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Title: The Status and Life History Traits of Endemic, Native and Introduced Species in Lake Lanao, Philippines

Abstract approved:

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The endemic cyprinids of Lake Lanao, Philippines have been described as a species flock and are thought to be an example of explosive evolution. However, based on historical surveys, 16 of the 18 cyprinid species endemic to Lake Lanao are now believed to be extinct. Furthermore, non-native species have been introduced in Lake Lanao and some have proliferated. Three of the world's one hundred worst invasive species are currently found in the Lake. This study focused on the status of the fish species in Lake Lanao and examined six life history traits thought to be associated with invasiveness.

In Chapter 2, results of landing and market surveys conducted from July to October 2008 were compared with similar information from historical surveys. Field sampling and fishermen interview were also conducted to collect additional information on the status of fish species in Lake Lanao. The survey recorded a total of two endemic, one native and ten introduced species. Although the endemic *Puntius lindog* used to be the most important fish in the lake in terms of fishery landings, it only comprised 0.01% of the total weight of the fish species surveyed during 2008.

The introduced *Hypseleotris agilis* have proliferated in the lake, comprising 66.6% of the total weight of fish caught.

Chapter 3 examines six life history traits of the endemic, native and introduced species found in the 2008 survey and of three other species reported in previous surveys. A comparative analysis showed that most of the introduced species in Lake Lanao have the characteristics generally related to invasion success. However, not all of the introduced species were successful. The analysis showed that the six life history traits are not entirely successful at predicting invasiveness in Lake Lanao.

The discovery by the field study that two endemic cyprinids remain in Lake Lanao was surprising and significant as the Lake during the past few decades has been imperiled by human disturbances, exploitation and introduced species. The thesis focused on the role of introduced species on the demise of the endemic species. Other factors also need to be investigated. Protecting and conserving the endemic species are highly recommended.

The Status and Life History Traits of Endemic, Native and Introduced Species in Lake Lanao, Philippines

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any readers upon request.

Gladys B. Ismail, Author

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CHAPTER 1

GENERAL INTRODUCTION

One of the threats affecting biodiversity and ecosystem functions is the introduction of non-native species, which can result in the extinction of native species (Mack et al. 2000). Non-native species, intentionally or unintentionally introduced, are estimated to number 10^2 – 10^4 in most countries. The number of new introductions is still increasing (Lodge 1993) in part because humans think the new species will be valuable additions.

Human disturbances to an ecosystem can benefit the establishment of the introduced or non-native species (Gido et al. 2004). Moreover, areas that are highly populated with humans are likely to have higher numbers of species introductions (McKinney 2001). Activities such as agriculture, aquaculture, recreation, pet trade and release and transportation are the common causes of the spread of introduced species, of which some have become established in the new areas and become invasive (Kolar and Lodge 2001). Invasive species are species that are non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

Characteristics of the introduced species and their interaction with species within the invaded community determine how successful the invasive the species will become (Kolar and Lodge 2001). In addition to modes of introduction, characteristics of the invaders, suitability of the invaded ecosystem, and species richness of the ecosystem are also considered to determine invasion success. A community with great species richness is less likely to sustain an invasive species than a community that is depleted and unproductive (Elton 1958). Although less than 10% of the introduced species become established, some successful introduced species have severely affected the ecology and the economy of their new areas of residence (Ricciardi and Rasmussen 1998).

Endemism in the Philippines and introduced species

The Philippines (Figure 1.1) has one of the most diverse ecosystems in the world in terms of the number of unique terrestrial and marine plant and animal species per unit area. As an archipelago, with varied geological histories, diverse climates, and topography, the islands of the Philippines are home to many unique and endemic species of plants and animals. An endemic species is a species found naturally in a single geographic area and no other place. In the Philippines, the biodiversity of the country has been detrimentally affected by the lack of knowledge concerning the importance of biodiversity, insufficient enforcement of environmental laws, human population pressure, global trade and the introduction of alien or non-native species.

Because of globalization, humans have created different pathways for the fast spread of exotic and invasive species throughout the world (Table 1.1). Aquaculture

(18%) and the aquarium trade (77%) (Casal et al. 2006) are the leading causes of the introduction of fish species in the Philippines. Since 1907, there have been more than 40 reported introductions of fish, crustacean and mollusk species (Guerrero 2002, Juliano et al., 1989). However, Casal et al. (2006) reported that 159 fish species were introduced to the Philippines, of which 39 were reported as being established in the wild and eventually becoming invasive, four did not become established and the remaining 116 have unknown status of establishment.

Data on the impacts of invasive species in the Philippines are limited, although non-scientific and anecdotal reports indicate that native species may be affected adversely through predation, competition, parasitism and habitat alteration (Joshi 2006). Alien freshwater fishes are currently invading some major lakes, rivers and marshes in the Philippines. The janitor fish (*Pterygoplichthys pardalis)*, which was introduced by the aquarium trade, escaped into natural waters and displaced native fish species in Laguna Lake, the Marikina River and Agusan Marsh by directly competing with native species for food (Joshi 2006). Recently, a piscivorous cichlid from Central America known as the ‘jaguar guapote’ (*Parachromis managuensis*) was found in Taal Lake. It is believed to have been introduced as an aquarium fish. Fishermen reported a decline of their catch, particularly of the native species, after the jaguar guapote was introduced (Agasen et al. 2006).

Lanao - an ancient lake and its endemic cyprinids

Lake Lanao (Figures 1.1 and 1.2), located at the southern part of the country in the province of Lanao del Sur, is one of the world's 19 ancient which are lakes thought to be older than 100,000 years (Naga 2002). Ancient lakes often support exotic and extremely valuable ecosystems. Lake Lanao, which is estimated to be about 5.3-5.6 millions years old, is also famous for its unusual fish species, which can only be found and only thrive in its waters. The endemic cyprinids consisted of five genera and 18 species (Appendix A). The species in the genus *Puntius*, and their evolution and taxonomy were first reported by Herre (1924, 1933) and later by Myers (1960).

Ancient lakes contain the highest known density of species and endemic species in the world. However, limited geographic range, poor dispersal capacity, low fecundity, small populations and frequent stenotopy of many of the endemics lead them to being vulnerable to extinction. These factors, coupled with introductions of non-native species, have been known to cause displacement and even extinction of the endemic species in ancient lakes such as Lake Malawi, Baikal, Titicaca, Biwa and Lanao (Cohen 1994).

Lake Lanao attracted a lot of attention from the scientific world regarding the origin and evolution of its large number of endemic fish species. Some scientists doubted the validity of this example of apparent explosive speciation (Reid 1980) and called the diversity of the cyprinids a taxonomic artifact (Kornfield and Carpenter 1984). Furthermore, various hypotheses were suggested to explain the complex diversity of the Lanao endemic cyprinids. These included: multiple colonization, extensive hybridization (Kosswig and Villwock 1964), allopatric origin (Woltereck 1941; Kosswig and Villwock 1964, 1974; Wood 1966) and some scientists believed that the lake itself was the cause of the species' complex evolution (Herre 1933; Myers 1960; Beadle 1974).

Nevertheless, scientists writing on the subject agreed that *Puntius binotatus,* is the ancestor of the *Puntius* species in the lake and that this ancestral species crossed land bridges from North Borneo through the Sulu chain during the Pleistocene period (Myers 1960). Although most of the endemic species bear a resemblance to this presumed ancestor, the ancestral species was never collected in the lake (Herre 1933; Kornfield and Carpenter 1984). It is however found in some bodies of freshwater in the Mindanao Island. Asian *Puntius* species usually show little morphological variation within species (Rainboth 1991). This has caused difficulty in the identification of the endemic species and in determining how many endemic species really are or were found in Lake Lanao. What has been acknowledged is that the cyprinids of Lake Lanao are endemic and a species flock (a diverse group of closely related species in an isolated area).

Research and surveys done in Lake Lanao

In this study, the fish species in Lake Lanao are categorized as endemic, native or introduced species. In general, an endemic species is a species that can only be found in a region and nowhere else in the world while a native species is a species that is indigenous to a particular area but can also be found elsewhere. An introduced species, also known as exotic, alien, or non-native species is a species that is outside its native range, usually transported there by humans either intentionally or unintentionally (Borges et al. 2006). According to Vilalluz (1966) studies on the fishes of Lake Lanao started as early as 1908 when Smith and Bartsch collected specimens. Herre (1924, 1926) formally identified the endemic species in Lake Lanao. In addition to the endemic cyprinids, Herre (1933) also identified two native species; Celebes longfin eel (*Anguilla celebesensis*) and mudfish (*Ophicephalus striatus*). Herre (1953) postulated the evolutionary relationships among these unique species. Herre's view was supported by Myers (1960).

Comparative electrophoresis was conducted to determine the taxonomic validity and evolutionary rates of the endemic cyprinids in the lake (Kornfield and Carpenter 1984). During the collection of the specimens for this study, only two endemic cyprinids were obtained: *Puntius lindog* and *Puntius tumba*. *Puntius lindog* was collected from the commercial fishers in the lake while *Puntius tumba* was collected in a stream, 100 m from the lake. Although these two species are quite similar in appearance, results of the electrophoresis showed that these two species are indeed two separate biological species and that the cyprinids in Lake Lanao are indeed diversely complex (Kornfield and Carpenter 1984) .

In 1966, Villaluz conducted a comprehensive research study on the Lake Lanao fisheries. He conducted fish landing surveys in 1963-1964 that included crustaceans and mollusks. He also studied the aquatic invertebrates of the lake, the ingenious fishing methods of the native Maranaos, and recommended conservation measures to increase fish production of the lake.

Of the total volume of fish landed in 1963-1964, 56.7% were endemic cyprinids, 15.6% native species and 27.6% introduced species. Because of the insufficient availability of fish required by the increasing human population living around the lake and the dwindling stocks of fish in the lake, Villaluz suggested means of increasing the lake's fish production. These included raising fish in the rice fields, in fish cages, and in fish ponds.

In 1974, Frey provided important information on the hydrology and physico-chemical characteristics of the lake while Lewis (1974, 1978) provided information on the composition of the lake's phytoplankton and zooplankton.

The surveys conducted by Escudero in 1990-91 (Escudero 1994) found different fish catch composition from the 1963-64 survey conducted by Villaluz. Between 1963 and 1964, the endemic cyprinids comprised 57% of the total weight in kilograms landed in the market compared in 1990-1991 when it went down to 12%. On the other hand, introduced species increased to 83% in the 1990's survey compared to 30% in the 1960's survey. The native species also declined from 14% to only 5% in 1990's.

Challenges in predicting impacts of invasive species in the Philippines

Lack of knowledge, a long unrecorded history of introductions, and lack of comprehensive technical and scientific information are the major reasons for the poorly understood effects of invasive aquatic and terrestrial species in the Philippines. Information from the published literature on invasive species is mostly on their mode of introduction. Introductions were usually intended for food production, reforestation, horticulture, and recreation. For instance, the golden apple snail (*Pomacea canaliculata*) was originally introduced to increase the protein available for humans but this species became a major pest in rice fields (Guerrero 2002). Chemical control of the snail pest with imported pesticides was estimated to cost $23 million during 1984-1998 (Joshi 2006). The mosquito fish (*Gambusia affinis)* was introduced in 1905 from Hawaii to control the outbreak of malaria but became a pest in rice fields and fish farms because mosquito fish prey on the eggs of native fish species (Joshi 2006).

Fish species have been introduced, intentionally and unintentionally into Lake Lanao, and these introduced species are thought to have caused the extinction of almost the entire set of endemic cyprinid species. There have been speculations that two successful introduced fish species (*Hypseleotris agilis* and *Glossogobius giurus*) are believed to have had negative impacts on the endemic cyprinids. A simple experiment conducted by Escudero in an aquarium showed that adult *Hypseleotris agilis* ate small *Hypseleotris agilis* (Escudero 1983) and *Puntius species* (pers. comm. 2008). Analysis on the food habits of *Glossogobius giurus* also showed that out of four hundred thirty-one gobies examined, forty-one or 10% of the gobies had fish species (*Glossogobius giurus* and *Puntius lindog*) in their stomach (Sanguila et al 1975). Based on these studies, we can deduce that these two introduced species may have had negative impacts on the endemic cyprinids.

Life history traits as a tool to predict invasiveness

Life history and ecological traits of non-native or introduced species, as well as how the species are used in human activities, are aspects that have been rigorously studied and used statistically and experimentally to predict whether a species would be a successful invader. The traits promoting successful invasion vary. Furthermore, the importance of a given trait depends on the species and the habitat where it is introduced (Williamson and Fitter 1996). Nevertheless, some traits can provide a significant basis for predicting the success of a wide variety of invasive species (Simberloff 1989; Lodge 1993).

Objectives and hypotheses of the study

Due to the lack of routinely collected fisheries data, it is difficult to assess the impact of the introduced fish species on the endemic and native fish species in Lake Lanao. The last market survey was done by Escudero in 1991. Based on that survey, it appeared that the introduced *Hypseleotris agilis* had already proliferated in Lake Lanao and would displace the endemic cyprinids, if the pattern of decline continued.

The endemic cyprinids in Lake Lanao seemed to be in danger of becoming totally extinct, without any human recording of the event. This thesis tells part of the story of the native and introduced fishes of Lake Lanao.

The objective of Chapter 2 is to provide information on the current status of the fish species in Lake Lanao based on surveys of landings and markets, field sampling, and interviews with fishermen. The collected information is then compared with the previous surveys done by Villaluz, Sanguila and Escudero. Chapter 3 discusses particular life history traits of the fish species found in Lake Lanao. The main objective is to determine if there are differences in some of the life history traits between the introduced and endemic species. The introduced species are assumed to have the following general characteristics of successful fish invaders, which allowed them to displace the specialist endemic species: broad diet, large body size, high fecundity, parental care, gregariousness and general habitat requirements. Chapter 4 summarizes the results overall and suggests that the number and abundance of endemic species have continuously declined due to introduction of nonnative species, alteration of the ecosystem, lack of concern and awareness by the people and no concrete implementation of measures to protect the endemic species and the lake.

Figure 1.1. Map of the Philippines.

Figure 1.2. Lake Lanao, Lanao del Sur.

Table 1.1 Pathways of some of the introduced and invasive species in the Philippines (Sinohin 2002, Guerrero 2002, Joshi 2006, http://www.fws.gov/invasives/volunteerstrainingmodule/bigpicture/onthemove.html and http://water.epa.gov/type/oceb/habitat/pathways.cfm).

Intentional introduction	Unintentional introduction	Other possible pathways
Aquaculture caused the introduction of *Tilapia spp.*, *Cyprinus carpio* and *Clarias batrachus* (three of the world's worst invasive species in the world).	Aquaria escapement (possibly intentional) of the *Liposarcus disjunctivus/pardalis*, Janitor fish and *Parachromis managuensis*, Jaguar guapote to Agusan Marsh, Laguna de Bay, Marikina River, Lake Paitan and Lake Taal.	Ballast water could carry sediment and different kinds of non-native species from other regions. Other forms of transportation are airways, railroads and roads.
Agriculture and trade caused the introduction of *Globadera rostochlensis*, potato cist nematode and *Pseudococcus sp.*, mealy bug	Ships/Vessels carried non-native species such as *Scotiniphora coarctata*, rice black bug.	Boat hulls, fishing gears and equipments and fishing boots could carry non-native mussels and other small non-native aquatic invertebrates.
Recreational interest in game fish caused the introduction of *Micropterus salmoides*, black bass.	Ornamental plants such as Orchids carried non-native insect such as the whitefly and leaf miner.	Biological control introductions, science/laboratory escapes, fish baits, live food industry, tourism/travel, online purchase of exotic species and pathogen spread.
Government Programs to produce cheap sources of protein and food caused the introduction of *Pomacea canaliculata*, golden apple snail and stocking of Tilapia and milkfish lead to the accidental introduction of *Glossogobius spp.*, white gobies and *Hypseleotris agilis*, sleeper goby in Lake Lanao.	Natural phenomena such as typhoon caused the introduction of *Heteropsylla cubana*, jumping plant lice. Other natural pathways are wind (carries plant seed and spores), ocean and rivers (carry floating organisms).	

CHAPTER 2

SURVEYS OF LAKE LANAO FISH SPECIES

Abstract

The fisheries condition in Lake Lanao is hard to assess due to very limited monitoring data. Available data from sporadic surveys during 1963 to 1991 however showed that the number of endemic species and their abundance had been declining. Surveys of fishery landings and fish markets, field samplings and interviews with fishermen were conducted from July to October 2008 to determine the current status of the fisheries in Lake Lanao. The landings and market surveys were then compared to the previous surveys to determine changes in the number and relative abundance of the fish species. Of the eighteen endemic species reported, *Puntius lindog* and *Puntius tumba* were the only two endemic species recorded in 2008, accounting for 0.01% and 0.04% respectively of the total weight caught. *Ophicephalus striatus* was the only native species recorded in 2008 with 5.17% of the total weight caught. The other known native species, *Anguilla celebesensis*, has not been recorded in the market since 1990. Ten of the twelve known introduced species were reported in the 2008 survey. The introduced *Hypseleotris agilis* dominated the catch in Lake Lanao with 66.6% of the total weight caught. This species was also found during the field sampling operations and were listed by the fishermen as being often caught, preferred by the consumers, easy to catch and abundant. Result of the surveys showed that introduced species dominate the landings from Lake Lanao. Lack of fisheries policy and effective enforcement place the remaining important endemic fishes of the lake in danger of extinction. A more comprehensive and further study on the fisheries of Lake Lanao is recommended.

Introduction

Lake Lanao (Figure 2.1) is both the second largest (surface area of 357 km^2; volume of 21.5 km^3) and deepest (maximum and mean depth of 112 m and 60.3 m) lake in the Philippines. It is located in the southern part of the country, on the island of Mindanao in the province of Lanao del Sur (Chapter 1, Figure 1.2). It is 702 meters above sea level with a mean monthly surface temperature varying between 22.2 ^{0}C and 27.6 ^{0}C (Naga 2010). The lake is of tectonic-volcanic origin and its basin is shallowest in the north and progressively becomes deeper towards the south. The lake is considered to be oligotrophic or relatively low in nutrients. The lake has four large main river tributaries: Ramain, Taraka, Gata, and Masiu, filling up to 21.5 cubic kilometer volume of freshwater. The main outlet is the Agus River.

Lake Lanao plays a significant role in the lives of the native Maranaos (lake dwellers). It is their main source of fish and transportation (Figure 2.2) and is the center of their socio-cultural and religious practices. Mosques are built around the shores of the lake (Figure 2.3) where the people can use the water for ablution (cleansing) before prayers. Lake dwellers also use the lake for agriculture (e.g. irrigation) and household purposes (Figure 2.4).

The lake is also highly important to the economy of Lanao del Sur and the whole island of Mindanao. Six hydroelectric plants of the National Power Corporation which are installed on the lake and along the Agus River system, have been in operation since 1950 and generate 70% of the electricity for the whole island (Figure 2.5).

The World Wide Fund reported that soil erosion from indiscriminate logging and agricultural activities using chemicals and pesticides have caused degradation of the water quality in the lake (wwf.panda.org). In 2006, the lake had a massive algal bloom, which some people suspected was the result of sewage, domestic wastes and agricultural discharge. Hydro-biological assessment of the lake was then conducted and showed that the lake had become eutrophic (Lake Lanao Fact Finding Technical Committee 2006).

The extreme degree of speciation of the endemic cyprinids in Lake Lanao has been widely used as an example in the formation of the concepts of the species flock and explosive evolution (Greenwood 1984; Beadle 1974). Their phenomenal evolution is so highly unique that some scientists have questioned its validity (Reid 1980). Unfortunately, because the lake has been subjected to heavy exploitation and has suffered the introduction of nonnative species, there are no longer opportunities to conduct critical studies on the fishery, biology and ecology of the endemic species.

Past fish market and landing surveys in Lake Lanao

During the past 50 years, several significant historical fish market and landing surveys have been conducted in the region of Lake Lanao. Villaluz conducted a landing survey in 1963-64, while Sanguila conducted a market survey in 1973.

Escudero conducted a series of market surveys in 1974-77, 1982-83 and 1990-91 (Villaluz 1966; Sanguila et al. 1975; Escudero 1980, 1983, 1994). The survey and reporting methods of the three researchers were a little different from each other. Villaluz combined all the weight of the endemic species surveyed. Sanguila et al. combined the weight volume of some of the endemic species while Escudero provided more details and recorded the weights the endemic species.

The results of the surveys showed a dramatic change of the numbers and abundance of the endemic species. In the 1963-64 survey, the total weight of fish caught comprised 57% endemic species, 29% introduced species and 14% native species. The apparent peak of the endemic species was in 1977 when Escudero recorded that the endemic species comprised 70% of the total weight of species caught. However, the decline of the endemic species became evident in the 1982-83 survey when endemic species only comprised 17% of the total weight caught while the introduced species comprised 68%.

One particular introduced species, *Hypseleotris agilis*, was discovered in the lake in the late 1970s. It did not take long before this species became well established in the lake. This species contributed 27% the total weight of all species and 40% of the total introduced species caught in the 1982-83 survey. In the same survey, the endemic species *Puntius lindog* only comprised 17% of the total weight of all species, a huge difference from the 1977 survey when it comprised 70% of the total weight caught. The *Hypseleotris agilis* continued to increase, as shown in the 1990-91 survey when it contributed 43% of the total weight caught. In contrast, the landings of *Puntius lindog* dropped to 12.13%.

Covering a short period of time, these surveys showed an alarming decline in the number and relative abundance of the endemic species, especially the *Puntius lindog*, while a number of introduced species such as the *Hypseleotris agilis* and even the Tilapia species, steadily increased. Frey (1974) even stated that,

> "Changes are proceeding so rapidly in Lake Lanao, according to the fisherman, that some of the species maybe threatened with extinction. Hence, any detailed studies on the species other than taxonomic may well have to be accomplished within the next few years if we are to get any reasonable understanding about this experiment in evolution."

It has been twenty years since the 1990-1991 survey collected information on the fish species in Lake Lanao. The objective of the study described in this Chapter was to collect and report information on the current status of the fish species in Lake Lanao based on 2008 landings and markets surveys. The collected information was then compared with the previous surveys done by Villaluz, Sanguila et al. and Escudero. Moreover, field samplings and interviews with the fishermen were also conducted to collect additional information that the market and landing surveys might not provide.

The working hypothesis of this study was that since the last survey, conducted during 1990-91, a) introduced species in Lake Lanao have continued to increase while the numbers of endemic species have continued to decrease, and b) human activities, preferences and overexploitation of the endemic species have contributed to the population decline of the remaining endemic species.

Methods

Surveys

Four types of surveys were conducted during this study to collect information on the fish species present in Lake Lanao: a) observations of fish and interviews with fishermen at places where the fishers land their catches, b) observation of fish and interviews with fish-sellers at the fish markets, c) directed field samplings by paid fishers, and d) questionnaire interviews with the fishermen (Table 2.1). Generally, the landing surveys were done in order to identify directly the fish species present in the lake and to establish the relative abundance of the various species found, while the market surveys were conducted in order to determine and record species that might not be seen during the landing surveys. Direct field sampling of fish from the lake was also conducted since the landing and market surveys might have excluded some fish species that fishermen caught but did not land because these species were unacceptable to consumers. Interviews with fishermen were conducted to provide broader information about the species caught in Lake Lanao, relative to the three other surveys. The interviews also provided information on human uses, consumer preferences for fish and human activities that might have effects on the fish species inhabiting Lake Lanao.

Political stability and peace and order have been issues for decades in the province of Lanao del Sur where Lake Lanao is located. Preliminary interviews with the local people, the fishermen and the fish market vendors were conducted before the surveys began to confirm the feasibility of the sampling approach. Permission from the local leaders was also obtained. Municipalities included in the surveys were chosen based on their locations around the lake and on the availability of contact people for security purposes. Furthermore, municipalities located in the southern part of the lake were included based on information in the report of Escudero (1980) that the endemic *Puntius lindog* is limited to the south were the lake is the deepest.

a. Landings Survey

Three landing ports were surveyed around Lake Lanao - Marawi City, Ganassi and Lumbatan (Figure 2.1). For each sampling event the samplers (myself and one or two assistants) would wait at the fishing port early in the morning and record for every fishing boat that arrived, the fish species landed, the total weight of each species caught, and the location or area where the species were caught in the lake. The survey operations would typically start at 6:30 and last until 9:00 A.M. or until all fishing boats on that particular day were sampled.

Marawi City has the largest landing port (Figure 2.6) and fish market in the province. Thus, the landing survey was concentrated on this area. Fish coming from the different towns around the lake were carried to the landing site in Marawi City by fishermen or middlemen. Middlemen refer to persons who bought fish from the fishermen in their respective town and carried it to the landing site where they would sell the fish to the market vendors.

Ganassi and Lumbatan are both located in the south of Lake Lanao. Both municipalities are accessible either by boat or car. The peace and order situation at the time of the survey was not stable and people living in the neighboring municipalities of Ganassi and Lumbatan were being displaced. We were advised by local people not to proceed with our survey. Both municipalities were surveyed once.

b. Market Survey

Four markets in different municipalities around Lake Lanao were surveyed: Marawi City, Ganassi, Poona Bayabao and Lumbatan. *Palitan* and *Banggolo* are the two major markets in Marawi City (Escudero 1980). Freshwater and marine fishes are sold in *Palitan* market, which is located on the lake shore of the city. On the other hand, *Banggolo* market exclusively sells marine fishes that come from neighboring towns such as in Iligan, Lanao del Norte and Malabang, Lanao del Sur.

For each sampling event in Marawi *Palitan* market, a maximum of ten vendors were surveyed to determine and record the kinds and prices of each species sold from Lake Lanao. Stalls of fish vendors that sell fish from the lake are all located in one particular area. Furthermore, fish vendors usually sell a particular kind of fish. For instance, a Tilapia vendor will only sell Tilapia and a mudfish vendor will only sell mudfish. Stalls at the markets were also carefully looked for any species not seen during any of the landing surveys.

Markets in Poona Bayabao and Lumbatan were smaller and exclusively sell fishes from Lake Lanao. Also, species not seen in the landing ports were identified and lengths and weights were recorded.

c. Field Sampling

Field samplings were conducted in the municipalities of Ganassi, Marantao and Masiu (Figure 2.1). For each sampling event a fisherman from each of the three towns was hired and instructed to catch fish using their regular fishing method. Since using regular methods of capture might result in uniformity of the species caught, in the second sampling, the fishermen were asked to use any alternative fishing methods that they knew and try to catch different species if possible. The fishermen were shown photos of the fish species that were known to thrive in the lake. All the fishermen said that they had not caught endemic species for a very long time and would not be able to catch them. One particular fisherman said that he could catch *Trichogaster pectoralis*, an introduced species that had not been recorded in the market nor landing survey at that time.

The fishermen's catches were sampled when the fishermen landed. The fish species, the total weight of each species caught, and information on the fishing location and capture method were recorded. When the field samplings were over, the fishermen were given a fixed cash incentive (P500 or $11). Compared to some self-employed fishermen earning at least P 1500 per month (www.igpinfo.com) and fish workers in commercial fishing receiving P100-250 a day (Pulatienez et al 2011), the cash incentive given to the fishermen was a generous amount. The selected fishermen were all personally known and referred by my two assistants.

d. Fishermen Interviews

Interviews with the fishermen were done to provide additional information concerning the fish species caught in Lake Lanao. Fishermen from the municipalities of Lumbatan, Ganassi, Marantao and Masiu were asked to complete a formal questionnaire (Appendix B). Approval from the Oregon State University Institutional Review Board (IRB) was acquired before conducting any fishermen interviews. A maximum of 60 fishermen only were approved by the IRB to participate in the survey. The number of participants approved by the IRB was then divided equally to each of the four municipalities.

Before we conducted the interviews, we met and coordinated with the local leaders and asked permission to interview fishermen in their respective communities. In the municipalities of Ganassi, Lumbatan and Masiu more fishermen wanted to participate in the survey than we needed. Therefore we made sure we included fishermen with many years of fishing experience.

Fishermen who participated in the interview were provided with photos of fish species caught in Lake Lanao to assist with species identification. We expected that some fishermen might be unable to read or write so we allowed them to be assisted by their family members, co-fishermen, me or my assistants. Examples of questions asked were the time of fishing, fish methods used, the kind of species they often, rarely or never caught, the kinds of species they preferred to catch and the reason of for the preferences. They were also asked if they engaged in fish culture or fish farming other than fishing in the lake, if they used fish as bait and to make comments on problems they encountered as fishermen.

Comparison with Past Surveys

Results of the current surveys were compared with the historical landing survey conducted by Villaluz in 1963-64, Sanguila et al. in 1973 and with the three market surveys conducted by Escudero in 1974-77, 1982-83 and 1990-91. The objective of the comparison was to determine if there had been changes in the number and abundance of species caught in Lake Lanao, whether the number of endemic species had changed and which species now dominated the lake.

Being the capital city of Lanao del Sur where Lake Lanao is located, Marawi City is the center for merchandise and has the biggest fish market and landing port in the province. Villaluz (1966) identified the various fish species caught as well as obtained a total weight of Lake Lanao fishes landed in Marawi market in 1963-64 but his report did not describe in detail how his survey was conducted or how much sampling he did. Because he mentioned the word ‘landed’, we assumed that he did a landing survey in Marawi City, the same area where we conducted our 2008 landing survey.

In August to December 1973, Sanguila et al. (1975) did a landing survey in Marawi City. No description on how the survey was done as well except that the total landed fish weight caught was compared with the Villaluz survey. Although Escudero (1980) mentioned in his methodology that he undertook a daily fish market survey at Marawi City market from 1974-1977, the results of his study showed only partial coverage and not the entire 12 months of a year.

The objective of Escudero’s fish market surveys was approximately the same as the objective of the historical landing survey of Villaluz and Sanguila et al. We therefore assume that it is valid to compare the estimates of total catch of Villaluz, Escudero and Sanguila. In addition to the Villaluz, Escudero and Sanguila surveys, we also included species-presence data from the landing survey of Sanguila et al. (1975). Furthermore, Kornfield (1982) collected endemic species in 1982. The results of his collection were included in a comparison with the other surveys to determine changes in the presence or absence of the species through the years.

Results

Surveys

a. Landings Survey

A total of 12 sampling events were conducted from July to October 2008 in the landing sites of Marawi (10), Ganassi (1) and Lumbatan (1) (Table 2.2). The number of fishermen or middlemen varied every sampling event with Marawi City (Figure 2.7) having the greatest number of fishermen or middlemen (12) and Ganassi (Figure 2.8) having the least number (5).

<u>Total weight of each species</u>

The total weight of the sampled catches brought to the three landing sites was 17560 kilograms (Table 2.2). The species with the highest sampled weight was the introduced *Hypseleotris agilis* with a total weight of 11705 kilograms followed by the Tilapia species with a total weight of 4532 kilograms. The native *Ophicephalus striatus* ranked third with a total weight of 1064 kilograms. Meanwhile, for the only endemic species caught, *Puntius lindog*, the total weight was 1.7 kilograms.

<u>Fish species caught</u>

There were 11 species recorded in the landings site of Marawi City: one native species, Os - *Ophicephalus striatus* (mudfish); and ten introduced species, At - *Anabas testudineus* (climbing perch), Cm - *Clarias macrocephalus* (Bighead catfish), Cb -

Clarias batrachus (walking catfish), Cc - *Cyprinus carpio* (common carp), Gg - *Glossogobius giurus* (white goby), Gc - *Glossogobius celebius* (Celebes goby), Ha - *Hypseleotris agilis* (sleeper goby), Om - *Oreochromis mossambicus* (Tilapia mozambique), On - *Oreochromis niloticus* (Nile tilapia), and Tp - *Trichogaster pectoralis* (gourami).

Meanwhile, in the municipality of Ganassi, the following species were recorded: one native species, *Ophicephalus striatus* and five introduced species, *Hypseleotirs agilis, Oreochromis mossambicus*, *Oreochromis niloticus*, *Glossogobius celebius* and *Glossogobius giurus*. The endemic species, Pli - *Puntius lindog* was only recorded in Lumbatan. Other species recorded in Lumbatan landing port were: one native species, *Ophicephalus striatus*; seven introduced species – *Clarias batrachus, Clarias macrocephalus, Hypseleotris agilis, Oreochromis mossambicus, Oreochromis niloticus, Glossogobius celebius* and *Glossogobius giurus*.

The common fish species found in the landing ports were: *Hypseleotris agilis* (Ha), *Tilapia spp*. (Om, On), *Ophicephalus striatus* (Os), *Clariid spp*. (Cb, Cm) and *Glossogobius spp*. (Gc, Gg). These species were also ranked in the top five in the total weight caught in the survey (Table 2.3).

Source of fish caught

For the sampling at the Marawi fish port, the landings of *Hypseleotris agilis, Glossogobius spp*., *Ophicephalus striatus, Tilapia spp*., and *Anabas testudineus* were mostly caught in the municipality of Taraka, located on the east side of Lake Lanao

(Chapter 1, Figure 1.2) while *Cyprinus carpio* and *Clariid spp*. were mostly caught in Masiu, in the southern part of the lake. *Trichogaster pectoralis* was recorded as being caught from Marantao. Fish landed in the ports of Ganassi and Lumbatan were all caught around but near the areas of their respective municipalities.

b. Market Survey

There were four markets in different municipalities around Lake Lanao (Figure 2.1) that were surveyed and a total of 13 sampling events were conducted from July to October 2008 (Table 2.4). A maximum of ten different vendors in Marawi (Figure 2.9), 8 in Ganassi (Figure 2.10) and also 8 in Lumbatan markets (Figure 2.11) were surveyed and interviewed. The market in Poona Bayabao (Figure 2.12) was small and only 2 vendors were present at the time of our sampling. The sampling events usually started from 9:00 A.M. until 11:00 A.M.

<u>Fish species sold</u>

All the eleven species recorded from the landing survey in Marawi City plus the endemic *Puntius tumba* were found in the market. The species found in the landing ports of Ganassi and Lumbatan were also all found in their respective markets.

<u>Fish Price</u>

Big species such as mudfish, tilapia, carp, and catfish were usually sold as individual fish and varied between 150-500 pesos (P) or 3-5 dollars depending on their size and condition. Sleeper goby on the other hand were sold by the kilo. Adult sleeper goby were sold between P25-30/kg while their fry were sold between P10-25/kg. *Puntius tumba* and *P. lindog* were both placed in a cellophane container with water and sold by groups (Figure 2.13) usually P100 per 5-8 pieces (about 150 grams), depending on the size.

c. Field Sampling

A total of six field samplings by three different fishermen were conducted in the municipalities of Ganassi (September 7th and 23rd), Marantao (August 8th and October 10th) and Masiu (September 2nd and 29th) (Figures 2.1). Fishing was usually done during the early hours at night, 6:00-11:00 P.M. or early morning 4:30-7:00 A.M. The preferred fishing method of the three hired fishermen was the gill net (Figure 2.14), with which *Hypseleotris agilis* was the only kind of species caught. The 174 fish caught had an average size of 108 mm and an average weight 24 g. Other species caught during the field sampling were mudfish (2 fish), gourami (2 fish), and tilapia (3 fish). The mudfish were caught in Masiu using fish arrows. This species had an average size of 300 mm and an average weight of 573 g. A bag net, locally known as 'siyor', was used to catch in Ganassi to catch gourami, which had an average size of 92 mm and an average weight of 17 g., while the Tilapia spp. were caught using a fish cage trap (Figure 2.15) that was set up in the town of Marantao. They had an average size of 184 mm and average weight 251 g.

d. Fishermen Interviews

A total of 55 fishermen (Table 2.5) were interviewed and completed questionnaires about their fishing methods and activities, thirteen from Lumbatan, fourteen from Ganassi (Figure 2.16), nine from Marantao, and thirteen from Masiu (Figure2.17). Six fishermen did not list where they were from. The questionnaire was administered during the month of September 2008 and each interview lasted for about two hours. Fishermen who participated were given t-shirts at the end of the survey. The data described below were gathered. An English-language version of the questionnaire form is provided in Appendix B.

Of the 55 fishermen questioned, forty three of them listed their years of fishing experience. Of these forty three fishermen, 2% (1) had less than one year of fishing experience, 49% (21) had 1-5 years experience, 33% (14) had 6-10 years experience, 2% (1) had 11-15 years experience, 2% (1) had 15-20 years, 7% (3) had 21-25 years experience and 5% (2) had 26-30 years of fishing experience (Figure 2.18).

Seventy five percent of the fishermen said they fished every day, 9% fished four times a week, 11% twice a week and 5% once a week. Sixty nine percent of the fishermen would go to the lake once a day, usually between 6-11:00 pm to install their fishing nets or cages and 4:30-7:00 am to harvest their catch. Seventeen of the fishermen or 31% would go to the lake once and fish between 7 am to 12 noon.

Fishing Methods Used

Of the fishermen who answered the question related to fishing methods (Table 2.6), 25 or 46% used gill net and 2 (4%) used handline as well as cage exclusively. The rest of the fishermen used one or more methods. Other fishing methods used were longline, lift net, fish arrow and electro-fishing. Gill nets are usually used to catch *Hypseleotris agilis*, *Glossogobius spp*., and other smaller size fish. The fish cage trap is used to catch Tilapia, while fish arrows and electro-fishing were used to catch catfish and mudfish. Nets or cage traps were usually set up between 6:00-11 pm, and fish were harvested between 4:30-7:00 am the next day.

Species Often, Rarely, or Never Caught

When answering the questionnaire the fishermen could choose from thirty one species included in the species identification list (Appendix A) which included the eighteen endemic species, two native species and eleven introduced species. The fishermen were also asked to write down any other kinds of species that they had caught in the lake that were not included in the list. Photos of each species were also provided for proper identification.

The fishermen were asked to report species that they caught often. Seven of the fifty five fishermen did not report any species that they caught often. Of the fishermen who answered the question, 98% listed *Hypseleotris agilis* followed by the *Glossogobius spp*. (66%), *Tilapia spp*. (64%), *Ophicephalus striatus* (27%), *Clariid* *spp*. (27%), *Trichogaster pectoralis* (14%), *Cyprinus carpio* (6%), *Anabas testudenius* (2%) and *Puntius lindog* (2%).

The fishermen were also asked to report species that they caught rarely. Twelve of the fifty five fishermen did not report any species that they caught rarely. *Anguilla celebesensis* had the highest percentage (58%) of fishermen listing it as rarely caught. This was followed by *Cyprinus carpio* (56%), *Ophicephalus striatus* (53%), *Trichogaster pectoralis* (48%), *Anabas testudenius* (44%), *Puntius tumba* (44%), *Clariid spp.* (37%), *Puntius lindog* (35%), *Tilapia spp*. (26%), and *Glossogobius spp.* (16%).

Thirty eight fishermen reported particular species from the identification list that they had never caught. One hundred percent of these fishermen reported that they had never caught thirteen of the sixteen believed extinct endemic species. These are the *Cephalakompsus pachycheilus*, *Mandibularca resinus*, *Ospatulus truncatulus*, *Puntius amarus*, *Puntius baoulan*, *Puntius flavifuscus*, *Puntius herrei*, *Puntius katolo*, *Puntius lanaoensis*, *Puntius manalak*, *Puntius sirang*, *Puntius tras* and *Spratellicypris palata*. Ninety seven percent (37) reported that they had never caught *Micropterus salmoides, Ospatulus palaemophagus, Puntius clemensi* and *Puntius disa* while 60% (23) and 42% (16) reported that they had never caught *Puntius lindog* and *Puntius tumba* respectively. Other species listed were: *Anabas testudineus* (47%), *Anguilla celebesensis* (32%), *Clariid spp*. (24%), *Cyprinus carpio* (26%), *Trichogaster pectoralis* (16%), *Ophicephalus striatus* (5%) and *Glossogobius spp*. (3%).

Areas where fishermen usually fish

Fifty of the fifty five fishermen reported where they usually fish around Lake Lanao. Thirteen different towns were listed by the fishermen (Chapter 1, Figure 1.2). Masiu was listed seventeen times, followed by Lumbatan (14), Ganassi (13), Marantao (10), Tugaya (8), Bayang (7), Poona-Bayabao (6), Balindong (4), Tamparan (3), Taraka (3), Bacolod (2), Madalum (1) and Madamba (1).

Months that fishermen usually fish

Thirty eight fishermen reported the month or months when they usually fish. Twenty six fishermen or 70% of them fish every month while eleven or 30% of them fish on a certain month. Months that some of the fishermen listed they usually fish were: January (2), February (1), March (2), April (1), June (2), July (2) and August (1). No reason was provided on why the fishermen fish on these particular months. A possible reason would be that fishing is not their full-time job.

Species fishermen prefer to catch, reasons for the preferences and methods used to catch the preferred species

Sleeper goby ranked first as the species most often listed as the fishermen's preferred catch (Table 2.7). This was followed by the Tilapia species, the gobies, mudfish, catfish, and common carp. The fishermen were also asked why they preferred to catch the species they listed and were prompted with four possible reasons: easy to catch, abundant, preferred by the consumers and all off the above.

Consumer preference was reported most frequently by the fishermen as their main reason why they caught the species, followed by abundance of the species and finally that it was easy to catch.

The gill net was reported most frequently as being used to catch the sleeper goby, gobies, the Tilapia species and the common carp. Long line was reported as being used to catch the goby species and the catfish. Other fishing methods that were reported were the spear and electro-fishing for catching mudfish and common carp, and the cage trap for the Tilapia species.

Use of fish bait and aquaculture

Two of the questions asked in the fishermen survey related to human uses and activities: the use of fish as bait and conducting aquaculture. Thirty nine of the fishermen said they do not use fish as bait while the rest did not answer the question. In relation to aquaculture, aside from fishing in the lake, only eleven of the forty three fishermen who answered the question reported practicing aquaculture (Figure 2.19). As their culture method these fishermen used fish pens that they install along the shores of the lake (Figure 2.20). Moreover, Tilapia and common carp are the only fish species the fishermen reported they culture.

Changes, fishing conditions and comments from the fishermen

Of the forty seven fishermen who answered the question on whether they had observed changes in the Lake, twelve or 26% said they had seen changes since they started fishing while 35 fishermen or 74% said no. When asked for specific changes, many answered that *Hypseleotris agilis* had increased while the endemic species and gobies were disappearing and declining. Species that were also reported to have increased were the Tilapia, catfish and freshwater shrimp. Other fishermen also reported that their catches were more variable. Some fishermen noted a decrease in their catch and fewer fish but some also reported there were more fish in their area. Other specific changes listed were increase in pollution and the observation of skin wounds in *Hypseleotris agilis*.

When asked about fishing conditions now compared to the six months earlier, only twenty fishermen answered the question. Eleven or 40% said their fishing conditions had become more difficult due to poverty, the economy and low fish catch. Seven or 25% said their catch had declined due to the monsoon condition. Seven percent of the fishermen noted an increase in their catch of *Hypseleotris agilis* and reported changes in the species' colorations. Only one fisherman reported that his current catch were better than six months before while seven fishermen reported that they had noticed no changes.

In the section for open-ended comments, 74% of the fishermen commented that they needed fishing equipment to improve their catch. Other notable comments were that: no fish policies had been implemented and that they hoped the government would provide them with education and assistance.

Comparison with Past Surveys

The past market surveys and the current market survey did not all follow a standard sampling protocol and they differed in the months of the year they covered. The 1973 survey of Sanguila started in the month of August until December while for the surveys by Escudero, the 1974 survey was conducted for 10 months (February-December), the 1975 survey was conducted for three months (March-May), the 1976 survey was conducted for seven months (June-December), and the 1977 was conducted for six months (January-June). The reports for the 1990-91 survey by Escudero and the 1963-64 survey by Villaluz did not specify what months these surveys covered. The 2008 survey was conducted for four months (July-October).

In the present landing site and market surveys, the introduced species *Clarias macrocephalus and Clarias batrachus* (Clariid species) were collectively recorded as one species since most of the fishermen could not distinguish their morphological differences. Similarly the *Glossogobius celebius* and *Glossogobius giurus* were recorded as Glossogobius spp. and *Oreochromis mossambicus* and *Oreochromis niloticus* were recorded as Tilapia spp. This method was also used in all the surveys conducted by Escudero and Villaluz. With the exception of the above species, the 2008 landing survey used the approach taken in Escudero's and Sanguila's surveys where the endemic species were weighed separately by species. On the other hand, Villaluz reported only a grouped weight for all the endemic species. Therefore we could not compare the weights of the individual endemic species that Villaluz recorded with the species-specific weights reported in the Sanguila and Escudero surveys and in the current survey.

Table 2.8 and Figure 2.21 compare the total weights in kilograms of species from the different surveys. The largest recorded total weight of species caught in the lake was in the 1963-64 survey which amounted to 1,729,005 kilograms. A 42% decreased was recorded in 1973 and further decreased by 60% in 1974. In the 1975 survey, the total weight of species was only 262970 or only 38% of the total weight in the previous year. It gradually increased up to the 1982-83 (543964 kg) survey until it decreased again in 1990-91. The 2008 survey only recorded 17566.4 kilograms of species caught in Lake Lanao.

Endemic cyprinids comprised about 60% of the total weight of the landings in the early surveys (Figure 2.22) but then decreased dramatically in the 1982-83 survey when they only contributed 17% of the total fish catch, a 53% difference from 1977 survey. This further decreased to 12% (1990-91) and then down to only 0.05% in 2008.

The landed weight of the native species as a fraction of the total landed weight showed little variation over the years, averaging 14% until the 1990-91 survey when it decreased to 5%. One notable exception was 1973 when no eel were recorded in the market survey. In the 2008 survey, the native mudfish, *Ophicephalus striatus*, ranked third with a total weight of 1063.7 kilograms contributing 6% of the total fish caught

The fraction of the recorded total fish catch that was introduced species followed a pattern that was more or less a mirror image of the endemic cyprinids. During the early surveys the introduced species comprised about 20-30% of the total landings weight but increased markedly starting with the survey in 1982-83, leaping from 17% in 1977 to 68% in 1982-83. Their relative abundance increased in the most recent two surveys, contributing 83% and 94% in the 1990-91 and 2008 surveys respectively.

Discussion

Surveys

a. Notes and Discussion on the Landing Surveys

Hypseleotris agilis

On the first day of the landing survey in the City of Marawi, the first things that I noticed in the fishing boats were wet rice sacks (Figure 2.6), which were then carried by the fish vendors and placed in their carts. Later I found out that the sacks contained *Hypseleotris agilis* fry. Prior to this experience I had not known that the fry of this species were caught and marketed.

The introduced *Hypseleotris agilis* highly dominated the landing survey, accounting for 67% of the total weight of all species or 11705 kilograms (Table 2.2).

Seventy six percent (8896 kilograms) of the landings of this species were fry and only 24% (2809 kilograms) were adults.

Adult *Hypseleotris agilis* were placed in large basins. Recycled plastic jars for cooking oil were used by the fishermen or middlemen to measure out adult *Hypseleotris agilis* depending on how much the fish vendors would buy. A plastic jar was equivalent to roughly 1 kilogram. *Hypseleotris agilis* fry were sold by sacks, with one sack being equivalent to 50 kilograms.

Puntius lindog

Specimens of *Puntius lindog* were seen by us for the first time in the month of September 2008 during our preliminary landing survey in Lumbatan. An old fisherman, who was about to deliver the endemic species to the house of one of his regular customers, was passing by the market when we were conducting interviews with the fishermen and vendors. He asked why we were there and what we wanted. We told him that we were looking for endemic species while showing him photos. Then he showed us his hand, which was holding a plastic container, half-filled with water. In it were three *Puntius lindog*. One of the fishes was even gravid.

When we asked the fisherman where he caught the species, he did not reveal any specific area and only said that he caught it around Lumbatan. Apparently the old man was the sole fisherman and local vendor of *Puntius lindog*. Some fishermen we spoke with did not know that the species still existed and that the old fisherman had been catching it. In fact, some local people who were present during the survey admitted to us that they had not seen the species in 10 years. Some had never seen it before. In addition, specimens of *Puntius lindog* were caught by the same old fisherman a week later, which we discovered when we conducted our market survey and fishermen interviews. The total weight that we observed of landings of this species was 1.7 kilograms.

b. Notes and Discussion on the Market Surveys

There were no differences between the kinds of species sold in the four markets and the kinds of species recorded in the landing surveys except for the endemic species *Puntius tumba* that was found in Marawi market but not in its landing port. Fish vendors in Marawi City would usually sell only one kind of species. For instance, a tilapia vendor would only sell tilapia and would not sell a mudfish and vice versa.

Puntius tumba

Unlike the seller of the *Puntius lindog* in Lumbatan who was also the one who caught the species, the vendor of *Puntius tumba* in Marawi sold fish that others had caught. Initially, the vendor told us that the species was caught from the lake. Eventually the only *Puntius tumba* seller admitted that his source of the species was a fisherman from Balo-i Lanao del Norte, the area where the stretch of the Agus River is located. The vendor said that he used to sell *Puntius tumba* from the lake. Unfortunately he had not sold *Puntius tumba* from Lake Lanao for at least five years as of the time of our survey. Moreover, this species was found in the market during all the survey months (July to October, 5 surveys), which implies that there was a stable source for this species. Its presence in the market was not an unusual event.

Puntius tumba were tiny fish and sold collectively. Based on fish size, the endemic species, *Puntius tumba* and *Puntius lindog* were the most expensive fishes sold in the markets of Marawi and Lumbatan respectively.

c. Notes and Discussion on the Field Sampling

Due to limited funds, only one fisherman was hired from each of the three field sampling sites. Moreover, prior to the surveys, all the fishermen said that *Hypseleotris agilis* was the most common species they would catch. Because the goal of the field sampling was to catch fish species that may have been excluded from the landing and market surveys, the hired fishermen were asked to use alternative fishing methods to try and catch different species.

Pokut a form of gill net, was the common fishing method of the three fishermen, but it caught primarily one kind of species – *Hypseleotris agilis*. Using the alternative fishing methods, three species or species groups were caught – *Tilapia spp*., *Ophicephalus striatus* and *Trichogaster pectoralis*.

d. Notes and Discussion on the Fishermen Interviews

Photos were provided to the fishermen to identify the species in Lake Lanao. However, the fishermen could have made mistakes and errors in identifying the endemic species. Due to the close morphological resemblance of some of these species there is scientific controversy on how many Lanao endemic species there really were due to the morphological resemblance of these species (Reid 1980, Kornfield and Carpenter 1984). Furthermore, based on the data we gathered, there are seven Lanao endemic species that have similar local names (Appendix A).

Fishing Methods

Maranao fishermen have invented fishing methods utilizing native and natural materials such as bamboos, rattan, stones, twigs and water plants. Villaluz (1966) made a comprehensive list and description on the fishing methods used by Maranaos in Lake Lanao. One notable difference between the fishing methods in the past and the current methods based on the 2008 survey was the discontinued use of poison and dynamite. Harmless to humans, the poison is a mixture of roots and leaves of different plants that is spread around an enclosed area killing all the fish. Dynamite is a powder mixture placed in a bottle with a ropelike connector. When lighted, the bottle is thrown directly in the water. Unlike the poison mixture, dynamite could cause serious injuries and even death if not used cautiously. Further, dynamite can be very destructive to the underlying habitat and structures that support the fish populations.

Fishing Experience in relation to species often, rarely or never caught

Endemic species

With the endemic species group, *Puntius lindog* was listed as never caught by 23 of the 38 fishermen who answered the question. This could mean that 23 may have caught this species. *Puntius tumba* was listed by 16 fishermen. This could also mean that 16 fishermen may have caught this species at least once in their lives. Approximately 97-100% or 37-38 of the fishermen listed the believed 16 extinct endemic species as species they had never caught. This could mean that one or two of the interviewed fishermen may have caught one or more of the believed 16 extinct endemic species.

Fishing experience can be significant for knowing the kinds of fish species caught and how the catch composition has changed through the years. Survey data showed that fishermen with longer fishing experience had recently or previously caught the believed extinct species. The fishermen with the greatest number of years of fishing experience had 30 and 28 years.

Native species

The native *Anguilla celebesensis* was not listed by any fishermen as a species they often caught, but it was listed by 58% of the fishermen as a species they rarely caught (58%). This could mean that although *Anguilla celebesensis* was not found in the landing and market surveys, more than half of the fishermen may have caught this species. Furthermore, during the 2008 landing survey in Ganassi, one fisherman said he had caught one eel in the month of August.

Ophicephalus striatus, the other native species, was listed by fishermen as being either often or rarely caught. Furthermore only two of the 38 fishermen said they had never caught this species. Just like with the introduced species, fishing experience may have influenced the fishermen's reporting these two native species.

Introduced species

Introduced species dominated the list of species often caught. *Hypseleotris agilis* was listed as the species most often caught. This was also the only species that was not listed as rarely and never caught. All of the introduced species except the *Micropterus salmoides* were listed as often or rarely caught. This species was listed as never caught by 37 of the 38 fishermen who answered the question. Furthermore, *Micropterus salmoides* was last recorded in the landing survey in 1963-64 (Villaluz 1966). This could suggest that the species is now extinct in Lake Lanao.

The survey showed that introduced species are being caught by fishermen with both long and short fishing experience. This means that fishing experience was not a limiting factor for the fishermen to catch the introduced species. This could also suggest that introduced species are now the most important commercial fisheries in Lake Lanao.

Factors that could influence fishermen’s catch preference

There are factors that could influence fishermen’s catch preference. Species are easily caught if they are abundant. Furthermore, demand from the consumers could affect the catch selection of the fishermen. In this survey, we asked the fishermen the following factors: abundance, easy to catch or preferred by the consumers.

Preferred introduced species

When asked to list species they preferred to catch, 100% of the 47 fishermen listed *Hypseleotris agilis,* making it as the most preferred species. Next in rank was the Tilapia which was listed by 42 (90%) fishermen. Fishermen preferred to catch the species they listed because these were preferred by the consumers (83%), were easy to catch (58%) and/or were abundant (54%).

There are also reasons why a species might be preferred by the consumers. Affordability and palatability are probably the two most important factors for consumers to choose and buy fish. *Hypseleotris agilis* has the cheapest price in the fish market survey. Two possible reasons why this species is inexpensive are its availability and abundance. This is supported by the total landed weight of this species observed in the landing survey. Moreover, *Hypseleotris agilis* is also considered a low-class food fish because of its being bony.

Preferred endemic species

The endemic species, *Puntius lindog* and *Puntius tumba*, were both not in the list of preferred species to catch. However, based on the landing and fish market surveys, if available, these species were still preferred by consumers provided they could afford them. These two species were also the most expensive species in the market. Regardless of being expensive, vendors who sold these species had regular customers and/or could sell the fish instantly. Moreover, the preference for *Puntius lindog* has a long history. According to Herre (1924) *Puntius lindog* was considered the second most prized cyprinid in Lake Lanao next to *Puntius baoulan*.

Areas where fishermen usually fish

Areas where fishermen usually fish could tell us the possible fishing grounds for the different fish species. The interviews were conducted in four municipalities (Marantao, Lumbatan, Masiu and Ganassi). Results showed that the majority of the fishermen fished close to their respective municipalities. However not all fishermen strictly fished around where they lived. Some would fish in neighboring municipalities or reaching far across their respective towns. Other towns listed in the interviews, such as Bayang, Poona-Bayabao, Bacolod, Madalum and Madamba, are located in the southern part of the lake. Other towns listed were: Tugaya and Balindong, located west of the lake, and Tamparan and Taraka, both located in the east. Note that the fishermen did not list any towns located in the northern part of the lake, but this may be an artifact of the sampling. Prior to beginning the interviews, we failed to find someone who could help us locate fishermen in the northern part of the lake. Nevertheless, the landing site survey in Marawi City revealed that some of the fishes brought by the fishermen or middlemen were caught around the northern part of the lake - Marawi, Ramain and Tuca.

Fishing ground of the endemic species

Herre (1924) discussed that *Puntius lindog* could be caught among the pond weeds in shallow bays of the lake. This was probably evident at that time because this species was still abundant. Escudero (1980) pointed out that the fishing ground for this species was in the southern part of the lake where it is the deepest. He also noted that the species was then limited to that area. In the current survey, *Puntius lindog* was only caught by a fisherman in Lumbatan, on the southern shore of the lake. This suggests that this species is limited now to the southern area of the lake.

Although Herre (1934) obtained *Puntius tumba* in Dansalan Market (now known as Marawi), it is not clear whether he collected this species in Lake Lanao itself. Herre (1924) however collected this species in a stream east of Lake Lanao, in Lake Uyaan, Lake Nunungan and the outlet of Lake Dapao. Furthermore, Kornfield and Carpenter (1984) collected this species in a stream 100 m from Lake Lanao. Escudero (1994) reported that this species was usually caught in the coves of the lake. In the 2008 market survey, vendor reported that *Puntius tumba* were caught in Agus River.

It is a concern that *Puntius tumba* may have become extinct in Lake Lanao itself. However, there were unconfirmed reports that *Puntius tumba* have been caught in the lake particularly, in Marantao. Because our survey was very limited in the area and time covered, we could not verify the report nor ascertain the real condition of this species.

Fish Bait and Aquaculture as Pathways for Nonnative Introductions

Herre (1924, 1933) mentioned that the introduction of fish species in the Philippines can be traced to the time when the Malays arrived in the country. One example is the *Ophicephalus striatus* that can be found in all parts of the country. According to Herre, this species had been introduced even in remote mountain lakes by both Christian and pagan Filipinos. Furthermore, this species had been so long established in Lake Lanao that it had been considered as a native species.

Table 2.9 shows the approximate date of introductions of the non native fish species in Lake Lanao. The introductions of these species were both intentional and unintentional. Intentional introductions were mostly to increase the availability of cheap sources of protein and fish production. *Tilapia spp.*, *Cyprinus carpio* and *Chanos chanos* have been restocked many times in Lake Lanao. The deliberate restocking of these species was believed to be the cause of the accidental introductions of species such as the *Glossogobius spp*. and *Hypseleotris agilis*, which has now become the dominant commercial fish in Lake Lanao.

Using live fish as bait and for aquaculture are some of the other possible pathways for species introductions. To determine if other species may have been recently introduced in Lake Lanao, the fishermen were asked if they used live fish as bait or if they cultured fish species in farms or ponds. The survey showed that the fishermen who were interviewed used native shrimps (*Macrobrachium)* instead of fish as bait.

When it comes to Philippine aquaculture, Tilapia and common carp are two of the most preferred species. These species were also the only species used in aquaculture by the fishermen interviewed in the current study. Kornfield (1982) investigated the biology of the endemic cyprinids of Lake Lanao. One major concern he pointed out was the project that was culturing *Puntius gonionotus/P. javanicus* (Thai/Indonesian cyprinid). The species was introduced in Lanao del Sur in 1973 and may have entered in the lake. Based on our survey, there no newly introduced fish species have become established in Lake Lanao.

<u>Changes, fishing conditions and comments from the fishermen</u>

Lake Lanao fishermen were mostly dependent on traditional fishing. They were hoping that the government could provide them with education and with improved fishing equipments and boats. They were also of the opinion that no policies have been implemented in the lake to protect its fishery.

Policies and agencies protecting Lake Lanao

It was not until in the early 1990s that legislation was enacted for the protection of Lake Lanao, following construction of the Agus 1 hydro-electric plant, which was constructed in the mouth of Agus River, the only outlet of Lake Lanao. In February 26, 1992, the Philippine President Corazon C. Aquino, declared the reservation and protection of the 194,000 hectare Lake Lanao watershed. The purpose of the law is to protect, maintain and improve its forest cover and water yield for hydropower, irrigation and domestic use of land. The Department of Environment and Natural Resources (DENR) was ordered by the President to manage the reservation of Lake Lanao.

In the same year, the Lake Lanao Watershed Protection and Development Council (LLWPDC) was created. Members of the council represented the different government agencies such as the DENR, National Power Corporation (NPC), Armed Forces of the Philippines, Philippine Chamber of Commerce and Industries, Mindanao State University, Save Lake Lanao Movement (SALLAM) and local officials such as mayors and governors. According to Naga (2010), the Council failed to meet regularly and no known projects or actions for the protection of Lake Lanao were implemented. Furthermore, up to now, the Protected Areas and Wildlife of DENR has not declared nor confirmed the protection of Lake Lanao.

One reason for the lack of action and implementation of policies for protecting Lake Lanao is the implemented law itself. The Autonomous Region in Muslim Mindanao, where Lake Lanao and part of its watershed are located, has no jurisdiction over the watersheds declared by the national government (Naga 2010). Even without jurisdiction, the Lake Lanao Development Authority (LLDA) was created by the Regional Legislative Assembly. Just like the LLWPDC, the LLDA was inoperative.

In March 2010, the Mindanao Development Authority planned to reactivate LLDA and SALLAM to help manage and protect the heavily denuded watershed causing the water level of Lake Lanao to drop by 75 meters in less than four months (Corrales 2010). Furthermore, no known agency has been created to specifically protect the endemic species in Lake Lanao. Complex laws, inadequate regulation and effort from the national government and lack of concern have resulted in the neglect and poor condition of the lake.

Comparison with Past Surveys

Number and abundance of endemic species

We could not tell precisely how many different kinds of endemic species Villaluz (1966) found in his survey or their relative weights. However, Villaluz mentioned finding five endemic species that were of great commercial value: *Puntius lindog*, *P. disa*, *P. baoulan*, *P. manalak* and *Spratellicypris palata*. These species produced average landings of about 2000 kilograms every day. Another endemic species, *Puntius clemensi*, which was the largest of all the cyprinids found in Lake Lanao was estimated to produce 10-70 kilograms daily. Other species mentioned were *Puntius tumba* and *P. disa*. The survey of Sanguila et al. (1973) obtained nine endemic species from three genera (Table 2.10). Then in 1974, 1975, 1976 and 1977, Escudero obtained ten, six, four and five endemic species respectively. Kornfield collected specimens in 1982 and found six cyprinids. In 1982-83, Escudero however found only two endemic species in the market. The last market survey done by Escudero was in 1990-91 where he found three endemic cyprinids. In our 2008 survey, we only found two species (*Puntius lindog* and *P. tumba*), the same species that Escudero found in his 1982-83 survey.

Moreover, the abundance of the endemic species appeared to be declining, even before some of them became ‘extinct’. In 1963-64 survey, the endemic species contributed 57% of the total weight caught in Lake Lanao. Ten years later, it had declined by 13% but then increased by 10% in the next year (1974). By 1977, it increased to 70% but dramatically declined in 1982-83 survey with only 17%. The relative weight of endemic species eventually did not recover in following years. In the 2008 survey, it further declined, contributing only 0.05% to the total weight sampled landings. The total weights of the different surveys varied since they did not all cover equivalent lengths of survey time. Furthermore, the historical surveys were vague regarding the sampling methods. However, production in the Lake could have possibly declined based on interviews with fishermen (Sheik 1990, Washburn 1978).

With the exception of the *Puntius lindog*, the endemic species showed very minimal abundance (Figure 2.21) until they became ‘extinct’. *Puntius tumba*, one of the only two endemic cyprinids found in the 2008 survey, was consistently low in relative abundance while *Puntius lindog* had consistently comprised most of the endemic catch in the past surveys until it drastically declined in 1982-83. In the present survey, *Puntius lindog* only contributed 0.01% of the total weight of the species landed. Although they were apparently caught in the Agus River and not in the lake, the specimens of *Puntius tumba* were 0.04% of the total landings weight, higher than *Puntius lindog*, even though in the past *P. lindog* dominated the landings.

Number and abundance of native species

Note that there was no native eel recorded in the 1990-91 and 2008 surveys (Figure 2.23). It is believed that *Anguilla celebesensis* travels from the sea to Lake Lanao through underground channels in Lake Nunungan and Maria Cristina Falls (Herre 1933). The Agus River leaps over Maria Cristina Falls, a drop of 98 meters. We remain uncertain if this species is already extinct in the Lake. However, Prof. Ruben B. Silang, the Dean of the College of Fisheries Mindanao State University, personally told me that he bought an eel from the Agus River in 2005 sold by vendors on the streets located on the side of the river. Since the *Anguilla celebesensis* is a catadromous species, the hydro-electric plants along the Agus River may have prevented the species from traveling all the way to the lake. I am unaware of any other information on when this species was last caught in the lake.

Based on the past two surveys, only one native species was found in Lake Lanao. Furthermore, based on our interviews, we could safely say that *Anguilla celebesensis* is still extant in Lake Lanao but very rare.

Number and abundance of introduced species

At least twelve nonnative species were intentionally or unintentionally introduced in Lake Lanao. Two of the introduced species, *Micropterus salmoides* (black bass) and *Chanos chanos* (milkfish), failed to establish in the Lake and eventually 'disappeared' even though they were restocked at least twice (Table 2.9). Although *Anabas testudineus* and *Trichogaster pectoralis* were able to become established in the lake, their abundances were relatively small. The common carp (*Cyprinus carpio*) was fairly abundant in 1963-64 but did not recover from a decrease in 1973. The introduced Tilapia species had consistently increased during the early years of the data series but had declined in 2008 by 12% from 1990-91 levels (Figure 2.24).

Three of the most recent nonnative species that were known to be 'accidentally' introduced in the lake were the *Glossogobius spp (Glossogobius celebius* and *Glossogobius giurus*) and *Hypseleotris agilis*. *Glossogobius spp*. were the introduced species that dominated landings from the Lake in 1963-1976. Since then, it has been declining, contributing only 0.65% to the total landings weight in 2008. Escudero (1983) believed that *Hypseleotris agilis* had contributed to the decline of the *Glossogobius spp*. After its discovery in 1977, *Hypseleotris agilis* has proliferated and now dominates the lake's catch, contributing 67% of the total landed weight in 2008.

Future of the Lake Lanao cyprinids

Of the 18 endemic species identified by Herre in the 1920's this study has found that at least two of these species remain living in Lake Lanao. However, both the endemic *Puntius lindog* and *Puntius tumba* are currently listed by the International Union for Conservation of Nature as vulnerable of extinction in the medium-term future. Based on past surveys through the years there is evidence that sometimes an endemic species would not be evident in the market but then would 'reappear' in following years. This happened in Kornfield's study in 1982 in which he only found one endemic species in the market but found five more species during his personal field collections. Another species that 'reappeared' over the course of the market surveys was the *Puntius baoulan.* This species was found in the market surveys during 1977 but was not reported again until it was recorded by Escudero in his 1990-91 survey. It is significant to note that except for the 1982-83 and 2008 surveys, the other surveys showed different numbers and mixes of the endemic species. What does this tell us? Does it mean that perhaps other 'extinct' endemic cyprinids still exist, but in relatively low abundance?

Kornfield (1982) argued that because of their relatively low abundance many of the endemic species never reached the market but instead were locally sold and consumed. This was also what happened in the current study with the endemic *Puntius lindog* where it was only locally sold in the municipality of Lumbatan.

Other possible reasons why an apparently extinct endemic species would 'reappear' in the market are changes in the fishing methods and the areas where the fishermen usually operate their fishing gear. Fishing methods could certainly affect the catch composition brought to the markets. Villaluz (1966) described the wide variety of indigenous fishing methods used to catch particular fish that the native Maranaos had invented. The fishermen would use a particular type of fishing gear depending on the kind and size of species they wanted to catch. However in our survey, the commercial fishermen now only use a few common types of fishing gear such as gill nets. In fact 83% of the fishermen interviewed said they used gill nets. It is important to note that most of the fishermen believed that all the endemic species were now extinct. When the endemic species abundance started to decline and the introduced species became more abundance, it probably led the fishermen to stop catching the endemic species and chose instead to catch more readily available fish, such as the *Hypseleotris agilis*.

Moreover, the fishermen's fishing operations were usually limited to particular areas and certain types of habitat. It is possible that the smaller endemic cyprinids, which may have specific habitat types and therefore require particular fishing methods to be caught, are still extant. An example of this phenomenon is the endemic *Puntius lindog* that was strictly limited to the deeper, southern part of the Lake.

Before conducting this study, I had the chance to talk with Prof. Escudero. He spent most of his professional working with the endemic cyprinids in Lake Lanao and was afraid for the fate of the cyprinids. He was overjoyed and surprised when I showed him the *Puntius lindog* from the fisherman in Lumbatan. A long term study with comprehensive field work in Lake Lanao is needed to further study the endemic species and verify what has happened to them. In the meantime, the future of the endemic cyprinids in Lake Lanao is uncertain – but there is hope that they will survive.

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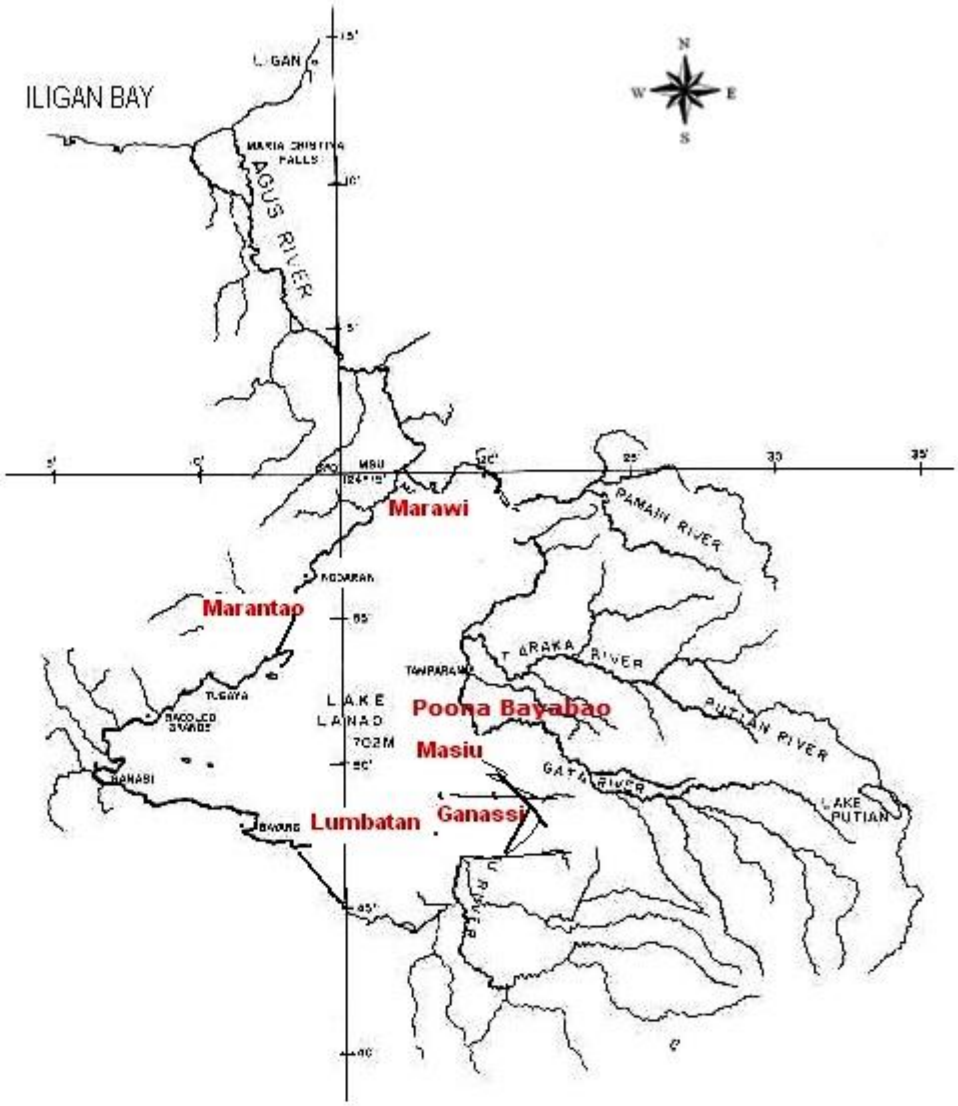

Figure 2.1. Map of Lake Lanao with the municipalities surveyed.

Figure 2.2. Ferryboat arriving in Marawi City port.

Figure 2.3. Mosque built close to the shore of Lake Lanao.

Figure 2.4. People bathing and doing their laundry at the Marawi City landing port.

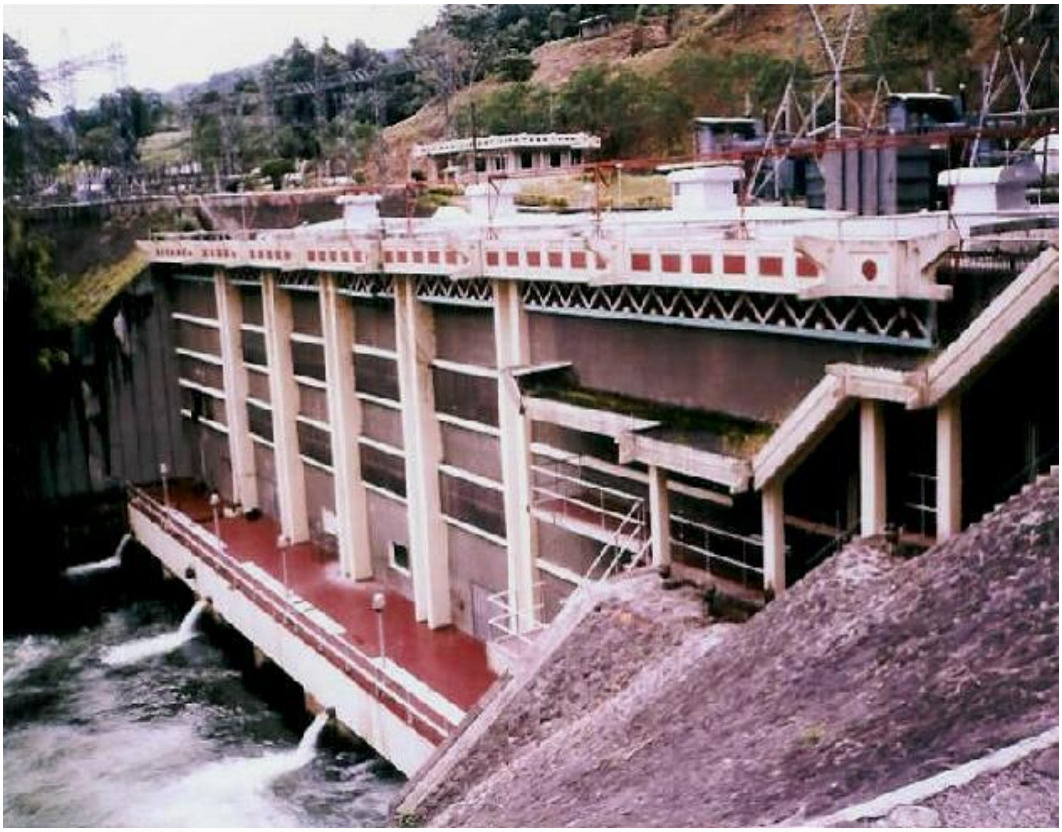

Figure 2.5. Agus 2 Hydroelectric Power Plant – one of the seven plants built along Agus River, the only outlet of Lake Lanao. (photo courtesy of National Power Corporation).

Figure 2.6. Marawi fish landing port.

Figure 2.7. Marawi City fish landing port.

Figure 2.8. Ganassi fish landing port.

Figure 2.9. Marawi City market.

Figure 2.10. Ganassi market.

Figure 2.11. Lumbatan market.

Figure 2.12. Poona-Bayabao market.

Figure 2.13 *Puntius tumba* in plastic bags.

Figure 2.14. Fisherman using gill nets.

Figure 2.15. *Tilapia* cage trap.

Figure 2.16. Ganassi fishermen.

Figure 2.17. Masiu fishermen answering the questionnaire.

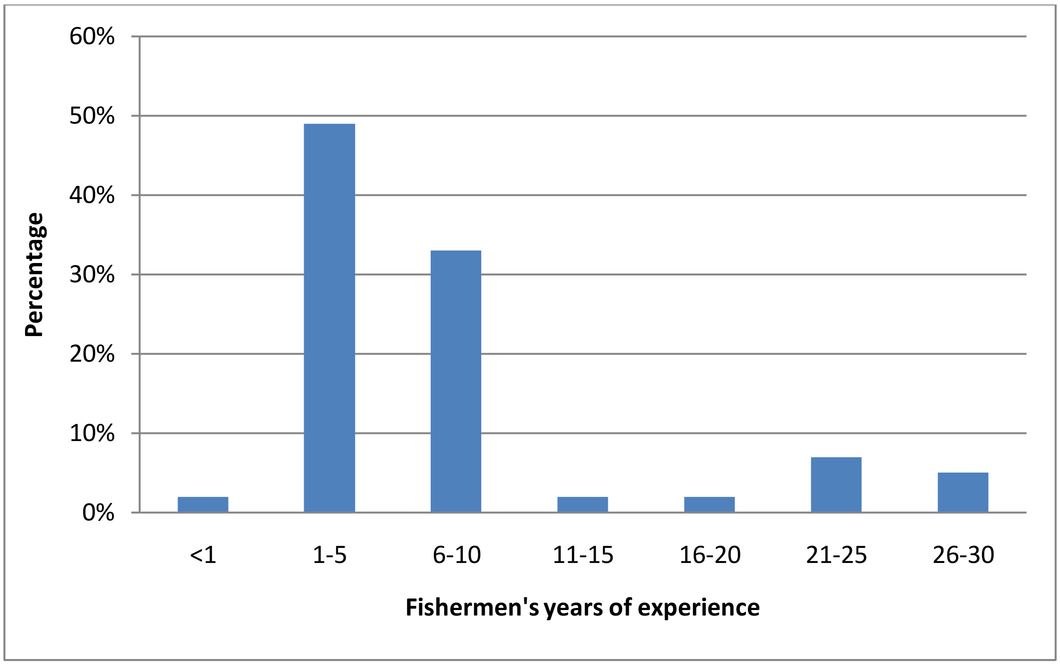

Figure 2.18. Fishermen’s years of experience.

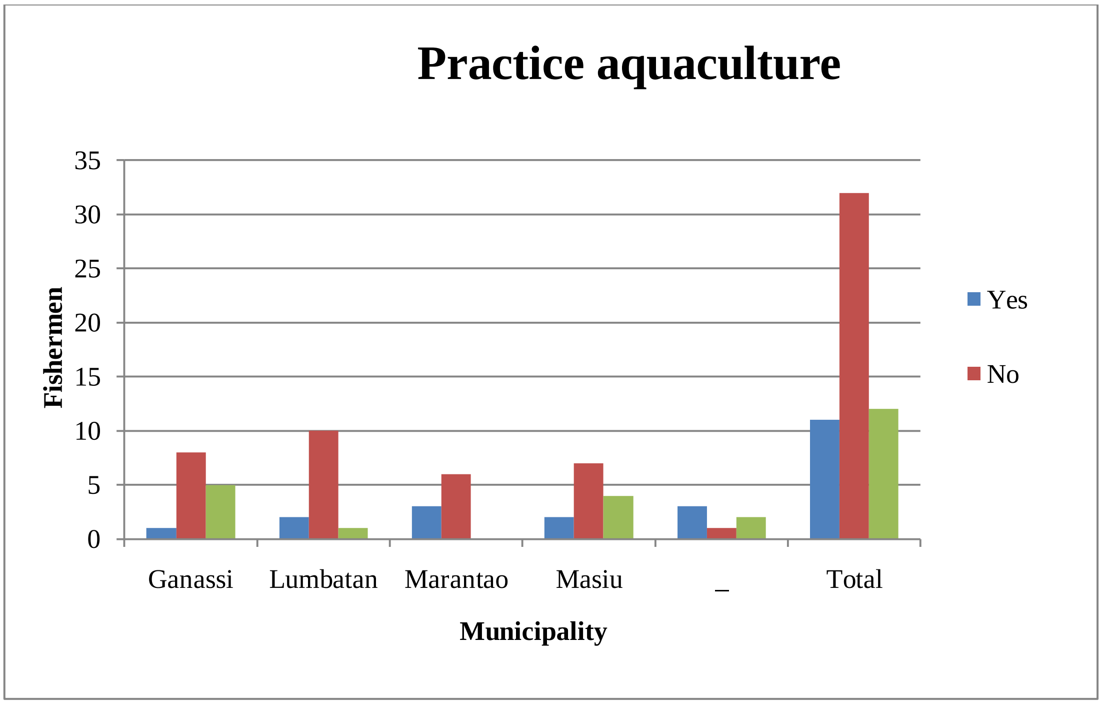

Figure 2.19. Number of fishermen that practice aquaculture.

Figure 2.20. Fish pen built along the shore of Lake Lanao.

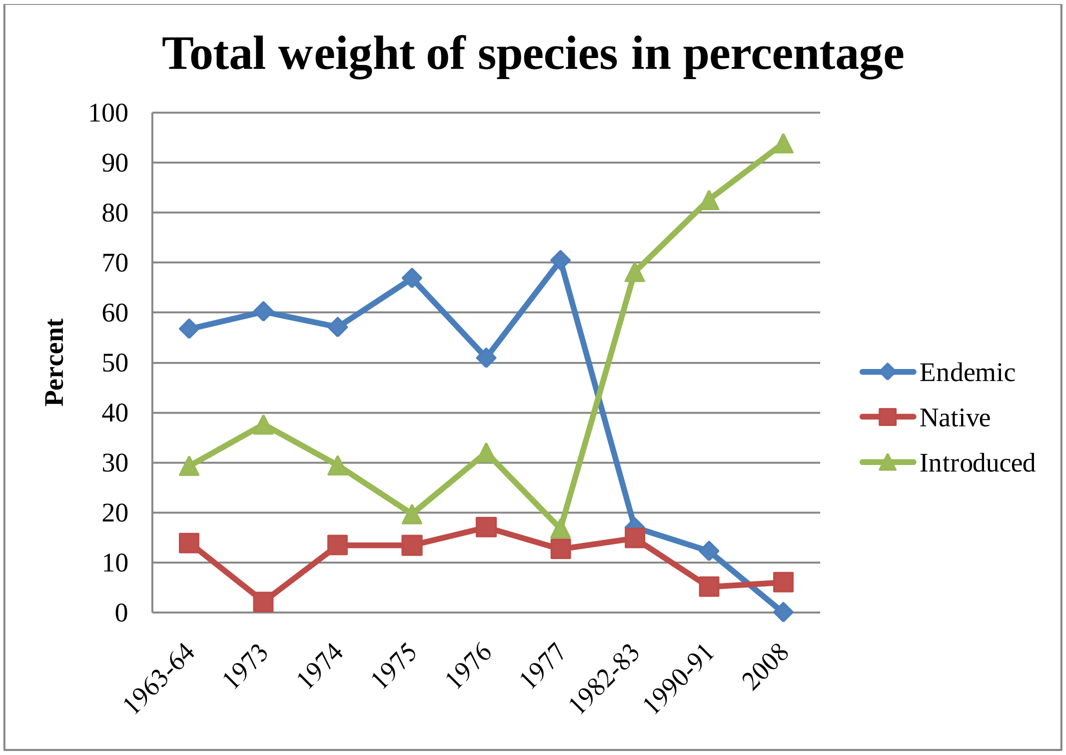

Figure 2.21. Weights (in percent of landings of all species) of the endemic, native and introduced species caught in Lake Lanao.

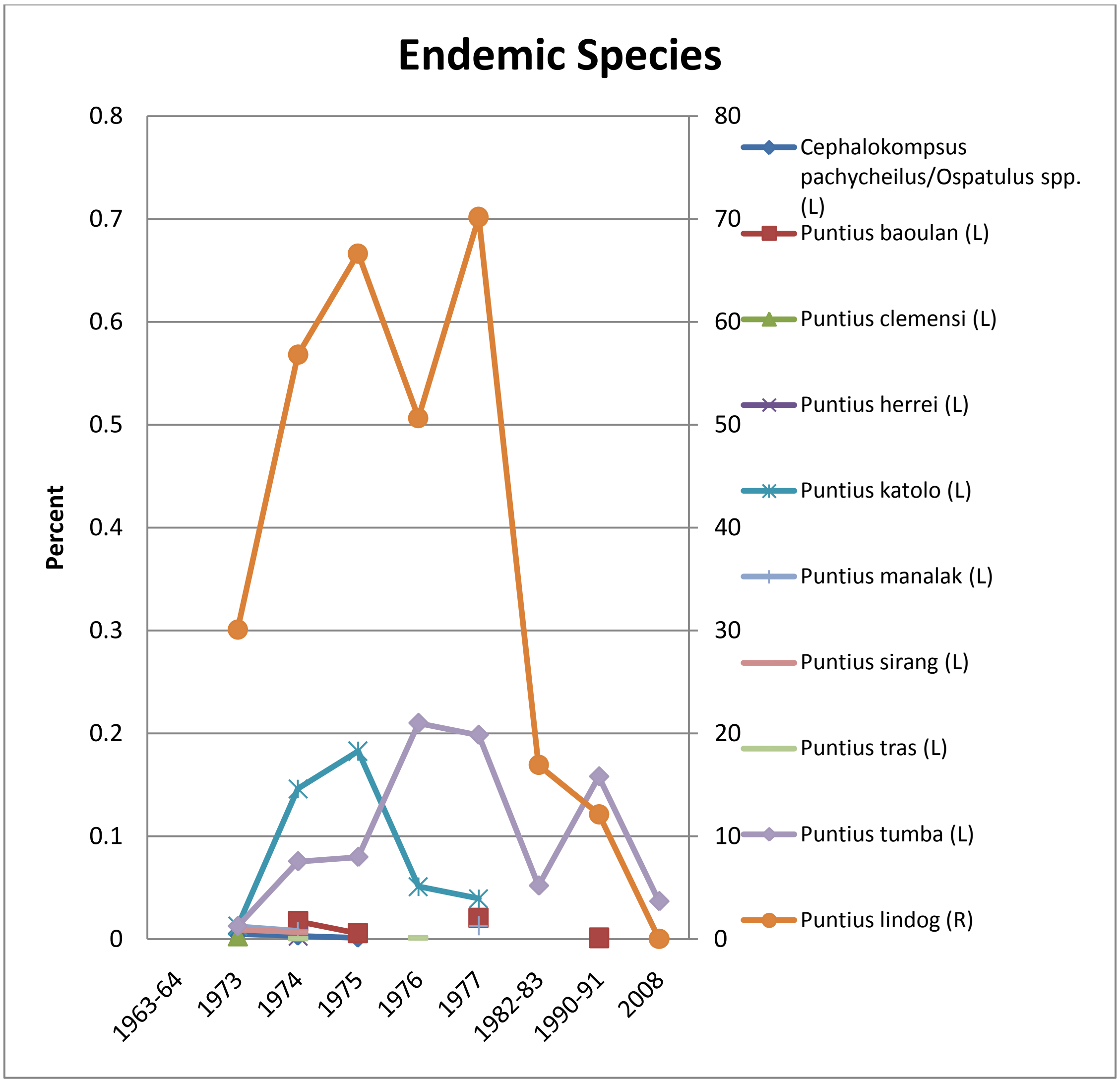

Figure 2.22. Relative weights (in percent of landings of all species) of the endemic species caught in Lake Lanao. (The scale of the right-hand axis, which applies only to *Puntius lindog* is 100 times larger than the scale of the left-hand axis.)

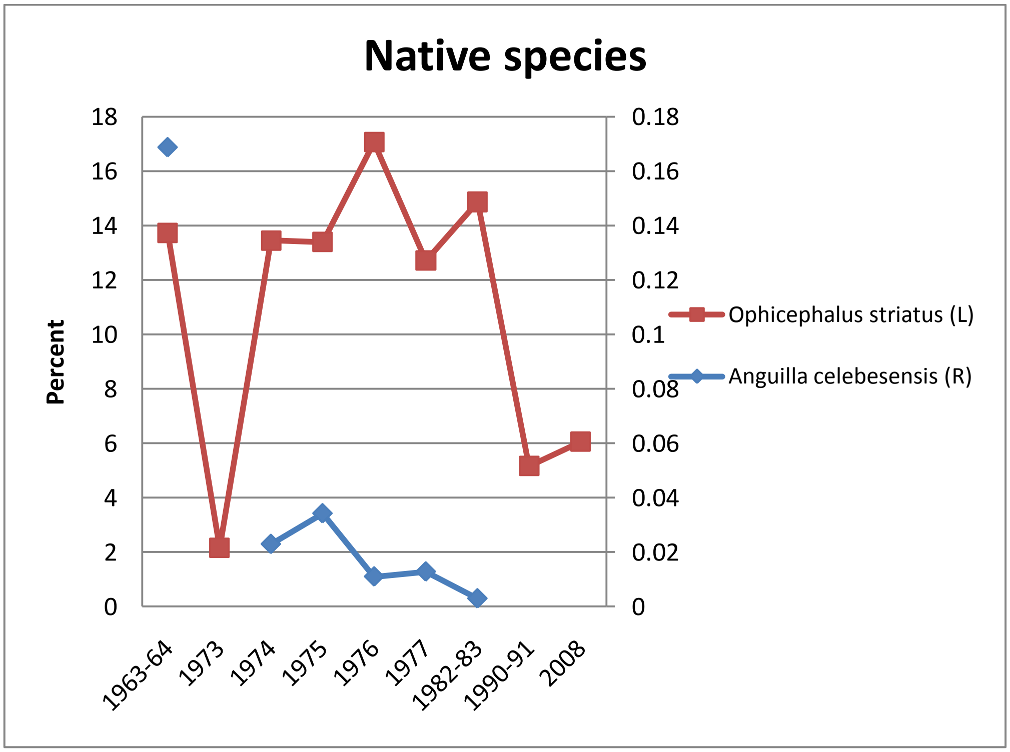

Figure 2.23. Relative weights (in percent of landings of all species) of the native species caught in Lake Lanao. (The scale of the left-hand axis, which applies to *Ophicephalus* striatus, is 100 times larger than the scale of the right-hand axis.)

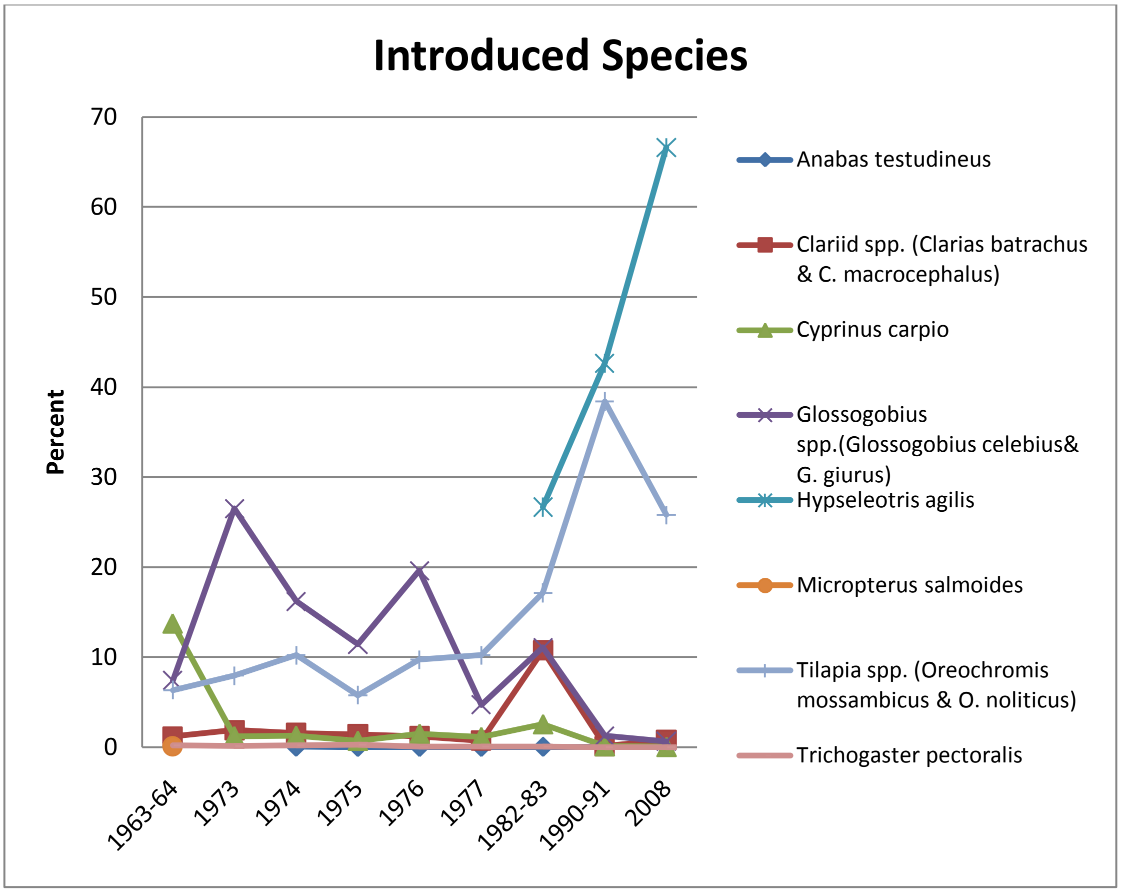

Figure 2.24. Relative weights (in percent of landings of all species) of the introduced species caught in Lake Lanao.

Table 2.1. Surveys and sampling activities conducted during 2008.

Survey Type	Areas conducted
a. Landing Survey	Marawi – north of the lake Lumbatan – south of the lake Ganassi – southwest of the lake
b. Market Survey	Marawi Ganassi Lumbatan Poona Bayabao – east of the lake
c. Field Survey	Ganassi Marantao – west of the lake Masiu – southeast of the lake
d. Fishermen Survey	Lumbatan Ganassi Marantao Masiu

Table 2.2. Landing surveys in Marawi, Ganassi and Lumbatan (July-October 2008).

Date	Number of Fishermen/Middlemen	Fish Species	Weight of Species (kg)
A. Marawi 24-July	9	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	4.05 46.8 266 816 356 5.25 --------- **1494.10**
31-July	8	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	14 57.5 238 600 295.5 12.55 ----------- **1217.55**
2-August	8	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	21 174.15 209 886 238 23 ----------- **1700.15**
8-August	8	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	13.7 108 171.5 1300 320.5 7.5 ----------- **1921.20**

Note: See Appendix A for the species scientific names associated with the 2-character species codes.

Table 2.2. Continued.

Date	Number of Fishermen/Middlemen	Fish Species	Weight of Species (kg)
5-September	10	Catfish spp. (Cb,Cm)	6.75
		Mudfish (Os)	161.6
		Sleeper goby (Ha)	
		Adult	114
		Fry	1850
		Tilapia spp. (Om, On)	465
		White gobies (Gc, Gg)	2.5

			2599.85
12-September	9	Climbing perch (At)	0.26
		Mudfish (Os)	35
		Sleeper goby (Ha)	
		Adult	172
		Fry	1200
		Tilapia spp. (Om, On)	363
		White gobies (Gc, Gg)	7.5

			1777.76
20-September	12	Catfish spp. (Cb, Cm)	1.35
		Common carp (Cc)	3.55
		Mudfish (Os)	269.8
		Sleeper goby (Ha)	
		Adult	213
		Fry	453
		Tilapia spp. (Om, On)	1115
		White gobies (Gc, Gg)	6

			2061.7
27-September	4	Catfish spp. (Cb, Cm)	40
		Gourami (Tp)	0.75
		Mudfish (Os)	16.5
		Sleeper goby (Ha)	
		Adult	38
		Fry	750
		Tilapia spp. (Om, On)	330.25
		White gobies (Gc, Gg)	3.25

			1178.75

Table 2.2. Continued.

Date	Number of Fishermen/Middlemen	Fish Species	Weight of Species (kg)
4-October	7	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	4.8 68.2 148 450 300 25.8 ---------- **996.8**
11-October	8	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	6.75 121.15 470.2 750 329 13.9 ----------- **1691**
B. Ganassi 9-August	5	Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	3 229 100 167 5.1 ----------- **504.10**
C. Lumbatan 6-September	6	Catfish spp. (Cb, Cm) Lindog (Pli) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)	27 1.7 2 31 250 104 2 ----------- **417.70**
TOTAL			**17560.66**

Table 2.3 Rank of Lanao fish species based on their total weight from landing surveys.

Species	**1963-64**	**1973**	**1974**	**1975**	**1976**	**1977**	**1982-83**	**1990-91**	**2008**
A. Endemic	1*								
1. Cp/Op/Ot		12	15	13					
2. Pb			12	11		10		11	
3. Pc		13							
4. Ph			16						
5. Pk		8	8	8	8	8			
6. Pli		1	1	1	1	1	3	3	8
7. Pm		10	13			11,12			
8. Ps		11	14						
9. Ptr			17		12				
10. Ptu		9	9	9	7	7	8	6	6
B. Native									
1. Ac	6,7		11	10	10	11,12	11		
2. Os	2,3	4	3	2	3	2	4	4	3
C. Introduced									
1. At	9		10	12	11	13	10	9	9
2. Cb/Cm	8	5	5	5	6	6	6	7	4
3. Cc	2,3	6	6	6	5	5	7	8	7
4. Gc/Gg	4	2	2	3	2	4	5	5	5
5. Ha							1	1	1
6. Ms	10								
7. Om/On	5	3	4	4	4	3	2	2	2
8. Tp	6,7	7	7	7	9	9	9	10	10

*Villaluz (1966) combined all the weights of the endemic cyprinids without species specification. Although he did mention the following species as having great commercial value: *Puntius lindog*, *P. disa*, *P. baoulan*, *P. manalak* and *Spratellicypris palata*. Note: See Appendix A for the species scientific names associated with the 2-character species codes.

Table 2.4. Market surveys in Marawi, Ganassi, Poona-Bayabao and Lumbatan (2008).

Date	Number of Vendors Sampled	Fish Species Seen
A. Marawi 18-July	7	Catfish spp. (Cb, Cm) Common carp (Cc) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On)
28-July	8	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) Tumba (Ptu) White gobies (Gc, Gg)
31-July	10	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) Tumba (Ptu) White gobies (Gc, Gg)
2-August	7	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)

Note: See Appendix A for the species scientific names associated with the 2-character species codes.

Table 2.4. Continued.

Date	Number of Vendors Sampled	Fish Species Seen
8-August	9	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) Tumba (Ptu)
4-September	8	Common carp (Cc) Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On)
27-September	10	Catfish spp. (Cb, Cm) Gourami (Tp) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) Tumba (Ptu) White gobies (Gc, Gg)
4-October	9	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) Tumba (Ptu) White gobies (Gc, Gg)

Table 2.4. Continued.

Date	Number of Vendors Sampled	Fish Species Seen
11-October	10	Catfish spp. (Cb, Cm) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)
B. Ganassi 9-August	8	Catfish spp. (Cb, Cm) Common carp (Cc) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On)
8-September	6	Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia spp. (Om, On) White gobies (Gc, Gg)
C. Poona - Bayabao 13-September	2	Mudfish (Os) Tilapia spp. (Om, On)
D. Lumbatan 13-September	8	Catfish spp. (Cb, Cm) Lindog (Pli) Mudfish (Os) Sleeper goby (Ha) Adult Fry Tilapia (Om, On) White gobies (Gc, Gg)

Table 2.5. Fishermen information

Municipality	Number of fishermen
1. Lumbatan	13
2. Ganassi	14
3. Marantao	9
4. Masiu	13
5. _	6
Total	**55**

_ - Fishermen left unanswered

Table 2.6. Fish methods.

Fish Methods	Number of fishermen (55)
1. Gill net	45 (25*)
2. Lift net	15
3. Hand line	23 (2*)
4. Long Line	18
5. Fish arrow	4
6. Cage trap	8 (2*)
7. Electro-fishing	2

* - Number of fishermen who exclusively used the indicated fish method. The rest of the fishermen either used more than one fishing methods or used them alternately.

Table 2.7. Interviewed fishermen's preferences for species to catch, reasons for the preference, and the methods used to catch the preferred species.

No. of fishermen = 47	Catfish spp.	Common carp	Sleeper goby	Glossogobius spp.	Mudfish	Tilapia spp.
No.(Rank)	8 (5)	2 (6)	47 (1)	38 (3)	19 (4)	42 (2)
Reasons of preference	E - 4 A - 2 P - 4	0 2 2	27 23 36	25 20 30	10 10 11	25 22 34
Methods used	Hand line Long line	Gill net Fish spear	Gill net	Gill net Long line	Fish spear Electro - fishing	Gill net Cage trap

E- Easy to catch
A – Abundant
P – Preferred by the consumers

Table 2.8. Total weight (kg) of species caught in Lake Lanao (Villaluz, 1963-64; Sanguila et al., 1975; Escudero 1980, 1983, 1994; 2008).

Species	**1963-64**	**1973**	**1974**	**1975**	**1976**	**1977**	**1982-83**	**1990-91**	**2008**
A. Endemic	**981120**	**604514**	**390285**	**175912**	**189835**	**258367**	**92300**	**22736**	**8.1**
1. Cp/Op/Ot		48	21	3					
2. Pb			117	15		75		2	
3. Pc		24							
4. Ph			18						
5. Pk		123.6	999	480	190	144			
6. Pli		301788	388515	175205	188859	257374	92019	22442	1.7
7. Pm		122	52			47			
8. Ps		90	45						
9. Ptr			3		4				
10. Ptu		123	515	209	782	727	281	292	6.4
B. Native	**240170**	**21648**	**92179**	**35309**	**63643**	**46682**	**80898**	**9562**	**1063.7**
1. Ac	2920		157	90	41	47	16		
2. Os	237250	21648	92022	35219	63602	46635	80882	9562	1063.7
C. Introduced	**507715**	**377666**	**201526**	**51749**	**119337**	**61709**	**370766**	**152760**	**16495.26**
1. At	9125		170	314	9	12	83	74	0.26
2. Cb/Cm	20075	18930	10748	3692	4475	2759	58409	184	139.4
3. Cc	237250	12206.4	8693	1868	5546	4129	13822	176	3.55
4. Gc/Gg	127750	266061	110767	29982	73031	17284	60136	2300	114.35
5. Ha							145032	78950	11704.7
6. Ms	1095								
7. Om/On	109500	79454	69741	15192	36200	37433	93150	71056	4532.25
8. Tp	2920	1014	1407	701	76	92	134	20	0.75
TOTAL	**1729005**	**1003827**	**683990**	**262970**	**372815**	**366758**	**543964**	**185058**	**17567.06**

Note: See Appendix A for the species scientific names associated with the 2-character species codes.

Table 2.9. Date of introductions and country/area of origin of introduced species in Lake Lanao (Herre 1924, Villaluz 1966, Escudero 1983, Fishbase)

Species	Country of Origin	Year
1. *Anabas testudineus* (At)	Unknown (could be native to the Philippines and Lake Lanao)	Unknown
2. *Chanos chanos* (Cch)	Fish farm in Agusan del Norte	~1955, 1962, 1963, 1964
3.*Clarias batrachus/ macrocephalus* (Cb, Cm)	Unknown (could be native to the lake)	Unknown
4. *Cyprinus carpio* (Cc)	Hongkong; China; Taiwan	1915, 1926
5. *Glossogobius celebius/ giurus* (Gc, Gg)	Fish farm in Agusan del Norte	~1963
6. *Hypseleotris agilis* (Ha)	Fish farm in Agusan del Norte	~1977
7. *Micropterus salmoides* (Ms)	California, USA	1915
8.*Oreochromis mossamibicus/ Niloticus* (Om, On)	Bangkok, Thailand; Fish farm in Agusan del Norte	1955, 1970, 1972, 1973 -
9. *Trichogaster pectoralis* (Tp)	Bangkok, Thailand	1938

Note: See Appendix A for the species scientific names associated with the 2-character species codes.
~ (estimate); Tilapia spp. (#8) have been restocked many times in Lake Lanao after the year 1973by the Bureau of Fisheries and Aquatic Resources.

Table 2.10. Presence of endemic, native and introduced fish species in Lake Lanao through the years (Herre, 1924, 1933; Villaluz, 1966; Sanguila et al., 1975; Kornfield, 1982; Escudero, 1980, 1983, 1994; 2008)

Species	1924-33	1963-64	1973	1974	1975	1976	1977	1982	1983	1990-91	2008
A. Endemic											
1. Cp	P		P								
2. Mr	P										
3. Op	P		P	P	P						
4. Ot	P		P								
5. Pa	P							P			
6. Pb	P	P		P	P		P			P	
7. Pc	P	P	P	P	P						
8. Pd	P	P									
9. Pf	P										
10. Ph	P			P							
11. Pk	P		P	P	P	P	P				
12. Pla	P	P						P			
13. Pli	P	P	P	P	P	P	P	P	P	P	P
14. Pm	P	P	P	P			P				
15. Ps	P		P	P				P			
16. Ptr	P			P		P					
17. Ptu	P	P	P	P	P	P	P	P	P	P	p
18. Sp	P	P						P			

Note: See Appendix A for the species scientific names associated with the 2-character species codes.

Table 2.10. Continued.

Species	1924-33	1963-64	1973	1974	1975	1976	1977	1982-83	1990-91	2008
B. Native										
1. Ac	P	P		P	P	P	P	P		
2. Os	P	P	P	P	P	P	P	P	P	P
C. Introduced										
1. At	P	P	P	P	P	P	P	P	P	P
2. Cb/Cm		P	P	P	P	P	P	P	P	P
3. Cch		P								
4. Cc	P	P	P	P	P	P	P	P	P	P
5. Gc/Gg		P	P	P	P	P	P	P	P	P
6. Ha								P	P	P
7. Ms	P	P								
8. Om/On		P	P	P	P	P	P	P	P	P
9. Tp		P	P	P	P	P	P	P	P	P

Note: See Appendix A for the species scientific names associated with the 2-character species codes.

CHAPTER 3

LIFE HISTORY TRAITS OF ENDEMIC, NATIVE AND INTRODUCED SPECIES IN LAKE LANAO, PHILIPPINES

Abstract

Six life history traits for two endemics, two native fish species and twelve introduced species in Lake Lanao Philippines were examined to determine if the introduced species have the general characteristics of successful invaders. Comparisons of the traits showed that the introduced species have broader diet preference, larger body size, higher fecundity, parental care, and are habitat generalists while the endemic species have the opposite characteristics. Apparently, gregariousness did not differ between the three species groups. Two of the world's worst invasive species, common carp (*Cyprinus carpio)* and black bass (*Micropterus salmoides*) had been introduced in Lake Lanao. Interestingly, these species did not establish well in the lake and the black bass eventually became extinct. Moreover, another introduced species, *Hypseleotris agilis*, has become very well established in the lake and been observed to prey on the eggs and youngs of the endemic species and common carp. An extensive study on the ecology and life history strategy of the remaining endemic and introduced species in Lake Lanao is suggested since the current study only conducted a preliminary comparison of the life history characteristics of the species in the lake.

Introduction

Life history, growth rates, and ecological traits have been used to predict which nonnative fish species and other aquatic species could become successful invaders and their potential impacts on the environment and native species (Alcaraz et al. 2005, Vila-Gispert et al. 2005, Koehn 2004, Marchetti et al. 2004, Vila-Gispert and Moreno 2003). Ricciardi and Rasmussen (1998) proposed valuable predictions and simple guidelines for identifying potential aquatic invaders. Invasion history, identification of potential donor regions and dispersal pathways, and use of biological criteria were suggested to be low-cost approaches for identifying potential invaders.

The above studies compiled hypothesized traits of invasive aquatic species that could be useful for predicting invasion. The traits were: high abundance and widely distributed in the original range, wide environmental tolerance, high genetic variability, early sexual maturity, short generation time, rapid growth, high reproductive capacity, broad diet, gregariousness, possessing natural mechanisms for rapid dispersal and commensal with human activity (e.g. ship ballast-water transport). For instance, the zebra mussel, *Dreissena polymorpha,* has a wide tolerance limit, high genetic variability and mechanisms for rapid dispersal (Groves and Burdon 1986). This species has invaded a wide geographical range particularly in the United States, causing great damage to the environment and economy (Pimentel et al. 2004). Ricciardi and Rasmussen (1998) also showed the importance of humans as shuttles for invasive species, such as the case of invasive bivalves and crustaceans that are easily transported in ship ballast water.

Although it is difficult to predict whether a species will be a good invader solely on the basis of its life history features (Rosecchi et al. 2001), some biological traits such as high fecundity, early sexual maturity and large body size could serve as biological predictors of successful invaders. This was the conclusion of the study by Vila-Gispert and Amich (2003) in which they used seven life history traits to describe life history strategies of native and introduced fish species from a lake in Spain. Another study of Vila-Gispert et al. (2005) showed differences between the native and introduced fish species from Catalan streams in fecundity, tolerance to pollution, water quality, age at maturity, and habitat.

U.S. Executive Order 13112 defines an invasive species as a species that is non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. A significant example of a successful invasive freshwater fish species is the common carp which exhibits most of the traits predicted for a successful invasive fish species. It has been introduced and successfully established in almost all parts of the world, has a wide environmental tolerance with temperature tolerance ranging from 2- 40.6^{0}C, salinity tolerance up about 14 $^0/_{00}$, pH tolerance from 5.0-10.5, can tolerate oxygen levels as low as 7% saturation and generally occurs in most types of freshwater habitat. Common carp has numerous genetic strains, is sexually mature at 1-2 years, has a generation time of 2-4 years, its eggs hatch in two days and its fry grow rapidly. It is highly fecund, is a broadcast spawner and produces as many as 2 million eggs per female. It is a generalist feeder (detrivore/omnivore), a schooling species; it is bred as an ornamental and aquaculture species, and is used as bait and targeted by some anglers (Koehn 2004). The common carp, which has most of the invasive species traits, has become the most abundant large freshwater fish in south-east Australia and is likely to invade larger river systems in the future (Koehn 2004).

Significance of studying life history traits of invasive species

Invasion and the introduction of nonnative species are two of the major causes of species extinction and ecosystem impairment (Mooney and Cleland 2001, Clavero and Berthou 2005, Jahadová et al. 2007, Pyšek and Richardson 2010). Life history traits of reported and potential invasive species have been studied to determine common traits of these species (Catot et al. 2011, Koehn 2004, Britton et al. 2008). However, studies showed the difficulties of searching for theoretical attributes and predicting the success of an invasive species (Rosecchi et al. 2001, Vila-Gispert et al. 2005, Moyle and Marchetti 2006).

Although significant and helpful, studying life history traits does not entirely predict invasiveness (Rosecchi 2001). Moreover, a known invasive species may not be invasive in a different type of ecosystem (Copp 2007). The objectives of this chapter are to assemble information for the fish species historically and currently found in Lake Lanao on six life history traits that are supposed to contribute to the success of invasive fish species and to evaluate the importance of these traits.

Fish Species Found in Lake Lanao

For this study the fish species in Lake Lanao are categorized as endemic, native and introduced species. An endemic species is a species that can only be found in a region and nowhere else in the world while a native species is a species that is indigenous to a particular area but can also be found elsewhere. Introduced species, also known as exotic, alien, or non-native species is a species usually transported by humans outside its native range either intentionally or unintentionally (Borges et al. 2006).

Endemic species

There used to be 18 endemic species (Appendix A) under five genera in Lake Lanao, identified by Herre in the 1920s. The genus Puntius (called Barbodes by Herre) consists of many species, extending from the Philippines through Borneo, and to tropical and temperate Asia and Africa (Herre 1953). However, the genera *Ospatulus Spratellicypris,* and *Cephalakompsus* were exclusively found in Lake Lanao while the *Mandibularca resinus* was only found in the Agus River, the only outlet of the lake. Twenty two endemic species of the genus Puntius are found in the Philippines and thirteen of these are or used to be found in Lake Lanao.

Herre (1933) explained the unique evolutionary pattern of the endemic cyprinids in Lake Lanao (Figure 3.1) and argued that *Puntius binotatus* must be the ancestor of all the native cyprinids in the Philippines. Described as a powerful swimmer, this species is able to ascend mountain cascades reaching as high as over a thousand meters. On the Mindanao Island, this species is found in the provinces of

Zamboanga, Bukidnon, Misamis and Lanao (Figure 3.2). Moreover, although found in the streams, rivers and lakes throughout the southern Philippines, including the Lanao plateau, this species is not found in Lake Lanao itself (Herre 1933).

Native species

Lake Lanao is home to two native fish species. The Celebes longfin eel (*Anguilla celebesensis*), which is distributed in Indonesia, Philippines and Papua New Guinea, is known to travel from the sea to Lake Lanao through underground channels in Maria Cristina Falls, which are not passable to other fishes (Herre 1933). Its biology and ecological importance are still not fully known (FishBase.org) and the species is believed to be presently “absent” from Lake Lanao. The native mudfish (*Ophicephalus striatus*) was thought to have been introduced to the Philippines long ago by Malay people, probably for consumption and aquaculture (Herre 1933).

Introduced species

Since the early 1900s a number of fish species have been introduced into the Lake and on multiple occasions (Chapter 2, Table 2.9). One example is the climbing perch (*Anabas testudineus*), which is widely distributed around the Philippines and Asia. The catfishes (*Clarias batrachus* and *C. macrocephalus)* are additional examples. The milkfish (*Chanos chanos*), locally known as 'bangus', is a marine species that enters estuaries, rivers and sometimes freshwater. It is one of the important food fishes in the Philippines, being cultured in pens, cages and fish ponds all over the country. Milkfish were introduced in Lake Lanao by the Bureau of

Fisheries around 1955. The Bureau initially stocked 108,000 fingerlings and repeated this process in 1962. In 1963-1964 the lake was again stocked with 54,000 fingerlings (Villaluz 1966).

The common carp (*Cyprinus carpio*) was introduced into Lake Lanao approximately in 1915 (Herre 1924). It is widely distributed globally and is considered to be invasive species in some countries where it has had adverse ecological impacts in several countries as in the Philippines. Common carp, along with the Tilapia species *Oreochromis niloticus and Oreochromis mossambicus* have been distributed widely for aquaculture. These species have been restocked many times by the Bureau of Fisheries in Lake Lanao to increase fish production. The last restocking of this species that I am aware of was in 2001, when I used to work with the Bureau. The black bass (*Micropterus salmoides*) was introduced into the Philippines and Lake Lanao by Alvin Seale from USA in 1915 as a food fish and for sport fishing. In 1938, gourami (*Trichogaster pectoralis*) was introduced by Dr. Eduardo Quisumbing elsewhere in the Philippines and then in the lake.

The white gobies (*Glossogobius celebius and G. giurus*) and the sleeper goby (*Hypseleotris agilis*) were known to be accidentally introduced in Lake Lanao by the Bureau of Fisheries and Aquatic Resources during their regular stocking of the lake with milkfish and tilapia. The Glossogobius species were introduced approximately in 1963 (Chapter 2, Table 2.9) while *Hypseleotirs agilis* was first noticed in the Marawi market at the end of Escudero's 1974-1977 market survey. According to Guerrero (2002), the introduction of these species is a case of indigenous fishes that have become invasive. Both species are omnivores and include in their diet small fish such as the endemic cyprinids (Escudero and Demoral 1983, Kornfield 1982, Sanguila et al.1975).

Data and Methods

Life History Traits

Life history traits are a set of co-adapted traits that have evolved as a result of natural selection and allow a species to solve particular ecological problems. The life history characteristics for the introduced, native and endemic species found in Lake Lanao were tabulated from related biological literature for each species and from internet data bases, the fishbase.org (http://www.fishbase.gr/search.php) and the global invasive species database (http://www.issg.org/database/). We also gathered information from personal interviews with Prof. Pedro Escudero of the College of Mindanao State University, Marawi Philippines who in the past conducted market surveys and biological research on the fish species in Lake Lanao.

Based on previous studies of life history-traits and the relative availability of different kinds of data, we chose to collect information on six general characteristics of successful invaders. The species chosen for the analysis were species identified during the historical surveys and 2008 surveys at fish landing areas and local fish markets around Lake Lanao, as described in Chapter 2. No study was done on the life history traits of the sixteen endemic species believed to be extinct. Therefore they were not included in the analysis.

1. Feeding habits. Species were identified as being planktivores, herbivores, carnivores or omnivores. In this case the feeding habits refer to the trophic level of the adult forms of the species as most of the species have different feeding habits at earlier life stages. Generalist or opportunist feeders such as omnivores should be more likely to survive than specialist feeders like planktivores or piscivores due to their broad diet preferences.

2. Maximum adult size. This trait refers to the maximum recorded length (mm) that individuals achieve during the adult stage. Naturally, smaller fishes can easily become preys of larger and predator fish species. In such a case, a larger fish species should have greater success at becoming invasive compared to smaller fish species.

3. Fecundity. Refers to the average range number of vitellogenic oocytes produced by mature females per spawning. Species with high fecundity may have higher chance to produced offspring that survive and proliferate and therefore species with high fecundity should be more likely to be successful invaders than species with low fecundity. The fecundity of the species was rounded off to the nearest one hundred oocytes.

If survival rate is high, a highly fecund introduced species has a greater chance of becoming well established and eventually becoming a successful invader. Furthermore, even in the presence of predators, a highly fecund species may simply overwhelm predators by producing large numbers of juveniles, and if the growth rate of juveniles is rapid, they can quickly reach a size that precludes their consumption by most predators (Koehn 2004).

4. Parental care. Species were classified according to the care the parents give to their eggs, young or both. Species with higher parental care increase the chances of survival of their offspring and therefore species that provide parental care should be more likely to be successful invaders than species that do not. The care measurement was "yes" if eggs or larvae were given care, such as by guarding or mouth brooding. Care was "no" if parents scattered their eggs in the environment and left them after spawning.

5. Gregariousness. Species were classified according to whether they are solitary or gregarious in their behavior. Gregariousness refers to the behavior of fish to form a school (gregarious) or not (solitary). Soria and Dagorn et al. (1992) define a school of fish as a provisional group of individuals, generally from the same species, the same size and within the same biological cycle, united by mutual attraction, and showing different degrees of coordination of their swimming ability within a centered group. The gregariousness trait is advantageous when it comes to dealing with predators, searching for food and looking for possible mates and therefore species that are gregarious should be more likely to be successful invaders than species that are solitary.

6. Habitat. Fishbase defines habitat as a specific type of area with environmental (biological, chemical, or physical) characteristics needed and used by an aquatic organism, population, or community. Attempts to define habitat specialization have never been easy or simple. In this case, we assume that species that are habitat specialists require significant physical or behavioral specialization to cope with their habitat while habitat generalists see their environment as a "continuous landscape" that requires no specific specialization. We also adopted the definition by Fridley et al. (2007) that a habitat generalist will co-occur with many species across their range, while a habitat specialist will co-occur with relative few species and therefore a habitat generalist should be more likely to be a successful invader than a habitat specialist.

Results

Lake Lanao Fish Species and their Traits

The market and landing surveys and fishermen's interviews, described in Chapter 2, found thirteen species in Lake Lanao. These are the endemic *Puntius lindog* (Figure 3.3) and *Puntius tumba* (Figure 3.4); the native *Ophicephalus striatus* (mudfish) (Figure 3.5); and the following introduced species: *Anabas testudineus* (climbing perch) (Figure 3.6), *Clarias batrachus* (Thai catfish) (Figure 3.7), *Clarias macrocephalus* (bighead catfish) (Figure 3.7), *Cyprinus carpio* (common carp) (Figure

3.8), *Glossogobius celebius* (Figure 3.9), *Glossogobius giurus* (white gobies) (Figure 3.10), *Hypseleotris agilis* (sleeper goby) (Figure 3.11), *Oreochromis mossambicus* (Mozambique tilapia) (Figure 3.12), *Oreochromis niloticus* (Nile tilapia) (Figure 3.12), and *Trichogaster pectoralis (*gourami) (Figure 3.13).

Glossogobius celebius (Celebes goby) and *G. giurus* (tank goby) are collectively called 'kadurog' by the native Maranaos around Lake Lanao, who have difficulty distinguishing between the two species. The most distinctive difference between the two species is the shape of their caudal fins, with *G. celebius* has fins that are more pointed (spear-like) while *G. giurus* has fins that are less pointed. Moreover, *G. celebius* has a larger head and fuller and rounded cheeks (Escudero 1980). Both species are called white gobies by Escudero in his studies.

Clarias batrachus and *C. macrocephalus* are collectively called 'katipa' by the native Maranaos. The two species differ in the shape of their occipital process with *C. batrachus* having one that is pointed while *C. macrocephalus* has one that is evenly curved. Moreover, two species of tilapia are known to have been introduced into Lake Lanao, the *Oreochromis mossambicus* (Mozambique Tilapia) and *Oreochromis niloticus* (Nile Tilapia). These species are collectively called Tilapia by the native Maranaos. The latter species is distinguished by the regular stripes throughout the depth of the caudal fin.

Three fish species that were recorded in the historical surveys but not in the 2008 survey were also included in the analysis (Table 3.1). These were the native species, *Anguilla celebesensis* (Figure 3.14) and the two introduced species, *Chanos chanos* (Figure 3.15) and *Micropterus salmoides* (Figure 3.16).

The various traits of the species considered in the analysis are summarized in Table 3.2.

1. Feeding habits

Endemic species

Analyses of the gut contents of *Puntius lindog* revealed that these fish are plankton feeders that feed mostly on *Tabellaria*, *Cosmarium* and the diatom, *Navicula* (Sanguila et al 1975, Escudero 1980). Later observations by Escudero showed that individuals of this species sometimes pick up morsels of food along the shore (pers. comm.), which is consistent with this species having pharyngeal teeth and a small pair of barbells, which it uses to locate food when vision is inadequate due low light or turbidity. According to Escudero, *Puntius tumba* is also a plankton feeder (pers. comm.) but no information was provided on what types of plankton this species feeds on. Although not he did not identify the particular species, Villaluz (1966) mentioned that an endemic cyprinid species in Lake Lanao fed heavily on snails (*Thiara* sp. and *Vivipara angularis)*, both the adult and younger stages.

Native species

No data are available on the feeding habits of the Celebes longfin eel, *Anguilla celebesensis*. *Ophicephalus striatus* (Mudfish), locally known as ‘aruan’, are highly carnivorous and piscivorous, eating both terrestrial and aquatic insects, worms, fish, frogs and other available organisms. Some aquatic invertebrates that form the diet of this and other fish species in Lake Lanao are: *Coleoptera* (beetles); *Diptera* (flies, mosquitoes, midges); *Hemiptera* (bugs); *Ephemeroptera* (mayflies); *Plecoptera* (stoneflies) and *Odonata* (dragonflies and damselflies) (Villaluz 1966). Although considered as one of the most valuable food fishes in Lake Lanao, this species is not desirable for pond culture due to their feeding habits.

Introduced species

Anabas testudineus (climbing perch) is a small omnivorous species that feeds primarily on young fish, shrimps, insects and macrophytic vegetation (Fishbase.org). *Chanos chanos* (milkfish) is also an omnivore that feeds on diatoms, algae, copepods, larvae and eggs of crustaceans and nematodes (Tampi 1958). Both *Clarias batrachus* and *C. macrocephalus* are carnivore species with broad diets consisting of annelids, aquatic insects, crustaceans, and the eggs or larvae of other fishes and small fishes (Villaluz 1966, Fishbase). These species are easily identified by their dark slimy skin and absence of scales.

Cyprinus carpio (common carp), locally known as ‘bongkaong’, is a generalist omnivore feeding on algae, aquatic plants, weeds, insects, annelids, invertebrates and even detritus (Fishbase). In Lake Lanao, this species, along with some of the endemic cyprinids, feeds heavily on snails (Villaluz 1966). Aside from the feeding habits of the species, the feeding mechanism can also be an important factor for species that search for food. The common carp has a mechanism to sieve through the substrate, thus allowing it to take advantage of potentially under-utilized resources, including detritus, at a base level of the food chain (Koehn 2004).

Glossogobius celebius (Celebes goby) is known to be carnivorous (De Guzman et al. 2009). On the other hand, *G. giurus* (tank goby) are omnivorous but feed heavily on 'odang' or *Palaemon spp.*, (fresh water shrimps) (Villaluz 1966). These species also feed on insects and prefer all kinds of baits. Moreover, cannibalism is relatively common for this goby fish. The stomach contents of three hundred eighty five white gobies were examined and found that 52% or two hundred one contained shrimps, 24% (91) contained phytoplankton, 11% (41) contained fish, 10% (37) contained *Spirogyra* and 3% (15) contained mayfly nymphs (Sanguila et al. 1975). Escudero (1980) also examined the stomach contents of forty three white gobies and showed that the species eat both plants (algae such as *Nitella*, *Oscillatori*a, and *Lyngbya*) and animals (shrimps and gobies). Thirty five percent of the stomachs sampled contained gobies, 25% contained shrimp and 40% of the stomachs examined were empty. A study on *Glossogobius giurus* in Lake Laguna, a lake located in the northern part of the Philippines showed that this species is highly herbivorous (Escudero 1980).

Locally known as 'katolong', the eleotrid *Hypseleotris agilis* has no particular preferred food type and is a voracious omnivore (Escudero 1983, 1994). One hundred fifty three stomachs examined by Escudero in 1983 showed a wide variety of food items such as plankton, algae, mollusks (*Melanoides punctata*, *M. tuberculata*, *Thiara scabia* and *Corbicula fluminea*), shrimps (*Macrobrachium latidactylus*), fish, debris (rice husks) and inorganic materials (fine sand and pebbles). This species also ‘feasts’ on freshly laid eggs of the white gobies, common carp and *P. tumba*. It also feeds on the young of other fishes and its own (Guerrero 2002, Escudero pers. comm.). The local people consider katolong to be a low class fish because it was known to feed on waste materials. *Hypseleotris agilis* in Lake Mainit however was classified as a carnivorous species (De Guzman et al. 2009).

Micropterus salmoides is a carnivorous species that feeds primarily on fish and invertebrates (Godinho and Ferreira 1994, Fishbase).

Both Tilapia species are non-specialized omnivores that eat mostly algae but also feed on almost anything available such as insects, small crustaceans and even bottom sediments (Villaluz 1966). Because of its very hardy characteristic and other traits including a broad diet (Coward and Little 2001), the Mozambique tilapia has been listed by the IUCN to be one of the 100 of the world’s worst invasive species.

Adult *Trichogaster pectoralis* (gourami) are highly vegetarian (Villaluz 1966).

2. Maximum adult size

Endemic species

Herre (1924) recorded a longest total length of 132 mm for the species *Puntius lindog*. The specimens he collected varied in size between 100-132 mm. The longest *P. tumba* that Herre recorded was 128 mm. and the sizes varied between 24-128 mm. The *Puntius lindog* that Escudero (1980) sampled varied between 54-122 mm.

In the 2008 landing site and market surveys, the maximum adult sizes recorded for *Puntius lindog* and *Puntius tumba* were 140 mm and 142 mm respectively. The sizes of the *P. lindog* varied between 100-140 mm while those of the *P. tumba* ranged from 75-142 mm.

Native species

The Celebes longfin eel reached a maximum adult size of 1500 mm while maximum adult size recorded for mudfish is 1000 mm (Fishbase).

Introduced species

The maximum adult size recorded for *Anabas testudineus* is 250 mm while the maximum adult size for *Chanos chanos* is 1800 mm (Fishbase). *Clarias batrachus* is reported to reach a maximum length of 470 mm while *C. macrocephalus* is reported to reach a maximum length of 1200 mm (Sanguila 2004, Fishbase).

The maximum length of the common carp is 1200 mm (Fishbase). In Lake Lanao, its size ranged between 178-760 mm (Villaluz 1966). The 2008 survey only recorded a maximum size of 148 mm. For *Glossogobius celebius* Escudero (1980) recorded a maximum total length of 358 mm. The maximum adult length for *G. giurus* was 500 mm (Fishbase). The *G. celebius* and *G. giurus* that Escudero sampled in 1980 had sizes that ranged between 69-358 mm and 37-374 mm respectively.

Escudero (1983) sampled sixty-six *Hypseleotris agilis*. Total lengths ranged between 54-180 mm. In 2008, thirty one sleeper gobies were sampled with total lengths ranging between 93-130 mm. The maximum adult size recorded for

Micropterus salmoides is 970 mm (Fishbase). For *Oreochromis mossambicus* the largest length recorded is 390 mm (Fishbase). *O. niloticus* on the other hand can reach a maximum size of 600 mm (Fishbase). *Trichogaster pectoralis* can reach a size of 260 mm (Villaluz 1966).

3. Fecundity

Endemic species

The fecundity of *Puntius lindog* ranges from 578-5605 ova per female (Escudero 1980). The smallest count of eggs was observed from a specimen measuring 65 mm. weighing 2.5 g while the highest count was observed from a female measuring 90 mm weighing 7.1 g. The fecundity of *P. tumba* is estimated to be less than 10,000 ova per female (Escudero, pers. comm.). Both endemic species breed the year round with a peak between October-March (Escudero 1980, pers. comm.).

Native species

No available data were found for the fecundity of *Anguilla celebesensis. Ophicephalus* striatus spawns throughout the year (Villaluz 1966) with an average fecundity of 1688 to 7146 ova per female (Kilambi 1986).

Introduced species

The climbing perch (*Anabas testudineus*) can produce up to 5,000 ova per female and breeds all year round (Fishbase, Hails and Abdullah 1982) while a female milkfish can spawn between 5,000,000-7,000,000 eggs (Fishbase and http://www.fao.org/fishery/culturedspecies/Chanos_chanos/en). A female Thai catfish (*Clarias batrachus*) can spawn more than 10,000 eggs and a bighead catfish (*Clarias macrocephalus*) that weighs 150-200 g can produce between 5000-10000 ova (PhilAquaculture). Common carp (*Cyprinus carpio*) have a relative fecundity ranging from 100000-300000 eggs per kilogram equivalent to 360000-599000 eggs per female, even reaching 1 million ova produced per female in a season (Global Invasive Species Database).

Escudero (1980) recorded the fecundity of the tank goby (*Glossogobius giurus*) as ranging between 8000-400000 ova per female. A specimen with a total length and weight of 150 mm and 22.2 grams respectively recorded the lowest count of ova. The highest number of ova was observed from a specimen with a total length and weight of 255 mm and 119.6 g respectively. No fecundity data for the Celebes goby (*Glossogobius celebius*) were collected.

The fecundity of sleeper goby (*Hypseleotris agilis*) ranged between 5300-104000 ova per female (Escudero 1983).

A study on the reproduction of *Micropterus salmoides* showed a fecundity ranging between 1300 to 3524 ova per fish (Dadzie and Aloo 1990). Mozambique tilapia can spawn up to 1775 ova per female, and Nile tilapia can spawn up to 2000 ova per female (Global Invasive Species Database). A mature female gourami can produce 3000-7000 eggs (Villaluz 1966).

4. Parental care

Endemic species

Both the endemic cyprinids scatter their eggs after spawning, and provide no parental care (Escudero 1980, pers. comm.)

Native species

No available data was gathered on the parental are of *Anguilla celebesensis.* More than two weeks before laying their eggs, the native mudfish (*Ophicephalus striatus*) build nests that usually measure one foot in diameter and are made from roots of water hyacinths (Villaluz 1966). Once the eggs are hatched, the parents guard their young until they reach an average length of 50-60 mm and become independent.

Introduced species

The climbing perch (*Anabas testudineus*) builds a nest for its eggs and cares for its young (Fishbase). The milkfish (*Chanos chanos*) are egg scatterers and do not guard their eggs (Fishbase). Both the catfish species show parental care. The male Thai catfish (*Clarias batrachus*) care for their eggs and young by building and guarding their nests. Female bighead catfish (*C. macrocephalus*) build the nests with grassy bottom materials while the male bighead catfish guard the eggs, which are then attached to aquatic plants in the nests until they are hatched (PhilAquaculture). Common carp (*Cyprinus carpio*) provide no care, instead scattering their eggs after spawning. Eggs then attach to aquatic vegetation, logs, rocks and any other submerged objects (Fishbase). The white gobies (Celebes goby, *Glossogobius celebius*, and tank goby, *G. giurus*) are both egg guarders (Fishbase), but the sleeper goby (*Hypseleotris agilis*) does not care for its eggs or its fry (Escudero pers. comm.)

The male of *Micropterus salmoides* builds a nest and guards the eggs during the reproduction period (Global Invasive Species Database). Both the tilapia species (*Oreochromis mossambicus, O. niloticus*) are mouth brooders as well as nest builders (Global Invasive Species Database). The male tilapia builds the nest and as soon as the eggs are fertilized, the female collects and incubates the eggs in her mouth. When the eggs are hatched, the female continues to take care of its young by letting them swim back into her mouth when threatened.

The gourami (*Trichogaster pectoralis*) spawns in shallow areas that are rich in aquatic plants where males can build nests in the form of floating bubbles (Villaluz 1966). The nests, which look like soap foam, are usually built in between floating aquatic plants. Males guard the eggs until they are hatched and both parents care for their young (Fishbase).

5. Gregariousness

Endemic species

Puntius lindog is described by Escudero (1980) as a small gregarious cyprinid that abounds in Lake Lanao. Meanwhile, *P. tumba* is generally a solitary species but becomes gregarious during some of its life stages (Escudero pers. comm.), making it both gregarious and solitary.

Native species

No data were found collected for the gregariousness of *Anguilla celebesensis*. Young native mudfish (*Ophicephalus striatus*) are gregarious and swim around in groups with protection from the parents (Villaluz 1966). Once they reach a size over 60 mm, they separate and live as solitary individuals.

Introduced species

Anabas testudineus is a solitary species (Lheknim 2004). The adults of *Chanos chanos* are perhaps gregarious as they are known to form small to large schools near the ocean coasts (http://www.fao.org/fishery/culturedspecies/Chanos_chanos/en). The catfishes *Clarias batrachus* and *C. macrocephalus* live as solitary individuals, except during the mating period (Fishbase). *Cyprinus carpio* is a gregarious species, often shoaling into schools (Koehn 2004). Juvenile *Glossogobius celebius* are known to be gregarious but become solitary as adults (De Guzman et al. 2009). Villaluz (1966) described the young of *G. giurus* as gregarious, usually ascending together in rivers and streams with swift currents.

Meanwhile the other goby, *Hypseleotris agilis*, is also a gregarious species (Escudero 1983). As adults *Micropterus salmoides* is a solitary species (Gilliland 2010). Both the tilapia species are solitary but form schools during the mating season and while mouth-brooding (Fishbase). No data were found for the gregariousness of *Trichogaster pectoralis* but the species of the same family like the *Trichopsis* vittata, is also a solitary species (Lheknim 2004).

6. Habitat

Endemic species

Puntius lindog is a pelagic fish and is limited to the southern area of Lake Lanao, which is also the deepest part of the Lake (more than 100 m). The Lake's littoral zone is narrow and also steep (Escudero 1980, pers. comm.). In 1984, Kornfield and Carpenter collected *P. tumba* from inflowing streams, less than 100 m from the lake but never in Lake Lanao proper. Furthermore, Escudero (1991) reported that fishing for this species is usually carried out in coves particularly where small creeks are found. During our Lake Lanao surveys (Chapter 2), *Puntius tumba* was only caught in limited amounts in the Agus River, the only outlet of the Lake. The river or streams may provide a specific type of habitat that helps this species thrive in the area. These suggest that both endemic species are habitat specialist.

Native species

The habitat of *Anguilla celebesensis* is mostly the rocky parts of the lake and caves along the river bank (Villaluz 1966). Since this species is catadromous, migrating from the sea to Lake Lanao, we considered this species to be a habitat specialist. The mudfish (*Ophicephalus striatus*) is both benthopelagic (living and feeding near the bottom, surface or in midwater) and potamodromous (making seasonal migrations) (Fishbase). During the flood season, this species undertakes lateral migrations into the flooded areas and returns to the permanent water bodies at the onset of dry season. This species usually prefers muddy waters and very commonly is found in rice fields or areas rich in aquatic vegetation, which provides hiding places. In Lake Lanao, the tributary rivers such as the Gata, Ramain, Taraka, Malaig and Matling rivers as well as the outlet river, the Agus, are known to be the nesting and nursing grounds for the native mudfish, except during the dry season when they migrate to Lake Lanao (Villaluz 1966).

Introduced species

Climbing perch (*Anabas testudineus*) is a hardy species and can be found in a wide range of environments. It can stay out of water for days provided its air breathing organs remain moist. It tolerates turbid and stagnant waters, and buries itself in the mud during the dry season. This species is demersal and mostly found in areas with heavy vegetation. It is also reported to undertake lateral migrations into flooded areas during the rainy season and returning to the permanent water body during the dry season (Fishbase). In Lake Lanao this species is usually found in grassy regions near the shore and at times is found crawling on dry land (Villaluz 1966).

We categorized milkfish (*Chanos chanos)* as being a habitat generalist. Although *Chanos chanos* is a marine fish, it occasionally migrates to estuaries, rivers and even freshwater lakes (Fishbase).

The Thai catfish (*Clarias batrachus*) is demersal species and thrives in areas where there is dense aquatic vegetation, which provides hiding places, in rice paddies, and muddy and stagnant waters. It has special breathing organs which allow it to stay out of the water for a period of time. In contrast, the bighead catfish (*Clarias macrocephalus*) is benthopelagic, living and feeding near the bottom, in midwater or near the surface. It usually thrives in shallow, open water but is also capable of burying itself in the mud, just like the *Clarias batrachus*. In Lake Lanao, both catfish species are usually found close to the shores and thrive in the same habitat as the native mudfish, such as in rice paddies, ponds and swamps. They can also survive in turbid and muddy waters (Villaluz 1966). This suggests that both catfish species are habitat generalists.

Although *Cyprinus carpio* commonly inhabits the benthopelagic environment, it is well adapted to a variety of habitats and extreme environments. It is also known to thrive in muddy bottoms (Fishbase). This species thrives in all parts of Lake Lanao and its tributaries (Villaluz 1966). The *Glossogobius celebius* is a habitat generalist and demersal species, living and feeding on or near the bottom and in rocky zones (De

Guzman et al. 2009). *G. giurus* is also a habitat generalist that can live either in sandy, gravel or rocky bottom habitats (De Guzman et al. 2009).

The young and juveniles of *Hypseleotris agilis* are usually found feeding close to the shoreline and in shallow, well lighted regions of the lake, while the adults tend to thrive in the deeper limits of the littoral zone. Furthermore, this species requires no specific type of water bottom and is conspicuously found everywhere around the lake (Escudero 1983), suggesting that this species is a habitat generalist. *Micropterus salmoides* is also considered to be a habitat generalist (Gilliland 2010).

Oreochromis mossambicus inhabits areas with almost any type of bottom substrate, and mostly thrive in waters with a depth range between 1 to 12 meters. *O. niloticus* also live and feed near the bottom, surface or in midwater (Fishbase). This suggests that the Tilapia species are habitat generalists. *Trichogaster pectoralis* also live and feed either near the bottom, surface or midwater. This species can also be found in shallow water with rich aquatic vegetation as well as in rice paddies, suggesting that this species is a habitat generalist. In Lake Lanao this species thrives in the littoral areas of the lake, tributaries and rice paddies (Villaluz 1966).

Discussion

Tabulated Species and their Traits

This study considered the traits of endemic, native and introduced species that are currently found in Lake Lanao. The native eel *Anguilla celebesensis* and two introduced species, the milkfish (*Chanos chanos*) and the black bass (*Micropterus salmoides*), were also included to determine whether the six life history traits that may have contributed to their ‘absence’ in Lake Lanao (Chapter 2, Table 2.10).

The endemic classification is unambiguous because these endemic species are found only in Lake Lanao, but the distinction between native versus introduced species is somewhat arbitrary. Villaluz (1966) and Sanguila (1975) categorized climbing perch (*Anabas testudineus*) and Thai catfish (*Clarias batrachus*) as native to Lake Lanao. However, Herre (1924) reported that these two species and also the native mudfish (*Ophicephalus striatus*) had been introduced to the Philippines by humans a long time ago. Herre (1924, 1933) reported only two native species in Lake Lanao – the eel, *Anguilla celebesensis* and the mudfish, *Ophicephalus striatus*. The date of the introductions of *Anabas testudineus*, *Clarias batrachus* and *C. macrocephalus* in Lake Lanao are not known (Chapter 2 Table 2.9), but it appears that Herre considered that climbing perch and Thai catfish had been introduced to the Lake much more recently than the native mudfish.

Studies on the life history traits of the fish species in Lake Lanao are very limited. Therefore most of the life history traits information of this study was collected from other related literature and databases such as Fishbase. The disadvantage of using Fishbase is that data do not always match the fish species being studied.

1. Feeding habits

The gathered data on the feeding habit traits of the species found in Lake Lanao from Fishbase and other related literatures may not be conclusive. Furthermore, depending on availability, fish may shift their diet during ontogenesis, feeding on zooplankton as young, then shifting to mainly benthic invertebrates, and finally becoming exclusively piscivorous (Perrson and Hansson 1999). Nevertheless, seven species were classified as omnivores, with broad diet preferences. These are the introduced *Anabas testudineus*, *Cyprinus carpio*, *G. giurus*, *Hypseleotris agilis*, *Oreochromis mossambicus*, *O. niloticus,* and *Trichogaster pectoralis*.

Introduced omnivores (not limited by food supply) or piscivores as adults (become predators) are predicted to become more established (Moyle and Light 1996). This is similar in the case in Lake Lanao as there are seven omnivores and four carnivores.

The endemic species *Puntius lindog* and *P. tumba* are both planktivores with the *P. lindog* also being observed to pick up morsels of food. Furthermore, Herre (1924) reported that in the municipality of Lumbatan, he had caught the extinct *Ospatulus palaemophagus* with a freshwater shrimp (Palaemon sp.) in its mouth, indicating that the species could have been a carnivore. It would be worth studying more the feeding habits of the remaining endemic species.

2. Maximum adult size

Naturally, not all individual fish survive to the adult stage due to predation, diseases and other natural causes. Moreover, smaller fishes are usually at greater risk of being eaten by larger predators. Recorded to become sexually mature at 65 mm and with a maximum adult size recorded to be less than 150 mm, the endemic *Puntius* species have the smallest average and maximum adult sizes among all species currently harvested in Lake Lanao. Thus the small size of the endemic species probably puts them at a disadvantage because they may be eaten by larger fish species and carnivorous species such as the *Hypseleotris agilis*, which has been observed to prey on the eggs and fry of the endemic species and the common carp (Escudero pers. comm.).

Herre (1924, 1926, 1932, 1933, and 1934) comprehensively described the Lanao endemic cyprinids with their size ranges (Table 3.3). Data showed that six out of 18 endemic species had maximum sizes less than 100 mm. Furthermore, the largest endemic species recorded was *Puntius manalak* with a size range of 185-275 mm. Ironically, *Hypseleotris agilis*, which becomes sexually mature at about 87 mm in length and attains a maximum length of 180 mm, is not much larger than the endemic species. Other small introduced species are *Anabas testudineus* (250 mm) and *Trichogaster pectoralis* (260 mm).

Body size influences invasion success (Roy et al. 2002). This seemed true in the case of Lake Banyoles in Spain in which the successful invasive species have high fecundity, late maturity and large body size compared to the native species (Vila-

Gispert and Moreno 2003). This also seems true in Lake Lanao as the endemic species are at a disadvantage in their size compared to most of the introduced species.

3. Fecundity

A study of Vila-Gispert et al. (2005) showed higher fecundity of the invasive species compared to the native species. However, this is not the case in Lake Lanao. The fecundity of the endemic and native species in the Lake is higher compared to some of the introduced species such as Tilapia. The T*ilapia spp.* have the lowest fecundity among the Lake Lanao species. However, due to their early sexual maturity and their ability to mouth-brood to protect their young, they have been nominated as among the worst invaders in the world.

Interestingly, the common carp, a highly fecund species and known to be invasive in many places around the world, was not particularly successful declined in Lake Lanao, and its apparent relative abundance declined over the years (Chapter 2, Figure 2.24).

4. Parental care

Parental care of the eggs and young can increase the survival of offspring and provide an advantage to introduced species to become well established in a non-native habitat. It is this characteristic and other traits that made *Oreochromis mossambicus* become established as successful invaders in various parts of the world (Costa-Pierce 2003). In Lake Lanao, the two *Oreochromis spp.* are well established, second to the

Hypseleotris agilis based on the landings and market surveys in 2008 (Chapter 2, Table 2.2).

5. Gregariousness

Gregariousness is one of the most remarkable characteristics of fish behavior. The majority of fish species are grouped in schools either permanently or occasionally (during one life episode or seasonally) (Gerlotto 1996). Some fish species do not exhibit schooling until they become mature and start swimming with others of the same kind. Fish may benefit more from gregarious behavior than being solitary because schooling can help in avoiding predators and in finding suitable foraging places and it increases the chances of finding a mate. Even predatory or carnivorous fish can gain from schooling as it gives them the ability to search for food more broadly.

There are certain factors that could affect the classification of fish species as gregarious or solitary. Such factors could be life stages and mating. For instance, the young of *P. tumba*, *Ophicephalus striatus* and *Glossogobius celebius* are gregarious but become solitary when they become adult. Furthermore, the catfish and tilapia species are generally solitary species but become gregarious during the mating period.

It is therefore difficult to assess the influence of this trait without proper scientific studies on the behavior of the fish species in Lake Lanao. Nevertheless, there seemed to be no difference in the gregariousness trait between the endemic, native and introduced species.

6. Habitat

Because of competition, habitat shifts are common among fish species (Werner and Gilliam 1984). Furthermore, some species may shift habitat as they grow. Therefore, the habitat trait may not be a good indicator of a successful invasive species. Nevertheless, based on our adopted definition of habitat requirements, we may expect low abundance of the *Puntius lindog* and *P. tumba* as these species need a special type of environment and may have lower survival than generalist habitat. The generalist *Hypseleotris agilis* for instance, can be found everywhere around the lake. Other species in the lake such as the native mudfish, catfish species, and tilapia species were categorized as habitat generalists since they are found to thrive in more than one type of environment.

Although *Puntius lindog* was classified as a habitat specialist, there is some evidence that it was either more of a generalist now than in the past or that its habitat has changed. Herre (1924) mentioned that *Puntius lindog* is caught in very large quantities among the pond weeds of shallow bays of Lake Lanao. In contrast Escudero (1980) said that the southern part of the lake, which is also the deepest part of the lake is the fishing ground of this species. Moreover, Escudero believed that the species was limited to this part of the lake. The 2008 landing and market surveys (Chapter 2) of

Lake Lanao fish species supported the finding of Escudero in that this species was only caught in Lumbatan, a municipality located in the southern part of the lake.

Common life history traits of the endemic species in Lake Lanao

The endemic species *Puntius lindog* and *P. tumba* have similar life history traits. They are both planktivores, small in size, are less fecund than some introduced species, they do not care for their eggs and young, and are gregarious and habitat specialists. Most of the endemic species in Lake Lanao are now extinct and the abundance of the two remaining endemic species is almost negligible compared to the other species in the lake (Chapter 2 Table 2.2).

Common life history traits of the native species in Lake Lanao

Based on the available life history traits data, maximum adult size is the only common trait of *Anguilla celebesensis* and *Ophicephalus striatus*, both being large species. *Anguilla celebesensis* was last recorded in Marawi market in 1982-83. One possible reason for the absence of this species is the hydroelectric dams that were built along the Agus River could have blocked the species from migrating from the ocean to the lake.

Common life history traits of the introduced species in Lake Lanao

Based on the six life history traits that we examined, the introduced species in Lake Lanao have the following common attributes: broad diet preference, large adult size, high fecundity, providing parental care and habitat generalists. Of all the introduced species, the sleeper goby *Hypseleotris agilis* seemed to be the most successful invasive, dominating the landed catch in the Lake since its introduction. The second most successful invasive species seems to be the *Tilapia spp*. (Chapter 2 Table 2.2).

Not all introduced/invasive species are successful

Three reasons for failure of an introduced species to become invasive are: genetic bottleneck, biological resistance such as predation and native diseases, and biological incompatibility such as insufficient habitat and/or dietary resources for persistent completion of the life cycle (Copp et al. 2007). Four of the species that were introduced in Lake Lanao are considered to be the four of the hundred worst known invasive species in the world. These are the *Clarias batrachus*, *Cyprinus carpio, Oreochromis mossambicus* and the *Micropterus salmoides*. This last species failed to become established in Lake Lanao and *Cyprinus carpio* also did not thrive well. Except for the *Clarias batrachus* and *Oreochromis mossambicus,* the other two species failed to establish in Lake Lanao.

Villaluz (1966) reported that the common carp (*Cyprinus carpio*) contributed the largest portion of the landed catch of all the introduced species in 1963-64 (Chapter 2 Table 2.2), but in subsequent surveys its relative contribution was much smaller. It is interesting to note that this decline began when there was an increase in relative catches of the *Glossogobius spp*. and *Hypseleotris agilis,* also introduced species. A possible reason for the *Cyprinus carpio* to be not successful in Lake Lanao is predation. According to Escudero (pers. comm.), the *Hypseleotris agilis* were observed to eat the eggs of the common carp.

We can only speculate on the causes of the extinction of *Micropterus salmoides*. However, one definite reason for the disappearance of *Chanos chanos* is their life cycle. Although this species is migratory and sometimes reach freshwater lakes, this species can only spawn in fully saline waters.

The white gobies contributed the largest relative catch among all the introduced species from 1973-1976. However, in the 1977 market survey, the white gobies declined by 15% from the previous year. It was also in this year when the *Hypseleotris agilis* was first noticed in the market. Since then *Hypseleotris agilis* has dominated all the market surveys while the rest of the Lake Lanao species have declined.

Life history traits of Hypseleotris agilis and Glossogobius spp. in Lake Lanao versus in Lake Mainit

Hypseleotris agilis is an endemic species in Lake Mainit while *Glossogobius celebius* and *G. giurus* are native species. Lake Mainit is located in the province of Surigao del Norte, northeast of Lake Lanao. In Lake Mainit these species live harmoniously along with other species without a serious threat from one another.

The life history traits of these species in Lake Lanao are different from the life history traits in Lake Mainit. In Lake Mainit, *Hypseleotris agilis*, *Glossogobius celebius* and *G. giurus* are carnivores. All three species feed on a combination of their young that is collectively called 'saguyon'. In fact, a study showed that the diet of *Glossogobius celebius* contained 60% fry of *Hypseleotris agilis* (De Guzman et al. 2009). Adult size ranges of these species in Lake Mainit are a little bit smaller compared to the adult size range in Lake Lanao. Fecundity of the *Hypseleotris agilis* in Lake Mainit is a little bit higher (64097-117416) compared to the recorded fecundity of the *Hypseleotris agilis* in Lake Lanao (5300-104000) while the fecundity of the *G. giurus* in Lake Mainit is lower (52618-248023) than the recorded fecundity of the *G. giurus* in Lake Lanao (8000-300000). Furthermore, a landing survey conducted in Lake Mainit from August 2007-September 2008 showed a huge difference in the catch of these species between the two lakes. The H*ypseleotris agilis* composed only 4.2% while the *Glossogobius spp.* composed 51.4% of the total weight caught.

Extinction of the Lanao endemic cyprinids

The introduction of non-native species in Lake Lanao could be one of the factors leading to the demise of the endemic species. Other factors could be overexploitation (Kornfield 1984), lack of concern by the people on the importance of preserving the endemic species (Escudero 1994) or ecological alteration such as building of the hydroelectric dams along the outlet Agus River. With the dam constructed near the mouth of Agus River, the native people have been experiencing flooding and drying of the shorelines (Naga 2002). The dams may have destabilized the water level of the Lake and altered its ecosystem. The breeding grounds and habitat of the endemic species could have affected by the dams as well. Furthermore, the effect of the dams on the lake and its species may be further exacerbated as another hydroelectric dam is set to be constructed (Crismundo 2010).

One particular endemic species, the *Mandibularca resinus*, was known to thrive in the Agus River. The native eel also migrates from the sea to the lake through the Agus River. Furthermore, the source of the *Puntius tumba* recorded in the 2008 Marawi market survey was from Agus River. It is important therefore to study the effects of the dams to the Lake Lanao fauna. It is also suggested that there be further studies of the biology of the remaining endemic species before they become totally extinct.

Some of the endemic species of Lake Lanao have been reported to occur outside the Lanao drainage basin, for example in Lake Dapao (Kornfield and Carpenter 1984), a lake located 7 km southwest of the municipality of Ganassi and Lake Lanao (Table 3.3). Unfortunately no recent data are available to determine the fate of the endemic species in Lake Dapao. Furthermore, *Hypseleotris agilis* has been introduced by men in Lake Dapao but with unknown effect. Surveying Lake Dapao and studying the life history traits of this species is recommended to further understand its capability for invasiveness and to determine if the reported endemic species in the lake are still extant.

It is imperative to help the native people understand the importance of preserving the endemic cyprinids as well as the effects of non-native species on Lake

Lanao and its ecosystem. The result of the tabulated life history traits of the endemic, native and introduced species in Lake Lanao could be used as a tool in the initial planning to protect and preserve the endemic cyprinids. Furthermore, the tabulated traits of introduced species, particularly the *Hypseleotris agilis*, could hopefully be useful for future studies such as controlling its population from increasing.

In summary, most of the introduced species in Lake Lanao have broader diets, larger size, higher fecundity, provide parental care and are habitat generalist compared to the endemic species. Although the life history traits examined are informative, they are not good indicators of the invasiveness of the introduced species in Lake Lanao. Moreover, some of the known invasive species in the world were not invasive in Lake Lanao, which suggests that invasive species have no common set of life history traits predicting their invasiveness.

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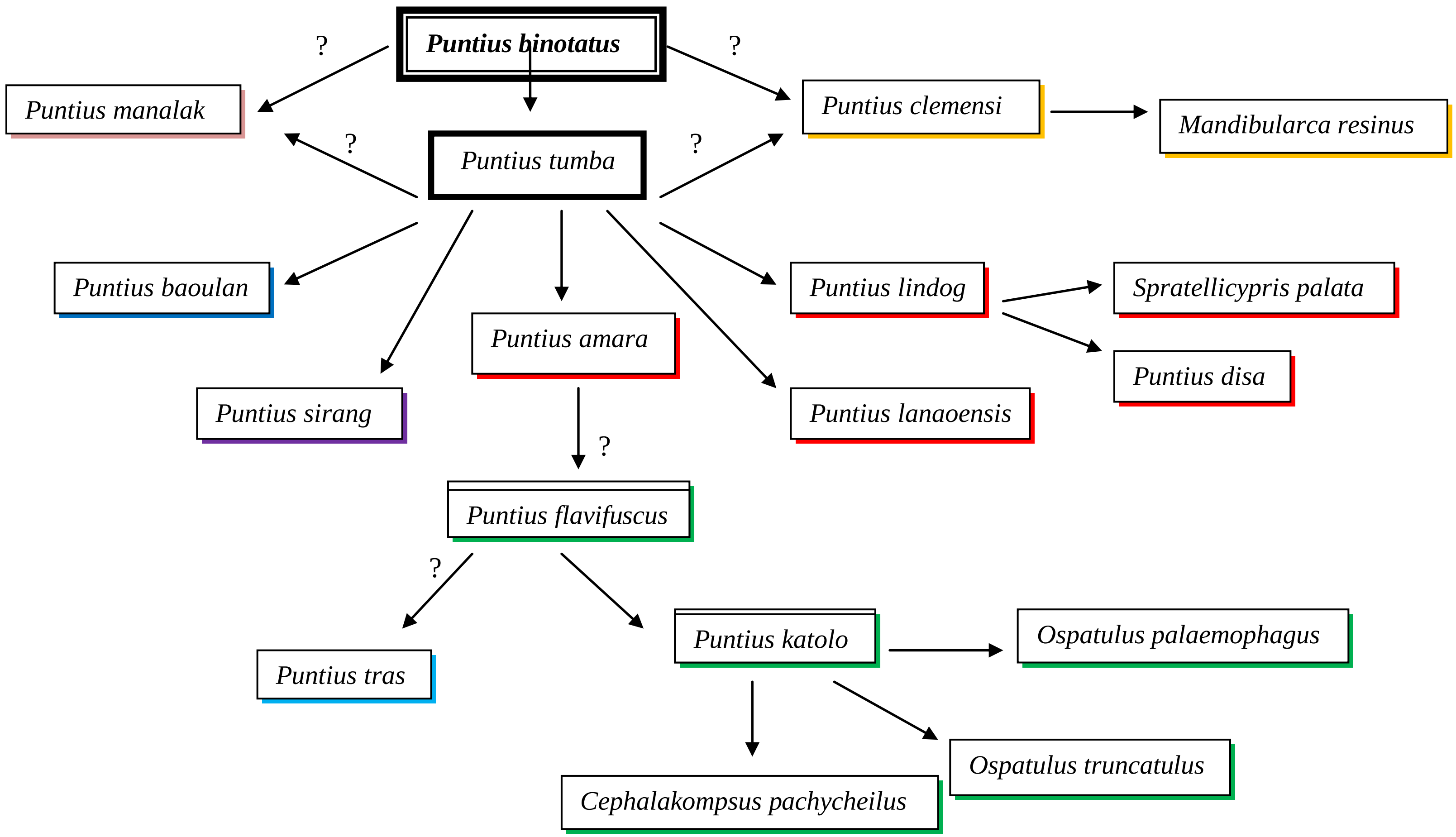

Figure 3.1. Evolutionary pattern of the Lake Lanao endemic cyprinids.

Figure 3.2. △ - Distribution of *Puntius binotatus* in Mindanao Island.

Figure 3.3. *Puntius lindog*.

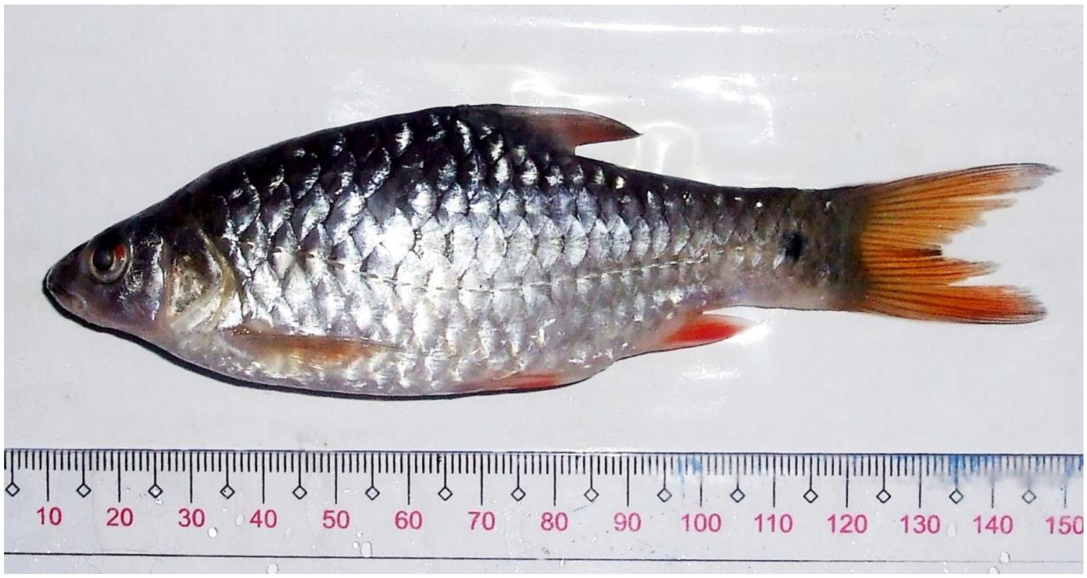

Figure 3.4. *Puntius tumba*.

Figure 3.5. *Ophicephalus striatus*.

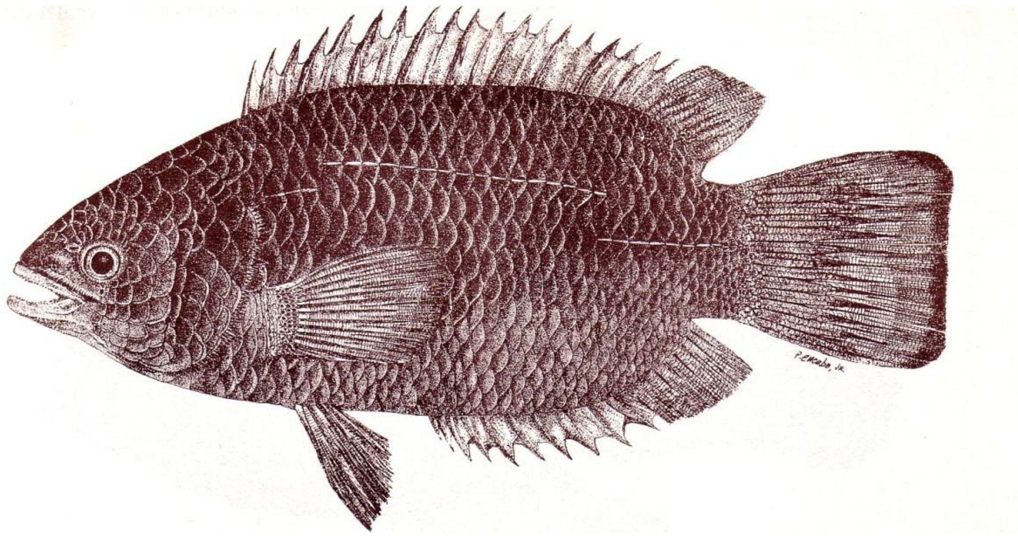

Figure 3.6. *Anabas testudineus* (drawing courtesy of Escudero 1980).

Figure 3.7. Clariid spp.

Figure 3.8. *Cyprinus carpio*.

Figure 3.9. *Glossogobius celebius* (photo courtesy of Lake Mainit Development Alliance).

Figure 3.10. *Glossogobius giurus* (photo courtesy of Lake Mainit Development Alliance).

Figure 3.11. *Hypseleotris agilis*.

Figure 3.12. Tilapia spp.

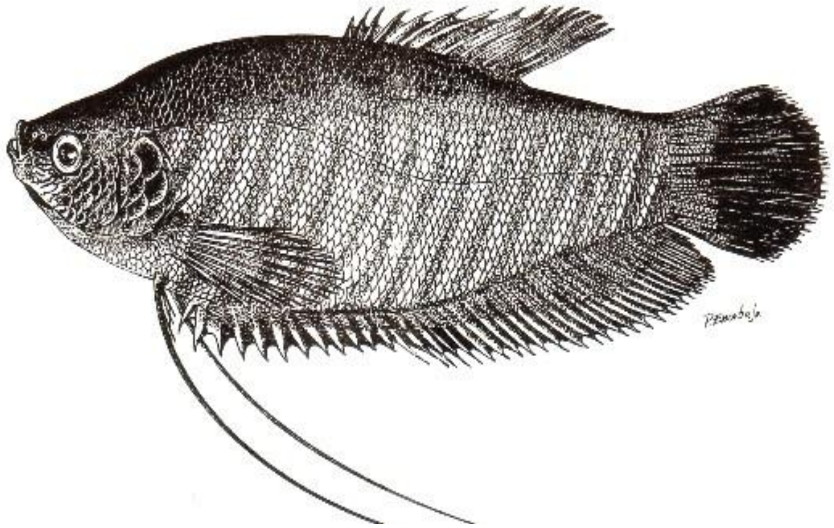

Figure 3.13. *Trichogaster pectoralis* (drawing courtesy of Escudero 1980).

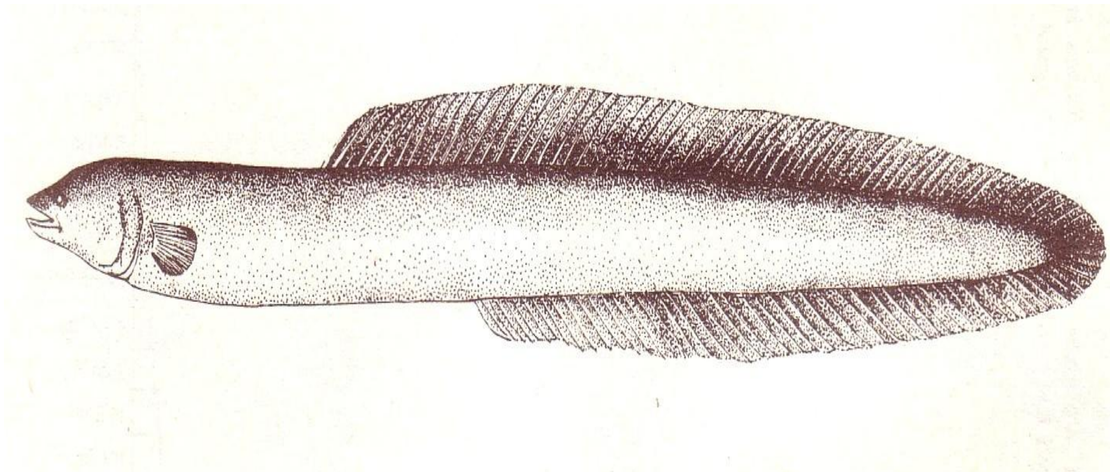

Figure 3.16. *Anguilla celebesensis* (drawing courtesy of Escudero 1980).

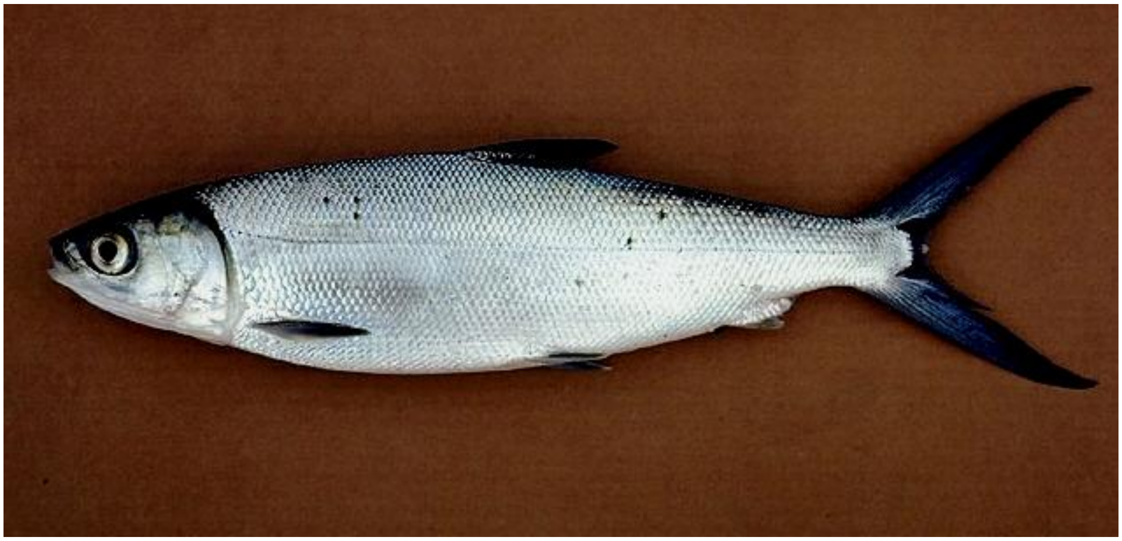

Figure 3.15. *Chanos chanos* (photo courtesy of U.S. Geological Survey).

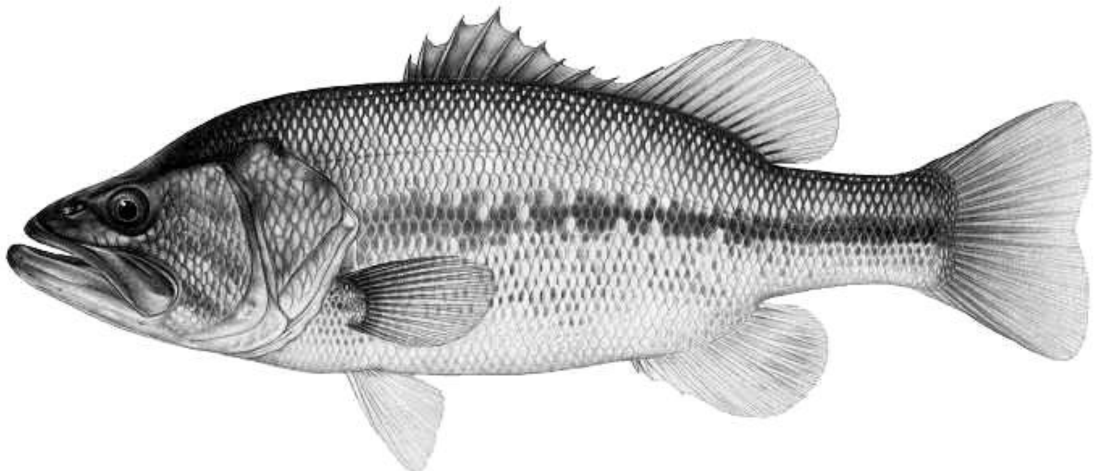

Figure 3.16. *Micropterus salmoides* (drawing courtesy of Escudero 1980).

Table 3.1 Species recorded to be caught in Lake Lanao, 2008.

Species	Common name
Endemic	
1. *Puntius lindog* (Pli)	Lindog
2. *Puntius tumba* (Ptu)	Tumba
Native	
1. *Anguilla celebesensis* (Ac)*	Celebes eel
2. *Ophicephalus striatus* (Os)	Mudfish
Introduced	
1. *Anabas testudineus* (At)	Climbing perch
2. *Chanos chanos* (Cch)*	Milkfish
3. *Clarias batrachus* (Cb)	Thai catfish (Catfish)
4. *Clarias macrocephalus* (Cm)	Bighead catfish (Catfish)
5. *Cyprinus carpio* (Cc)	Common carp
6. *Glossogobius celebius* (Gc)	Celebes goby (White goby)
7. *Glossogobius giurus* (Gg)	Tank goby (White goby)
8. *Hypseleotris agilis* (Ha)	Sleeper goby
9. *Micropterus salmoides* (Ms)*	Black bass
10. *Oreochromis mossambicus* (Om)	Mozambique tilapia (Tilapia)
11. *Oreochromis niloticus* (On)	Nile tilapia (Tilapia)
12.*Trichogaster pectoralis* (Tp)	Gourami

* These fish species were recorded in the past surveys but not in the 2008 survey.

Table 3.2. Tabulated life history traits of species found in Lake Lanao.

Species	Feeding habit	Max. adult size (mm)	Fecundity Range	Parental care (Yes/No)	Gregariousness (Gregarious/Solitary)	Habitat (Generalist/Specialist)
Endemic						
1. Pli	Planktivore (Sanguila et al. 1975, Escudero 1980); observed to pick up morsels of food (Escudero pers. comm..)	140 (2008 landing survey)	578-5,605 (Escudero 1980)	No (Escudero 1980, pers. comm.)	Gregarious (Escudero 1980)	Specialist (Escudero 1980, pers. comm..)
2. Ptu	Planktivore (Escudero pers. comm..)	142 (2008 market survey)	10,000 (Escudero pers. comm..)	No (Escudero 1980, pers. comm.)	Solitary but becomes Gregarious at some point of its life (Escudero pers. comm.)	Specialist (Herre 1933)
Native						
1. Ac*	No data	1500 (Fishbase)	No data	No data	No data	Specialist (Villaluz 1966)
2. Os	Carnivore (Villaluz 1966)	1,000 (Fishbase)	1,688-7,146 (Kilambi 1986)	Yes (Villaluz 1966)	Young – gregarious; >60 mm in size becomes solitary (Villaluz 1966)	Generalist (Fishbase, Villaluz 1966)
Introduced						
1. At	Omnivore (Fishbase)	250 (Fishbase)	5000 (Fishbase, Hails and Abdullah 1982)	Yes (Fishbase)	Solitary (Lheknim 2004))	Generalist (Fishbase)
2. Cch*	Omnivore (Tampi 1958)	1800 (Fishbase)	5,000,000-7,000,000 (Fishbase, FAO)	No (Fishbase)	Gregarious (FAO)	Generalist (Fishbase)

Table 3.2. Continued.

Species	Feeding habit	Max. adult size (mm)	Fecundity Range	Parental care (Yes/No)	Gregariousness (Gregarious/Solitary)	Habitat (Generalist/Specialist)
3. Cb	Carnivore (Villaluz 1966, Fishbase)	470 (Sanguila 2004, Fishbase)	10,000 (PhilAquaculture)	Yes (PhilAquaculture)	Solitary except during mating season (Fishbase)	Generalist (Villaluz 1966)
4. Cm	Carnivore (Villaluz 1966, Fishbase)	1,200 (Sanguila 2004, Fishbase)	5,000-10,000 (PhilAquaculture)	Yes (PhilAquaculture)	Solitary except during mating season (Fishbase)	Generalist (Villaluz 1966)
5. Cc	Omnivore (Fishbase) but feeds heavily on snail (Villaluz 1966)	1,200 (Fishbase)	1,000,000 (Global Invasive Database)	No (Fishbase)	Gregarious (Koehn 2004)	Generalist (Fishbase, Villaluz 1966)
6. Gc	Carnivore (De Guzman et al. 2009)	358 (Escudero 1980)	No data	Yes (Fishbase)	Juveniles- gregarious; Adults- solitary (De Guzman et al. 2009)	Generalist (De Guzman et al. 2009)
7. Gg	Omnivore but feed heavily on shrimp (Villaluz 1966, Sanguila et al. 1975, Escudero 1980)	500 (Fishbase)	8,000-400,000 (Escudero 1980)	Yes (Fishbase)	Young – gregarious (Villaluz 1966)	Generalist (De Guzman et al. 2009)

Table 3.2. Continued.

Species	Feeding habit	Max. adult size (mm)	Fecundity Range	Parental care (Yes/No)	Gregariousness (Gregarious/Solitary)	Habitat (Generalist/Specialist)
8. Ha	Omnivore (Escudero 1983, 1994, pers. comm.., Guerrero 2002)	180 (Escudero 1983)	5,300-104,000 (Escudero 1983)	No (Escudero pers. comm.)	Gregarious (Escudero 1983)	Generalist (Escudero 1983)
9. Ms*	Carnivore (Godinho and Ferreira 1994, Fishbase)	970 (Fishbase)	1,300-3,524 (Dadzie and Aloo 1990)	Yes (Global Invasive Species Database)	Solitary (Gilliland 2010)	Generalist (Gilliland 2010)
10. Om	Omnivore (Villaluz 1966)	390 (Fishbase)	1,775 (Global Invasive Species Database)	Yes (Global Invasive Species Database)	Solitary except during mating and spawning seasons (Fishbase)	Generalist (Fishbase)
11. On	Omnivore (Villaluz 1966)	600 (Fishbase)	2,000 (Global Invasive Species Database)	Yes (Global Invasive Species Database)	Solitary except during mating and spawning seasons (Fishbase)	Generalist (Fishbase)
12. Tp	Herbivore (Villaluz 1966)	260 (Villaluz 1966)	3,000-7000 (Villaluz 1966)	Yes (Villaluz 1966, Fishbase)	Solitary (Lheknim 2004)	Generalist (Villaluz 1966)

Note: See Appendix A for the species scientific names associated with the 2-character species codes.
* These fish species were recorded in the past surveys but not in the 2008 survey.

Table 3.3. Some traits of the extinct endemic cyprinids (Herre 1924, 1926, 1932, 1933, 1934)

Species	Size range (mm)	Diet	Area caught
1. *Cephalakompsus pachycheilus* (Cp)	134		Lake Lanao (Marawi)
2. *Mandibularca resinus* (Mr)	133 - 220		Agus River
3. *Ospatulus palaemophagus* (Op)	128	shrimp	Lake Lanao (Lumbatan)
4. *Ospatulus truncatulus* (Ot)			Lake Lanao
5. *Puntius amarus/amara* (Pa)	67-96		Lake Lanao (Marawi)
6. *Puntius baoulan* (Pb)	68-94		Lake Lanao
7. *Puntius clemensi* (Pc)	143-205		Lake Lanao (Marawi)
8. *Puntius disa* (Pd)	81-82		Lake Lanao (Marawi)
9. *Puntius flavifuscus* (Pf)	65-99		Lake Lanao (Lumbatan)
10. *Puntius herrei* (Ph)			
11. *Puntius katolo* (Pk)	95-126		Lake Lanao (Marawi)
12. *Puntius lanaoensis* (Pla)	90-96		Lake Lanao (Marawi)
13. *Puntius lindog* (Pli)	77-105		Lake Lanai (Marawi)
14. *Puntius manalak* (Pm)	185-275		Lake Lanao (Marawi)
15. *Puntius sirang* (Ps)	40-61		Lake Lanao (Lumbatan and Marawi)
16. *Puntius tras* (Ptr)	126		Lake Lanao (Camp Keithley)
17. *Puntius tumba* (Ptu)	35-112		Lake Uyaan, Lake Nunungan, Lake Dapao, Siwagat River
18. *Spratellicypris palata* (Sp)	71-109		Lake Lanao (Marawi)

Table 3.3. Reported occurrence of endemic cyprinids outside the Lake Lanao drainage basin. [1] (Kornfield and Carpenter 1984) *

Species	**Distribution**	**Reference**
Mandibularca resinus	Lake Uyaan, [2] small streams & lakes of Lanao plateau[3] Agus River watershed	Herre (1924) Woltereck (1941) Wood (1966)
Puntius baoulan [4]	Lake Dapao	Kosswig & Villwock (1964)
Puntius clemensi	Lakes of the Lanao plateau Lake Dapao	Herre (1933) Kosswig & Villwock (1964)
Puntius manalak [5]	Lakes of the Lanao plateau	Brooks (1950)
Puntius tumba	Lake Dapao Lake Nunungan Lake Talao Lake Uyaan	Herre (1924); Woltereck (1941); Kosswig & Villwock (1964); Kornfield (1982) Herre (1924); Woltereck (1941) Woltereck (1941) Herre (1924); Woltereck (1941)
Puntius lindog [6]	Lake Dapao	Kornfield (1982)

* All information except the *Puntius lindog* was reproduced from Kornfield and Carpenter (1984)

[1] Wood and Wood (1963) reported that they collected virtually all Lanao endemics outside the lake proper, but this report is uniformly viewed with skepticism.

[2] Reported by fishers but discounted by Herre (1924).

[3] Though Woltereck (1941: 150) states: "*Mandibularca* wurde auch in einigen der Kleinseen und Bache des Lanaoplateaus gefunden", he did not list this species as present in his systematic account of the fauna of Lakes Dapao, Nunungan, Talao and Uyaan, examined during the 1932 Wallacea expedition.

[4] Both Kosswig & Villwock (1964) and Wahl (1972, 1976) mention that Woltereck also found *P. baoulan* in Lake Dapao, but Woltereck (1941) does not mention it in his collections.

[5] Herre (1933) stated that this species is *only* known from Lake Lanao; Brooks (1950) clearly misread Herre's distributional account.

[6] Kornfield (1982) reported from his collection that this species and *P. tumba* were identified by fishermen from illustrations, and were reported to be found at the center deep part of the lake, the area where he was not able to sample.

CHAPTER 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

> "*Let one of the 'new' biologists leave his laboratory and apply his methods to the fishes of Lake Lanao; perhaps he might then make a real contribution to the study of evolution.*"

The above inspiring and challenging statement, from Herre (1933), attempted to focus attention on the extraordinary example, largely overlooked by the scientific community, of explosive speciation provided by the diversity of endemic fish species in Lake Lanao. The text was also used as a prelude to Kornfield and Carpenter's 1984 paper. Although my thesis study makes no contribution to the study of evolution, I hope it tells a story that will rekindle interest in the fishes of Lake Lanao. The study was hampered by having limited time and resources, and it began with no expectations of what would be found. However, I was thrilled, and a little surprised, to find still alive two of the endemic species that Herre had discovered and carefully described for the scientific community early in the last century. I hope this thesis will provide a new beginning rather than the last chapter in the story of the endemic fish species in Lake Lanao. It is also my hope that it will be useful as a reference and guide for future students who may be interested in studying the fish species in the lake.

Chapter 2 discussed the kinds and relative abundance of fish species in Lake Lanao observed in the 2008 surveys and compared the results to the historical surveys done by Villaluz (1963-64), Sanguila (1973), and Escudero (1974, 1975, 1976, 1977, 1982-83 and 1990-91). The comparison demonstrated that the kinds and relative abundance of fish species in Lake Lanao had changed markedly through the years. Across all the historical surveys there were a total of 18 endemic species, two native species and 12 introduced species recorded in Lake Lanao. Of all these species, the 2008 surveys found only two endemic species, one native species and ten introduced species. Although the surveys conducted were very limited in time, the pattern from the historic surveys showed a decline of the endemic cyprinids and an increase of the introduced species.

Proliferation of a fish species in a body of water can have either beneficial or detrimental consequences – beneficial in the sense that a highly abundant species may support a significant fishery thereby providing income to the local fisherman in the locality and protein to the inhabitants. On the other hand, extreme proliferation can cause havoc to other species in the afflicted environment by way of direct predation, parasitism or by sheer competition for food and space (Frey 1974). In Lake Lanao the proliferation of *Hypseleotris agilis,* since its introduction in the late 1970s, is believed not only to have caused the extinction of some of the endemic cyprinids and the decline of others, but also the decline of the introduced *Glossogobius celebius, G. giurus* and *Cyprinus carpio* (Escudero, personal letter).

Chapter 3 tabulated and discussed a set of life history traits of the fish species in Lake Lanao to determine if the introduced species had the general traits that are thought to contribute to the success of invasive species. Tabulated traits showed that the introduced species have broader diet, larger size, higher fecundity, provide parental care and are habitat generalists in contrast to the still extant endemic cyprinids, which showed mostly the opposite characteristics. However, the results of this study suggest that life history traits are not completely accurate predictors of invasiveness (Rosecchi et al. 2001) and that not all introduced species become successfully established in their new surroundings.

In modern times invasive species have been one of the leading causes of animal population extinctions (Clavero and Berthou 2005) and biologists have studied the significance of life history traits in relation to invasiveness (Jaremo and Bengtsson 2011). Unfortunately there are no available data on the biological traits of the extinct cyprinids (although Herre comprehensively described the morphological characteristics of the endemic cyprinids and their sizes) to compare them to the traits of the introduced invasive species. There is however strong evidence that the endemic cyprinids started to decline and disappear at the same time that non-native species were introduced intentionally and unintentionally into the lake. Other factors were also at work, however.

Human disturbance and habitat loss have also greatly contributed to species extinction (Mattila et al. 2008). Aside from introduced species, over exploitation (Kornfield and Carpenter 1984) and habitat destruction such as soil-erosion, sewage, agricultural run-off and hydro-electric dams (Naga 2002) are possible causes of the disappearance of the endemic cyprinids in Lake Lanao, but these factors were not examined as part of this thesis research.

The 2008 surveys led to a positive result as they showed that there are still endemic species left in Lake Lanao. Further, it is worth noting that the presence or absence of the endemic species was inconsistent over the course of the historic surveys. With proper tools for field collection and methods for species identification, it is possible that future surveys might discover more than the two extant endemic cyprinids found during the limited sampling conducted during 2008. If the surveys had been conducted for a longer period of time and with more extensive geographic coverage, who knows what other species might have been found?

Below are recommendations for future studies of the fishes of Lake Lanao.

1. According to the International Union for Conservation of Nature, habitat loss (dams, sedimentation, dredging and other anthropogenic factors), over-exploitation (hunting and fishing), pollution, disease, introduced species and global climate change are the major causes that threaten species with extinction. The Philippines has the most threatened endemic species, mostly caused by habitat destruction (Brooks et al. 2002). Construction of dams, an example of habitat destruction, can block fish migration, degrade habitats for aquatic species and change hydrology of rivers and streams, which have resulted to extinction and displacement of fish and other aquatic species (Kang et al. 2009, McCartney 2009, McAllister et al. 2001). Based on previous studies, some of the endemic species thrived in the Agus River and other

tributaries and streams around the lake. Possible effects of the dams on the Lake Lanao ecosystem should be carefully examined and monitored. For instance, physico-chemical and hydrological aspects of the lake should be studied. Future surveys should also include other techniques for collecting fish and should sample from all areas of the lake including deep water areas, tributaries, the Agus River and small streams, to identify areas that could be set aside for the protection of the endemic species. Fish ladders could be built for migratory fishes such as the native eel, *Anguilla celebesensis* and other possible migratory endemic cyprinids.

2. Studies of the biology and ecology of the remaining endemic cyprinids should be conducted before these species become totally extinct. The basic biology of the endemic cyprinids has not yet been well described and without a better understanding of these species it will not be possible to resolve why most of the endemic cyprinids disappeared in a very short period of time while the two of the endemic species are still extant.

3. Understanding the evolution of the endemic cyprinids is still a great challenge. The endemic species in Lake Lanao have been called an example of “explosive” evolution due to the fact that it apparently happened in a relatively short period. Comprehensive studies are suggested on the genetics and possible evolutionary relationships among the endemic cyprinids.

4. Surveys should be conducted to determine the occurrence of endemic cyprinids outside the Lanao drainage basin for the purpose of preserving and protecting them.

Kornfield and Carpenter (1984) tabulated the possible occurrence of endemic cyprinids reported by various scientists.

5. Previous attempts at artificially culturing *Puntius tumba* were successful but not with *Puntius lindog*. Attempts at stock enhancement through artificial propagation should be continued by improving and modernizing captive breeding and hatchery techniques. At present, the Mindanao State University is artificially culturing *Puntius binotatus*, believed to be the ancestor of the endemic cyprinids in Lake Lanao. Ironically, this species has never been recorded in Lake Lanao and its source was from another lake on Mindanao Island. The purpose of culturing this species is to test if it will thrive in Lake Lanao.

6. Intensive catching should be considered to control the further growth of the *Hypseleotris agilis* population in Lake Lanao. Fish that are harvested in excess of the local market demand could be processed to fish meal. Fish meal industries close to Lake Lanao used to operate during the early 1980’s. Reopening and operating the fish meal plant could promote jobs in the local industry as well as reduced the abundance of this predatory fish species.

7. Develop other options to control and manage the population of *Hypseleotris agilis*.

8. Several Laws had been created and Councils have been formed to protect Lake Lanao and its watersheds (Naga 2010). Unfortunately, these have had only a paper existence. There needs to be active implementation and enforcement of these laws as well as development of fish policies, in consultation with the local governments, stake

holders, sociologists, ecologists, biologists and legislators to help protect this ancient lake and its endemic cyprinids.

9. Next to their religion Islam, the native Maranaos proudly consider Lake Lanao as their most cherished treasure in life and part of their heritage. It is therefore essential to raise the level of awareness of the Maranao people to impress on them their responsibilities and roles in protecting Lake Lanao. This can be achieved by developing educational and stakeholder outreach plans. For example, educational outreach specialists could develop, interactive games and activity books fit to the education level of students to help them learn about the fish species in Lake Lanao. Materials for teachers could be prepared for including in the curriculum the study the of the fish species in Lake Lanao so that students as early as primary levels would be able to identify endemic and native species from introduced species and would learn the importance of endemic species conservation. Field trips to the lake and its rivers could also be recommended. For stakeholders, seminars and workshops could be conducted to inform the public about the effects of invasive species on the endemic species. The people could thus be informed of the importance of conserving the remaining endemic species. Community plays an important role in the success of conservation programs. It is therefore important for the stakeholders to feel that they are part of the program by involving them in the conservation of the endemic species. Fishermen could be used as data collectors for research and fisheries studies in Lake Lanao, with incentives provided to those who want to participate. Consultation and collaboration with the local religious and political leaders are also important for the

effective dissemination of information. Other forms of stakeholder outreach are the printing and distribution of informational brochures and the creation of a website about Lake Lanao and its endemic species. By means of the website, information on Lake Lanao and its unique species will be more accessible to the general public.

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APPENDICES

Appendix A. Fish species in Lake Lanao: their scientific names, their common/local names and codes used in tables and figures.

Species	Local Name
A. Endemic	
1. *Cephalakompsus pachycheilus* (Cp)	Bitungu
2. *Mandibularca resinus* (Mr)	Bagangan sa Erungan
3. *Ospatulus palaemophagus* (Op)	Bitungu
4. *Ospatulus truncatulus* (Ot)	Bitungu
5. *Puntius amarus/amara* (Pa)	Pait (bitter), Dipura
6. *Puntius baoulan* (Pb)	Baoulan
7. *Puntius clemensi* (Pc)	Bagangan
8. *Puntius disa* (Pd)	Disa
9. *Puntius flavifuscus* (Pf)	Tumba, Katapa-tapa
10. *Puntius herrei* (Ph)	Herrei
11. *Puntius katolo* (Pk)	Katolo
12. *Puntius lanaoensis* (Pla)	Kandar
13. *Puntius lindog* (Pli)	Lindog
14. *Puntius manalak* (Pm)	Manalak
15. *Puntius sirang* (Ps)	Sirang
16. *Puntius tras* (Ptr)	Tras
17. *Puntius tumba* (Ptu)	Tumba
18. *Spratellicypris palata* (Sp)	Palata

Appendix A. Continued.

Species	Common Name	Local Name
B. Native		
1. *Anguilla celebesensis* (Ac)	Celebes Longfin eel	Kasili
2. *Ophicephalus striatus* (Os)	Mudfish	Aruan
C. Introduced		
1. *Anabas testudineus* (At)	Climbing perch	Popoyo
2. *Chanos chanos* (Cch)	Milkfish	Bangus
3. *Clarias batrachus* (Cb)	Thai catfish	Katipa
4. *Clarias macrocephalus* (Cm)	Bighead catfish	Katipa
5. *Cyprinus carpio* (Cc)	Common carp	Bungkaong/Karpa
6. *Glossogobius celebius* (Gc)	Celebes goby (White goby)	Kadurog
7. *Glossogobius giurus* (Gg)	Tank goby (White goby)	Kadurog
8. *Hypseleotris agilis* (Ha)	Sleeper goby	Katolong
9. *Micropterus salmoides* (Ms)	Black bass	Tamban
10. *Oreochromis mossambicus* (Om)	Mozambique Tilapia	Tilapia
11. *Oreochromis niloticus* (On)	Nile Tilapia	Tilapia
12. *Trichogaster pectoralis* (Tp)	Gourami	Gourami

Appendix B. Questionnaire

SURVEY BACKGROUND INFORMATION

WHAT IS THE PURPOSE OF THIS STUDY?

You are being invited to take part in a research study designed to learn the current status of Lake Lanao and its fishes (endemic, natives and introduced). It is believed that the introduction of nonnative fish and human use contributed to the extinction of most of the endemic fish species and is now contributing to the decline of the remaining endemic fish. The data that will be gathered will be used for making recommendations on how to protect the remaining endemic cyprinids in the future. The information that will be collected from you and from other fishermen in the area will be used to complete the MS thesis for Gladys Macaosip. We are conducting this study because the endemic cyprinids in Lake Lanao are listed as critically endangered species by the International Union for Conservation of Nature (IUCN). This study will provide a benchmark for the status of the endemic cyprinids of Lake Lanao. It will also determine the possible contributions of introduced species to the population decline of the remaining endemic cyprinids and, lastly, the stakeholders will benefit by being made aware of the importance of protecting Lake Lanao and its special inhabitants.

WHY AM I BEING INVITED TO TAKE PART IN THIS STUDY?

You are being invited to take part in this study because you are a fisherman in Lake Lanao.

WHAT WILL HAPPEN DURING THIS STUDY AND HOW LONG WILL IT TAKE?

You will be asked series of questions such as: your fishing methods, kinds of fish caught and problems you encounter while fishing. The survey will take place in the participant’s home. If you agree to take part in this study, your involvement will last for an hour.

WHAT ARE THE RISKS OF THIS STUDY?

There are no foreseeable risks and/or discomforts associated with the procedures described in this study.

WHAT ARE THE BENEFITS OF THIS STUDY?

As one of the stakeholders, you will benefit from being in this study because after the research is completed you will be informed and be made aware on the current status of Lake Lanao.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study. However, you will be given a t-shirt, printed with Lake Lanao and its endemic species to show that you were involved in the study

WHO WILL SEE THE INFORMATION I GIVE?

The information you provide during this research study will be kept confidential to the extent permitted by law. To help protect your confidentiality, we will use identification code numbers only on data forms.
If the results of this project are published your identity will not be made public.

DO I HAVE A CHOICE TO BE IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decide not to take part in this study, your decision will have no effect on the quality of care, services, etc., you receive.

You will not be treated differently if you decide to stop taking part in the study. Note however that you are free to skip any questions you prefer not to answer. If you choose to withdraw from this project before it ends, the researchers may keep information collected about you and this information may be included in study reports.

Code No. _____

SURVEY QUESTIONNAIRE FORM

Section 1. PERSONAL INFORMATION

Years being a fisherman:

Municipality/Barangay:

Section 2. FISH OPERATION INFORMATION

General Instructions. Answer by marking the corresponding circles of the letters you choose.

1. How often do you fish every week? Choose one.
   O a. everyday

   O b. every other day

   O c. twice a week

   O d. once

   O e. others, specify: ________________

2. What time of the day do you usually fish? Choose all that apply.
   O a. 4:30 – 7:00 A.M.

   O b. 7:00 – 12 NN

   O c. 12:00 – 5:00 P.M.

   O d. 6:00 – 11:00 P.M.

   O e. others, specify: __________

3. What are the types of fishing method you used? Choose all that apply.
   O a. gill net

   O b. lift net

   O c. handline

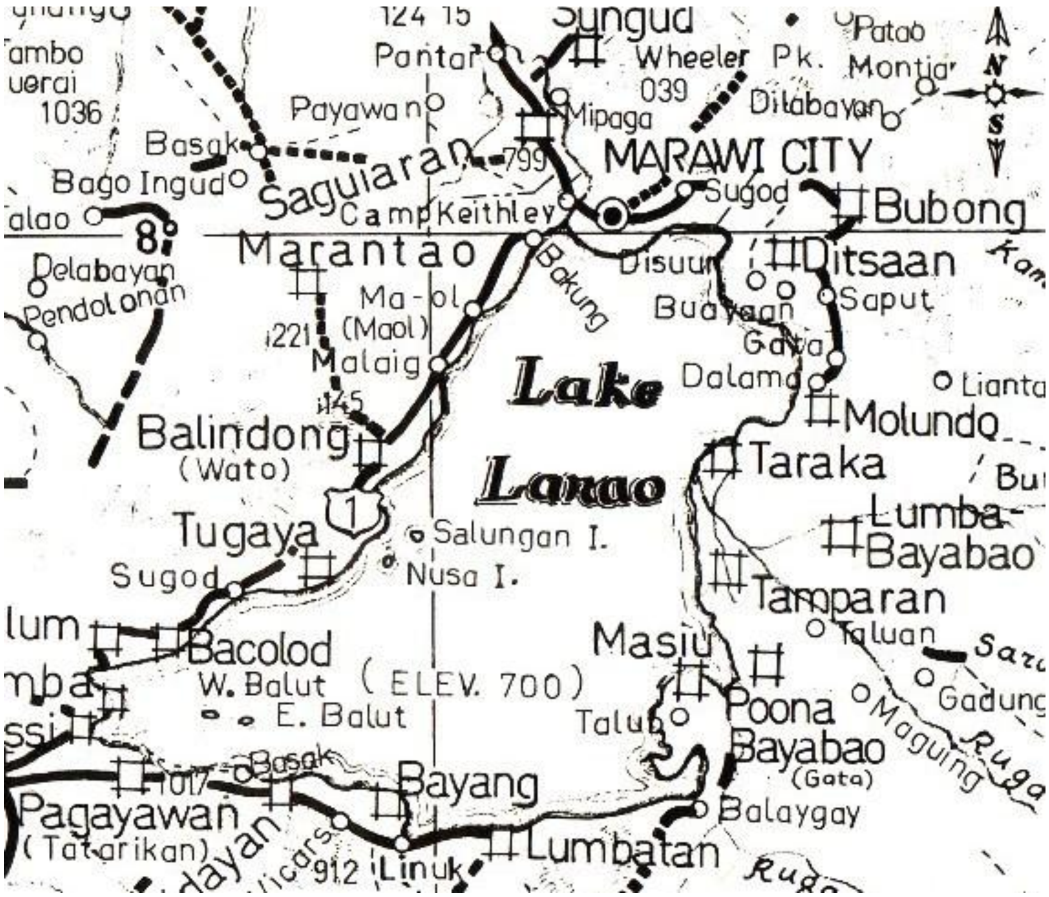
   O d. longline

   O e. Others, specify: ________________

4. What are the fish you often, rarely, or never caught (please refer to photos attached). Write O for often, R for rarely and N for never.

___1. *Mandibularca resinus*
___ 2. *Cephalakompsus pachycheilus*
___ 3. *Ospatulus palaemophagus*
___ 4. *Ospatulus truncatulus*
___5. *Puntius baoulan*
___ 6. *Puntius amarus*
___ 7. *Puntius clemensi*
___ 8. *Puntius disa*
___ 9. *Puntius flavifuscus*
___ 10 *Puntius katolo*
___ 11. *Puntius herrei*
___ 12. *Puntius lanaoensi*
___ 13. *Puntius lindog*
___ 14. *Puntius manalak*
___ 15. *Puntius sirang*
___ 16. *Puntius tras*
___17. *Puntius tumba*
___ 18. *Spratellicypris palata*
___19. *Anguilla celebesensis*
___20. *Ophicephalus striatus*
___21. *Micropterus salmoides*
___22. *Clarias macrocephalus*
___23.*Clarias batrachus*
___ 24. *Anabas testudineus*
___ 25. *Cyprinus carpio*
___ 26. *Oreochromis niloticus*
___ 27. *Oreochromis mossambica*
___ 28. *Glossogobius giurus*
___ 29. *Glossogobius celebius*
__ 30.*Trichogaster pectoralis*
__ 31. *Hypseleotris agilis*
___ 32. *Others, specify.*

5. Please mark X on the map where you usually fish.



6. What month you usually fish? ______________________________

7. What kind of fish you prefer to catch? Kindly list down the fish below (refer to photos attached).

____

____

____

____

8. Do you catch the above fish because they are:

O a. easy to catch

O b. abundant

O c. preferred by consumers

O d. all of the above

9. If you use hooks or traps, do you use fish as bait?

O a. yes

O b. no

9.1 If yes, kindly list down the fish you catch (refer to photos attached) and baits used.

Fish caught: ________________ Baits used:

____

____

10. Aside from fishing on the lake, do you practice aquaculture?

O a. Yes

O b. No

10.1 If yes, what type of aquaculture?

O a. fish cage in Lake Lanao

O b. pond culture

O c. others, specify: ______________

10.2 What kind of fish do you culture? Kindly list down the fish you culture (please refer to photos).

____

____

____

11. Since you have start fishing, are there any changes you have noticed?

O a. Yes

O b. No

11.1 If yes, please give specifications.

12. Compared to six months ago, how are fishing conditions today?

Other comments:

Thank you for your patience in providing your answers to the questions. If you have comments or questions, you may write to:

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Wassalam!