more likely to take ownership for their own local resources (Wood 2001; Fujita et al. 2014; Fabinyi et al. 2015). Consequently, the species in this assessment may be more or less vulnerable to other small-scale aquarium fisheries or fisheries at larger scales. Nevertheless, there are several suggestions that can be made to help guide the management of the Calatagan fishery. There is no catch limit for any species collected for the aquarium trade in Calatagan. However, species could be made subject to certain quotas. Species categorized as least vulnerable may be given lower priority; however, an aggregate quota could be applied (Fujita et al. 2014). An aggregate quota would provide a maximum amount of fish that could be collected regardless of species. Most species selected for this study currently fall into this category. Species categorized as moderately vulnerable should be given more attention and population studies may be carried out as well as species-specific quotas (Fujita et al. 2014). Underwater surveys and quotas for both the zebra lionfish as well as the palette surgeonfish are recommended for better management of the Calatagan aquarium fishery. The Maldives, another large exporter of aquarium fish, has a species-based quota system based on export data and species' life history traits and adaptability to captivity (Saleem and Islam 2008). This system places species into one of three categories: species banned from export, species subject to a species' specific export quota, and species subject to an aggregate quota (Saleem and Islam 2008). While this system appears to be relatively effective, it still has difficulties with monitoring as different agencies are involved throughout the process (Saleem and Islam 2008). This leads to a lack in clarity of each agency's responsibilities regarding quota monitoring. In contrast, enforcement in the Philippines is carried out by the LGU, which usually lack the resources for proper management. Therefore, introducing species-based quotas will only be beneficial if they are regularly enforced.

The species selected for this study have previously undergone other vulnerability assessments (Table 2.5). However, each analysis was carried out at a different scale and looked at vulnerability through slightly different perspectives. This PSA analysis was at a very small scale and the results are only applicable to the aquarium fishery in Calatagan. Therefore, care should be taken when applying the results to other areas of the Philippines where the same species may be more or less vulnerable. The PSA conducted by Fujita et al. (2014) used the same attributes (except aquarium suitability) and analysis as this study; however, it looked at a different 21 species. Only five of the species used are the same as the ones in the 2014 study. Furthermore, the study by Fujita et al. (2014) was carried out in five regions of the greater Indonesian basin and so covered a larger scale. Cheung et al. (2005) incorporated heuristic rules using species' life history traits to estimate their intrinsic vulnerability to extinction. The results presented here are similar to those of Cheung et al. (2005) because half of the PSA is based on species' intrinsic vulnerability via the productivity attributes. The approach used by Cheung et al. (2005) can be applied to any marine fish species, but it does not directly incorporate collection rates. It does incorporate extinction risks such as categories from the IUCN Red List. The IUCN categorizes species according to their level of global threat. According to IUCN (2017), 12 species in this study have global populations of least concern, while 8 species have not yet been evaluated for global assessment. While it is useful to compare these vulnerability assessments, it is critical to understand at which scale each one was conducted and therefore how to interpret their results.

Overall, all of these assessments show similar findings. Most of these species do not appear to be highly vulnerable, and in fact seem to have lower vulnerabilities, regardless of scale. The largest incongruence lies with the false clownfish (*Amphiprion ocellaris*). Both this study, as well as Cheung et al. (2005) calculated a low vulnerability for this species. However, Fujita et al. (2014) calculated a high vulnerability for this species. As mentioned above, the approach used by Cheung et al. (2005) does not directly incorporate collection rates and focuses primarily on intrinsic life history traits. This study does take collection into consideration; however, it is on a smaller scale with lower collection rates. Fujita et al. (2014) examined a much larger area, presumably with a larger fishery. Furthermore, that study was conducted in Indonesia, meaning the distribution of this species as well as harvest techniques could be different compared to those in the Philippines. The IUCN global assessment for this species cannot be compared, as it has not yet been evaluated. Another smaller disjunction between this study and Cheung et al. (2005) regards the Koran angelfish (*Pomacanthus semicirculatus*) and the emperor angelfish (*Pomacanthus imperator*). Because this species has a lower fecundity and reaches sexual maturity later, Cheung et al. categorizes it as moderate-highly vulnerable. However, in this study, these two species were very rarely caught according to receipts and interviews with local fishers. It may be more intrinsically vulnerable, but a low enough collection rate should not threaten a local population. For these two species, the IUCN statuses were deemed as least concern, more closely aligning with the results in this study.

Table 2.5 Vulnerability scores for the 20 species selected for this study compared to other vulnerability assessments.

Common Name	This study	Fujita et al. (2014)	Cheung et al. (2005)	IUCN (2017)
Jeweled blenny	Low	-	Low-Moderate	LC
Blue green chromis	Low	Moderate	Low	NE
Bluestreak cleaner wrasse	Low	-	Low	LC
Threadfin butterflyfish	Low	-	Low	LC
Fire dartfish	Low	Moderate	Low	LC
Yellowtail coris	Low	-	Moderate	LC
King demoiselle	Low	-	Low	NE
Koran angelfish	Low	-	Moderate-High	LC
Zebra lionfish	Moderate	-	Moderate-High	LC
Palette surgeonfish	Moderate	Low	Low-Moderate	LC
Emperor angelfish	Low	-	Moderate-High	LC
Clown triggerfish	Low	-	Moderate	NE
Bluegirdled angelfish	Low	-	Low-Moderate	LC
Black damselfish	Low	-	Low-Moderate	NE
Spiny chromis	Low	-	Low-Moderate	NE
Blueband goby	Low	-	Low	NE
False clownfish	Low	High	Low	NE
Sapphire devil	Low	Moderate	Low	NE

Common Name	This study	Fujita et al. (2014)	Cheung et al. (2005)	IUCN (2017)
Japan surgeonfish	Low	-	Low	LC
Blackfin dartfish	Low	-	Low	LC

While it appears as though vulnerability to overharvest in Calatagan is quite low, there are two species that are moderately vulnerable and two species (*Balistoides conspicillum* and *Pomacanthus semicirculatus*), which are close to being moderately vulnerable. The fishers themselves have indicated that fish populations are decreasing (Table 2.6). The fishermen, above anyone else, should be considered experts when it comes to local fish populations due to the amount of time they spend in the marine environment. It is particularly interesting that fishers believe the fire dartfish population is stable, even though it is overwhelmingly the most caught species for the fishery. This may be interpreted in several ways. First, the fire dartfish population may indeed be stable due to high rates of fecundity and a significant depth range. Second, the population may be declining due to exporter demand, but the fishers are looking harder for individuals and so they perceive the population as stable. Third, the population may be declining but not at a significant enough rate for the fishers to detect a decrease yet. Based on quantities of fire dartfish on receipts as well as scientific literature, I believe that the first or third interpretation is more likely. However, fish monitoring surveys could support or contradict their observations and help better understand the health of the coral reef ecosystem.

Table 2.6 Aquarium fishers' perceived population status and calculated vulnerability category of each species assessed in PSA.

Common Name	Perceived Population Status	Vulnerability
Jeweled Blenny	Increasing	Low
Blue Green Chromis	Decreasing	Low
Bluestreak Cleaner Wrasse	Decreasing	Low
Threadfin Butterflyfish	Decreasing	Low
Fire Dartfish	Stable	Low
Yellowtail Coris	Decreasing	Low
King Demoiselle	Decreasing	Low
Koran Angelfish	Decreasing	Low
Zebra Lionfish	Decreasing	Moderate
Palette Surgeonfish	Decreasing	Moderate
Emperor Angelfish	Decreasing	Low
Clown Triggerfish	Decreasing	Low
Bluegirdled Angelfish	Decreasing	Low
Black Damselfish	Decreasing	Low
Spiny Chromis	Decreasing	Low
Blueband Goby	Stable	Low
False Clownfish	Decreasing	Low
Blue Devil Damselfish	Stable/Increasing	Low
Japan Surgeonfish	Increasing	Low
Blackfin Dartfish	Stable	Low

This study focused primarily on the vulnerability of species to overharvest based on life history traits and characteristics of the aquarium fishery. It does not consider other factors that may classify a species as vulnerable. In addition to overharvest, the fishers mentioned several other components that would affect fish populations at the local level. Calatagan has an array of resorts along its coasts for tourism (Figure 2.3). The resorts release chemicals, such as chlorinated pool water, into the ocean. It is also acknowledged by both the local government as well as fishers that both dynamite and cyanide fishing have occurred in Calatagan, mainly in the past but also at a smaller scale in the present. Both cyanide and dynamite fishing are destructive to fish and the coral reefs in which they take refuge. Furthermore, the vulnerability assessment does not take into account larger scale factors as climate change, coral bleaching, warmer water temperatures, and pollution. These components also undoubtedly play a role in species' vulnerability.

Figure 2.3 Google Earth image showing Manuel Uy Beach, Santa Ana (fish collection area) in proximity to three nearby resorts. Google Earth Pro 7.3.0.3832. Copyright © 2017. Santa Ana, Calatagan from http://www.earth.google.com.

Table A2.1 List of 180 identified species from receipts according to family, genus, species, functional group, and IUCN category.

Family	Genus	Species	Functional Group	IUCN
Blenniidae	*Salarias*	*fasciatus*	herbivore	LC
Callionymidae	*Synchiropus*	*ocellatus*	carnivore	NE
Pomacentridae	*Chromis*	*viridis*	planktivore	NE
Pomacentridae	*Amphiprion*	*polymnus*	omnivore	NE
Pomacentridae	*Chrysiptera*	*rex*	herbivore	NE
Mullidae	*Parupeneus*	*cyclostomus*	carnivore	LC
Scorpaenidae	*Dendrochirus*	*zebra*	carnivore	LC
Tetraodontidae	*Arothron*	*nigropunctatus*	omnivore	LC
Tetraodontidae	*Arothron*	*meleagris*	omnivore	LC
Acanthuridae	*Acanthurus*	*triostegus*	omnivore	LC
Acanthuridae	*Naso*	*lituratus*	herbivore	LC
Zanclidae	*Zanclus*	*cornutus*	omnivore	LC
Labridae	*Labroides*	*dimidiatus*	carnivore	LC
Labridae	*Macropharyngodon*	*meleagris*	carnivore	LC
Labridae	*Coris*	*gaimard*	carnivore	LC
Pomacentridae	*Neoglyphidodon*	*melas*	omnivore	NE
Pomacentridae	*Dascyllus*	*melanurus*	omnivore	NE
Pomacentridae	*Acanthochromis*	*polyacanthus*	herbivore	NE
Pomacentridae	*Amphiprion*	*frenatus*	omnivore	NE
Labridae	*Halichoeres*	*hortulanus*	carnivore	LC
Acanthuridae	*Zebrasoma*	*scopas*	herbivore	LC
Chaetodontidae	*Chaetodon*	*auriga*	omnivore	LC
Chaetodontidae	*Chaetodon*	*vagabundus*	omnivore	LC
Balistidae	*Rhinecanthus*	*aculeatus*	omnivore	NE
Microdesmidae	*Nemateleotris*	*magnifica*	planktivore	LC
Pholidichthyidae	*Pholidichthys*	*leucotaenia*	planktivore	NE
Microdesmidae	*Ptereleotris*	*heteroptera*	planktivore	LC

Family	Genus	Species	Functional Group	IUCN
Acanthuridae	*Acanthurus*	*japonicus*	herbivore	LC
Pomacentridae	*Amphiprion*	*clarkii*	omnivore	NE
Microdesmidae	*Ptereleotris*	*zebra*	planktivore	LC
Microdesmidae	*Ptereleotris*	*evides*	planktivore	LC
Gobiidae	*Valenciennea*	*strigata*	carnivore	NE
Blenniidae	*Ecsenius*	*bicolor*	herbivore	LC
Gobiidae	*Amblygobius*	*phalaena*	omnivore	NE
Labridae	*Epibulus*	*insidiator*	carnivore	LC
Apogonidae	*Pristicon*	*trimaculatus*	carnivore	NE
Pomacentridae	*Amblyglyphidodon*	*curacao*	planktivore	NE
Pomacentridae	*Amphiprion*	*ocellaris*	omnivore	NE
Malacanthidae	*Malacanthus*	*latovittatus*	carnivore	NE
Labridae	*Gomphosus*	*varius*	carnivore	LC
Balistidae	*Balistoides*	*conspicillum*	carnivore	NE
Haemulidae	*Plectorhinchus*	*chaetodonoides*	carnivore	NE
Chaetodontidae	*Chaetodon*	*kleinii*	omnivore	LC
Haemulidae	*Plectorhinchus*	*polytaenia*	carnivore	NE
Haemulidae	*Plectorhinchus*	*vittatus*	carnivore	NE
Labridae	*Halichoeres*	*melanurus*	carnivore	NE
Labridae	*Novaculichthys*	*taeniourus*	carnivore	LC
Labridae	*Anampses*	*geographicus*	carnivore	LC
Pomacentridae	*Pomacentrus*	*moluccensis*	omnivore	NE
Pomacentridae	*Chrysiptera*	*cyanea*	omnivore	NE
Labridae	*Pseudojuloides*	*cerasinus*	carnivore	DD
Balistidae	*Melichthys*	*vidua*	omnivore	NE
Labridae	*Thalassoma*	*lunare*	carnivore	LC
Serranidae	*Pseudanthias*	*dispar*	carnivore	LC
Chaetodontidae	*Chaetodon*	*lunulatus*	corallivore	LC

Family	Genus	Species	Functional Group	IUCN
Labridae	*Pseudodax*	*moluccanus*	omnivore	LC
Pomacentridae	*Pomacentrus*	*auriventris*	herbivore	NE
Serranidae	*Pseudanthias*	*huchtii*	carnivore	LC
Labridae	*Halichoeres*	*chrysus*	carnivore	LC
Chaetodontidae	*Chaetodon*	*ephippium*	omnivore	LC
Chaetodontidae	*Chaetodon*	*lunula*	omnivore	LC
Chaetodontidae	*Chaetodon*	*melannotus*	corallivore	LC
Pomacentridae	*Abudefduf*	*vaigiensis*	omnivore	NE
Centriscidae	*Aeoliscus*	*strigatus*	planktivore	DD
Chaetodontidae	*Chaetodon*	*lineolatus*	omnivore	LC
Chaetodontidae	*Chaetodon*	*adiergastos*	omnivore	LC
Chaetodontidae	*Chaetodon*	*trifascialis*	corallivore	NT
Acanthuridae	*Acanthurus*	*lineatus*	herbivore	LC
Labridae	*Bodianus*	*mesothorax*	carnivore	LC
Labridae	*Hemigymnus*	*melapterus*	carnivore	LC
Labridae	*Hemigymnus*	*fasciatus*	carnivore	LC
Syngnathidae	*Corythoichthys*	*intestinalis*	carnivore	LC
Scorpaenidae	*Pterois*	*volitans*	carnivore	LC
Ostraciidae	*Lactoria*	*cornuta*	carnivore	NE
Pomacanthidae	*Pomacanthus*	*imperator*	omnivore	LC
Labridae	*Thalassoma*	*quinquevittatum*	carnivore	LC
Apogonidae	*Ostorhinchus*	*compressus*	carnivore	LC
Scorpaenidae	*Pterois*	*lunulata*	carnivore	LC
Pomacentridae	*Pomacentrus*	*coelestis*	omnivore	NE
Blenniidae	*Meicanthus*	*grammistes*	planktivore	LC
Labridae	*Halichoeres*	*hartzfeldii*	carnivore	LC
Pomacentridae	*Dascyllus*	*trimaculatus*	omnivore	NE
Chaetodontidae	*Heniochus*	*singularius*	carnivore	LC

Family	Genus	Species	Functional Group	IUCN
Chaetodontidae	*Chaetodon*	*citrinellus*	omnivore	LC
Gobiidae	*Valenciennea*	*sexguttata*	carnivore	NE
Pomacentridae	*Dascyllus*	*reticulatus*	omnivore	NE
Pomacanthidae	*Centropyge*	*vroliki*	omnivore	LC
Chaetodontidae	*Chaetodon*	*ornatissimus*	corallivore	LC
Scaridae	*Cetoscarus*	*bicolor*	herbivore	LC
Monacanthidae	*Aluterus*	*monoceros*	omnivore	LC
Pomacanthidae	*Apolemichthys*	*trimaculatus*	omnivore	LC
Monacanthidae	*Acreichthys*	*tomentosus*	omnivore	LC
Acanthuridae	*Acanthurus*	*olivaceus*	herbivore	LC
Pomacanthidae	*Pomacanthus*	*semicirculatus*	omnivore	LC
Labridae	*Thalassoma*	*amblycephalum*	planktivore	LC
Acanthuridae	*Zebrasoma*	*velifer*	herbivore	LC
Balistidae	*Rhinecanthus*	*verrucosus*	carnivore	NE
Mullidae	*Parupeneus*	*barberinoides*	carnivore	LC
Holocentridae	*Myripristis*	*murdjan*	planktivore	LC
Holocentridae	*Sargocentron*	*diadema*	carnivore	LC
Scorpaenidae	*Dendrochirus*	*brachypterus*	carnivore	LC
Congridae	*Heteroconger*	*taylori*	planktivore	DD
Chaetodontidae	*Chaetodon*	*octofasciatus*	omnivore	LC
Chaetodontidae	*Chaetodon*	*rafflesii*	carnivore	LC
Chaetodontidae	*Chaetodon*	*baronessa*	corallivore	LC
Chaetodontidae	*Chelmon*	*rostratus*	carnivore	LC
Ostraciidae	*Ostracion*	*meleagris*	omnivore	NE
Serranidae	*Plectropomus*	*laevis*	carnivore	VU
Balistidae	*Odonus*	*niger*	carnivore	NE
Muraenidae	*Gymnomuraena*	*zebra*	carnivore	NE
Muraenidae	*Echidna*	*nebulosa*	carnivore	NE

Family	Genus	Species	Functional Group	IUCN
Pomacentridae	*Pomacentrus*	*vaiuli*	omnivore	NE
Ephippidae	*Platax*	*orbicularis*	omnivore	NE
Acanthuridae	*Naso*	*brevirostris*	herbivore	LC
Acanthuridae	*Naso*	*unicornis*	herbivore	LC
Balistidae	*Balistoides*	*viridescens*	carnivore	NE
Balistidae	*Balistapus*	*undulatus*	omnivore	NE
Chaetodontidae	*Chaetodon*	*falcula*	omnivore	LC
Labridae	*Coris*	*batuensis*	carnivore	LC
Serranidae	*Grammistes*	*sexlineatus*	carnivore	LC
Siganidae	*Siganus*	*unimaculatus*	omnivore	NE
Siganidae	*Siganus*	*vulpinus*	omnivore	LC
Chaetodontidae	*Chaetodon*	*xanthurus*	omnivore	LC
Acanthuridae	*Paracanthurus*	*hepatus*	planktivore	LC
Lutjanidae	*Symphorichthys*	*spilurus*	carnivore	LC
Balistidae	*Sufflamen*	*chrysopterum*	carnivore	NE
Blenniidae	*Cirripectes*	*quagga*	herbivore	LC
Pomacentridae	*Pomacentrus*	*bankanensis*	omnivore	NE
Ostraciidae	*Ostracion*	*cubicus*	omnivore	NE
Tetraodontidae	*Canthigaster*	*valentini*	omnivore	LC
Tetraodontidae	*Canthigaster*	*solandri*	omnivore	LC
Tetraodontidae	*Arothron*	*manilensis*	carnivore	LC
Balistidae	*Pseudobalistes*	*flavimarginatus*	omnivore	NE
Pomacentridae	*Neoglyphidodon*	*nigroris*	omnivore	NE
Siganidae	*Siganus*	*virgatus*	omnivore	NE
Syngnathidae	*Dunckerocampus*	*dactyliophorus*	carnivore	DD
Caesionidae	*Pterocaesio*	*tile*	planktivore	LC
Acanthuridae	*Acanthurus*	*pyroferus*	herbivore	LC
Pinguipedidae	*Parapercis*	*hexophthalma*	carnivore	NE

Family	Genus	Species	Functional Group	IUCN
Pomacentridae	*Chromis*	*vanderbilti*	planktivore	NE
Scorpaenidae	*Pterois*	*antennata*	carnivore	LC
Pomacentridae	*Neoglyphidodon*	*oxyodon*	omnivore	NE
Serranidae	*Cromileptes*	*altivelis*	carnivore	VU
Acanthuridae	*Acanthurus*	*mata*	herbivore	LC
Pomacanthidae	*Centropyge*	*bicolor*	omnivore	LC
Gobiidae	*Gobiodon*	*citrinus*	planktivore	NE
Balistidae	*Rhinecanthus*	*rectangulus*	carnivore	NE
Pomacanthidae	*Pygoplites*	*diacanthus*	omnivore	LC
Nemipteridae	*Pentapodus*	*emeryii*	carnivore	LC
Chaetodontidae	*Chaetodon*	*unimaculatus*	omnivore	LC
Blenniidae	*Meicanthus*	*atrodorsalis*	carnivore	LC
Pomacentridae	*Dascyllus*	*aruanus*	omnivore	NE
Muraenidae	*Rhinomuraena*	*quaesita*	carnivore	LC
Chaetodontidae	*Heniochus*	*varius*	carnivore	LC
Monacanthidae	*Pervagor*	*janthinosoma*	omnivore	LC
Scaridae	*Chlorurus*	*sordidus*	herbivore	LC
Nemipteridae	*Scolopsis*	*bilineata*	carnivore	LC
Pomacentridae	*Amphiprion*	*perideraion*	omnivore	NE
Pomacanthidae	*Centropyge*	*tibicen*	omnivore	LC
Muraenidae	*Pseudechidna*	*brummeri*	carnivore	NE
Muraenidae	*Gymnothorax*	*flavimarginatus*	carnivore	NE
Labridae	*Anampses*	*meleagrides*	planktivore	LC
Labridae	*Halichoeres*	*nebulosus*	carnivore	LC
Chaetodontidae	*Chaetodon*	*speculum*	corallivore	LC
Callionymidae	*Dactylopus*	*dactylopus*	carnivore	NE
Plesiopidae	*Calloplesiops*	*altivelis*	carnivore	NE
Chaetodontidae	*Chaetodon*	*mertensii*	omnivore	LC

Family	Genus	Species	Functional Group	IUCN
Acanthuridae	*Ctenochaetus*	*striatus*	herbivore	LC
Pomacanthidae	*Pomacanthus*	*navarchus*	omnivore	LC
Scorpaenidae	*Dendrochirus*	*biocellatus*	carnivore	LC
Siganidae	*Siganus*	*corallinus*	herbivore	LC
Siganidae	*Siganus*	*puellus*	carnivore	LC
Plotosidae	*Plotosus*	*lineatus*	omnivore	NE
Labridae	*Halichoeres*	*marginatus*	carnivore	LC
Haemulidae	*Plectorhinchus*	*lessonii*	carnivore	NE
Pomacanthidae	*Centropyge*	*heraldi*	omnivore	LC
Pomacentridae	*Premnas*	*biaculeatus*	omnivore	NE
Callionymidae	*Synchiropus*	*morrisoni*	omnivore	NE
Ephippidae	*Platax*	*teira*	carnivore	NE
Acanthuridae	*Acanthurus*	*nigricans*	herbivore	LC

Table A2.2 Productivity attribute scores for all species in the PSA.

Species	r	Maximum age	Maximum size	k	Estimated natural mortality	Fecundity	Breeding strategy	Recruitment pattern	Age at maturity	Mean trophic level
Jeweled blenny	3	3	3	3	3	-	2	3	3	3
Blue green chromis	3	2	3	3	3	2	2	3	3	2
Bluestreak cleaner wrasse	3	3	3	3	3	2	3	2	3	2
Threadfin butterflyfish	3	3	3	3	3	3	3	3	3	1
Fire dartfish		3	3		3	-	2	3	3	2
Yellowtail coris	2	2	3	2	3	3	3	2	2	2
King demoiselle	3	2	3	3	3	2	2	3	3	2
Koran angelfish	2	2	3	2	3	2	3	2	2	2
Zebra lionfish	2	2	3	2	3	2	3	2	1	1
Palette surgeonfish	3	2	3	3	3	2	3	3	3	2
Emperor angelfish	2	2	3	2	3	2	3	2	2	2
Clown triggerfish	2	2	3	2	3	3	2	2	2	2
Bluegirdled angelfish	3	2	3	3	3	2	3	2	2	2
Black damselfish	3	3	3	3	3	2	2	2	2	2
Spiny chromis	3	2	3	3	3	1	2	3	3	2
Blueband goby	3	3	3	3	3	3	2	3	3	1
False clownfish	3	2	3	3	3	1	2	3	3	2
Sapphire devil	3	2	3	3	3	2	2	3	3	2
Japan surgeonfish	3	2	3	3	3	2	3	3	3	3
Blackfin dartfish	-	2	3	-	3	-	2	3	3	2

Table A2.3 Susceptibility attribute scores for all species in the PSA. The attributes 'fishing rate relative to M' and 'biomass of spawners' was not included in the PSA due to no data. Those attributes are included in the data quality index scores table.

Species	Management strategy	Areal overlap	Geographic concentration	Vertical overlap	Seasonal migrations	Schooling	Morpology	Survival after capture	Value to fishery	Habitat impact	Aquarium suitability
Jeweled blenny	3	3	1	2	2	2	3	1	1	1	1
Blue green chromis	3	2	1	2	2	3	2	1	1	1	1
Bluestreak cleaner wrasse	3	2	1	1	2	2	2	1	1	1	3
Threadfin butterflyfish	3	2	1	1	2	2	2	1	2	1	1
Fire dartfish	3	1	2	1	2	2	2	1	2	1	1
Yellowtail coris	3	1	1	1	2	2	2	1	1	1	1
King demoiselle	3	2	1	2	2	2	3	1	1	1	1
Koran angelfish	3	2	1	2	2	2	1	1	3	1	1
Zebra lionfish	3	2	1	1	2	2	3	2	1	1	1
Palette surgeonfish	3	1	1	2	2	3	2	2	3	2	2
Emperor angelfish	3	1	1	1	1	2	1	2	3	1	2
Clown triggerfish	3	1	2	2	1	2	2	1	3	2	1
Bluegirdled angelfish	3	1	1	3	1	2	1	1	3	1	2
Black damselfish	3	2	1	2	2	3	3	1	1	1	1
Spiny chromis	3	2	1	1	2	3	3	2	1	1	1

Species	Management strategy	Areal overlap	Geographic concentration	Vertical overlap	Seasonal migrations	Schooling	Morphology	Survival after capture	Value to fishery	Habitat impact	Aquarium suitability
Blueband goby	3	1	2	1	2	2	3	1	1	1	3
False clownfish	3	2	1	2	2	2	3	1	2	1	1
Saphire devil	3	1	1	2	2	3	3	2	1	1	1
Japan surgeonfish	3	1	1	2	2	2	2	1	2	1	2
Blackfin dartfish	3	1	1	3	2	3	2	1	1	1	1

Table A2.4 Data quality scores of productivity attributes for all species in the PSA.

Species	r	Maximum age	Maximum size	k	Estimated natural mortality	Fecundity	Breeding strategy	Recruitment pattern	Age at maturity	Mean trophic level
Jeweled blenny	3	2	1	2	2	5	1	3	2	1
Blue green chromis	3	2	1	2	2	2	1	3	2	1
Bluestreak cleaner wrasse	3	2	1	2	2	1	1	3	2	1
Threadfin butterflyfish	3	2	1	2	2	1	1	3	2	1
Fire dartfish	5	4	1	5	2	5	3	3	3	1
Yellowtail coris	3	4	1	2	2	3	2	3	2	1
King demoiselle	3	3	1	2	2	3	1	3	2	1
Koran angelfish	3	2	1	2	3	3	2	3	2	1
Zebra lionfish	3	3	1	2	3	3	1	3	2	1
Palette	3	2	1	2	2	2	2	3	2	1

Species	r	Maximum age	Maximum size	k	Estimated natural mortality	Fecundity	Breeding strategy	Recruitment pattern	Age at maturity	Mean trophic level
surgeonfish										
Emperor angelfish	3	1	1	2	3	1	3	3	2	1
Clown triggerfish	3	2	1	2	2	3	1	3	2	1
Bluegirdled angelfish	3	1	1	2	2	3	2	3	2	1
Black damselfish	3	3	1	2	2	3	1	3	2	1
Spiny chromis	3	4	1	2	2	1	1	3	2	1
Blueband goby	3	1	1	2	2	1	1	3	2	1
False clownfish	3	1	1	2	2	1	1	3	2	1
Sapphire devil	3	3	1	2	2	3	1	3	2	1
Japan surgeonfish	3	3	1	2	2	2	2	3	2	3
Blackfin dartfish	5	4	1	5	2	5	3	3	3	1

Table A2.5 Data quality scores of susceptibility attributes for all species in the PSA.

Species	Management strategy	Areal overlap	Geographic concentration	Vertical overlap	Fishing rate relative to M	Biomass of spawners	Seasonal migrations	Schooling	Morphology	Survival after capture	Value to fishery	Habitat impact	Aquarium suitability
Jeweled blenny	1	1	1	1	5	5	1	1	1	2	1	4	1
Blue green chromis	1	1	1	1	5	5	1	1	1	2	1	4	1
Bluestreak cleaner wrasse	1	1	1	1	5	5	1	1	1	2	1	4	1

Species	Management strategy	Areal overlap	Geographic concentration	Vertical overlap	Fishing rate relative to M	Biomass of spawners	Seasonal migrations	Schooling	Morphology	Survival after capture	Value to fishery	Habitat impact	Aquarium suitability
Threadfin butterflyfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Fire dartfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Yellowtail coris	1	1	1	1	5	5	1	1	1	2	1	4	1
King demoiselle	1	1	1	1	5	5	1	1	1	2	1	4	3
Koran angelfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Zebra lionfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Palette surgeonfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Emperor angelfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Clown triggerfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Bluegirdled angelfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Black damselfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Spiny chromis	1	1	1	1	5	5	1	1	1	2	1	4	3
Blueband	1	1	1	1	5	5	1	1	1	2	1	4	1

Species	Management strategy	Area l overlap	Geographic concentration	Vertical overlap	Fishing rate relative to M	Biomass of spawners	Seasonal migrations	Schooling	Morphology	Survival after capture	Value to fishery	Habitat impact	Aquarium suitability
goby													
False clownfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Sapphire devil	1	1	1	1	5	5	1	1	1	2	1	4	1
Japan surgeonfish	1	1	1	1	5	5	1	1	1	2	1	4	1
Blackfin dartfish	1	1	1	1	5	5	1	1	1	2	1	4	1

4 Fish Collection Areas and a Detailed Description of the Aquarium Fishers in Calatagan

Introduction

Chapter 3 focused on which species are collected for the aquarium trade in Calatagan as well as their vulnerability to being locally overharvested. This chapter will provide insight into who the aquarium fishers are and where they are collecting their fish. It will explore fishers' motivations, fishing patterns, livelihoods, and threats facing aquarium fishers. It will also emphasize the role family plays regarding the aquarium trade. Without aquarium fishing being passed on from generation to generation, small-scale aquarium fishing is unlikely to continue. Additionally, while aquarium fishers tend to like their jobs, they would not encourage others to join the trade. Therefore, this chapter will suggest that, at least in some respects, aquarium fishers in Calatagan are perhaps more vulnerable than the species they collect.

Results

Demographics

All aquarium fish collectors are men ranging from 27-75 years old (av. 47) (Table 3.1). Some started collecting at age 12 while others did not start until 35 years of age (av. 18). Their education ranged from no formal education to being a high school graduate. The average grade fishers completed before entering the aquarium trade was grade 6. In the Philippines, grade 6, at which point an individual is approximately 12 years old, is the end of primary school. Therefore most of the fishers completed primary school and then entered the aquarium trade instead of finishing high school. Two thirds of the fishers were born in Calatagan, while the remaining fishers were born in other parts of the Philippines. These fishers were recruited by friends or family members to join the Calatagan aquarium fishery. There appears to be a minor trend in that older fishers started fishing at a slightly older age than younger fishers, possibly due to this recruitment. A possible explanation for this is the fact that most fishers born outside of Calatagan were middle-aged or older fishers. These results also indicate that most of the younger fishers were born in Calatagan, suggesting that the recruitment of newer fishers from other areas is diminishing.

Table 3.1 Demographic data for aquarium fishers.

Number of fishers	Age	Born in Calatagan	Grade completed	Age started fishing	Number of people in household
7	27-35	86%	6	16	3
17	36-45	76%	5	17	5
11	46-55	45%	5	19	4
5	56-65	60%	5	19	3
5	66-75	60%	5	21	4

Motivations

Several studies suggest that people participate in wildlife trade due to lack of alternative livelihoods (Mamauag et al. 2013; Muallil et al. 2014). While this is undoubtedly true for some fishers, it does not appear to be a primary explanation for aquarium fishing in Calatagan. The main reason why most fishers got involved in the aquarium trade was due to a family member, such as their father, brother, or uncle. Furthermore, aquarium fishers cited the desire to make money and family reasons as their main motivations for working in the aquarium fish trade (Table 3.2). Only one fifth of fishers listed lack of alternative options as a motivation for joining the aquarium trade. This suggests that aquarium fishing for many fishers was not a profession of last resort and that it may have actually been favorable compared to other livelihoods.

Table 3.2 Motivations of fishers for joining the aquarium trade.

Motivation	Percent
Family	97.6%
Income	100%
Pride/Prestige	14.0%
Desire to add to collection	11.6%
Lack of alternatives	20.9%
Easy	2.3%

When asked if they enjoyed aquarium fishing, 100% of fishers responded that they do. The most common reasons why they enjoy aquarium fishing was that it provides them with an income, supports their families, and there are no requirements/boss. However, when asked of they would encourage younger fishers to enter the aquarium trade, 33

(76.7%) of fishers said they would not. Their top reasons were because aquarium fishing is difficult (60.5%), the pay is low/no increase in fish prices (18.6%), and they want younger people to stay in school and get better jobs (23.3%) (Table 3.3). The top reasons why the minority of fishers would encourage younger fishers to join were because aquarium fishing provides an income and has no boss (11.6%) and they want more people to continue their work (7.0%). One aquarium fisher remained neutral on this aspect.

Table 3.3 Reasons why aquarium fishers would encourage/discourage others to join the aquarium trade.

Encourage	Percent	Discourage	Percent
Want others to continue their work	7.0%	Difficult	60.5%
Better than other fishing	2.3%	Low pay/no increase in fish prices	18.6%
No boss/provides an income	11.6%	Want younger people to stay in school and get better jobs	23.3%
		Sea is dangerous	7.0%
		Fish are decreasing	9.3%

Fish Collection Methods

In order to collect fish in a particular municipality, all fishers need to register with the local government in accordance with the Philippine Fisheries Code of 1998 (RA No. 8550). Once registered, legally fishers may only collect fish within the designated areas of that municipality. Focus groups indicated that aquarium fishers in Calatagan collect their fish throughout most of the municipality, which has a land area of 43.24 square miles and a coastline length of 48 km (see Figure 3.4) (Province: Batangas 2016). The most heavily fished area is between Barangay 1 and Calambuyan due to proximity to fishers' houses. The Philippines, like many islands, is affected by monsoons and typhoons. There are two monsoons that impact Calatagan and other nearby islands, Amihan (northeast monsoon) and Habagat (southwest monsoon). As a result the fishers have adapted different strategies for coping with the changing weather patterns. Fishers in Barangay 1 collect in their smaller area all year round; however, they collect less often during Habagat when the current is stronger at their primary collection site. Many of the fishers in Santa Ana collect on the west side of Calatagan during Amihan (October-May), and then travel to the east side of Calatagan during Habagat (June-October). In Sri Lanka, monsoons also moderate where and when aquarium fishers can collect (Wood 2001). It is thought that these periods of restricted collection allow for some juveniles to grow to large enough sizes that they are no longer targeted and for some mature adults to reproduce (Wood 1985). This further supports the conclusion in Chapter 3 that fish collected for the aquarium trade in Calatagan have a low vulnerability to overharvest simply due to changing collection areas. Fishers that travel to other islands, such as Mindoro, also migrate from the west to the east in the same way. However, they must brave the open sea in order to travel to and from Calatagan

Most aquarium fishers in Calatagan collect fish by free diving and capturing fish in small-mesh nets (Figure 3.1). Different species are caught with different nets depending on size, morphology, and behavior. Almost all fishers use some kind of boat in order to collect fish and collect both in groups and alone (Figure 3.2). However, fishers differ on having boats with (58.0%) or without (42.0%) motors and whether they collect in groups (63.6%) or not (36.4%). All aquarium fishers collecting in groups use boats with motors. Fishing group sizes range from 2-10 people, with most groups (79.3%) containing 2-5 people.

Figure 3.1 Aquarium fisher diving down to collect fish using a ‘saplad’ net.

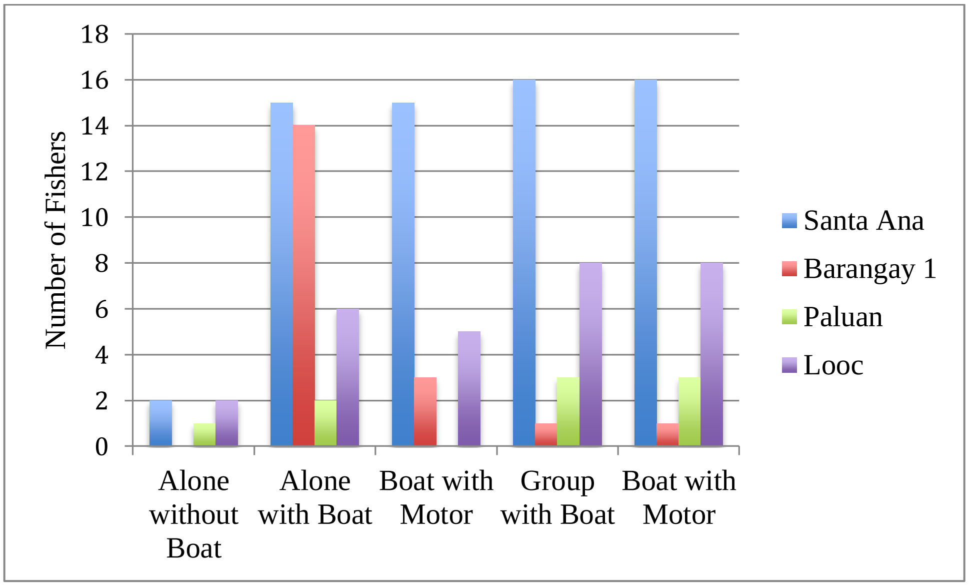


Figure 3.2 The four groups of aquarium fishers and how they collect fish. Many fishers use multiple collection strategies, which is represented in this chart.

Fishers were asked how often they collect fish and if this is seasonally dependent. The majority of fishers stated that they fish every day year-round (Figure 3.3). For fishers who vary their collection rate due to Amihan and Habagat, more fishers collect more often during Amihan than Habagat. All fishers also mentioned that they do not collect on days when there are storms.

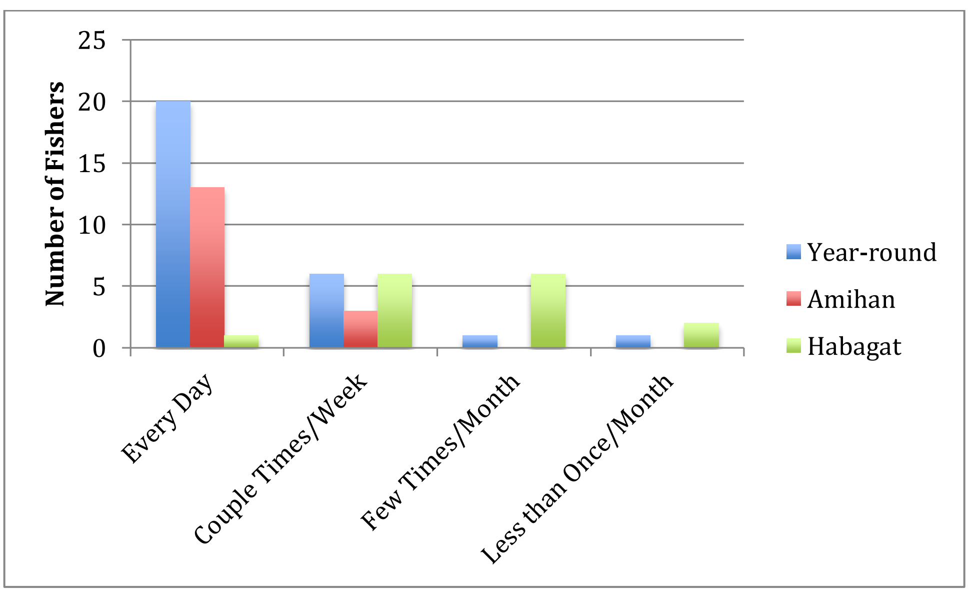


Figure 3.3 Frequency and seasonality of aquarium fish collection.

Collection Conflicts

While the fishers are mostly free to fish in Calatagan, there are places where aquarium fishing is restricted (Figure 3.4). According to the Philippine Fisheries Code of 1998 (RA No. 8550), fishers cannot collect outside their registered municipality or in marine protected areas. Informal discussions with the local government unit (LGU) in Calatagan revealed that there are two marine sanctuaries within Calatagan that do not allow aquarium fishing. Focus group discussions verified both of these laws, but also revealed that thirteen aquarium fishers travel to other islands, therefore different municipalities, for aquarium fish.

Aquarium fishers noted that they collect around Ambil Island, Golo Island, Looc, and Paluan, Mindoro, islands approximately 40 km away from Calatagan. Fishers stated that it takes approximately 3-6 hours to travel by boat from Calatagan to Looc or Paluan, Mindoro and uses 50-60 liters of fuel. Each liter of fuel costs Php 40-50 depending on whether fishers' boats use diesel or gasoline. Similarly to Calatagan, there is one marine sanctuary in Looc, Mindoro where aquarium fishing is also prohibited according to focus group discussions. Focus group discussions also revealed that several of the fishers collecting in Mindoro are not registered there and are thus illegally fishing. The main reason the fishers are traveling to other islands such as Mindoro is to collect the fire dartfish (*Nemateleotris magnifica*). According to the fishers, the fire dartfish cannot be found in Calatagan, but is a popular aquarium fish that is heavily demanded from the exporters. Furthermore, there was some debate as to whether the fire dartfish could be found in Calatagan in the past. Therefore, it would be interesting to compare the marine environment in Calatagan to that in Mindoro to understand horizontal and vertical firefish distribution. Fishers relayed that there are more fish in Mindoro and that the water visibility is better as well. Their reasoning behind this observation was due to more tourism in Calatagan than Mindoro.

Conversely, the fishers also identified places that they are legally allowed to fish, but do not collect fish due to other types of restrictions, including conflicts with barangay captains, resorts, and other fishers. Indeed, Stevenson et al. (2011) found that bureaucracy and conflict was the number one aspect that fishers disliked about the aquarium fishery in Hawaii. According to the focus group discussions, two barangay captains in Calatagan as well as several more in Mindoro have told the aquarium fishers that they cannot collect fish within their barangays. Both the local government and other barangay captains said that banning aquarium fishing in their barangay is not within a barangay captain's power. Yet, the fishers say they obey these requests out of respect for their governing position. When asked why barangay captains do not want aquarium fishing in their barangays, both fishers and barangay captains replied that they do not want cyanide fishing to occur.

Cyanide fishing is thought to have originated in Taiwan and/or the Philippines in the 1960s (McAllister 1995; Wabnitz et al. 2003). Some estimates suggest that more than 80% of all fish collected for the marine aquarium trade in the Philippines were caught with cyanide in the mid-1980s (Wabnitz et al. 2003). According to several of the oldest fishers, the aquarium trade in Calatagan began in the 1950s, and that a doctor from Zambales, Luzon introduced cyanide to Calatagan about 30 years ago. Cyanide fishing is destructive to both the fish and the coral reefs in which they take refuge. The collection of fish using sodium cyanide is now illegal in the Philippines and efforts, such as the Haribon Foundation in the early 1990s, have been made to encourage the collection of fish using nets (Rubec et al. 2001). According to both aquarium fishers and government officials, cyanide fishing was a very common method used in the past in Calatagan and Mindoro, but has greatly reduced in the present. However, the stigma that all aquarium fishers use cyanide is alive and well and is something that the aquarium fishers must deal with. In fact, aquarium fishers in Hawaii stated poor industry reputation as the second-most reason for what they liked least about the aquarium fishery (Stevenson et al. 2011).

Additionally, some resort owners in Barangay Hukay do not want aquarium fishing to occur in front of their resorts. This again, is not within the power of the resort owners according to government officials, but the aquarium fishers abide by their requests. Lastly, fishers that travel to Mindoro do not collect as often in one particular barangay to avoid conflict with other fishers, primarily food fishers. Both of these conflicts are direct results of the decentralization of government. The first example identifies issues over who is and is not responsible for enforcing certain laws at the local level. Other countries, such as the Maldives, also have this problem particular to the aquarium trade (Saleem and Islam 2008). The second example highlights the conflict between commercial fishers and small-scale fishers, which is common in the Philippines and other coastal areas (Green et al. 2003; Bavinck 2005). Small-scale municipal fishers are often overlooked or ignored by management due to the larger commercial industry (Green et al. 2003). As a result, aquarium fishers may perceive themselves as inferior to other fishers (Fabinyi et al. 2015). In an effort to reduce these conflicts, Calatagan aquarium fishers become restricted by more than the law.

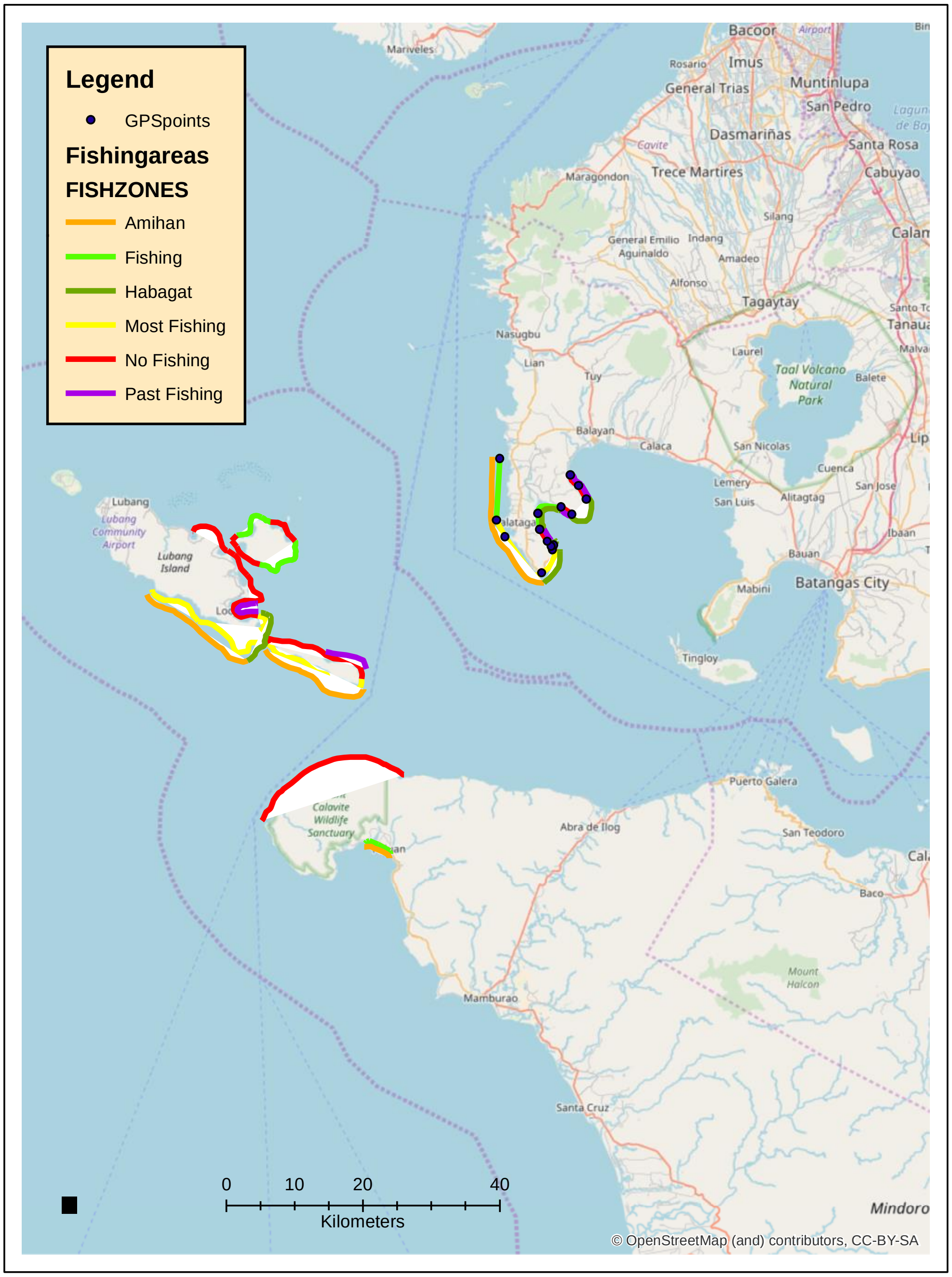


Figure 3.4 ArcGIS Map of different fishing areas, according to maps drawn by aquarium fishers in Calatagan.

Livelihoods

Fishers were asked what jobs they would do if they did not work in the aquarium trade. The top three answers were other fishing activities (food fishing, squid fishing, gleaning) (34.3%), construction (25.4%), and farming (19.4%). All of these jobs are similar to aquarium fishing in that they also entail a great deal of autonomy and lower educational requirements as well as involve working outdoors via manual labor.

Wealth and poverty are difficult concepts to define. What may seem like a lot of money to one person may be minimal to another; therefore, wealth is highly subjective (Duffy et al. 2015). Fishers, principally referring to harvesters of fish for food, are reported as the poorest of the nine basic sectors in the Philippines (Fishery and Aquaculture Country Profiles: Philippines 2014). Therefore it was hypothesized that aquarium fishers would also be classified as among the poorest in their communities. Aquarium fishers were asked indirectly about their income and wealth, including about the financial situation of their household relative to their day-to-day costs. The majority (62.8%) said that their income covered their day-to-day costs of living, but not luxuries/savings/unexpected expenses. The second income-related question they were asked was if they perceived themselves to be poor, rich, or average compared to others in their barangay. Thirty-two (74.4%) fishers felt they were average while 11 (25.6%) fishers felt that they were poorer. There was alignment in self-reported economic status across these two questions. Fishers' perceptions about their income is consistent with another study that found that in many countries in the Pacific region, the income generated by aquarium collectors is reported to be equivalent to or above the average salaries for the country (Pyle 1993). Thus, while an outsider may view an aquarium fisher as poor, aquarium fishers do not necessarily view themselves as poor relative to these two aspects.

Another income-related aspect examined in this study was the importance of aquarium fishing to fishers' households. Most aquarium fishers have other jobs besides collecting fish for the aquarium trade, and so this section of interviews was used to see how the aquarium trade compared to other household activities (Table 3.4). Aquarium fishing was reported as the primary source of household income (71.7%) as well as the most important activity that contributed to fishers' households overall (80.4%). Tourism came in second in both categories at 13.0% and 4.3% respectively. Nine fishers are also employed as boatman for nearby resorts. Tourist season in Calatagan runs approximately from January-June. During tourist season, many aquarium fishers only collect part-time. When tourism season ends, fishers begin collecting full-time. In some instances, aquarium fishers are the only income providers for their household, but in most households there are multiple income providers. This suggests that aquarium fishing alone does not provide enough money to support a family. Therefore, aquarium fishing may not provide as much income as needed, but to remove it completely would seriously impact these households.

Table 3.4 List of additional income generating and non-income generating jobs held by aquarium fishers as well as all other jobs that contribute to aquarium fishers' households income. Jobs marked with an * indicate household use in addition to providing an income.

Jobs held by fishers	Number of Fishers	Jobs that contribute to household income	Number of Households
Aquarium fishing only	6	Aquarium fishing only	10
Byahero	12	Tourism	6
*Food fishing	11	Byahero	7
Boatman	9	Invertebrate collection	10
Construction	5	Vendor	5
Billiards	1	Food fish collection	5
Mangrove planting	1	Sari-sari store	4
Invertebrate collection	13	Restaurant	3
*Net-making	3	Construction	2
*Farming	4	Barangay council	2
Tricycle driver	1	Other	9

Discussion

Monetary vs. Non-monetary Motivations

Studies on the motivations of harvesters in the wildlife trade, whether illegal or legal are few, due to the sensitive nature of the topic (Duffy et al. 2015). Many socio-economic factors influence peoples' participation in the wildlife trade including income, harvest opportunities, available livelihoods, and access to wildlife resources (Phelps et al. 2016). TRAFFIC (2008) looked at a variety of species, both plants and animals, in the wildlife trade in south-east Asia and found that most harvesters surveyed listed the need for income as their primary motivation for harvest, with very few mentioning other reasons such as enjoyment, culture, and pest removal. Aquarium fishers also listed the need for income as their primary motivation for partaking in the trade, emphasizing its importance. Both the wildlife trade in general and fishing in particular has been associated with poverty (Panayotou 1982; Wright 1990; Cunningham 1993; Payne 2000; Duffy et al. 2015). Wildlife trade can be appealing to people, especially poorer people, because it can be technically simple, cheap to participate, provide quick economic gains, and easy access to resources (Neumann and Hirsch 2000). This assumption is contradicted in this study because the majority of fishers stated how difficult their job was.

Even though harvesters generally receive a severely reduced income for their products compared to those higher up in the trade network, this does not mean that this money is not important to their overall household income (de Beer and McDermott 1996; Belcher and Kusters 2004). The aquarium trade was cited as the most important source of household income for over 70% of all fishers' households, demonstrating just how important the trade is for their survival. A technical solution to reducing wildlife harvest and therefore poverty is alternate livelihoods along with disincentives. However, alternative livelihoods oftentimes just become additional livelihoods, whereby harvesters' income increases but collection continues regardless (Roe et al. 2015). Most aquarium fishers do indeed have additional jobs and so policies encouraging alternative livelihoods would be relatively ineffective. Furthermore, wildlife harvesters may be poor in an absolute respect, but the same if not better off than their neighbors (Vira et al. 2014).

Again, most fishers described themselves as average compared to others in their barangays, implying that aquarium fishing does not necessarily provide less income than other livelihoods.

While aquarium fishing does seem to be linked to economic motivations, non-monetary motivations associated with the trade also seem significant. Fishers often are attached to their job due to more than material benefits (Pollnac et al. 2001; Pollnac and Poggie 2008). In many instances, there is usually a sense of pride associated with being a fisherman and fishing is viewed as a way of life instead of merely a job (Acheson 1988; van Ginkel 2007). Non-monetary motivations such as exposure to nature, autonomy, and the challenge were cited as the some of the top reasons of what fishers liked most about the aquarium fishery (Stevenson et al. 2011, Santos 2015). In fact, the most commonly listed jobs aquarium fishers stated they would do if they did not work in the aquarium trade also entailed a great deal of autonomy and lower educational requirements as well as involve working outdoors via manual labor. This result may also be an indication of the importance of non-monetary benefits these men seek from their work.

Job satisfaction and well-being of fishers may be comparatively higher than non-fishers (Coulthard et al. 2011). Stevenson et al. (2011) used a similar approach to this study by looking at job satisfaction of aquarium fishers in Hawaii. That study also found that most fishers would not leave the aquarium trade for another job that provided an equal income, and that most fishers would not encourage younger fishers to enter the aquarium trade due to conflict, competition, decreasing fish populations, regulations, and initial start-up costs (Stevenson et al. 2011; Santos 2015). This suggests that while there may or may not be many alternative options available to aquarium fishers, income is only one factor that they consider. A desire to earn money to support one’s family is clearly top priority; however, aquarium fishing appears to provide additional non-monetary benefits that some alternative livelihoods cannot and as such should be considered in future management.

The Role of Women

The general literature illustrates that the role of women in natural resource-based livelihoods in developing countries has been acknowledged but rarely assessed (Bennett 2004) and remains an area for greater research. While the men received the most attention as fishers in this study, this research also revealed some of the important roles women play in the aquarium trade. Some studies, mainly pertaining to subsistence fisheries, demonstrate how women play a significant role in fisheries by collecting invertebrates (Teh et al. 2009; Santos 2015; Gupta et al. 2016). Based on observations and informal discussions, this is also true in Calatagan as many women collect invertebrates such as crabs, snails, and sea stars for the marine aquarium trade. A couple of women also make nets for the fishers to collect their fish. While these nets can also be bought in town, this work helps these families save money by not always having to purchase their nets.

Generally, in fisheries, men are primarily responsible for collection while women are primarily responsible for post-collection, signifying a symbiotic relationship between the two genders (Bennett 2004). This is supported in the Calatagan fishery as several women also serve as byaheros (intermediaries) and are therefore responsible for the transportation of fish to Manila and income distribution. These women are aquarium fishers' wives, mothers, and sisters. Because many people living in the same household earn income from the aquarium trade via various jobs (fisher, invertebrate collector, byahero), this maximizes the amount of money they can make. The price aquarium fishers receive for their catch can depend on the number of links in the chain of custody (Wood 2001). If a fisher's wife or sister acts as his intermediary, this may increase the amount of money that household makes from the exporter. This demonstrates how some fishers in Calatagan may have found ways to mitigate any substantial pay cut as a result of a needing a middleman.

While women are not in charge of the aquarium trade, they are still in important positions. Because both men and women act as byaheros, it would be intriguing for further studies to see if one gender receives more income than the other. Bennett (2004) conducted a workshop regarding the roles of men and women in fisheries. The workshop revealed that high prices associated with greater demand did not seem to benefit women traders (Bennett 2004). Instead, male traders or middlemen were more likely to benefit from rising prices (Bennett 2004). Therefore, it would be interesting to discover if this also applies to the Calatagan aquarium fishery.

Poor or Vulnerable

The traditional perception in literature is that fisheries, particularly small-scale ones in developing countries, and chronic poverty are related (Panayotou 1982; Wright 1990; Cunningham 1993; Payne 2000). However, this view has been more recently disputed by several studies and instead argues that fishers are not necessarily the poorest of the poor but rather among the most vulnerable socio-economic groups (Béné 2003; Allison and Horemans 2006; Allison et al. 2006). Support for this argument lies with the facts that fishers have high exposures to natural, economic, and health-related risks (Allison et al. 2006). Chronically poor fishing households cannot maintain their standard of living even though they have access to the resource. On the other hand, vulnerable fishing households, those above the poverty line, may be relatively stable until a risk factor such as the loss of a boat drives them back into poverty (Béné 2009). Policies should therefore address the risks and uncertainties that fishing households face. This can be done through reducing income dependence on fishing, diversification of livelihoods, and the provision of social safety nets (Béné 2009). In the Calatagan fishery, most aquarium fishing already appears to part of a diversified livelihood strategy due to the prevalence of additional income-generating jobs by both fishers and other members of their households. Livelihood diversification is a means by which individuals strive to reduce risk and cope with uncertainty (Badjeck et al. 2010; Coulthard et al. 2011). There is also some literature that shows that full-time fishers, while highly productive, are exposed to greater risks. Part-time fishers are less exposed to risks but usually less efficient (Béné 2009). According to interviews, most aquarium fishers in Calatagan collect fish every day; however, the majority also has additional income-generating jobs. This suggests that aquarium fishers are striving to increase their productivity while at the same time decreasing their vulnerability and reliability on the aquarium trade.

Risky Business

While many conservationists are concerned that species collected for the aquarium trade are vulnerable to overharvest (Best 2000; Friedlander 2001; Moore 2001; Best 2002; Inskipp 2003), this study actually suggests that aquarium fishers may have a higher risk of extinction. Tuler et al. (2008) suggests that fishers and fishing communities may be vulnerable to seven categories of factors: demographic, individual decision-making, institutional, economic, socio-cultural, technological, and environmental. Aquarium fishers in Calatagan are indeed vulnerable to several of these factors. Aquarium fishers collect fish by free diving and capturing fish in small-mesh nets. This requires a lot of energy, breathing and equalization techniques. Fishers have reported both eye and ear problems as a result of aquarium fishing. Indeed, three interviews were unable to be completed due to fishers' hearing loss. A known long-term effect of skin diving is a change in the ear drum (Butterfield et al. 1963). The constant change in pressure associated with diving undoubtedly causes barotrauma to different parts of the ear, especially if not properly equalized. One study showed that hearing impairment was common in 60% of abalone fishers, who had been diving for an average of six years and spent four hours underwater approximately 100 days per year (Klingmann et al. 2004). Aquarium fishers in Calatagan similarly spend half or whole days collecting fish throughout most of the year, so it is likely that their profession also poses a health risk.

Most aquarium fishers collect all year-round, therefore having to endure various weather conditions. However, where collection takes place and the frequency in which it takes place varies among fishermen. As previously mentioned, aquarium fishers are restricted as to where they are and are not allowed to collect. Many of the older aquarium fishers complained that aquarium fishing was much easier in the past due to fewer restrictions on the trade. Restrictions on collection areas certainly complicate their job. While most fishers collect every day, some collect more or less often due to monsoons and other jobs. Many fishers collect less during Habagat because that affects their primary collection area between Barangay 1 and Santa Ana. A portion of fishers travels to Calambuyan on the east side of Calatagan in order to continue fishing with minimal affects from Habagat.

Other fishers, primarily Barangay 1 fishers with paddleboats, collect in the same location all year-round but have to be mindful of the changing weather conditions. Furthermore, a portion of fishers travels to Mindoro to collect the fire dartfish (*N. magnifica*) to satisfy demands from exporters. Chapter 3 demonstrated that the vast majority of fish harvested for the Calatagan aquarium fishery belongs to this one species. If the fire dartfish population in Mindoro was to disappear, fishers may have to travel even further to meet market demands or find a different livelihood altogether.

Fishers need to make sure their boats are in proper condition to travel, especially those traveling greater distances. Monsoons can create strong currents, big waves, and poor visibility. This not only makes collection harder, but also puts fishers' lives at risk. Storms prohibit aquarium fishers from collection and thus from making income to support themselves. The income that aquarium fishers receive compared to what consumers pay for a fish is minimal (Wabnitz et al. 2003). According to informal discussions with aquarium fishers, fish prices have remained static for several years, while the cost of living has increased. As a result, fishers said that they need to catch more fish in order to make enough money to support their families. Fishers that travel to Mindoro not only brave the open seas and spend more money on gasoline for their boats, but they also spend a lot of time away from their families. These men have houses, wives, and children in Calatagan, but spend most of their time collecting fish in Mindoro. There is no doubt on the strain that that puts on their relationships. In fact, several studies have looked at how fishing families deal with long separations and found that couples cope in different ways with varying success (Smith 1995; O'Dell et al. 1998; Tuler et al. 2008). Therefore, these fishers are allocating significantly more effort into collection and as a result are subject to even greater risks.

All in the Family

The fact that the aquarium trade in Calatagan is a family enterprise cannot be overemphasized as it has many implications for both the present and the future of the aquarium fishery. According to Wabnitz et al. (2003), aquarium fish collectors are generally small-scale fishers from tropical countries. Aquarium fishers tend to work alone or in small groups, oftentimes comprised of family members (Wabnitz et al. 2003). The vast majority of aquarium fishers in Calatagan are related in some way. Many are brothers, father and son, cousins, or related through marriage. Several fishers were recruited by friends or family members to join the Calatagan aquarium fishery.

In order to collect fish in a particular municipality in the Philippines, fishers must be registered there. However, the results show that fishers who are not registered in Mindoro are still collecting there. In the focus groups, fishers explained that one person in each boat collecting in Mindoro is legally registered there and claims the other fishers are his family members if questioned. Therefore, family appears to be an exception to the rule.

Most of the aquarium fishers are middle-aged or older. Only three fishers are less than 30 years old, and more than three quarters of all fishers are over 40. Aquarium fishing in Calatagan is passed down from generation to generation, with many learning how to fish at an early age. Fishing as an 'inherited livelihood' has also been documented in artisanal fisheries in Brazil (Santos 2015). According to the interviews, most aquarium fishers have children; however, their children do not seem to be as keen to join the aquarium trade. The fishers themselves mentioned that they do not want their children to enter the aquarium trade, and that they work hard to make sure their children can get a better education than they received. This opinion is also shared by the artisanal food fishers in Brazil (Santos 2015). Therefore, although fishers seem to enjoy their job for various reasons, it appears that it is also an undesirable profession. Lastly, several fishers also mentioned that overall there are not many young people entering the aquarium trade and so they are unsure if their livelihood will be continued (Tuler et al. 2008). According to fisher demographics, most fishers born outside of Calatagan were middle-aged or older individuals. These results also indicate that most of the younger fishers were born in Calatagan, suggesting that the recruitment of newer fishers from other areas is diminishing. If fisher families are not encouraging their own children to enter the trade and people from other areas are not being recruited for it, it seems plausible that the trade will die off in the not too distant future.

Future of the Fishery and Policy Implications

The decline in aquarium fishers is not unique to Calatagan only. Two ornamental fisheries in north Bali also have reported a decrease in fishers for similar reasons (LINI 2015). Age, income, difficulty, and the desire for higher education all appear to be influencing this trend (LINI 2015). Therefore, the future of aquarium fishing in Calatagan as well as other leading export countries may become questionable. As a result, there are several approaches that governments can incorporate to provide aquarium fishers and their families with greater support.

According to Fabinyi et al. (2015), there are six commonly cited approaches to policy regarding fishers: resilience and social-ecological systems (Walker and Salt 2006), common property and institutional perspectives (Ostrom 2009; Cinner et al. 2012), interactive governance and governability (Kooiman et al. 2005), human rights-based approaches (Allison et al. 2011, 2012), the sustainable livelihoods approach (Allison and Ellis 2001), and the well-being approach (Coulthard et al. 2011). The overall objective of all of these approaches is increasing engagement and inclusion of local fishers.

The well-being approach aims to change policies in order to reduce well-being conflicts (Coulthard et al. 2011). For example, fishers who want to earn enough money from the fishery to ensure their children enter a different profession, such as the majority of aquarium fishers in Calatagan, have different conflicts and needs than fishers who want to maintain fishing as a livelihood for future generations. All conservation policy changes include trade-offs and so it is vital to identify these trade-offs and how these may affect all parties involved, both animal and human (Coulthard et al. 2011). The loss of fishers, whose occupations often entail pride, social identity, and cultural heritage leads to problems concerning the trade-offs between conservation, development, and livelihoods (Coulthard et al. 2011).

Generally, fisheries policy in developing countries perceives fishing as a full-time job in one distinct economic sector (Allison and Ellis 2001). This is also true for farming and forestry and is apparent in the division of government ministries or sub-sectors within ministries (Allison and Ellis 2001). Capacity building and livelihood programs should be implemented and encouraged in Calatagan. Fishers vary in their willingness to leave the fishery sector (Muallil et al. 2014). Younger fishers, especially those with growing children, should particularly be targeted because they are the ones who exert greater fishing effort and therefore most vulnerable to risks (Muallil et al. 2014). Fishers' children also need access to education systems in order to increase their likelihood of finding non-fishing jobs that they and their parents appear to desire. Furthermore, diversified livelihoods in developing countries have often been ignored by policies that are based on different sectors, including fishing. The livelihoods approach reveals that most fishers in developing countries pursue diversified livelihoods (Allison and Ellis 2001), which is also true for aquarium fishers in Calatagan. Fishers pursue diversified livelihoods for various reasons including high risks associated with fishing, seasonal fluctuations in stock and location, and to reduce failure by earning an income across various sectors (Allison and Ellis 2001). As a result, diversified livelihoods and movement across geographic areas, which aquarium fishers are also doing, may in fact be beneficial to resource conservation. This means that they should be supported by policy, rather than restricted.

5 Conclusion

Conclusion

Recommendations for Management of the Aquarium Trade in Calatagan

This study identified actions that the local government in Calatagan can implement to improve trade management. The species selected for the vulnerability assessment were deemed to be species that were most likely to be vulnerable to local overharvest due to attributes such as their collection frequency and ease, their desirability, and their availability in the wild. However, species' current vulnerability was calculated to be low to moderate. Many conservationists are concerned with the sustainability of wildlife trade, including the marine aquarium trade (Best 2000; Friedlander 2001; Moore 2001; Best 2002; Inskipp 2003; Coulthard et al. 2011). While unsustainable wild harvest has been documented in many studies (Wood 2001; Bellwood et al. 2004; TRAFFIC 2008; Knudsen 2016), this study indicates that not all harvest is unsustainable and assuming so may be incorrect.

Although the aquarium trade is currently sustainable in Calatagan, it is not clear how long this will continue. Two species in this study (*Dendrochirus zebra* and *Paracanthurus hepatus*) were calculated to be moderately vulnerable to overharvest and an additional two species (*Balistoides conspicillum* and *Pomacanthus semicirculatus*) were calculated to be close to moderately vulnerable. While this assessment used both species' life history traits and fishery-specific characteristics, it is did not include every environmental or anthropogenic factor that affects species' vulnerability. The PSA is also limited in that can only prioritize species based on available data. For some species, such as the fire dartfish (*Nemateleotris magnifica*), some attributes could not be included in the assessment due to lack of data. Although this was accounted for in the data quality score, it is paramount that vulnerability scores for all species be treated with a certain level of precaution. Furthermore, the aquarium fishers themselves perceived 14 of the 20 species in the PSA to have decreasing populations. As the fishers spend most of their time in the marine environment, their perceptions should not be dismissed. All of these points should be considered when evaluating the overall sustainability of the Calatagan aquarium fishery.

The majority of fish collected for this particular fishery come from only a few species, which is also common in other regional aquarium fisheries (Aguilar 1992; Graham 1996; Division of Aquatic Resources unpublished data quoted in Tissot 1999). These more targeted fisheries have a higher probability to potentially impact ecosystem function than fisheries with a greater variety of catch (Stevenson et al. 2011). There is an increasing trend in purchasing herbivorous reef fish, such as surgeonfish, for aquariums (Stevenson et al. 2011). Herbivorous fish provide key ecosystem services by feeding on macro algae, which can outcompete and smother corals. It is precisely for this reason that aquarists desire these species for their reef tanks. However, a decrease in herbivorous fish combined with increased nutrients from anthropogenic sources can cause ecological phase shifts (Stevenson et al. 2011). Furthermore, Chapter 3 mentioned that the bluestreak cleaner wrasse (*Labroides dimidiatus*) is a popularly demanded species both in Calatagan and globally. As its name implies, this species is responsible for grooming other fish, thereby removing parasites and mucous (Michael 2001). The removal of this particular species could negatively affect ecosystem function. Thus, further actions should be made to evaluate the health and function of reefs where aquarium fishing is occurring.

Underwater surveys could be beneficial to assess habitat conditions as well as population levels. This would not only provide insight as to whether or not there are ecological shifts occurring, but also where they are occurring. This would be valuable in the implementation of marine sanctuaries. Population surveys may be useful in detecting species declines; however, rare species' populations are challenging to assess because the probability of observing them in underwater surveys is low (Dee et al. 2014). Nonetheless, perhaps the most beneficial surveys would be comparisons between the marine ecosystems in Calatagan and Mindoro. This could validate fishers' perceptions that both the fish populations as well as water quality are greater in Mindoro. Surveys could also be indicative of fire dartfish populations and determine if it can actually be found in Calatagan at greater depths.

Additionally, either aggregate or species-specific quotas for more vulnerable species could be established as currently there are no catch limits for the aquarium trade in Calatagan (Saleem and Islam 2008; Fujita et al. 2014). However, quotas would only be beneficial if properly enforced, which is a known problem in other fisheries (Wabnitz et al. 2003). The Philippines in particular often lacks proper enforcement of fishery laws due to lack of resources, capacity, and a multitude of local, social, and political factors (Fabinyi et al. 2014). Another technical, practical, and perhaps more qualitative solution would be the use of daily pro-forma log books (Saleem and Islam 2008). In these books, fishers could record the number of fish collected and mortality of fish as well as hours spent on collection and information on collection areas (Wood 2001; Saleem and Islam 2008). This would provide more localized, detailed data on catch, mortality, and effort- all of which are data deficient in for the aquarium trade (Wood 2001; Rhyne et al. 2012; Militz et al. 2016). Log books could then be analyzed after a set time period to determine if/what quotas or laws should be implemented to maintain sustainability.

Another recommendation that would be beneficial to both the government and fishers is more communication regarding places where aquarium fishers cannot collect fish. According to the Philippine Fisheries Code of 1998 (RA No. 8550), aquarium fishers are not allowed to collect fish inside marine sanctuaries. Calatagan has two marine sanctuaries that overlap where aquarium fishing takes place. The fishers state that they were not consulted in implementation of these areas. The two marine sanctuaries are located on the eastern side of Calatagan, right in the center of where aquarium fishing takes place during Habagat (June-October). As a result, fishers are restricted by both the weather and regulations in where they can fish during this time, placing seasonal stress on fishers and potentially motivating illegal harvest. While the aquarium fishers acknowledge the marine sanctuaries, many of them are unsure of their purpose and benefits. If their collection areas are being restricted without their input, they should understand why. Marine protected areas may have success in terms of fish regeneration, but they have also been criticized for failing to involve locals (Coulthard et al. 2011). Thus an MPA may be a "biological success", but a social "failure" (Christie 2004). MPAs can therefore incite social and economic marginalization and conflict. This can lead to the breakdown of the policy and weaken the ecological intentions. The local government should include local people in management decisions because this has been shown to increase ownership of natural resources and a sense of pride in being a part of their stewardship (Drew 2005). Community involvement has also been reported to have longer-lasting environmental policies due to more appropriate socio-cultural and environmental needs (Beierle 2002; Koontz and Thomas 2006; Newig 2007). Furthermore, higher rates of compliance and the reduction of conflicts are associated with community involvement (Yates and Schoeman 2013).

Furthermore, several barangay captains do not want aquarium fishers to collect in their barangays. However, they do not have the legal responsibility or right to ban it. While the fishers obey these requests, they are technically legally able to fish there. The Philippines uses a very decentralized system of management, which can have negative effects on fishers, particularly small-scale municipal fishers (Fabinyi et al. 2015). The Philippine government has many levels: national, provincial, municipal, and barangay. As a result, issues over who is and is not responsible for enforcing certain laws, particularly at the local level, can arise. This study highlights one such issue. Therefore, the local government should either give barangay captains the power to ban aquarium fishing in their barangays, or clarify that it is not under their jurisdiction and inform the fishers that they may collect there. Either way, the local government needs to communicate more effectively with aquarium fishers, especially when its laws significantly affect them.

The results from this study indicate that although the harvest of fish currently appears sustainable, it is unclear how long aquarium fishers in Calatagan will remain. Aquarium fishers are vulnerable to economic, socio-cultural, institutional, environmental, and demographic factors (Tuler et al. 2008). Current demographics indicate that aquarium fishing is family-oriented profession conducted by older generations with very few younger fishers entering the trade. As a result, the aquarium trade in Calatagan may die off naturally with its participants. Therefore, the government may not even need to impose more policies concerning aquarium fishing.

Uncertainty is an innate characteristic for fisheries management (Badjeck et al. 2010). Over-exploitation and degrading coral reefs due to anthropogenic factors already threaten fisheries worldwide; however declining fisheries also threatens human development as millions of people depend on fishing for their livelihoods (Coulthard et al. 2011). Therefore, fisheries management needs to focus on supporting diverse livelihood strategies and dynamic fisheries to reduce poverty and promote sustainability.

Recommendations for Future Studies

The purpose of this study was to provide on-the-ground baseline data for the aquarium trade. As such, further studies should be carried out for more in-depth analysis. For example, price data both of individual species of fish as well as throughout the chain of custody would be desirable yet quite complex. While prices are listed on fishers' receipts, the receipts also identify many factors that contribute to an individual fish's price such as species, size, quality, sex, age, and even exporter (Wood 2001; Wabnitz et al. 2003). Price can also be an indication of a species' rarity or desirability (Courchamp et al. 2006). Harris et al. (2015) looked at how market data, such as price trends, was useful in identifying population trends in bird species traded in Indonesia. This study concluded both price and trade volume data can be a great source of knowledge regarding how supply and demand influences wildlife trade (Harris et al. (2015). A similar approach could thus be taken for the marine aquarium trade.

Additionally, price can depend on the number of links in the chain of custody (Wood 2001). Without a middleman, a fisher may receive half as much as the export price while if he sells to a middleman, he may only receive one tenth of the export price (Wood 2001). For the Calatagan fishery, it is still largely unclear how much an individual makes regarding his or her position in the chain of custody (fisher, byahero, exporter). Price data could help determine the overall income generated by a fisher to indicate if he is the poorest of the poor or more average compared to others in his barangay as this study suggests. Some fishers are also byaheros or have wives who are byaheros and so it would be interesting to see how being a byahero or having another member of the household as a byahero influences their income.

Chapter 4 highlighted the importance of women in the aquarium trade. Women have often been overlooked in regards to fisheries because they are typically male-dominated (Bennett 2004). As a baseline study, this thesis focused on aquarium fishers, all of whom are men. However, many women in Calatagan serve as byaheros, invertebrate collectors, and even net-makers for the aquarium trade. They may also provide different perspectives and opinions on the sustainability of the fishery that would be beneficial for policy-makers. The Calatagan fishery is relatively small and as such would make an ideal site to learn in-depth information about the role women play in the aquarium trade in the Philippines.

A major theme that reoccurred throughout this research was the regional nature of trade, notably connections between Calatagan and Looc, Mindoro. Thirteen fishers living in Calatagan are spending the majority of their time collecting fish on other islands away from their families. The fishers indicated that Mindoro has more fish as well as better water visibility. In addition, the most caught species for this fishery, the fire dartfish, is found there. Mindoro should be further examined in order to obtain a more holistic and comprehensive view of the Calatagan aquarium fishery. Without it, there is a missing link in this story.

The fishers also listed other places where aquarium fishing takes place in the Philippines and so a comparative study between the Calatagan fishery and another fishery would be interesting. A comparative study could assess fishers' demographics and motivations, targeted species, collection techniques, and species vulnerabilities. This would help clarify if other small-scale aquarium fisheries in the Philippines were similar in nature to Calatagan or if Calatagan is an exception. It would also provide valuable data to local fisheries management.

The fire dartfish (*Nemateleotris magnifica)* is undeniably a key species for the aquarium fishery in Calatagan. While the fire dartfish is listed as a species of Least Concern (LC) according to the IUCN Red List and has a low vulnerability of local harvest in this study, it is lacking crucial data. There is relatively no data available on firefish reproduction, therefore making it difficult to examine fecundity in relation to collection rate (Froese and Pauly 2017). In fact, both members of the family Microdesmidae, the fire dartfish and blackfin dartfish (*Ptereleotris evides),* received the lowest data quality scores in the PSA as a result of this gap. With firefish being the majority of fish collected for the Calatagan fishery, they should be given more attention, especially because fishers cannot collect them in Calatagan and thus have to travel to Mindoro to meet the exporters' demands. Currently, there are no species at risk of global extinction due to the aquarium trade; however, there is evidence of species being depleted locally (Wood 2001). The fire dartfish may serve as the best example of a local depletion in this study, but more research needs to be done to verify this.

As a whole, there needs to be more evaluations done specifically for species targeted by the aquarium trade. While conservation evaluations are being conducted at multiple scales (Alison et al. 2009; Graham et al. 2011; Mamauag et al. 2013; Fujita et al. 2014; Giakoumi et al. 2015; IUCN 2017), these seem to have broadly overlooked some of the families, genera, and species that are being the most intensively targeted for harvest. For example, all species listed on fishers' receipts belonging to two families, Pomacentridae (damselfish & clownfish) and Balistidae (triggerfish), are listed as Not Evaluated (NE) according to IUCN's Red List. These are some of the most collected fish in the aquarium trade globally and yet none of their populations have been evaluated. This is a remarkable gap that should be acknowledged and rectified. Additionally, receipts identified several species that are not listed as part of the aquarium trade on FishBase. FishBase is a valuable tool when looking at species' life history traits and attributes and was consulted many times throughout this study; however, it is only as accurate as the data it receives from scientific research. Therefore, this study can provide additional data to help update FishBase.

Ideally, all species collected for the aquarium trade would have been evaluated based on their vulnerability to local overharvest. Due to species' richness and limited time, this was unable to be carried out for this thesis. It is therefore possible that some species collected are more vulnerable, but did not make the list of twenty. However, future studies could examine a greater number of species for this assessment to provide a more comprehensive data set. This assessment could also take place at a larger scale at the provincial, regional, or national level. Nonetheless, it is important to note that different scales have different implications to be considered during research design.

Research design and analysis is a very important part of the research process and to some degree influences the results. In retrospect, there are a few things I would give more consideration or change entirely. First, I chose four categories (most commonly caught, most desirable to catch, easiest to catch, and species that were once commonly caught but now are rarely caught) that I believed would help identify some of the most vulnerable species collected in the Calatagan aquarium fishery. While I was able to assemble a list of species, this list may not have included some of the most vulnerable species. Furthermore, there was a significant amount of overlap of species among categories, particularly among most commonly caught, most desirable to catch, and easiest to catch. Therefore, vulnerable species not mentioned in these categories may have been overlooked. As a result, I would have liked to spend more time determining different categories and selecting species that may be vulnerable due to a wider range of reasons. Greater consultations with fishers' receipts may have been able to assist in that endeavor.

Another aspect I believe I should have further explored was the sustainable livelihoods approach (Allison and Ellis 2001). Most of this project was based on the hypothesis that the fish would be more vulnerable than the fishers. Because of this, my research questions and therefore my analysis did not primarily focus on the vulnerability of fishing communities. However, the Calatagan fishers do seem to be more vulnerable than the fish they collect and so further studies using the livelihoods approach as well as related approaches would be meaningful both for the fishers and the local government. Understanding how policies affect local communities as well as developing policies to support these communities is key to inducing compliance as well as protecting against the loss of important livelihoods in developing countries such as the Philippines.

Collectors vs. Consumers

Obviously there are many factors and roles that drive the aquarium trade. Aquarium fish collectors are often the ones blamed by conservationists for decreasing populations (Wabnitz et al. 2003). This makes sense since they are the people physically removing fish from coral reefs. However, without a demand from consumers, there would be no reason for fishers to collect aquarium fish. A survey by Murray and Watson (2014) looked at the most important factors consumers in Europe and America consider when purchasing a new species for their aquarium. The two most important factors were compatibility with current stock and aesthetics (Murray and Watson 2014). Other factors such as easy to care for, function in the aquarium, and price were not as important (Murray and Watson 2014). Furthermore, consumers stated they would like more information on potential purchases such as whether the species was wild caught or aquacultured (Murray and Watson 2014). Accurate scientific names were the least important to surveyed consumers (Murray and Watson 2014).

Ideally, consumers would research species before purchase; however, this does not always appear given the reported importance of aesthetics. As previously mentioned in Chapter 3, two of the top 10 most caught species in this study, the blueband goby (*Valenciennea strigata*) and bluestreak cleaner wrasse (*Labroides dimidiatus*), had poor aquarium suitability scores. According to the PSA, these species had low vulnerabilities; however, their collection could just result in premature deaths in an aquarium. This could actually make them more vulnerable than their PSA scores imply and as such aquarium suitability should be given more consideration in further vulnerability assessments regarding the aquarium trade. Consequently, the sustainability of the aquarium trade not only relies on collectors, but also consumers.

Furthermore, an accurate scientific name is not an important characteristic for consumers, and so it is not necessarily a priority for others involved in the trade network. Yet, one of the main problems of the aquarium trade is a lack of accurate trade data on species level quantifications (Wood 2001; Wabnitz et al. 2003; Rhyne et al. 2012). For example, a consumer may want to purchase a butterflyfish because it is pretty, not realizing there are at least 129 species of butterflyfish, all of which have different distributions, life histories, levels of threat, and suitabilities to aquarium life (Froese and Pauly 2017). Unless there is a greater demand for scientific accuracy from the public, species quantification will remain difficult.

This thesis sought to explore the aquarium trade from the ground level using a mixed methods approach. This approach was highly participatory and demonstrated how fishers' knowledge and scientific literature can be used simultaneously. The aquarium trade is a multi-million dollar global industry that is still quite research-deficient. There is a lack of bottom-up, site-specific data that this study addresses. While this study was performed at the municipal scale, it nevertheless identified some interesting findings that can be applied at larger scales. Important baseline data gathered from this research will be reported back to the community so that both the fishers as well as the local government are aware of its findings. The decentralized nature of management in the Philippines means that local data is valuable. It is hoped that the results from this study may then be used to help guide policy-makers' decisions regarding the sustainability of the aquarium trade in Calatagan.

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