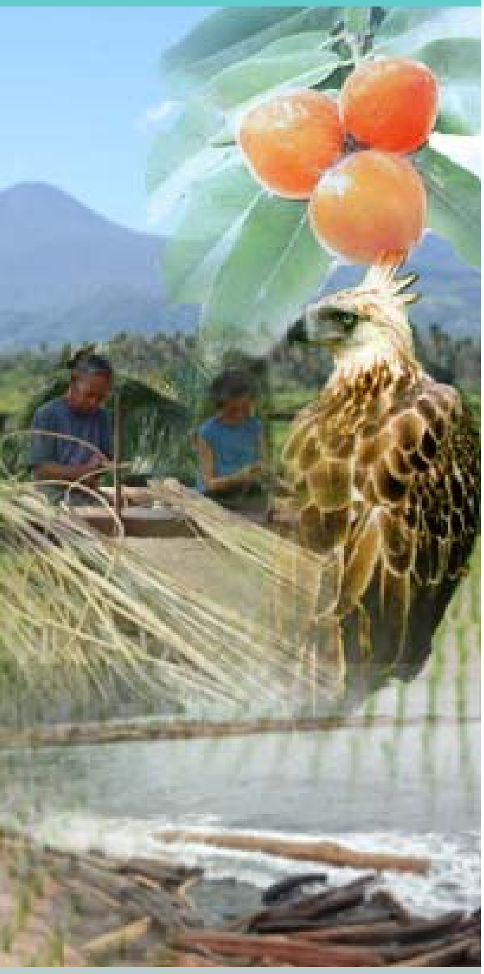
ISSN 0119-1144



Journal of Environmental Science and Management

University of the Philippines Los Baños

Journal of Environmental Science and Management

Volume 10 • Number 1 • 2007

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Journal of Environmental Science and Management 10(1):1-9 (June 2007)
ISSN 0119-1144

Alien Fish Species in the Philippines: Pathways, Biological Characteristics, Establishment and Invasiveness

C.M.V. Casal, S. Luna, R. Froese, N. Bailly, R. Atanacio and E. Agbayani

ABSTRACT

Aquaculture (18%) and aquarium (77%) species comprise most of the species which are brought into the Philippines, and although meant to be confined to culture and aquarium facilities, some have escaped to natural waters, established themselves and have become invasive – with adverse impacts to indigenous species and/or the ecosystem.

Of the 159 fish species introduced to the Philippines, only 39 have been reported as established in the wild, four have not established and the remaining 116 have unknown status of establishment. The biological characteristics of the species from the three groups are discussed and the potential establishment of the unknown species is explored.

Results reveal that there are significant differences in average maximum length, longevity in the wild, degree of parental care and species resilience between the established and the unestablished species groups. Established species were predominantly r-strategists with medium size and high productivity. These species stemmed more often from other tropical countries compared to the group that did not establish itself. The suit of biological and ecological characteristics of the group with unknown establishment, however, were similar to the established group indicating a high degree of establishment potential or their probable unreported presence in the wild. Results also provide insights on the various introduction pathways.

***Keywords**: introduction pathways, biological characteristics, climate match, risk assessment, establishment, invasiveness, r-strategists*

INTRODUCTION

Alien invasive species are the second leading cause of biodiversity loss next to habitat destruction, particularly in freshwater ecosystems (*Moyle et al 1986; Vitousek et al 1997, Bartley and Casal, 1998, 1999 and Mack et al 2000*). Once an invasive species has established itself in the wild it is usually impossible to eradicate (*Callaway et al 2006*). The impact of invasive aquatic organisms is estimated to cost globally more than $314 billion per year in damage and control costs (*Pimentel 2002*). Economic losses associated with the entry of the golden apple snail in the Philippines alone, is estimated at US$425 M to US$1.2 B in 1990 (*Naylor 1996*). The government's quarantine procedures must be focused to keep species introductions at safe level and to keep new invaders from being introduced while attempting to slowdown the spread of those invasive species already present (*Kerr et al 2005*). Vector control or prevention of the entry of invasives or potential invasives is the most cost effective means for dealing with them, since it is both more effective and less expensive than post introduction control measures (*Shields and Foster 2005*).

The need for risk assessments prior to the introduction of alien species is a major concern. In lieu of field work, most risk assessments are done desktop and qualitatively, expert opinions based on published or prior studies because of limited resources. The strength of any such desktop assessments lie on the availability of information, prior knowledge of any adverse impact based on previous introductions, biological characteristics of the species being proposed for introduction and similarity in the characteristics of the species native environment and new environment. This paper will discuss the pathways of fish introduction in the Philippines, biological characteristics of the species reported established and unestablished and their invasiveness in the Philippines. This paper will provide a scientific basis in allowing or banning the entry of particular species into the country.

Pathways of Introduction

Most of the species which have been brought into the country were utilized by the ornamental industry. Other introductions were used for aquaculture, mosquito control and fisheries. Only species which were introduced for mosquito control and fisheries were meant to be released to natural waters. Species introduced for the ornamental and aquaculture industry were meant to be placed in confined facilities like aquariums, culture ponds, pens and cages. Data reports showed a higher level of reported establishment in species which were meant to be released to natural waters (mosquito control and fisheries). This is expected as they may have been chosen for their capacity to adapt to the existing environmental conditions as well as being deliberately released to the wild. Furthermore, some monitoring may have been done after their release to check on their efficiency as biological control agents (for the mosquito control fishes) and their status in the wild after being released.

The lower level of reported establishment particularly for the ornamental fishes may be a result of two things: 1.) unavailability of data and/or 2.) data inaccessibility. Unavailability of data may stem from lack of species monitoring information or lack of reports from monitoring activities. Data inaccessibility may stem from monitoring data kept in researcher's notebooks in different regulatory agencies which have not been made publicly available through reports and publications.

From the different pathways of introduction, most introductions in the country came from the ornamental trade although it's establishment is low. The values provided however do not paint a full picture of the issue on the pathways and their establishment, the point being raised that reports on species establishment are quite sparse if not absent. Data on this alone can not point to which pathways the government should focus on its efforts against invasive alien fish species although it definitely should be on the list.

Allowing the introduction of an alien species into the country for aquaculture is tantamount to allowing its probability of escaping to natural waters. Most of the species which reportedly established in Philippine waters entered via aquaculture (*Pullin et al 1997*). Currently, about 82% of species introduced to the Philippines for aquaculture have established in the wild (**Table 1**). Aquaculture activities in the country are usually in cages or pens in natural waters. The high incidence of typhoons and flooding allowed the unintentional release of hundreds of cultured fishes into natural waters. Their acclimatization may have allowed the survival, growth and reproduction of these fishes in the new and wider environment. Herbivore and demersal fishes which do not require clear water will thrive (e.g. *Clarias* spp., *Oreochromis* spp., and *Pterygoplichthys* spp. among others) in eutrophic lakes like Laguna de Bay, .

Of the top 20 species which have caused detrimental environmental impacts to some of the countries where they have been introduced, 11 species have been introduced to the Philippines (nine of which have established in the wild) and eight of these have been introduced for aquaculture (**Table 2**). These 11 species should be included in the list of species of major ecological concern. The environmental and socio-economic impacts and movement of these species within the country should be evaluated and closely monitored.

Current Risk Assessment Methodologies

Two of the most frequent approaches to studying invasion biology are identifying species traits which might predict invasion success (*Williamson and Fitter 1996; Mack et al 2000; and Kolar and Lodge 2001, 2002*) and identifying attributes of communities that affect their susceptibility or resistance to invasion

Table 1. Pathways of species introduction and their reported establishment.

Pathways of introduction	Number of species	Number of reported establishment	Unknown status	% of species establishment
Ornamental	122	8	114	7
Aquaculture	29	24 (3 species have not established)	2	83
Mosquito control	6	5	1	86
Fisheries	1	1	0	100
Unknown	1	0	1	?

Table 2. Top 20 introduced species with adverse impacts to countries where they have been introduced (Froese and Pauly, 2006).

Species	Common Name	No. of countries that reported adverse ecological impacts	Introduced to the Philippines	Establishment	Reason for introduction
Ameiurus melas	Black bullhead	8	No	-	-
Carassius auratus auratus	Goldfish	7	Yes	Yes	Ornamental
Clarias batrachus	Walking catfish	5	Yes	Yes	Aquaculture
Ctenopharyngodon idella	Grass carp	4	Yes	No	Aquaculture
Cyprinus carpio carpio	Common carp	19	Yes	Yes	Aquaculture
Gambusia affinis	Mosquito fish	7	Yes	Yes	Mosquito control
Hypophthalmichthys molitrix	Silver carp	9	Yes	No	Aquaculture
Lepomis gibbosus	Pumpkinseed	9	No	-	-
Lepomis macrochirus	Bluegill	6	Yes	Yes	Aquaculture
Micropterus salmoides	Largemouth bass	11	Yes	Yes	Aquaculture
Neogobius melanostomus	Round goby	6	No	-	-
Oncorhynchus mykiss	Rainbow trout	16	No	-	-
Oreochromis mossambicus	Mozambique tilapia	14	Yes	Yes	Aquaculture
Oreochromis niloticus niloticus	Nile tilapia	14	Yes	Yes	Aquaculture
Poecilia reticulata	Guppy	8	Yes	Yes	Mosquito control
Pseudorasbora parva	Stone moroko	11	No	-	-
Salmo trutta trutta	Sea trout	10	No	-	-
Salvelinus fontinalis	Brook trout	5	No	-	-
Sander lucioperca	Zander	4	No	-	-
Xiphophorus hellerii	Green swordtail	4	No	-	-

(*Levine and D'Antonio 1999*).

Biological Comparisons

There are several methods of identifying the biological traits of invaders in any given area, e.g. analyzing successful vs. unsuccessful introductions (*Forsyth et al 2004 and Marchetti et al 2004*), comparing native species with established introductions (*Williamson and Fitter 1996 and Vila-Gispert et al 2005*) or comparing invasive with non invasive species (*Kolar and Lodge 2001*). Comparisons like these provide different information because different species characteristics may determine success in different invasion transitions (*Kolar and Lodge 2001*).

The most widely available information are comparisons between native species and established introductions simply because unsuccessful introductions and invasive potentials are poorly known (*Alcaraz et al 2005*). However, these studies may help elucidate the overall success of invasive over native species while other types of comparisons may provide information on specific invasions transitions.

Casal and Froese in 2004 showed from FishBase data revealed that resilience, maximum length and longevity in the wild were the strongest predictors of species establishment based on Pearson (continuous) and Spearman (categorical) correlation coefficients.

Human Use

The utility of a species is one of the main factors differentiating native against invasive fish species in the Iberian Peninsula. The diversity of human use of introduced species have obscured life history trait characterization of established fish species (*Alcaraz et al 2005*). The propagule pressure, particularly in intentionally introduced species, is important to species establishment. High introduction rates for aquaculture species for example has influenced high species establishment (*Mack 1996, Williamson 1996, Kolar and Lodge 2001, Garcia-Berthou et al 2005 and Casal and Froese 2006*). If these species were not utilized for aquaculture they may not have been introduced worldwide and hence would have lesser chance of establishing populations where introduced.

Ecosystem Matching

The significance of latitudinal range in invasiveness has been reported by several researchers (*Scott and Panetta 1993, Ricciardi and Rasmussen 1998, Duncan et al 1999, Goodwin et al 1999, Duncan et al 2001 and Alcaraz et al 2005*). Species with a wider latitudinal range or distribution are likely to succeed in a new environment (*Alcaraz et al 2005*) because of wider tolerance to environmental factors such as temperature ranges (*Goodwin et al 1999 and Marchetti et al 2004*). A wide distributional range may indicate flexible or generalist species which will have a higher chance of successful establishment because of the likelihood of encountering suitable environments (*Williamson 1996*).

Phylogeny

The importance of phylogeny in the success of introduced species has been pointed out. Introduced species will be more successful if they are less related and therefore probably ecologically distinct from the community they are invading (*Lockwood et al 1993, Moyle and Light 1996 and Williamson 1996*). Since they will be able to exploit a resource untapped by native species, competition is avoided. Also they may be less likely affected by predators or parasites (*Lockwood et al 2001*).

Eighty percent of the variation in age at maturity, length and fecundity can be explained by phylogenetic effects at the order and family levels, which suggests that these are largely intrinsic and relatively stable characters (*Alcaraz et al 2005*). This would allow proxy data from related species to be utilized in risk assessment.

Moreover, the best predictor of whether a non-indigenous species will have negative effects is whether it had such effects where it has already been introduced (*Daehler and Gordon, 1997*).

METHODS

Biological Characteristics of Alien Species Introduced to the Philippines

The following species characteristics have been evaluated: type and variety of food, degree of parental care, maximum length, longevity, temperature range, resilience and percent of establishment elsewhere. **Table 3** shows the biological characteristics evaluated and the assumptions on probability of establishment.

Data were taken from FishBase and care was taken to ensure that prior to analysis all available sources of biological information were checked and encoded into the database to increase the reliability of the analyses. More information meant more species and characteristics evaluated. For species without information, data from other members of its genus (congeners) or family were used.

RESULTS AND DISCUSSION

For the purpose of this study we considered all species brought into the country as introduced, even if they have not (yet) been reported from the wild, as in the case of most ornamental fishes. There are 159 fish species introduced into the country dating back from 1905 up to the present. These comprised of species from 25 families and 105 genera which have been introduced for aquaculture (18%), ornamental (77%), mosquito control (4%) and fisheries (1%). Several (24%) of these fish species have now been reported to occur in natural waters. **Table 1** provides the number of species, their introduction pathways in the country, and their corresponding reported establishment in Philippine waters. Note that for most of the species, there was no record of their fate after introduction nor of any place in the country where they have been brought to.

Based on the analysis of data (as presented in **Table 3**) resilience, maximum lengths, longevity and the degree of parental care are strong predictors of species establishment. On the other hand, resilience was the strongest predictor of adverse ecological impact. Species with higher resilience, smaller with short lifespan and high parental care (guarders and bearers) are more likely to establish in a favorable new environment. In addition, species with high resilience are directly correlated to the survival in adverse ecological impact. Since resilience is a combination of life-history parameters (growth, age at maturity, longevity and fecundity), it became obvious why it has been identified as the strongest predictor of adverse environmental impact. These species that are fast growing, early maturing, highly fecund with short life span were able to increase their population in any suitable new environment.

Table 4 shows the values of biological characteristics of species with reported establishment using all available introduction records including those from the Philippines. Records that provided no information on establishment were not included. As can be seen, except for trophic level, all examined biological characteristics were clearly different between the two groups. Species which have established in over 50% of countries where they have been introduced have higher parental care (60% are either bearers or guarders), shorter (average maximum length of 48.75 cm SL), short-lived (average longevity is about 11 years), resilient (~90% with medium or high resilience). Although there was a slight difference in the source natural environments of species with higher (62.4% were from tropical and subtropical sources) and lower establishments (51.51% were from tropical and subtropical sources), this may be an artifact of the dataset. Most of reported global species establishments were aquaculture species which were dominated by tropical and subtropical species.

Records were separately analyzed for reported adverse ecological impacts (**Table 5**).They were divided into two groups, those with >20% adverse impacts recorded composed the high impact group and those with <20% were designated as the lower impact group. As reported in an earlier study (*Casal and Froese 2004*), resilience was the only factor which showed significant correlation to adverse impact or invasiveness. However, looking at the current values from this study, degree of parental care, resilience, average maximum length, longevity and reported establishment elsewhere revealed a clear difference to reported adverse impacts. Invasive species with major ecological impacts have r-selected life history and reproductive traits– allowing achievement of massive population densities soon after invading a new habitat.

Tables 4 and 5 dealt with global species data while **Table 6** deal only with species which were introduced to the Philippines. Records were divided

Table 3. Species biological characteristics, assumptions on probability of establishment and evaluation

Species Characteristics	Probability of Establishment		How species were evaluated
	LOW	HIGH	
Kind of food taken in	Higher trophic level	Lower trophic level	Trophic level
Food Items	Narrow range	Wide range	Count of types of food
Temperature range (°C)	Narrow	Wide or matches that of receiving country	Temperature range
Climate	Narrow	Wide or matches that of receiving country	Environment where species is native.
Salinity range (ppt) (freshwater, brackish or marine)	Narrow	Wide	Count of types of salinity regimes
Longevity (years)	High	Low	Life span of the species (years)
Maximum length (SL)	High	Low	Size of longest individual recorded.
Reproductive guild	Non-guarders	Guarders, live bearers	Degree of parental care: non-guarders, guarders to internal bearers
Resilience (growth, maturity, fecundity, etc.)	Low	High	The capacity to withstand change or exploitation.
Reported establishment elsewhere	Low	High	% establishment from global information

Table 4. Biological characteristics of species with high (>50%, n= 336) and low (< 50%, n= 100) percentages of establishment, given as average or percentage across the respective group of species (*Froese and Pauly 2006*).

Species Characteristics	Establishment	
	High (>50%)	Low (<50%)
Reported establishment elsewhere (average %)	80.21	34.23
Average trophic level	3.19	3.28
Environment/Climate	45 tropical, 33 subtropical, 44 temperate, 3 others 62.4 (tropical and subtropical)	24 tropical, 10 subtropical, 26 temperate, 6 others 51.51 (tropical and subtropical)
Parental Care (% of species either bearer or guarder)	60	28.33
Average Maximum length (cm) (SL)	48.75	89.80
Average Longevity (years)	11.29	23.84
Resilience (% of species with medium and high)	88.71	34.33

Table 5. Biological characteristics of species with high (n= 48) versus low (n= 46) adverse impacts (*Froese and Pauly, 2006*).

Species Characteristics	% Adverse Impact Reported	
	>20% (high)	≤ 20% (low)
Average trophic level	3.17	3.23
Average maximum length (SL)	50	65
Average longevity in wild (years)	15.8	17.7
Parental Care (% of species either bearer or guarder)	55.2	47.4
Average reported establishment elsewhere (%)	78.3	61.8
Resilience (% medium and high)	89.3	79

Table 6. Biological characteristics of 159 species introduced to the Philippines, (*Froese and Pauly, 2006*).

Species Characteristics	Established (39 species)	Not Established (4 species)	Unknown (30 of 122 species)
Reported establishment elsewhere (average %)	64	47.31	50
Average trophic level	2.91	2.59	3.14
Environmental match	23 tropical, 9 subtropical, 7 temperate	1 subtropical, 3 temperate	25 tropical, 4 subtropical, 1 temperate
Parental Care (% of species either bearer or guarder)	56.41	50	56.67
Average maximum length (SL)	61.72	137.50	23.73
Longevity (years) (data not sufficient)	10.27	21	15
Resilience (% of species with medium and high)	92.31	50	96.67
Reason for introduction	25 aquaculture, 8 ornamental, 1 fisheries, 5 mosquito control	4 aquaculture	1 aquaculture, 28 ornamental, 1 mosquito control

into three categories, 1.) those which have been reported as established, 2.) those which have not established and 3.) those which have unknown establishment. Species which have established in the country were those which have: come from a similar climate (higher percentage of species from tropical and subtropical regimes), higher degree of parental care, smaller with relatively shorter life spans, higher resilience and reported establishment elsewhere. In contrast, those which have not established came mainly from temperate countries, had lower degree of parental care, were larger with relatively longer life spans, and had lower resilience and reported establishment elsewhere. However, species with unknown establishment were also composed of those with climate similarities to the country (higher percentage of species from tropical and subtropical regimes), higher degree of parental care, smaller size with relatively shorter life spans, higher resilience (higher than those which have established) and high reported establishment elsewhere.

This implies that the composition of species with unknown establishment was very similar to those which have established, meaning these species have a high probability of establishing feral populations or may have already established in the wild but have gone unnoticed and unreported.

SUMMARY AND CONCLUSION

Some alien fish species introduced to the country have definitely contributed to the food security of the country, providing a cheaper protein source. However, some of them have also had detrimental impacts to some indigenous and endemic species.

Species which have established in the country were those which have: come from a similar climate, have a high degree of parental care, are small with relatively short life spans, have high resilience and have reported establishment elsewhere. Many species which have unknown establishment in the country showed similar characteristics implying either: 1.) the species were already established however they have not been reported because of the paucity of available information or 2.) they have the potential to establish in the very near future.

Invasive species with major ecological impacts have r-selected life history and reproductive traits – allowing achievement of massive population densities soon after invading a new habitat.

This study of invasiveness potential correlated to biological and environmental characteristics can be a sieve that decision-makers can utilize to regulate or ban entry of specific species. This may lessen or put a stop to the entry of probable invasive species to an area.

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Journal of Environmental Science and Management 10(1): 10–23 (June 2007)
ISSN 0119-1144

Janitor Fish *Pterygoplichthys disjunctivus* in the Agusan Marsh: a Threat to Freshwater Biodiversity

Marianne Hubilla, Ferenc Kis and Jurgenne Primavera

ABSTRACT

The aim of this study is to verify reports on the presence of invasive alien catfish, known locally as janitor fish, including their possible impact on freshwater biodiversity in the Agusan Marsh, Northeastern Mindanao in southern Philippines. Morphological analysis, field sampling and questionnaire survey were conducted to determine the exact taxonomic status, habitat, distribution, and the population and size estimates of the fish. The results showed that the South American vermiculated sailfin catfish, Pterygoplichthys disjunctivus, a species earlier reported from Laguna Lake and nearby rivers in Luzon, northern Philippines, has invaded the Agusan Marsh. The exotic fish can be found in lakes, rivers and creeks of the municipalities of Talacogon, La Paz, Loreto, Bunawan, Rosario, San Francisco, Veruela and Sta. Josefa. They may also be present in upstream and downstream areas. Total catches of fishermen ranged from 0 to 146 individuals per fishing trip. Practical control measures to reduce the janitor fish population in the Agusan Marsh were discussed.

Keywords: Janitor fish, *Pterygoplichthys disjunctivus*, Agusan Marsh, invasive alien species

INTRODUCTION

Invasive species are considered a threat to aquatic ecosystems worldwide. Dramatic changes in species diversity, abundance and energy flow have been observed following the establishment of a single new species *(Vander et al 1999; Munro et al 2005)*. Many of the world's aquatic fauna are in immediate danger of extinction due to biological invasion. Oftentimes, invasive species displace native species, diminish diversity, disrupt ecosystems and cause significant economic impacts. About 80% of the world's endangered species are at risk due to non-native species introductions *(Armstrong 1995)*. In the United States alone, 400 of the 958 species listed as threatened or endangered under the Endangered Species Act are considered to be at risk because of competition with or predation by non-native species *(Wilcove et al 1998)*.

In the Philippines, well-known cases of biological invasion are the freshwater fishes that have been introduced to freshwater habitats. In the 2006 ichthyofaunal list in Fishbase, there are approximately 3,100 known species of fish in the Philippines, of which about 310 (10%) are found in freshwater habitats. About 221 (72%) of the freshwater fishes are native, 46 (15%) are endemic, 38 (12%) are introduced while 5 (1%) are questionable or not established.

In the 1980s and 1990s, the most alarming instance of aquatic invasion was the Nile tilapia, *Oreochromis niloticus* invasion. In Lake Lanao, Lanao del Sur province, *O. niloticus* was responsible for the displacement of more than 15 species of carp known to exist only in this lake *(Hubilla and Kis 2006)*. The introductions of *Glossogobius giurus (Guerrero 2002; Bianco 2005)* and *Micropterus salmoides (Bianco 2005)* in Lake Lanao also contributed to the displacement of carp species. Currently, these carp species fall under the Critically Endangered, Endangered, Vulnerable and Near Threatened species categories in the 2006 ichthyofaunal Red List of the International Union for the Conservation of Nature (IUCN). A similar case happened to "sinarapan", scientifically known as *Mistichthys luzonensis*, the smallest known commercial fish in the world, which is endemic to Lake Buhi and Lake Bato in Camarines Sur province (*Hubilla and Kis 2006*).

After the Nile tilapia was introduced in the 1950s for pond culture in the Philippines, the South American sailfin catfish, *Pterygoplichthys disjunctivus* and *P. pardalis* (previously known as *Hypostomus plecostomus*) were caught in the Laguna Lake and nearby rivers. The presumed mechanism of introduction was aquarium release and aquaculture farm escape *(Chavez et al 2006)*.

News reports in 2002 mentioned that the catfish population was escalating and that they were responsible for the decline in fishery catch, either by displacing commercially important fish species or by destroying fishing gear and fish cages *(Chavez et al 2006)*. Recently, one of these two invasive catfish, *P. disjunctivus* was reported from the Agusan Marsh. They were probably introduced through an intentional release within the Agusan Marsh Wildlife Sanctuary (AMWS), and possibly fish farm escapes upstream (near Davao) sometime between 2002 and 2005 *(Hubilla and Kis 2006)*.

The Agusan Marsh is one of the largest marshlands in Asia. It is also one of the ecologically significant wetland ecosystems in the Philippines of international importance. The Marsh is endowed with seven biologically important habitats, namely, floodplain and oxbow lakes, herbaceous swamps, peat forest, mixed swamps and the upstream, midstream and downstream areas of the Agusan River *(Davies 1993; Talde et al 2004); Hubilla and Kis 2006)*. The *Critical Ecosystem Partnership Fund (CEPF) (2001)* reported that the Eastern Mindanao Biogeographic Region, which includes the Agusan Marsh, is one of the ten priority protected areas in the Integrated Protected Areas System because this region has one of the largest remaining blocks of dipterocarp forest in the country. In fact, 75% of the country's extracted timber comes from this area. *CEPF* (*2001*) further added that the corridor is home to 85 bird species, 81% of all Philippine endemics recorded in the Mindanao Biogeographic Region; 25 endemic mammal species (57%), including two species found only in Dinagat Island; 36 endemic reptiles (53%), several of which are confined to Mindanao; 26 amphibians; 62 reptiles; and 16 amphibian species. Recent aquatic faunal inventory conducted by *Hubilla et al (2006)* show that the Agusan Marsh has about 40 known species of fish, 7 mollusks (2 bivalves, 5 gastropods), 6 crustaceans (2 crabs, 4 shrimps), and 6 reptiles (2 lizards, 2 turtles, 2 crocodiles). The Marsh is also home of the indigenous people, the Manobos, who live in floating houses in the marsh. They survive there by practicing agriculture, hunting and fishing *(Cembrano 1998)*. Thus, this 113,000-ha marshland, is a home for both aquatic organisms and indigenous people *(Hubilla and Kis 2006)*.

Freshwater biology in the Marsh has not yet been fully explored by researchers, which leads to the apprehension that the presence of janitor fish may change the present aquatic faunal composition before this can be fully studied.

The purpose of this study is to gather baseline information on the taxonomy, distribution, population and biology of the janitor fish in the Agusan Marsh, including its possible impacts on freshwater biodiversity.

METHODOLOGY

Description of the study area

The Agusan Marsh (8^{o}00'N–19^{o}00'N and 125^{o}52'E–126^{o}02'E) is a protected marshland located in Agusan del Sur, Northeastern Mindanao, in the southern Philippines (**Fig. 1**). This vast complex of freshwater marshes and water courses with numerous small shallow lakes and ponds is an important source of water irrigation in the province and supports the fishery and livelihood of the Marsh inhabitants. Besides fishing, marsh inhabitants also practice aquaculture and agriculture, mainly consisting of rice and corn crops. There is some confusion as to the correct area measurement of the Marsh. For the purpose of this study, we measured the Marsh area using ArcGIS 9 based on the forest and land use plan of the Department of Environment and Natural Resources (DENR), topography (of flood proneareas) and vegetation (peat forests and swamp areas) of Agusan del Sur, the proposed

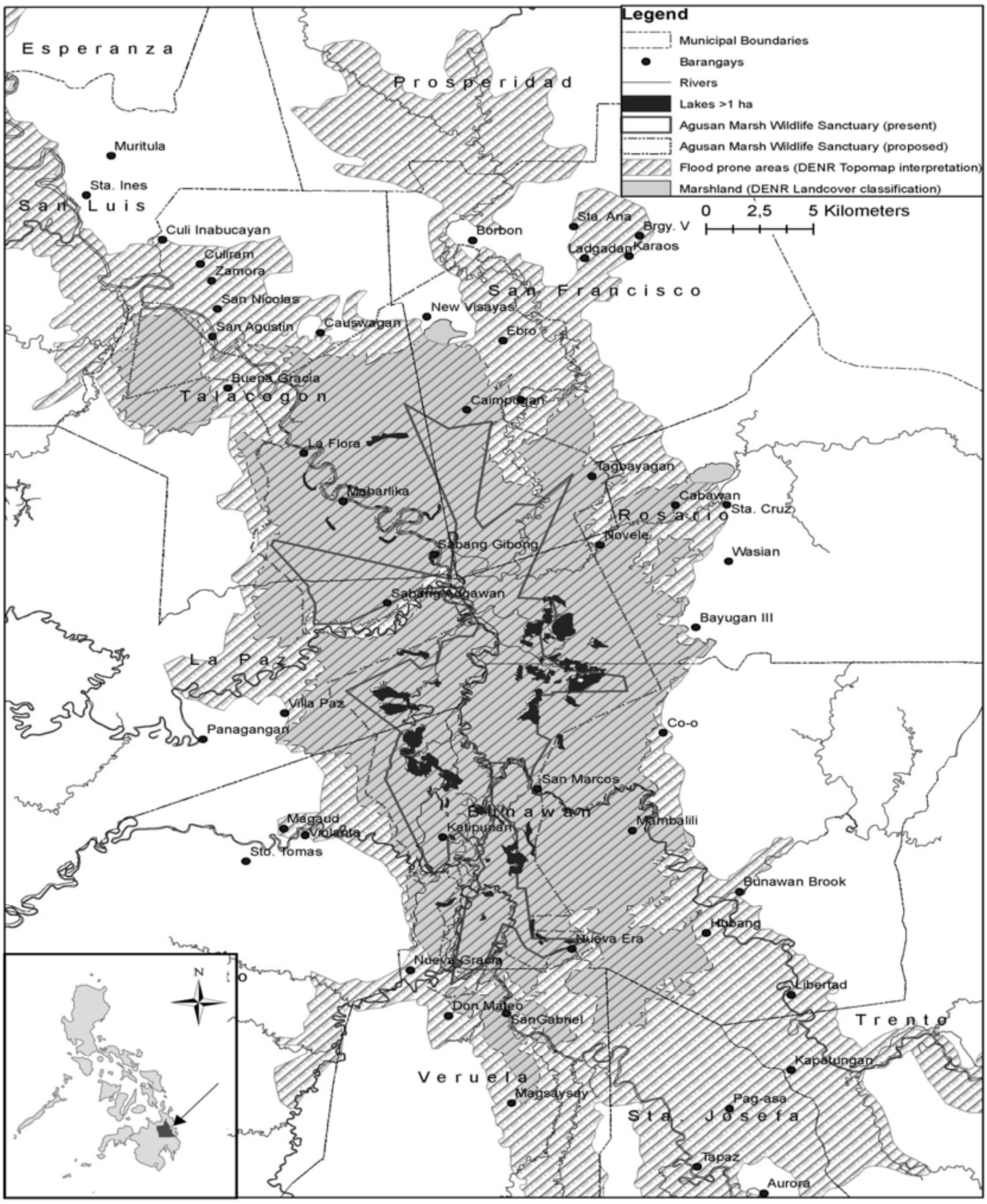

Fig. 1. Map of Agusan Marsh showing the present protected area as declared by the Ramsar Convention on Wetlands, the proposed protected area by the DENR and the flood prone areas of Agusan del Sur.

protected area of the DENR, and the protected area covered by the Ramsar Convention on Wetlands. Total Marsh area is 113,000-ha based on the forest and land use plan of the DENR; 110,000-ha based on the topography (ArcGIS 9 map data); 55,400-ha based on the vegetation (ArcGIS 9 map data); 40,868-ha based on the proposed protected area of the DENR; and 14,835.9-ha based on the declared protected area of the Ramsar Convention on Wetlands.

Sampling sites

Sampling for janitor fish was conducted by local fishermen using gillnet from April to July, 2006 in San Jose, Sta. Josefa (Hinaliman Creek and Lake Kabuhayan); Poblacion, Sta. Josefa

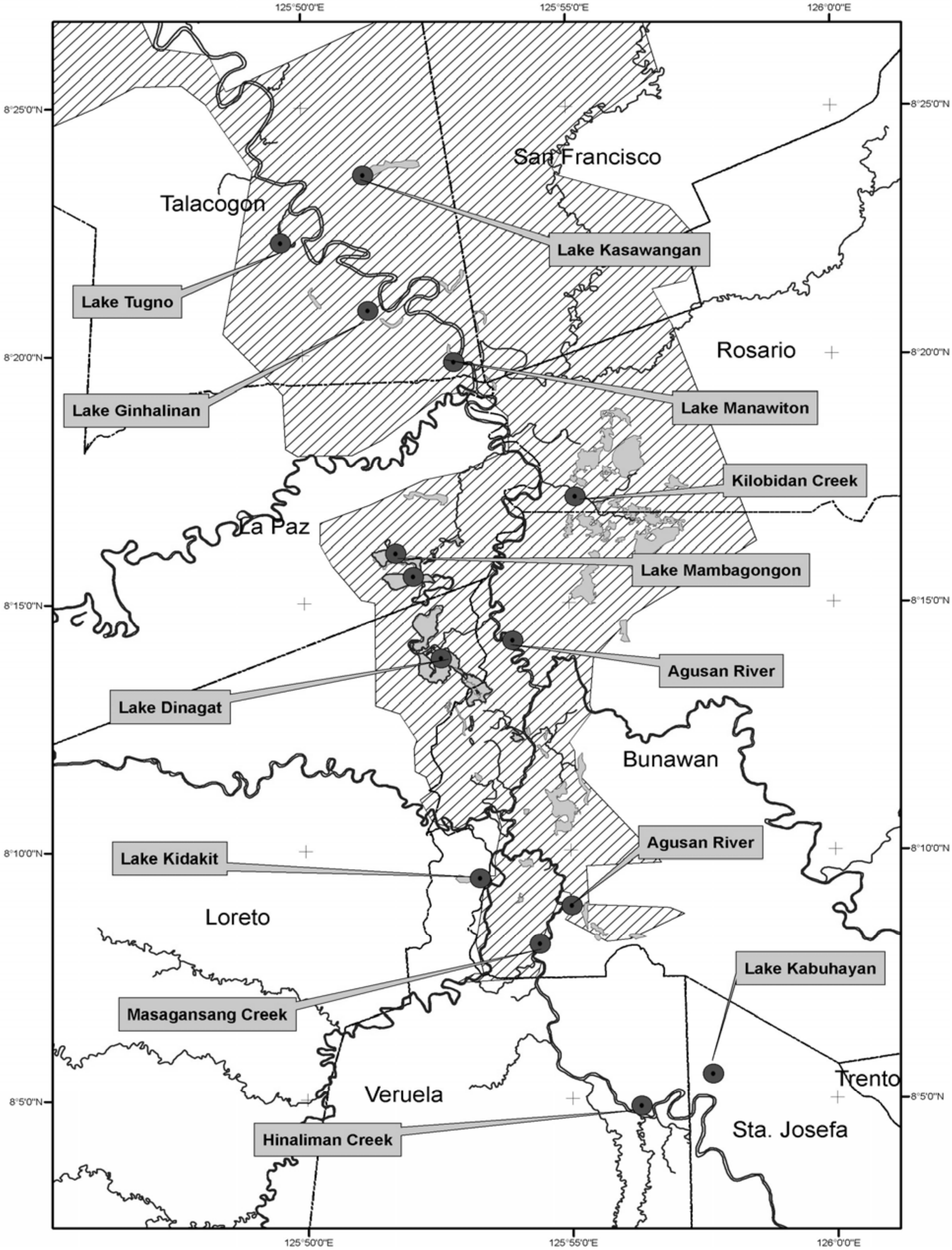

Fig. 2. Map of the Agusan Marsh showing the sites where fishing for janitor fish was conducted by local fishermen using gillnet.

(Agusan River); La Flora, Talacogon (Lakes Tugno, Kasawangan and Ginhalinan); Sabang-Adgawan, La Paz (Lakes Mambagongon and Manawiton); Katipunan, Loreto (Lake Kidakit); Osmena, Loreto (Agusan River); Villa Paz, Loreto (Lake Mambagongon); Kilubidan, Rosario (Kilubidan Creek); and Nueva Era, Bunawan (Masagansang Creek) (**Fig. 2**). Fishermen recorded the fishing ground, the number of janitor fish caught, and the smallest and longest lengths (total length) of the janitor fish caught.

Taxonomy

The external morphology of the fish was examined, specifically: body shape, mouth type; type of teeth; type of caudal peduncle; body color; total length (smallest and longest fish caught); number of anal and dorsal fins (spinous and soft rays); and the distinguishing characteristics (abdominal spots and vermiculations). Data on the external morphological features of the fish including photos were sent to Dr. Jonathan Armbruster, catfish expert and curator of fish at Auburn University, Alabama, USA for taxonomic identification.

Identification of habitat and distribution

To verify the presence of janitor fish, a questionnaire survey was conducted in the nine municipalities of Agusan del Sur: Bunawan (Brgys. Consuelo, San Marcos, Nueva Era, Mambalili); La Paz (Brgys. Villa Paz, Agpangon, Sabang-Adgawan and Poblacion); Loreto (Katipunan, Panlabuhan, Magaud, Nueva Gracia and Violanta); San Francisco (Brgy. Caimpugan); San Luis (Brgys. Baylo and Dimas-alang); Sta. Josefa (Brgys. San Jose); Talacogon (Brgys. Maharlika, La Flora and Sabang-Gibong); Rosario (Brgy. Novele) and Veruela (Brgys. Binuangan, Don Mateo). Habitat and distribution of the janitor fish were described and tabulated.

Population and size estimates based on catch data

A 12-hr fishing trip for janitor fish was conducted by local fishermen in coordination with the barangay captain and local officials using gillnet (length= 5 to 10 m; height = 1 to 2 m; mesh size = 2.5 to 5 cm) from April to July, 2006 in the following sites: San Jose, Sta. Josefa (Hinaliman Creek and Lake Kabuhayan); Poblacion, Sta. Josefa (Agusan River); La Flora, Talacogon (Lakes Tugno, Kasawangan and Ginhalinan); Sabang-Adgawan, La Paz (Lakes Mambagongon and Manawiton); Katipunan, Loreto (Lake Kidakit); Osmena, Loreto (Agusan River); Villa Paz, Loreto (Lake Mambagongon); Kilubidan, Rosario (Kilubidan Creek); and Nueva Era, Bunawan (Masagansang Creek).

Fishermen recorded the fishing ground, janitor fish catch, and the smallest and longest lengths (total length) of the janitor fish caught. Catch data was tabulated and the fishing grounds were classified as downstream, midstream and upstream areas based on their geographic location in the Marsh. Mean and total janitor fish catch were obtained.

Identification of possible impacts on freshwater biodiversity

Possible impacts of janitor fish on freshwater biodiversity were determined by comparing the habitats and diet composition of economically important fish species in the Agusan Marsh with that of the janitor fish. Other environmental and socio-economic impacts were also included and discussed. Proposed management schemes for the species were also drafted based on its impact to freshwater biodiversity. These schemes may be implemented by the Local Government Unit of Agusan del Sur to control and manage the janitor fish population in the area.

RESULTS AND DISCUSSION

Taxonomy

External morphological analysis showed that the janitor fish in the Agusan Marsh is *Pterygoplichthys disjunctivus* (previously known as *Hypostomus plecostomus*), as identified by Dr. Armbruster. The catfish has a long, tapered, dark brown body covered with rows of armor plating. Nearly all spots on the abdomen coalesce to form vermiculations. It has a sucker-mouth with viliform teeth. The caudal penduncle is short but slightly broad with an adipose fin and a forked caudal fin with one lobe longer than the other. The fish has one dorsal spine and twelve dorsal soft rays. The anal fin has one spine and four soft rays. The total length of the fish ranges from 7.6 to 61.0 cm (**Figs. 3-4**).

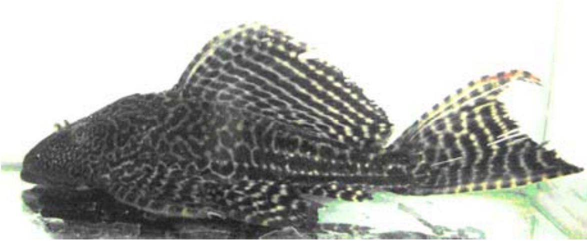

Fig. 3. Dorso-lateral view of *Pterygoplichthys disjunctivus* showing its body shape, dorsal fin and caudal fin and body color

Fig. 4. Ventral view of *Pterygoplichthys disjunctivus* showing its mouth and the vermiculated spots on the abdomen

Pterygoplichthys disjunctivus belongs to Family Loricariidae (Order Siluriformes), the largest catfish family with 80 genera and 680 known species *(Reis et al. 2003)*. They are characterized by large dorsal fins with 9 or more dorsal fin rays, presence of adipose fin, and an enlarged stomach connected to the dorsal abdominal wall by a connective tissue sheet *(Armbruster 1998)*. Loricariids with 10 or more dorsal fin rays are members of the genus *Pterygoplichthys*, and are referred to as sailfin catfish. The adult size of the janitor fish can range from up to 70 cm (total length) *(Nico and Fuller 2006)*, and has medium, minimum population doubling time of 1.4 - 4.4 years *(Fishbase, 2006)*.

Loricariids can be recognized by a ventral, suctorial mouth and jaws that are designed for rasping along submerged surfaces and they possess a very long gut where the food is processed. They are the largest algivorous family of fishes typically feeding on algae and the organic biofilm or detritus (which includes plankton, bacteria and algae) that covers submerged surfaces *(Armbruster 2002)*. Native to the Rio Madeira River drainage of Brazil and Bolivia *(Page and Robins 2006)*, *P. disjunctivus* is popular among fish hobbyists because of its ability to graze and remove attached algae and detritus on the aquarium tank, thus keeping the surfaces and sand clean, hence the common name, "janitor fish" *(Chavez et al, 2006)*. *P. disjunctivus* are voracious feeders and can tolerate adverse climactic conditions. Their morphological features make them difficult to be preyed upon, and their mode of living allows them to be an opportunistic species. With no natural predators, they can multiply fast and out-compete the native fish and other freshwater organisms on food and habitat *(Hubilla and Kis 2006)*.

Habitat and distribution

The results of the questionnaire survey conducted in nine municipalities (22 barangays) of Agusan del Sur showed that the janitor fish inhabits lakes, rivers and creeks in the Agusan Marsh but not the peat forest and mixed swamps (**Table 1**). *Hubilla and Kis (2006)* mentioned that the janitor fish was probably introduced through an intentional release within the Agusan Marsh Wildlife Sanctuary (AMWS), and possibly fish farm escaped upstream (near Davao) between 2002 and 2005. With no natural predators in the Marsh, they continued to proliferate, reaching several areas in Agusan del Sur such as the municipalities of Talacogon, La Paz, Loreto, San Francisco, Rosario, Bunawan, Trento, Veruela and Sta. Josefa. They may also be present in the upstream and downstream areas of the Agusan River. There have been reports of presence of janitor fish in Laguna Lake, Pasig River, Zamboanga City, Aparri Cagayan *(Chavez et al. (2006))* and Liguasan Marsh, North Cotabato province (undocumented report).

The natural *P. disjunctivus* habitat used to be limited to the rivers of the South American continent. Now, this species has spread across the globe and can be found in streams, canals and other water bodies such as in Hillsborough County, Florida *(Ludlow and Walsh 1991)*, Lake Thonotosassa, Florida and Baker Creek, South Carolina *(Page 1994)*, and in Asian countries like Singapore, Java and Taiwan *(Page and Robins 2006)*.

Table 1. Habitat and distribution of *Pterygoplichthhys disjunctivus* in the Agusan Marsh.

Municipality	Barangay	Distribution	Habitat
Bunawan	Consuelo	+	Rivers and creeks
	Mambalili	+	Rivers and creeks
	Nueva Era	+	Lakes, rivers and creeks
	San Marcos	+	Lakes, rivers and creeks
La Paz	Agpangon	+	Lakes, rivers and creeks
	Sabang-Adgawan	+	Lakes, rivers and creeks
	Villa Paz	+	Lakes, rivers and creeks
Loreto	Katipunan	+	Rivers and creeks
	Magaud	+	Rivers and creeks
	Nueva Gracia	+	Rivers and creeks
	Panlabuhan	+	Lakes, rivers and creeks
	Violanta	+	Rivers and creeks
Rosario	Novele	+	Rivers and creeks
San Francisco	Caimpugan	-	Peat forest, mix swamps
San Luis	Baylo	+	Rivers and creeks
	Dimas-alang	+	Rivers and creeks
Sta. Josefa	San Jose	+	Rivers and creeks
Talacogon	La Flora	+	Lakes, rivers and creeks
	Maharlika	+	Rivers
	Sabang-Gibong	+	Rivers
Veruela	Binuangan	+	Rivers and creeks
	Don Mateo	+	Rivers and creeks

Population and size estimates base on catch data

Population and size estimates of janitor fish in the Agusan Marsh were obtained from catch and length data, respectively (summarized in Table 2). There are more janitor fish in downstream (461 individuals) and upstream (160 individuals) areas, and their total length ranges from 7.6 to 61.0 cm. There are three possible reasons why the midstream area has the highest number of janitor fish: 1.) habitat diversity (many lakes, rivers and creeks); 2.) food diversity (plenty of detritus, algae and other decaying matter); and 3.) possible site of janitor fish introduction or release. The midstream area has fewer janitor fish (62 individuals) and this may be attributed to water salinity. The midstream area is close to the estuary and since the estuary is saline, the midstream can be relatively saline too, especially during high tide. Since janitor fish are a true freshwater species, they cannot tolerate a saline environment.

Possible impacts to freshwater biodiversity

Loricariids are endemic to South America and Panama (Southern and Central America). However, *Pterygoplichthys* could become widely established in Southeast Asia with negative impact on native species, most likely, the alteration of food web dynamics. *Pterygoplichthys* species are generally herbivores, and large populations can significantly alter the energy budget of a water body by reducing the amount of energy available to other herbivores, such as aquatic insects and other arthropods *(Kottelat et al 1993); Fuller 1998; Nico and Martin 2001)*. Reductions in the population of the arthropods will lead to reduced populations of other animals that feed on arthropods *(Inger and Chin 2002; Page and Robins 2006)*.

Table 3 shows the habitat and food of the janitor fish as compared to those economically important fish species in the Agusan Marsh. The data show that most of these species share the same habitat and food with the *P. disjunctivus*. Most of them are found in lakes, rivers, streams,

Table 2. Number of janitor fish caught by fishermen per fishing trip from April to July, 2006.

Date of fishing	Fishing ground	Barangay/ Municipality	Catch (no. of fish)	Lowest and longest total length (cm)
Upstream				
Jun 19	Hinaliman Creek	San Jose, Sta. Josefa	32	17.8 – 30.6
May 31	Lake Kidakit	Katipunan, Loreto	0	-
Jun 2	Lake Kidakit	Katipunan, Loreto	0	-
May 29	Masagansang Creek	Nueva Era, Bunawan	3	15.3 – 40.5
Jul 7	Agusan River	Poblacion, Sta. Josefa	10	10.1 – 25.4
May 30	Masagansang Creek	Nueva Era, Bunawan	5	15.3 – 25.4
Jul 9	Agusan River	Poblacion, Sta. Josefa	19	10.1 – 20.4
Jul 8	Agusan River	Poblacion, Sta. Josefa	14	15.3 – 33.1
Jun 21	Lake Kabuhayan	San Jose, Sta. Josefa	25	17.8 – 30.6
Jun 20	Hinaliman Creek	San Jose, Sta. Josefa	50	7.6 – 46.7
Jun 1	Lake Kidakit	Katipunan, Loreto	0	-
May 31	Masagansang Creek	Nueva Era, Bunawan	2	10.1 – 20.4
		MEAN	**13.0**	**9.9 – 22.8**
		SUBTOTAL	**160**	
Downstream				
Apr 11	Lake Mambagongon	Villapaz, Loreto	100	15.3 – 30.6
Apr 22	Agusan River	Osmena, Loreto	13	7.6 – 22.9
May 29	Lake Mambagongon	Sabang-Adgawan, La Paz	50	10.1 – 35.5
Apr 10	Lake Mambagongon	Villapaz, Loreto	50	15.3 – 30.6
Apr 20	Agusan River	Osmena, Loreto	10	10.1 – 20.4
May 31	Lake Manawiton	Sabang-Adgawan, La Paz	36	22.9 – 38.1
May 30	Kilubidan Creek	Kilubidan, Rosario	146	20.4 – 61.0
Apr 21	Agusan River	Osmena, Loreto	6	12.7 – 25.4
Apr 12	Lake Mambagongon	Villapaz, Loreto	50	15.3 – 30.6
		MEAN	**51.0**	**14.4 – 32.8**
		SUBTOTAL	**461**	
Midstream				
Jun 6	Lake Ginhalinan	La Flora, Talacogon	18	20.4 – 30.6
Jun 1	Lake Dinagat	Panlabuhan, Loreto	3	10.1 – 15.3
May 31	Lake Dinagat	Panlabuhan, Loreto	0	-
Jun 4	Lake Tugno	La Flora, Talacogon	12	20.4 – 30.6
Jun 2	Lake Dinagat	Panlabuhan, Loreto	6	10.1 – 20.4
Jun 5	Lake Kasawangan	La Flora, Talacogon	23	20.4 – 30.6
		MEAN	**7**	**9.0 – 14.2**
		SUBTOTAL	**62**	
		OVER-ALL MEAN	**26**	**26.7 – 14.2**
		TOTAL CATCH	**683**	

Table 3. Habitat and food of *Pterygoplichthys disjunctivus* as compared to the habitat and food of some economically important fish species in the Agusan Marsh.

Family	Species	Habitat	Food
Anguilidae	*Anguilla marmorata*	Streams, rivers, marine habitats *(James and Suzumoto 2006)*	Crustaceans, insects, amphibians, fish *(James and Suzumoto 2006)*
Anabantidae	*Anabas testudineus*	Low lying swamps, marsh lands, lakes, canals, pools, small pits, and puddles *(Jayaram 1981)*; medium to large rivers, brooks, flooded fields and stagnant water bodies including sluggish flowing canals *(Taki 1978)*	Plant debris, detritus *(Rainboth 1996)*, macrophytic vegetation, shrimps *(Pethiyagoda 1991)*, invertebrates, small fish *(Riehl and Baensch 1991)*
Chandidae	*Ambassis sp.*	Brackish-water, mangrove, estuarine and freshwater-stream habitats, usually within 20 km of the sea *(Allen 1991)*	Small aquatic insect larvae, insects from terrestrial source, small crustaceans *(Coates 1990)*
Channidae	*Channa striata*	Freshwater ponds and streams, usually in stagnant muddy waters *(Talwar and Jhingran 1992)*, rivers, lakes, swamps, rice paddies, mining pools, roadside ditches *(Lee and Ng 1991)*	Detritus *(Talde, Mamaril, and Palomares 2004)*, young fry feed on algae and protozoan; juveniles feed on small crustaceans; adults are highly carnivorous *(Conlu 1986)*, feeding on worms, prawns, frogs, small fishes *(Mohsin and Ambak 1983)*
Cichlidae	*Oreochromis niloticus*	Rivers, lakes, sewage canals, irrigation channels *(Bailey 1994)*	Phytoplankton *(Gwahaba 1973)*, algal filaments, diatoms, unidentified organic matter *(Fagade and Olaniyan 1973)*, blue-green algae *(Ofojekwu and Ejike 1992)*, detritus *(Talde, Mamaril, and Palomares 2004)*
Clariidae	*Clarias batrachus*	Swamps, ponds, ditches, rice paddies, pools left in low spots after rivers have been in flood *(Herre 1924)*, stagnant, muddy water *(Rahman 1989)*, medium to large-sized rivers, flooded fields, sluggish flowing canals *(Taki 1978)*	Insect larvae, earthworms, shells, shrimps, small fish, aquatic plants and debris *(Ukkatawewat 1999)*, detritus *(Talde, Mamaril, and Palomares 2004)*, rotifers, organic debris *(Rainboth 1996)*
	C. gariepinus	Quiet waters, lakes and pools; flowing rivers, rapids *(Teugels 1986)*	Insects, plankton, invertebrates & fish, young birds, rotting flesh and plants *(de Moor and Broton 1988)*
	C. macrocephalus	Shallow, open water and is capable of lying buried in mud for lengthy period if ponds & lakes evaporate during dry seasons; spawns in small streams *(Frimodt 1995)*; medium to large-sized rivers, stagnant water bodies including sluggish flowing canals, flooded fields *(Taki 1978)*	Aquatic insects, young shrimps, small fishes *(Ukkatawewat 1999)*
Cyprinidae	*Cyprinus carpio*	Large water bodies with slow flowing or standing water and soft bottom sediments, large turbid rivers *(Scott and Crossman 1973)*	Aquatic insects, crustaceans, annelids, mollusks, weed & tree seeds, wild rice, aquatic plants, algae *(Scott and Crossman 1973)*; detritus *(Rainboth 1996)*

	Puntius binotatus	Found below waterfalls in isolated mountain streams and on small islands inhabited by few other freshwater fishes *(Roberts 1989)*; medium to large rivers, stagnant water bodies including sluggish flowing canals and brooks *(Taki 1978)*	Zooplankton, insect larvae and some vascular plants *(Rainboth 1996)*
Eleotridae	*Ophiocara poro-cephala*	Brackish estuaries, river mouths and freshwater creeks *(Allen 1991; Kuiter and Tonozuka 2001)*; lower courses of rivers, often upstream from the tidal zone *(Rainboth 1996)*; young are usually found while wading in rocky creeks near the coast *(Allen 1991)*	Plant fiber and debris, fish fragments *(Rainboth 1996)*
Gobiidae	*Glossogo-bius giuirus*	Rivers *(Hoese 1986)*, inland freshwater bodies *(Keith et al. 1999)*, estuaries, sea *(Talwar and Jhingran 1992)*; occurs in canals, ditches, ponds *(Rainboth 1996)*, clear to turbid streams with rock, gravel or sand bottoms *(Allen 1991)*	Plant debris *(Talde, Mamaril, and Palomares 2004)*, fish bones, nektons *(Rainboth 1996)*
Loricariidae	*Pterygop-lichthys disjuncti-vus*	Rivers, streams, fishpond *(Page and Robins 2006)*, lakes *(Talde, Mamaril, and Palomares 2004; Chavez et al. 2006)*, marsh *(Hubilla and Kis 2006)*	Algivorous, detritivorous, insectivorous, granivorous, moluscivorous or scavengers *(Armbruster 2002)*
Megalopi-dae	*Megalops cyprinoides*	Adults are generally found at sea but young inhabit river mouths, inner bays and mangrove forests; in freshwater, it occurs in rivers, lagoons, lakes, swampy backwaters *(Allen 1991)*	Small fishes and crustaceans *(Fischer et. al 1990)*
Mugilidae	*Mugil sp.*	Coastal species *(Eschmeyer, Herald, and Hammann 1983)* that often enters estuaries and rivers *(Allen 1991; Thomson 1986; Yamada et. al 1995)*, usually in schools over sand or mud bottom *(Eschmeyer, Herald, and Hammann 1983)* and dense vegetation *(Billard 1997)*	Zooplankton, benthic organisms and detritus; adult fish tend to feed mainly on algae while inhabiting fresh waters *(Thomson 1951)*
Osphrone-midae	*Osphrone-mus gouramy*	Inhabits swamps, lakes and rivers *(Frimodt 1995)*, enters flooded forest *(Roberts 1993)*, found in medium to large rivers and stagnant water bodies including sluggish flowing canals *(Taki 1978)*	Detritus, plant debris, phytoplankton *(Rainboth 1996)*, feed on both plants and animals such as aquatic weeds, fish, frogs, earthworms, dead animals *(Ukkatawewat 1999)*
	Trichogas-er pectoralis	Shallow sluggish or standing-water habitats with a lot of aquatic vegetation, flooded forests *(Rainboth 1996)*	Algae, phytoplankton *(Rainboth 1996)*, detritus, insects, water mites, copepods, cladocerans, rotifers *(Talde, Mamaril, and Palomares 2006)*
	T. trichop-terus	Lives in lowland wetlands *(Vidthayanon 2002)*, marshes, swamps and canals *(Kottelat 2001)*, shallow sluggish or standing-water with a lot of aquatic vegetation, occurs in seasonally flooded forests *(Rainboth 1996)*	Detritus *(Talde, Mamaril, and Palomares 2006)*, zooplankton, crustaceans and insect larvae, cladocerans *(Rainboth 1996)*
Scatophagi-dae	*Scatopha-gus argus*	Inhabit harbors, natural embayments, brackish estuaries and the lower reaches of freshwater streams, frequently occurring among mangroves *(Mills and Vevers 1989; Kuiter and Tonozuka 2001)*	Worms, crustaceans, insects and plant matter *(Mills and Vevers 1989; Kuiter and Tonozuka 2001)*

creeks and canals, and feed on algae, detritus and other organic matters. Some species are euryphagous (they can be herbivores, carnivores, omnivores or scavengers) such as migratory scad and eels but they share similar habitats with *P. disjunctivus*.

The diet composition of some economically important fishes in the three floodplain lakes in the Agusan Marsh was studied by *Talde et al (2004)*. Results indicated that fishes of the same group in the Agusan Marsh have overlapping food choices and competition for food may possibly be higher among related species with overlapping food preferences. However, the order of preference for such food items differ in habitats, and the order of preference for these food choices were different in each of the related species of the same family.

Talde et al (2004) revealed that the importance of the non-living organic fraction (e.g. detritus) lies in the fact that it is a principal source of nutrition for primary consumer fishes. This non-living organic matter, which is selectively ingested by most fishes in the Agusan Marsh, is actually the extra-cellular matrix called the biofilm or detritus secreted by the microorganisms. Aside from detritus, freshwater fishes in the Agusan Marsh also feed on insects and insect larvae (dragonflies, ants, aquatic beetles, midge larvae, arachnids), mollusks larvae, crustaceans, copepods, cladocerans, rotifers and small fishes such as *Trichogaster trichopterus* and spotted barb, *Puntius binotatus*.

Environmental and socio-economic impacts

Aside from biological impacts, *P. disjunctivus* may also cause serious environmental and socio-economic impacts in the Agusan Marsh. Their burrowing behavior in river banks may contribute to water turbidity and soil erosion. High water turbidity alters the amount of light that can pass down through the water column, and thus, slows down photosynthesis. This may cause problems in the food web and the energy flow in the marsh ecosystem. On the other hand, local fishermen, especially the Manobos, complained that their gill nets were damaged while removing the janitor fish. Destruction of fishing gears subsequently Destroys their livelihood. Another problem of the fishermen is that *P. disjunctivus* now comprises the bulk of their catch. Target species for gill nets are tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*) and giant gourami (*Osphronemus gourami*). However, they end up catching more janitor fish than their target species.

Proposed management schemes

Based on the findings of the study, the janitor fish in the Agusan Marsh are considered threat to freshwater biodiversity. Their wide distribution in the Marsh may lead to increase in numbers rapid enough to displace the native fish species, because they are voracious feeders and they have no natural predators in the Marsh. The larger the number of janitor fishes in Agusan Marsh, the higher their corresponding contribution to water turbidity and soil erosion. Socio-economic impacts, such as the destruction of fishing gears and livelihood should be addressed accordingly before it gets worse. Therefore, we recommend the following management schemes for the species: 1.) conduct of long term assessment to monitor the status of janitor fish in the Agusan Marsh; 2.) purchase of janitor fish catches from the fishermen (through the provincial government of Agusan del Sur) by companies that can use them as raw material for leather, feeds and fertilizer; 3.) make use of the janitor fish for home and office décor; and 4.) strengthen the enforcement of wildlife and environmental laws in the country. For home and office décor, the fish will be preserved with 10% buffered formalin for two weeks, dried them under the sun for a month, then dipped in natural plant dye to make the dried fish more attractive. This could be a feasible source of livelihood for inland inhabitants.

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Journal of Environmental Science and Management 10(1): 24–33 (June 2007)
ISSN 0119-1144

Decline of Small and Native Species (SNS) in Mt. Isarog National Park: Impacts of Illegal Fishing and Introduced Exotic species

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ABSTRACT

The assessment of the impact of introduced exotic fish species into the small and native fish species covered 18 major rivers and 31 creeks spread all over 6 municipalities and a city bordering Mt. Isarog Natural Park (MINP). Considered as a distinct sub-region of the Southern Luzon biogeography zone because of its high genetic, species, and ecosystem diversity, other form of threats exist in MINP aside from the threats still perpetrated by forest-edged communities and external interest that caused the destruction of its natural habitats and degradation of interacting ecosystems.

The population of introduced fish species relatively increased by more than a quarter in ten-years time. From the combined estimated annual catch from both fishing methods used, the proportion of introduced fish species increased by 10% in 1988 to more or less one half of their proportions in catch relative to the native fish species in 2002. While the proportion of the endemic fish species relative to the introduced fish species caught from the same methods dropped from more than 80 percent to a little more than 50 percent over the ten-year period

It demonstrated that the introduction of exotic species has negatively affected the availability and the diversity of SNS in MINP areas with only the introduced fish species commonly sighted, while the sightings of the most endemic ones have become uncommon to extremely rare in the areas considered. Particularly, the invasion of introduced species to MINP waters in all probability caused the reduction of abundance of the native catfish to alarming level and could eventually lead to extinction. Biodiversity conservation measures should be implemented, assessment of the population of SNS, habitat enhancement, and repopulations strategies.

Keywords: Small and Native Fish Species, Mount Isarog Natural Park Biodiversity, Exotic Freshwater Fish Species, Threat Reduction Assessment

INTRODUCTION

Mount Isarog Natural Park (MINP) is one prominent land feature in the province of Camarines Sur encompassing six municipalities and a city. Covering an area of 10,112 hectares, MINP is home to a number of important species of the region. Several endemic species of birds, mammals and reptiles have been recorded in Mt. Isarog since 1961 and have been the basis for the conservation of its biodiversity. Close to 1,300 species of flora have been recorded and still more are studied for their endemicity. For this reason, MINP has been identified by the World Wildlife Fund (WWF) and International Union for the Conservation of Nature (IUCN) as one of the 18 Centers of Plant Diversity and Endemism in the Philippines and one of the 6 identified Centers for Animal Diversity and Endemism being part of the Luzon faunal region (*MINP GNP, 2001*). Among the resources inventoried for MINP conservation priorities, the small and native fish species (SNS) of aquatic ecosystems have received the least, if not given much attention.

Mt. Isarog is considered a distinct sub-region of the Southern Luzon biogeography zone because of its high genetic species and ecosystem diversity. Despite its immense value, direct and indirect threats to Mt. Isarog are still perpetrated by forest-edged communities and external interest groups in a manner and magnitude that cause the gradual erosion, dilution or replacement of indigenous and endemic genetic pool, deterioration of species'

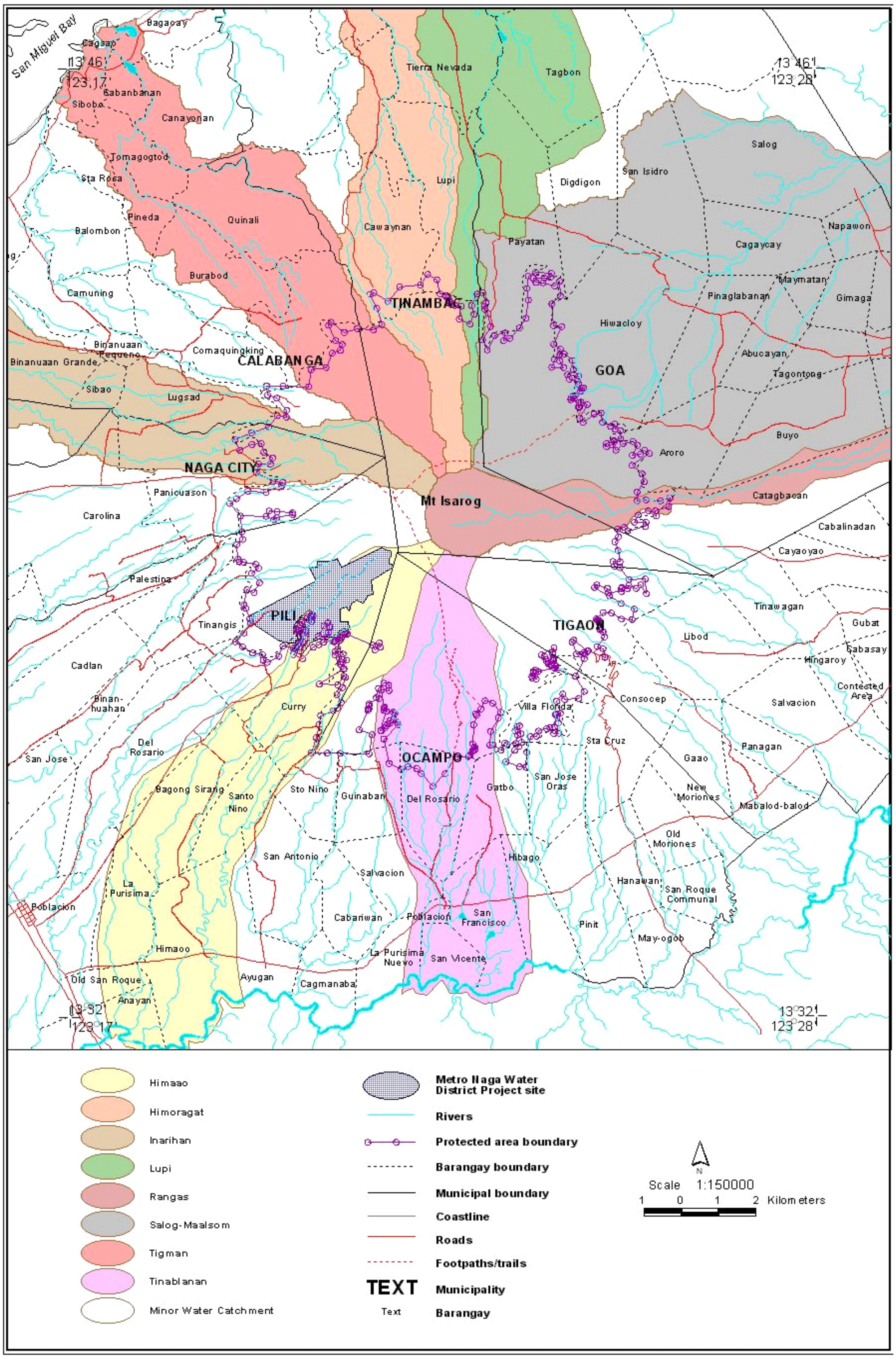

Fig. 1. Spot Map of Mt. Isarog showing major rivers and water bodies spread in 6 municipalities and a city surrounding it.

Table 1. Number of Households in MINP.

Municipality	Barangays close or within the PA	Total Population 1995 census	Total No. of Households	Average no. per Household	Land area in sq. km	Population density (ind/ km2)
Naga City	Panicuason	1,366	214	6.38	8.81	155.05
Ocampo	Del Rosario	1,269	214	5.93	5.23	242.64
	Gatbo	2,052	348	5.90	4.22	486.26
	Guinaban	1,004	175	5.74	4.16	241.35
	San Jose Oras	1,414	276	5.12	3.61	391.69
	Santa Cruz	1,182	211	5.60	5.55	212.97
	Santo Niño	634	112	5.66	2.83	224.03
	Villaflorida	502	102	4.92	2.67	188.29
Pili						
	Curry	2,159	394	5.48	8.75	246.74
	Del Rosario	2,068	383	5.40	7.15	289.23
	Santo Niño	817	150	5.45	3.29	248.33
	Tinangis	2,163	348	6.22	4.00	540.75
Tinambac						
	Lupi	1,184	211	5.61	8.66	136.72
	Cawaynan	1,152	213	5.41	12.59	91.50
Goa						
	Aroro (San Pedro)	703	137	5.13	6.07	115.82
	Catagbacan	2,561	484	5.29	14.36	178.34
	Hiwacloy	1,696	303	5.60	13.49	125.72
	Payatan	1,542	293	5.26	10.80	142.78
Tigaon						
	Consocep	261	62	4.21	3.24	80.56
	Libod	987	180	5.48	7.77	127.03
Calabanga						
	Comaguinking	1,080	187	5.78	6.06	178.27
	Harubay	1,184	225	5.26	5.79	204.44
	Lugsad	839	153	5.48	5.77	145.51
	TOTAL	**29,819**	**5,375**	**5.91**	**154.86**	**192.55**

richness and evenness, destruction of natural habitats, and degradation of interacting ecosystems.

The Threat Reduction Assessment (TRA) a low-cost, practical alternative to more cost-and-time-intensive approaches to measuring the success of biodiversity conservation interventions was done in two phases in MINP. The first phase was done in April – May 2002 covering a total of an estimated area of 293,845.99 hectares and the freshwater bodies in 23 barangays of the six municipalities and a city surrounding it. The second phase was done in March 2004 covering the same barangays.

The results of the TRA was intended to provide the Protected Area Management Board and the stakeholders with the information on the status of the threats to its biodiversity in terms of the area covered, urgency and percentage reduction of threats. Among the threats identified by the participant stakeholders include electric fishing and poison fishing and are considered among the ten highest-ranking threats to its biodiversity (*Bradecina, 2004*). Of the ten, electric fishing ranked 3rd, while poison fishing ranked 10th.

The views of community folks on the estimated annual catch of the small and native fish species (SNS) from these identified threats to the aquatic ecosystem, the study not only yielded vital information that provided indicative evidence of the decline in production of fishery resources in MINP water bodies due to pressure from the identified threats, but also the decline in the population of SNS possibly due to invasion by the introduced exotic fish species. Exotic species of fishes have been accidentally introduced into the environment when farmers started their aquaculture in the early 80s (*Dickson et al., 2002*). This paper explores the context of this development in terms of the impact of the

Table 2. Communities Covered and the Corresponding Freshwater Bodies IN MINP covered by the Assessment.

Municipality /City	Barangay	Assessment Period	No. of Years	Main catchments/ Rivers	Remarks (no. of tributaries, creeks, falls)
1. Calabanga	1. Harubay	1990-2002	12	Tigman River	4 rivers
	2. Lugsad	1989-2002	13		1 river
	3. Comaguinking	1992-2002	10		2 rivers
2. Naga City	1. Panicuason	1992-2002	10	Inarihan River	2 falls, 2 springs
3. Pili	1. Sto. Nino	1982-2002	20	Himaao River	
	2. Curry	1982-2002	20		2 falls
	3. Tinangis	1980-2002	22		2 creeks
	4. Del Rosario	1989-2002	13		2 creeks
4. Ocampo	1. Guinaban	1982-2002	20	Tinablanan River	1 river
	2. Gatbo	1988-2002	14		2 springs, 2 creeks
	3. S. Jose Oras	1992-2002	10		2 springs, 2 rivers
	4. Villaflorida	1989-2002	13		2 rivers
	5. Sto. Niño	1989-2002	13		1 river, 1 creek
	6. del Rosario	1985-2002	17		3 springs, 3 creeks
5. Tigaon	1. Libod	1992-2002	10	Rangas River	2 rivers, 3 creeks
	2. Consocep	1989-2002	13		3 falls, 2 rivers, 2creeks
6. Goa	1. Digdigon	1992-2002	10	Salog-Maalsom River	6 creeks,1 lakelet
	2. Hiwacloy	1992-2002	10		3 rivers,1 creek
	3. Catagbacan	1980-2002	22		3 rivers
	4. Payatan	1983-2002	19		2 rivers, 1lakelet, 8 creeks
	5. San Pedro	1992-2002	10		3 rivers, 3creeks
7. Tinambac	1. Cawaynan	1990-2002	12	Himoragat River Lupi River	4 rivers
	2. Lupi	1988-2002	14		4 falls

introduced fish species on the SNS biodiversity as inputs for their rational management.

The MINP has 18 major rivers and 31 creeks spread all over the 6 municipalities and a city surrounding it (**Fig. 1**). These rivers drain in San Miguel Bay at the northwestern section, in the flood plains of the province in the west to southwestern section, and as far as Lagonoy Gulf in the southeastern section. From their source inside the park are numerous tributaries, connected to these rivers. They do not only serve to irrigate more than 15,000 farmlands in these municipalities and a city but also provide habitat to small and native species of fish that provide cheap protein source to more than 5,000 households living within the communities of the MINP (**Table 1**).

METHODOLOGY

The data used were the result of the Biodiversity Threat Reduction Assessment (TRA) done in two phases in MINP. The first phase conducted in April 2002 covered 23 barangays and their freshwater bodies. The second phase was done in March 2004 covering the same barangays. Both phases of assessment covered an estimated area of 293,845.99 hectares encompassing 18 major rivers and 31 creeks traversing the MINP-rim municipalities of Pili, Ocampo, Goa, Tigaon, Tinambac, Calabanga and the city of Naga. The rivers and creeks by barangays covered by the two assessment phases are presented in **Table 2**. The average assessment period adopted for Phase 1 TRA was 12 years, based on a range of 10-22 years. Participants to the threat reduction assessments represented the barangay and municipal governments, PAMB, municipal departments (LGOO, MAO, MPDO, MAO), government agencies (DENR, PAO, CENRO, DepEd, DSWD, DOH) tribal councils, Sangguniang Kabataan, CBOs organized by SuMMIT, e.g., PAPCO, SMBI, MASADIGDI, LISTO, ISA, BAGPLAI, MAYCANDA, LBCDAI, PICDAI, etc.), Aksyon Bata, farmers and agricultural producers group (DFIA, SNPFDAI, SNSPWA), Plan Families Association, Parents and Teachers Association, Pastoral Council, Senior Citizens, Women in Nation Building (WIN), Sampaguita Club, Rural Improvement Club, Community-Based Biodiversity Monitoring Group (CBBMG), Mount Isarog Guardians (MIGs), forest rangers, academe, and CARE Philippines.

The data that form part of the indicators used in assessing poison and electric fishing threats such as catch volume, species composition of catch, and relative frequency among sites were processed and analyzed.

The composition of catch was calculated using percentage. The catch was categorized into introduced fish species and endemic fish species. The introduced species was used to refer to exotic fish species like Thai catfish and Nile tilapia believed by stakeholders not native to MINP. Endemic species refer to the native species endemic to Mt. Isarog and its adjacent areas.

Relative frequency was calculated by giving a single score to the reported observations of catch of the fish species in each site by both fishing methods used. The percentage occurrence of each fish species is determined by dividing the sum of the frequencies observed per site by the number of sites and multiplied by 100.

RESULTS AND DISCUSSION

A more obvious effect of the introduction of exotic species is manifested in the species composition of the estimated catch for electric and poison fishing in MINP in 2002. The most noticeable is the increase in abundance of freshwater eel (Local name: Kasili; Sc. name: *Anguila sp*.), Nile tilapia (Local name: Tilapia: Sc. name: *T. nilotica*) and Thai catfish (C. batrachus). The substantial decline of native catfish (local name: *Pantat*, Sc. name : *C. macrocephalus*), native mudfish (local name: Talusog, Sc. name: *O. striatus*) and a small freshwater goby (Local name: Oroon, Sc. name: ?) can be observed (**Table 3**). These estimates of fish population from fish catch reflect an emerging pattern of species succession in MINP dominated by introduced and catadromous fishes.

Table 3. Species Composition from Combined Estimated Annual Fish Catch from Electric and Poison in 2002

Species	**Fish Catch (Kg)**			
	Electric fishing	**Poison Fishing**	**Combined**	
	N	N	N	%
Hito	150	16	166	17.5
Tilapia	271	2	273	28.8
Talusog	5	1	6	0.6
Kasili	408	26	434	45.8
Oroon	3	9	12	1.3
Kalayuhan	50	0	50	5.3
Kiskisan	0	2	2	0.2
Pantat	0	1	1	0.1
Karpa	4	1	5	0.5
Total	891	57	948	100

The slow invasion of MINP freshwater ecosystems by introduced exotic fish species is evident in the observed change in catch composition parallel with declining catch rates over years. Back in 1989, catch composition of introduced species caught by poison fishing merely comprise 14 % of the total annual catch estimate. This more than doubled to 31% ten years later. On the other hand, endemic fish species comprised 86 % of the total annual estimates of catch by poison fishing in 1989, but declined to 69% after ten years. Over a ten-year period, population of endemic species in MINP as determined from fish catch by poison fishing was reduced by 17 %, while a similar proportion was noted in the increase of

Table 4. Relative Abundance of Species from Estimated Annual Catch by Poison Fishing In MINP.

Year	**Introduced Species**			**Native Species**		
	Species	Kg	%	Species	Kg	%
1999						
	Hito	631	13	Talusog	52	1
	Tilapia	57	1	Kasili	3682	75
				Oroon	405	8
				Kalayuhan	14	0
				Kiskisan	25	1
				Pantat	25	1
				Karpa	1	0
	Total	*688*	*14*		*4204*	*86*
2000						
	Hito	15.5	28	Talusog	1	2
	Tilapia	1.5	3	Kauli	26	47
				Oroon	9	16
				Kalayuha	0	0
				Kiskisan	2	4
				Partot	0	0
				Karpa	1	1
	Total	*17*	*31*		*38*	*69*
% Increase (Decrease)			17			(-17)

Table 5. Relative Abundance of Species from Estimated Annual Catch by Electric Fishing in MINP.

Year	**Introduced Species**			**Native Species**		
1999	Species	Kg	%	Species	Kg	%
	Hito	418.3	13	Talusog	314	9
	Tilapia	582	18	Kasili	1744	53
				Oroon	21	1
				Kalayuhan	214	6
				Kiskisan	2	0
				Pantat	0	0
				Karpa	18	1
	Total	*1000.3*	*30*		*2313*	*70*
	Increase (Decrease)					
2000	Hito	150	17	Talusog	5	1
	Tilapia	271	30	Kasili	408	46
				Oroon	3	0
				Kalayuhan	50	6
				Kiskisan	0	0
				Pantat	0	0
				Karpa	4	0
	Total	*421*	*47*		*470*	*53*
% Increase (Decrease)			17			-17

Table 6. Relative Abundance of Species from Combined Estimated Annual Catch by Poison and electric Fishing in MINP.

Year	**Introduced Species**			**Endemic Species**		
1999	Species	Kg	%	Species	Kg	%
	Hito	781	10	Talusog	366	5
	Tilapia	639	8	Kasili	5426	68
		1420		Oroon	426	5
				Kalayuhan	228	3
				Kiskisan	27	0
				Pantat	25	0
				Karpa	19	0
	Total	*1420*	*18*		*6517*	*82*
	Increase (Decrease)					
2000	Hito	165.5	17	Talusog	7	1
	Tilapia	272.5	28	Kasili	455	47
		438		Oroon	12	1
				kalayuhan	50	5
				Kiskisan	2	0
				Pantat	0	0
				Karpa	5	0
	Total	*438*	*45*		*530*	*55*
	Increase (Decrease)		27			27

introduced species' relative catch (**Table 4**). Except for a marked difference in their catch volumes, these situations are almost duplicated in the estimated annual catch estimates from electric fishing in MINP for the same period (**Table 5**).

Overall, the composition of the introduced fish species in the observed estimated catch relatively increased by 27%, while the endemic species correspondingly declined on the same magnitude over a ten-year period. A lower estimated 18% catch for introduced species against an 82% catch for endemic species was noted in the species composition reckoned from the estimated fish catch in 1988. A reversed scenario was shown in the observed estimated catch in 2002 with the proportion of introduced fish species climbing to 45% against the endemic species falling to 55%. (**Table 6**).

An analysis of the relative frequency distribution of perceived estimates of fish catch in freshwater bodies of the 22 communities (covering 7 LGUs) is presented in **Table 7**. Among the SNS, Thai catfish (*C. batrachus*) and freshwater eel (*Anguila sp*) figured predominantly by 23 % having been reportedly observed in all of the sites considered. This is followed by Nile tilapia (local name: Tilapia: Sc. n.: *Tilapia nilotica*) (19%), having been seen to occur in five out of six sites, and mud fish (Local name: Talusog, Sc. name: *O. striatus*) (12 %), having been observed caught in three out of six sites. The rarely caught species are native freshwater goby (Local name: Oroon, Sc. name: ?) and native carp (Local name: Karpa, Sc. name: *C. carpio*) (both 8%), native cichlids (Local name: Kalayuhan, Sc. name: ?) and (Local name: Kiskisan, Sc name: ?) (both 4 %). The disappearance of the native catfish (Local name: Pantat, Sc. name: *C. macrocephalus*) can be observed from the non-mention of the species having been caught in all of the sites (**Table 7**).

The population of SNS as gleaned from estimated catch from electric fishing and poison fishing could be arranged in this order of decreasing importance: Thai catfish and freshwater eel >Nile tilapia for commonly caught species. For the rarely caught SNS, the arrangement in decreasing importance is in this order: native goby (Local name: Oroon, Sc. name: ?) and native

Table 7. Relative Frequency Distribution of Estimated Fishes Caught by both Electric and Poison Fishing in Aquatic Ecosystems of Local Government Units in MINP in 2002.

Species	Municipality						Total	
	Calabanga	Pili	Ocampo	Tigaon	Goa	Tinambac	N	%
Hito	1	1	1	1	1	1	6	23
Tilapia	1	1	1	1	1		5	19
Talusog		1	1		1		3	12
Kasili	1	1	1	1	1	1	6	23
Oroon	1	1					2	8
Kalayuhan		1					1	4
Kiskisan	1						1	4
Pantat							0	0
Karpa		1	1				2	8
						Total	26	100

carp (Local name: Karpa, Sc.name; C. carpio) > native cichlids (Local name: Kalayuhan; Sc. name: ? and Local name: Kiskisan, Sc. name:?).

These observations are suggestive of the impact of introduction of exotic species against the SNS population that inhabits the freshwater habitats in MINP. The dominance of eel is partly explained by the annual up-migration of elver stocks to the riverine systems of the MINP from the beaches of Lagonoy Gulf. This helps explain the high resilience of the eel despite the continuing pressure from electric and poison fishing. Species with fewer percentages like the native goby, Oroon, the native carp, the native cichlids, Kalayuhan and Kiskisan have started to become less common to extremely rare in the communities cited. The absence of native catfish in all of the freshwater bodies among the six municipalities surrounding MINP is indicative of its threatened status, though these require more intensive investigation in the field for confirmations.

CONCLUSION AND RECOMMENDATIONS

Although exploratory, the brief appraisal via threat reduction assessment has highlighted concerns relating to the impact of introduced fish species to the availability of SNS in the freshwater bodies of municipalities around MINP. The data gathered can only provide indicative count of SNS population and diversity in MINP resultant to the invasion of alien species in its aquatic ecosystems. Standard assessment procedures and indicators are needed to quantify the impact of these invasive alien species and secure the actual estimate of the SNS stocks population in the freshwater ecosystems of MINP.

While the declining trend of the perceived volume of catch through poison and electric fishing methods could be attributed to either the reduction of incidences of illegal fishing activities due to successful integrated conservation development initiatives in MINP since 1998, or Malthusian over fishing (*Pauly et al. 1998*), it is very much evident that the introduction of exotic species has negatively affected the availability and the diversity of SNS in MINP areas. Among the SNS, the population of the endemic fish species is the most threatened. The resiliency of the native freshwater eel is explained by the fact that some tributaries and rivers of the MINP that are adjacent to Lagonoy Gulf and San Miguel Bay are recognized as fry grounds by folks.

As found out in this study, of the SNS, only the introduced fish species are commonly sighted, the rest particularly the most endemic ones have started to decline in number since their sightings or estimate of catch from massive and destructive form of fishing methods available have become uncommon to extremely rare in the areas considered. The invasion of introduces species to MINP waters in all probability caused the reduction of abundance of the native catfish to alarming level due to its aggressive feeding behavior (*Na-nakorn et al, 2002*). Such could eventually lead to extinction.

The following facts and key issues in the MINP constraints SNS biodiversity conservation andexotic species management: limited local institutional capacity for freshwater ecosystem biodiversity management; and the issues and economic contribution of freshwater ecosystem biodiversity are not adequately recognized and appropriately integrated in development plans The LGUs lack the personnel with capability for planning and implementing initiatives for rational management of SNS. This is a common fact among institutions that hinders effective freshwater ecosystem biodiversity conservation and management. There are no adequate mechanisms to ensure sustainable use of biodiversity due to lack of sound knowledge on freshwater biodiversity that result in stakeholders having different perceptions on the economic, social and cultural values of biodiversity.

According to the Convention on Biological Diversity (CBD), “Invasive alien species are species introduced deliberately or unintentionally outside their natural habitats where they have the ability to establish themselves, invade, out compete natives and take over the new environments.” Parties to the CBD are expected to prevent the introduction of, control or eradicate those alien species, threaten ecosystems habitat (Article Bh of CBD).

The convention intends to protect the aquatic ecosystem and its biodiversity against introduction of exotic species in the natural habitats. Full implementation of the goals of this convention must be done that should include: sustained monitoring of incidences of introduction of exotic species into the ecosystem; IEC on invasive alien species; advocacy for protection of endemic fish species by CBOs; and enactment of ordinance protecting endemic fish species against introduction of exotic species The Local Government Code of 1992 provides some sections that will help LGUs confront the concern for capability building through community-based fish sanctuary management in partnership with some stakeholders.

Equally urgent are the following recommendations that will prevent the impending collapse of the SNS population and loss of valuable endemic SNS species due to invasion of alien species and illegal fishing: assessment of the population of SNS, habitat enhancement, and repopulations strategies. Given the importance of the SNS for the subsistence of upland folks, the integration of SNS into aquaculture systems in the lowland areas of MINP may be an effective method of increasing their availability to the local population and to conserving the reservoir of biological diversity that they represent.

The culture of native fish species such as native catfish would provide an alternative way to reduce adverse environmental of caused by alien species. The stakeholders and government agencies should extend more effort on developing culture systems for native catfish with sufficient concern on genetic management of cultured stocks. In addition to increasing income from aquaculture, the use of native species could contribute to the conservation of native species.

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ACKNOWLEDGEMENT

The authors would like to thank the following: Dr. Rosa F. Macas, Regional Director of the Bureau of Fisheries and Aquatic Resources-Region IVA, for her support and funds used in the study; Ms. Madeleine Paras of the South Harbor Laboratory for the microbial analyses; UP-NSRI, Diliman, Quezon City for the heavy metal analyses; LGUs of Binangonan, and Jala-Jala, Rizal, Siniloan, Laguna and Taguig, Metro Manila and fish corral operators; and BFAR-RFRDC-FFRS staff, Mr. Generoso Panisales and Ms. Natividad Efondo in the collection of janitor fish samples.

Journal of Environmental Science and Management 10(1): 34–41 (June 2007)
ISSN 0119-1144

Habitat Disturbance and the Ecology of Small Mammals in the Philippines

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ABSTRACT

The unique mammal fauna of the Philippines, which includes one of the highest concentration of endemic species in the world, is dependent on natural forest habitats. Currently, perhaps less than 8% of the original primary forest cover of the Philippines remains intact, although many areas retain disturbed forest or support second-growth. Recent field surveys conducted across gradients of habitat disturbance reveal how native and non-native small mammals (rodents and insectivores) respond to disturbance. In general, non-native pest species are restricted to areas of heavy human disturbance where they may become very abundant. On geologically young islands where there are few native species, some non-natives may be common in undisturbed mature forest. On older islands with many native species, non-natives are absent or very rare in mature forest, although they often occur in remote disturbed sites that are surrounded by mature forest. In general, native species are most diverse and abundant in habitats that are relatively undisturbed, but many occur in disturbed forest and some persist in second-growth. A few native species reach peak abundance in moderately disturbed habitats. Occurrence patterns indicate that non-native species readily colonize disturbance sites and are predominant in severely disturbed habitat, but are unable to invade areas of intact forest that support rich communities of native small mammals. Native species have variable tolerance for disturbance; many can persist in moderately disturbed habitat and can re-colonize areas that have been severely disturbed (i.e., deforested) if such areas are allowed to regenerate. These results suggest that protection of remaining forests together with restoration of degraded habitats can be an effective conservation strategy for native small mammals.

Keywords: forest, habitat disturbance gradients, mammals, native, non-native

INTRODUCTION

More than a century ago, Oldfield Thomas described a remarkable series of small mammals from Mt. Data in the highlands of northern Luzon (*Thomas 1898*). Since then, knowledge of Philippine biodiversity has increased tremendously and now zoologists recognize that the country supports one of the world's most distinctive faunas (*Heaney and Regalado 1998*). However, our understanding is far from complete. With each passing year, undescribed species continue to be discovered and additional areas of the country are recognized as unique centers of biodiversity (*Rickart et al 2005; Heaney et al 2006; Balete et al (a & b) in press*).

The evolutionary history and ecological relationships of Philippine mammals have been shaped by their dependence on natural forest habitats. Unfortunately, nearly all areas of the country have seen the degradation of old-growth forests and it is obvious that forest destruction is the primary threat to Philippine wildlife (*Heaney and Regalado 1998*; **map ref**). However, the manner in which species and communities respond to different levels of disturbance, as well as their responses to habitat restoration, are largely unknown.

Over the past several years, we have conducted field surveys of mammals at sites throughout the country using standardized methods (*Heaney et al. 1998*). These surveys have produced comparative data on local mammal faunas by assessing patterns of species richness and relative abundance across elevation gradients (*Rickart 1994; Heaney 2001*). Although these surveys have focused on areas with the "best" habitat that presumably support the most intact animal communities, they also have

Table 1.Non-native small mammals occurring in the Philippines (*Heaney et al. 1998*).

Scientific name	Common name	Distribution in Philippines	Habitat distribution
Suncus murinus	Asian house shrew	widespread	widespread (including forest)
Mus musculus	House mouse	widespread	narrow (buildings)
Rattus argentiventor	Rice-field rat	widespread	narrow (cropland)
Rattus exulans	Polynesian rat	widespread	widespread (including forest)
Rattus nitidus	Himalayan rat	Luzon only	narrow (cropland)
Rattus norvegicus	Brown rat	widespread	narrow (buildings, cropland)
Rattus tanezumi	Oriental house rat	widespread	widespread (including forest)
Rattus tiomanicus	Malaysian field rat	Palawan only	widespread (including forest)

involved sampling in disturbed areas, allowing some generalizations on how mammals respond to disturbance (*Rickart 1994*).

This research summarized information on the disturbance ecology of native and non-native (=alien) small mammals of the Philippines (rodents and insectivores) with respect to rodent ecology and conservation. The distribution of species across gradients of habitat disturbance ranging from nearly pristine forest to severely disturbed agricultural lands was documented, thereby information on both the disturbance tolerance of native species and the conditions that promote invasion by non-native species was presented. Furthermore, comparative data from second growth habitat and secondary forests in the process of recovery from past disturbance allowed us to make generalizations on the potential for faunal restoration.

MAMMALS AND ISLANDS

The mammals discussed in this paper include both native and non-native species of rodents and insectivores. Currently, only eight non-native small mammals are known from the Philippines, including some that are firmly established and geographically widespread and others that have restricted distributions (**Table 1**; *Heaney et al 1998*). Most notable are two species of *Rattus*, the Oriental Horse rat, *(R. tanezum*) and the Polynesian rat, (*R. exulans)* both of which are very significant pest species that occur throughout country, and the house shrew, *Suncus murinus.* Native small mammals include a wide assortment of rodents of the family Muridae (mice and rats), and insectivores of the families Soricidae (shrews) and Erinaceidae (gymnures). Native murids include members of several genera that are endemic to the Philippines, and include many species that have very restricted geographic distributions (*Steppan et al 2003; Jansa et al 2006*). Native shrews (genus *Crocidura*) also occur throughout the country, whereas the gymnures (*Podogymnura*) are restricted to the Mindanao faunal region.

Data included here were derived from faunal surveys conducted by the authors and their associates over the past two decades at survey sites on the islands of Leyte, Biliran, and Maripipi (*Heaney et al 1989; Rickart et al 1993*), Mindanao (*Heaney et al in press*), Camiguin (*Heaney and Tabaranza 1997; Heaney et al 2006*), Catanduanes (*Heaney et al 1991*), Negros (*Heaney et al 1989*), Sibuyan (*Goodman and Ingle 1993*), and at multiple sites on Luzon (*Rickart et al 1991, in prep.; Heaney et al 1999, 2005, unpublished data; Balete et al submitted*).

METHODS

Trapping surveys involved standardized field methods described elsewhere (*Rickart et al 1991; Heaney et al 1999, in press*). At each survey locality, we continued sampling until the number of species recovered appeared to level off, indicating that results were adequate for assessing basic patterns of species richness and relative abundance. Sites were assessed as to levels of anthropogenic disturbance, and in some cases we obtained specific information on disturbance history (e.g., number of years since forest clearing or selective logging). We recorded characteristics of collection locations to determine microhabitat preferences of species, and also collected data on diet, diurnal-nocturnal activity patterns, and reproductive habits. Captured animals were preserved as museum voucher specimens or released at the place of capture.

RESULTS AND DISCUSSION

In general, native Philippine mammals are closely associated with, and dependent upon, natural forest habitat (*Heaney and Regalado 1998*). This is clearly reflected in distributions across local disturbance gradients in Luzon; native species are most diverse in relatively undisturbed habitat, and decline in diversity with increasing levels of disturbance (**Tables 2 - 4**). Occurrences across disturbance gradients tend to form a pattern of "nested" groups of native species in which assemblages at highly disturbed sites are subsets of those in less disturbed habitats, which in turn are subsets of the most diverse communities found in minimally disturbed habitats (**Tables 2 and 3**). Data on relative abundance (**Table 5**) indicates that some native species are actually more abundant in moderately disturbed habitats than they are under more pristine conditions.

The ecological distribution of non-native species is strikingly different from that of natives. On large islands such as Luzon and Mindanao, non-native species generally are restricted to disturbed habitats (*Heaney et al 1989; Rickart et al. in prep.*). Some, such as the house mouse (*Mus musculus*), are found only in close association with buildings, whereas others (e.g., *R. exulans* and *R. tanezumi*) are more widely distributed in croplands, brushy second growth, and disturbed forest. In general, the occurrence and relative abundance of non-native species is dependent on the degree of habitat disturbance; the number of species and their abundance tends to increase with increasing levels of disturbance (**Tables 2-4**). Although non-natives are clearly rare in mature forest habitat on Luzon and Mindanao, they occur infrequently in such places, particularly in areas of local disturbance such as along heavily used trails, or where there is natural disturbance as in areas with frequent wind damage from storms or on steep slopes prone to landslides. The presence and numerical dominance of non-natives in pockets of heavily disturbed sites that are surrounded by intact forest (where they are rare or absent) indicates great capacity for invasive dispersal (Heaney et al. 1999, in press; unpublished data).

Non-native species have very different occurrence patterns on islands that have few native species either because they are geologically young (such as Negros) or relatively small (such as Camiguin and Maripipi). On such islands, some non-native species have become "naturalized"; they occur in relatively undisturbed mature forest where they may become abundant and even numerically dominant (*Heaney and Tabaranza 1997; Heaney et al 1989, 1998, 2006; Rickart et al 1993*).

The occurrence of small mammal species across gradients of habitat disturbance is not at all random. Strongly nested patterns indicate that factors regulating both the invasion potential of non-native species and the persistence of native species tend to shape local communities in a predictable manner. For non-native species, the most fundamental requirements for successful invasion of forest habitat include proximity to a local colonization source, life history characteristics that drive rates of population growth and dispersal, and ecological tolerances (both biotic and abiotic). For native species, persistence appears to be determined by ecological factors such as the degree of habitat specificity and other specializations, adaptation to natural disturbance, and ability to cope with novel conditions in altered habitats.

The non-native mammals now present in the Philippines appear to have originated on mainland Asia and arrived in the country through human agency. At least some of them (e.g., *Suncus murinus* and *Rattus exulans*) appear to have reached the Philippines and other island groups prehistorically (*Wilson and Reader 2005*). There are relatively few species that are widespread in the Philippines (**Table 1**), but these include three that are most often encountered in forests (*Suncus murinus, Rattus exulans, R. tanezumi*). Compared to native species, non-natives have large litters, rapid growth and maturation rates, and consequently great potential for rapid growth and spread of invasive populations. However, non-natives have variable ecological tolerances; species such as

Table 2. Occurrence of small mammals across a disturbance gradient. Balbalasang, Kalinga, Luzon.

Native species	**Mature forest**	**Regenerating forest**	**Fire-maintained pine forest**	**Crop edge second-growth**	**Rice terrace**
Rattus everetti	present	present	present	present	-
Chrotomys whiteheadi	present	present	present	present	-
Phloeomys pallidus	present	present	present	present	-
Apomys datae	present	present	present	-	-
Apomys microdon	present	present	-	-	-
Bullimus luzonicus	present	present	-	-	-
Archboldomys sp.	present	-	-	-	-
Batomys granti	present	-	-	-	-
Carpomys phaeurus	present	-	-	-	-
Chrotomys silaceus	present	-	-	-	-
Rhynchomys soricoides	present	-	-	-	-
Crocidura grayii	present	-	-	-	-
Non-native species					
Rattus exulans	-	present	present	present	present
Rattus tanezumi	-	-	present	present	present
Disturbance level	low	intermediate	intermediate	high	highest

Table 3. Occurrence of small mammals along a disturbance gradient on Mt. Banahaw, Quezon, Luzon.

Native species	**Montane forest (1400 m)**	**Regenerating lowland forest (620 m)**	**Cropland & second-growth (620 m)**
Rattus everetti	present	present	present
Bullimus luzonicus	present	present	
Apomys microdon	present	present	
Apomys musculus	present		
Apomys sp. 1	present		
Apomys sp. 2	present		
Rhynchomys sp.	present		
Crocidura grayi	present		
Undescribed murid genus		present	
Non-native species			
Rattus tanezumi			present

Table 4.—Occurrence of small mammals across a disturbance gradiant, Mt. Natib, Bataan, Luzon.

Native species	**Mature forest**	**Regenerating forest**	**Ridge top disturbed forest**	**Mixed second-growth**
Rattus everetti	present	present	present	present
Chrotomys mindorensis	present	present	present	present
Apomys sp.	present	present	present	
Apomys microdon	present		present	present
Bullimus luzonicus	present			
Non-native species				
Suncus murinus			present	present
Rattus exulans			present	present
Disturbance level	low	intermediate	intermediate	highest

Table 5. Relative abundance of small mammals across a disturbance gradiant, Mt. Natib, Bataan, Luzon.

	Mature forest	**Regenerating forest**	**Ridge top disturbed forest**	**Mixed second-growth**	χ^2	***P***
total trap nights	817	531	700	550		
total captures	39	43	45	59		
trap success (%)	4.8	8.1	6.4	10.7		
Native species						
Rattus everetti	3 (0.37)	3 (0.56)	6 (0.86)	**15 (2.73)**	**19.98**	**< 0.001**
Chrotomys mindorensis	2 (0.24)	2 (0.38)	4 (0.57)	3 (0.55)	1.21	n.s.
Apomys sp.	31 (3.79)	**38 (7.16)**	23 (3.29)	**31 (5.64)**	**12.12**	**< 0.01**
Apomys microdon	2 (0.24)	0	1 (0.14)	0		
Bullimus luzonicus	1 (0.12)	0	0	2 (0.36)		
Non-native species						
Suncus murinus	0	0	**8 (1.14)**	2 (0.36)	**15.68**	**< 0.001**
Rattus exulans	0	0	3 (0.43)	**6 (1.09)**	**13.57**	**< 0.01**
total trap nights	817	531	700	550		
total captures	39	43	45	59		
trap success (%)	4.8	8.1	6.4	10.7		
Disturbance level	low	intermediate	intermediate	highest		

Note: Chi-square values and probabilities are for comparisons of species observed abundances across the gradient compared to expected values based on trapping effort and total number of captured animals. Values in parentheses are the number of individuals trapped per 100 trap-nights. Values greater than expected are in bold.

the house mouse (*Mus musculus*) and brown rat (*Rattus norvegicus*) appear to be true commensals. They are largely restricted to human dwellings and other buildings and apparently have very limited tolerance for conditions away from buildings. Accordingly, these species are very unlikely to invade forest habitats even if these are heavily disturbed.

In contrast, *Rattus exulans*, *R. tanezumi*, and *Suncus murinus* can successfully adapt to natural conditions and are therefore more likely to become established in forest habitats. The most important factor determining the invasion success of these species involves their interactions with native mammals. Our data from islands with different levels of native faunal diversity indicates that the likelihood of invasion of non-natives into forest habitat is inversely related to native species richness. On islands where native communities are very species-poor, invasion can occur even in relatively undisturbed habitat, but where native communities have high species richness non-natives are rare or absent except where disturbance levels are high. This strongly suggests that in healthy habitats, native mammals have a competitive advantage and a rich native community is resistant to invasion by non-natives (*Rickart 1994; Heaney et al 1999, in press*).

Based on distributions across disturbance gradients, native species can be categorized with respect to their inferred disturbance tolerance. Some species restricted to habitats that are minimally disturbed presumably have the lowest tolerance. These include locally endemic species that may be relatively uncommon even under the most favorable conditions. Some, such as *Rhynchomys* or *Carpomys* on Luzon (**Table 2**) have dietary or other specializations that may render them unusually vulnerable to habitat disturbance. Even if they are relatively intolerant to disturbance, species that are abundant in primary forest may also occur in disturbed habitat adjacent to forest simply by virtue of their numerical dominance.

Several native species can persist in disturbed habitats, and some may even reach peak abundances in areas of moderate disturbance. *Rattus everetti* is geographically widespread and occurs over a broad range of habitats. In mature forest, this species is often found in areas of natural forest, this species is often found in areas of natural disturbance such as tree falls, and as an ecological generalist it appears to be "pre-adapted" to disturbance (*Heaney et al in press; unpublished data*). The large arboreal cloud rats (*Phloeomys*) also are commonly associated with disturbed sites. Although largely folivorous, they apparently have a wide dietary tolerance and can persist even in areas of intense disturbance, particularly when these are near remnant forest (*Heaney et al 1991, 1999, 2005*). Although specialized worm-eating rodents such as *Rhynchomys* and *Archboldomys* are relatively intolerance of disturbance, the vermivores *Chrotomys mindorensis* and *C. whiteheadi* are highly tolerant and may be locally common even in highly disturbed croplands (**Tables 2-4**). In part, this appears to be due to the ability of these species to feed on non-native earthworms and other invertebrates that may be abundant in disturbed areas (*Stuart 2004; Rickart et al 2005, in prep*.).

Surveys of communities in areas of disturbed but regenerating habitat are particularly interesting because they provide insight into the potential for biological restoration. Areas known to have been heavily disturbed in the past (in some case, entirely deforested) but then allowed to regenerate naturally now support some native mammals (***Tables 2–4***). It can be inferred that these areas have experienced a corresponding reduction in non-native species over time. These results suggest that native species are capable of re-colonizing degraded habitat as it regenerates, thereby reversing the cycle of degradation and dominance by non-natives. However, this capacity is dependent on the retention of at least some intact forest habitat as a colonization source. Although we know that some native species can re-establish after recovery times of only a few years or decades, we do not know how long complete recovery would take. Furthermore, there is no information on whether non-volant mammals act as agents for habitat restoration in a manner similar to fruit bats (*Utzurrum 1995, 1998; Ingle 2003*).

These results have important implications for conservation of terrestrial communities in the Philippines. Clearly, protection of all remaining mature forests, particularly those in lowland areas, remains the highest priority. It is equally clear that protection of secondary forest and the restoration of natural forest communities on previously disturbed lands should also be a very high priority. Available data suggest that invasive mammals do not, at present, pose a major threat to the native mammal fauna of the Philippines. This is in contrast to the situation seen elsewhere in the world, such as on Madagascar where non-native *Rattus* may be a major threat to native Malagasy mammals (*Goodman 1995*). The only places in the Philippines where invasive non-natives may pose a threat to native species are on islands that are naturally species poor, but at present we do not have the necessary data to examine this possibility. It is also important to emphasize that the introduction of any additional non-native mammals to the Philippines may well represent an important potential threat.

FUTURE DIRECTIONS

Comparative surveys along disturbance gradients clearly provide powerful insight into the ecology of invasive species and the conservation of native communities. Additional surveys of this sort are needed throughout the Philippines. Additionally, there is a critical need for direct information on the ecology and behavior of Philippine mammals, especially from telemetry or mark and recapture studies (*Balete and Heaney 1997*). Studies of the population dynamics, movement patterns, and reproductive biology of both native and non-native in relation to habitat disturbance would be particularly informative in clarifying conditions that either allow invasive species to become established or enable native communities to resist invasion. On islands such as Negros, studies on the ecological interactions of the native endemic species with the "naturalized" non-natives are needed to clarify the conservation status of such areas. Long-term studies should be initiated to determine how small mammal communities respond to habitat regeneration, including the potential role of non-volant mammals as agents of seed dispersal or in shaping forest invertebrate communities. Finally, although this study deals only with non-volant mammals, disturbance gradient studies reveal responses of bat communities that are equally informative and worthy of further investigation (*Rickart 1994; Utzurrum 1998*).

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Journal of Environmental Science and Management 10(1): 42–47 (June 2007)
ISSN 0119-1144

REVIEW PAPER

Red-bellied Pacu in the Philippines

Arsenia G. Cagauan

ABSTRACT

Exotic species, particularly those introduced in the ornamental aquarium fish trade industry, some of which have origins in South America and Africa contribute to fish fauna diversity in the country. They have very well adapted to the Philippines as the climatic conditions are very much similar to their places of origin. One of the ornamental aquarium fishes that has adapted very well in the Philippines is the red-bellied pacu, a native of Brazil and a food fish in South America, introduced to the Philippines in the 1980s. The fish can now be reproduced and cultured in ponds for use as an ornamental fish.

Pacus are native of the Amazon and Orinoco basins in South America. It is an aquaculture species and important fish in capture fishery in South America but an expensive ornamental fish in the Philippines. In the Philippines, the red-bellied pacu spawn naturally in riverine condition and can also reproduce through artificial spawning using hormone. The production of red-bellied pacu is still confined in aquaculture ponds.

Although basically a plant eater, it was found to exhibit molluscivorous eating habit when it controlled the abundance of the golden apple snail Pomacea canaliculata in simulated rice field in screenhouse condition. Large-sized pacu was found to damage 20-day old transplanted rice plants by cutting and uprooting them while small-sized pacu did not damage the rice plants. The damage that it caused the rice plants mimics that of rat damage. The molluscivorous feeding may be a potential invasive impact when loose to the natural waters as it may impact on native mollusks such as the native snail Pila conica and freshwater clam Corbicula manilensis.

Keywords: red-bellied pacu, *Piaractus brachypomus*, *Colossoma macropomum*, snail control, *Pomacea canaliculata*, Philippine alien species

Introduction

Introduced aquarium ornamental fishes have contributed to fish fauna diversity in the Philippines. In fact, most of the aquatic organisms with invasive reports are introduced alien species from the ornamental fish industry. Most of these introduced alien species coming from South America and Africa have adapted and reproduced very well in the Philippine condition. An ornamental fish that grows very well in freshwater is the red-bellied pacu and first reported as *Colossoma bidens*, *C. mitrei* and *C. macropomum* and lately *Piaractus brachypomus*, all refer to species of pacus. These pacu species are South American fishes which are native of Brazil, Peru and Venezuela that mainly feed on plants and detritus and have also been reported to feed on zooplankton, insects, snails and decaying plants (*FishBase 2000*). Based from the records of Fishbase (*2000*), there were 11 introductions to different countries outside its native range. It was introduced to the Philippines as an ornamental aquarium fish from Singapore between 1984-1986. Mallari farm of Tanay, Rizal was the first who cultured and reproduced this fish in the country. On February 25, 1997, another introduction of pacu was done by the private sector which was allegedly mixed with piranha. There are now several hatcheries in the Philippines reproducing this fish by hormone injection mainly for ornamental aquarium purposes. There is a concern to grow it as food fish in ponds.

The purpose of this paper is to describe the biology, feeding habits and recent research on the use of red-bellied pacu as biological control for

Table 1. Species of pacu and their common names and importance. (*Fishbase 2000*)

Pacu species	Common name	Importance
1. *Batrachoides surinamensis*	Pacuma toadfish	Aquarium fish
2. *Colossoma macropomum*	Blackfin pacu Tambaqui	Aquaculture food fish Aquarium fish
3. *Metynnis aregenteus*	Pacu marreca	Aquarium fish
4. *Myleus pacu*	Pacu dente	Food fish
5. *Myleus rhomboidalis*		Food fish
6. *Myleus rubripinnis*	Redhook myleus	
7. *Myleus schomburgkii*	Black ear pacu; disk pacu	
6. *Myleus ternetzi*		Aquarium fish
8. *Myleus torquatus*	Pacu bronco	
9. *Mylossoma aureum*	Pacu comum; pacu manteiga	
10. *Mylossoma duriventre*	Pacu comum; pacu manteiga	
11. *Piaractus brachypomus*	Red-bellied pacu; Pirapatinga	Aquaculture food fish Aquarium fish
12. *Piaractus mesopotamicus*		

Table 2. Characteristics and other features of *C. macropomum* and *P. brachypomus* (*Fishbase 2000*)

Common name/scientific name	Length (cm)	Weight (kg)	Feeding Habit	Native occurrences and introductions to Asia	Other features	Importance
1. Red-bellied pacu *Piaractus brachypomus*	Max= 45 cm	Max= 25 kg	Feed mainly on plants/detritus, fruit; Feeds on zooplankton, insects, snails and decaying plants; possesses powerful dentition that can crush hard food and cause serious bites	Occur in the Amazon and the Orinoco Basins 1984- Taiwan to Malaysia 1985- Hong Kong to China 1985- Taiwan to Indonesia 1986- Brazil to Taiwan	Head round and broader adipose fins rayed	Aquaculture and capture fishery in South America Ornamental fish in Asia
2. Black fin Pacu/Tambaqui *Colossoma macropomum*	Max= 95 cm Common= 70 cm	Max= 30 kg	Feed mainly on plants/detritus, fruit; Feeds on zooplankton, insects, snails and decaying plants; Have strong teeth that can chew hard nuts that fall in water during flowering season. Feed on feces, fish, algae and wood	Occur in the Amazon and the Orinoco Basins 1980-1986- Singapore to the Philippines 1986- Taiwan to Indonesia 1986- Brazil to Taiwan Unknown- Taiwan to China	Head longer and narrower adipose fins rayed	Aquaculture and capture fishery in South America Ornamental fish in Asia

Fig. 1. Three major genera of pacus. (*Fishbase,2000*)

golden apple snail *Pomacea canaliculata*. Moreover, this paper will attempt to differentiate the characteristics of a red-bellied pacu (pirapatinga) (*Piaractus brachypomus*) and blackfin pacu *Colossoma macropomum* ("tambaqui). Potential invasive impacts of pacu on biodiversity and potential contribution of this fish as food source are discussed in this paper.

Biology and Feeding Habit

The information on the morphological characteristics and biology of pacus found in this paper heavily relied on Fishbase (*2000*) as there are only few available references. Pacus belong to the Characidae family in the order of Characiformes and subfamily Serrasalmidae which is grouped into pacus and piranhas. The pacus are plant eaters and some species are excellent sources of food in South America while the piranhas having some species that are carnivores and herbivores (*Vari and Weitzman 1995*). There are 12 species of pacus based from the records of Fishbase (2000) as listed in **Table 1**. The pacu reported in the Philippines is referred in different scientific names such as *Colossoma bidens*, *C. mitrei* and *C. macropomum* and *Piaractus brachypomus*. It can be noted that *C. bidens* and *C. mitrei* are not found in the list. *C. bidens* is a junior synonym for *Piaractus brachypomus* while *C. mitrei* for *P. mesopotamicus*. Based from the record of Fishbase (*2000*), *C. macropomum* was introduced to the Philippines between 1980-1989 but there is no record of introduction to the Philippines

The *Piaractus, Colossoma* and *Mylossoma* genera are considered structurally different from the other pacu species because of the absence of the predorsal spine. *Mylossoma* is referred to silver dollar fish while the other two genera are pacus. The differences in these three genera can be seen in picture in **Figure 1**. Generally, half of the 12 pacu species are traumatogenic, a behavior considered dangerous, and exhibited in the piranhas. The *Piaractus brachypomus* and *Colossoma brachypomum* have teeth that are powerful and can cause serious bites. The juveniles of *P. brachypomus* mimic the red-belied piranha *Pygocentrus nattereri*.

The *C. macropomum* reported from the Philippines is differentiated with *P. brachypomus* in terms of the average weight they can attain i.e. 30 kg and 25 kg, respectively (**Table 2**). *C. macropomum* can attain a maximum length of almost a meter (95 cm) but the most common size is 70 cm. The maximum size *P. brachypomus* can attain is 45 cm. Both fishes possess powerful teeth that can crush fruits, snails and plants. Red-bellied pacu is a plant eater and also consume the golden apples snails (*Cagauan and Joshi, 2002*). Both fishes eat also insects, zooplankton, fruits and detritus. The head of *C. macropomum* is longer and narrower compared with *P. brachypomus* that has a head that is round. At the Bluebay Aquaculture farm in Munoz, Nueva Ecija, sexual maturity starts at 4-5 years old, with length about 40 cm and weight 1-1.5 kg. In the same farm, pacu breeders are reproduced by hormone injection using breeders 1-1.5 kg. Male breeders have been noted to be larger than the female. Sexual dimorphism exists such that the urogenital papillae, hidden by flaps of muscles, are two and rounded for female and one and oblong for male (**Figure 2**). Both fishes have rayed adipose fins. Based from the several characteristics discussed, *P. brachypomus* seemed to fit the red-bellied pacu rather than *C. macropomum.*

Importance of pacu

In the Philippines, pacu is used as an ornamental fish. In South America, it is a food fish. FAO

Figure 2. Male and female pacu urogenital papillae (photos above) and body size (photo below). (*AGCagauan*)

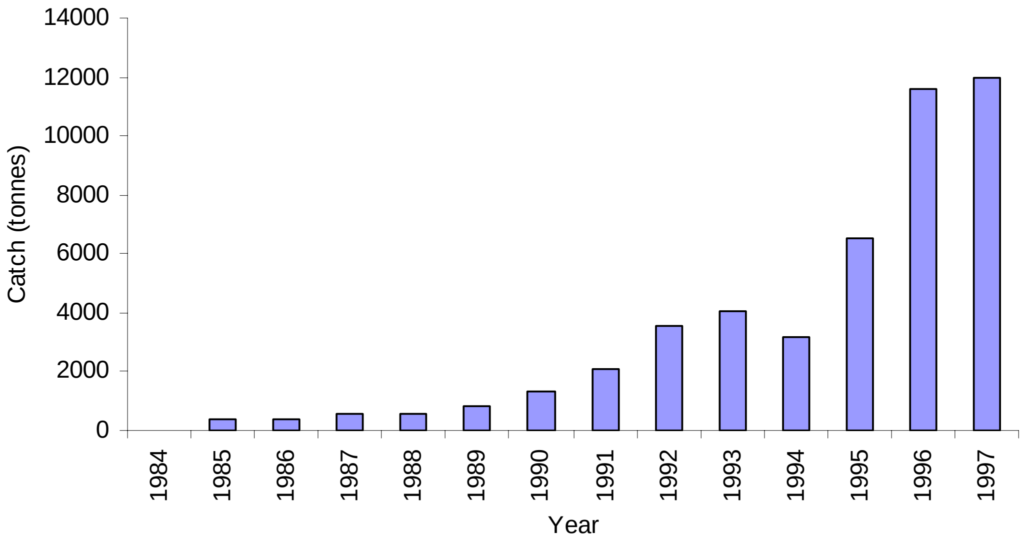

Figure 3. Annual total catch data (tons) mainly from Colombia and Peru of red-bellied pacu *Piaractus brachypomus*. (*FAO*)

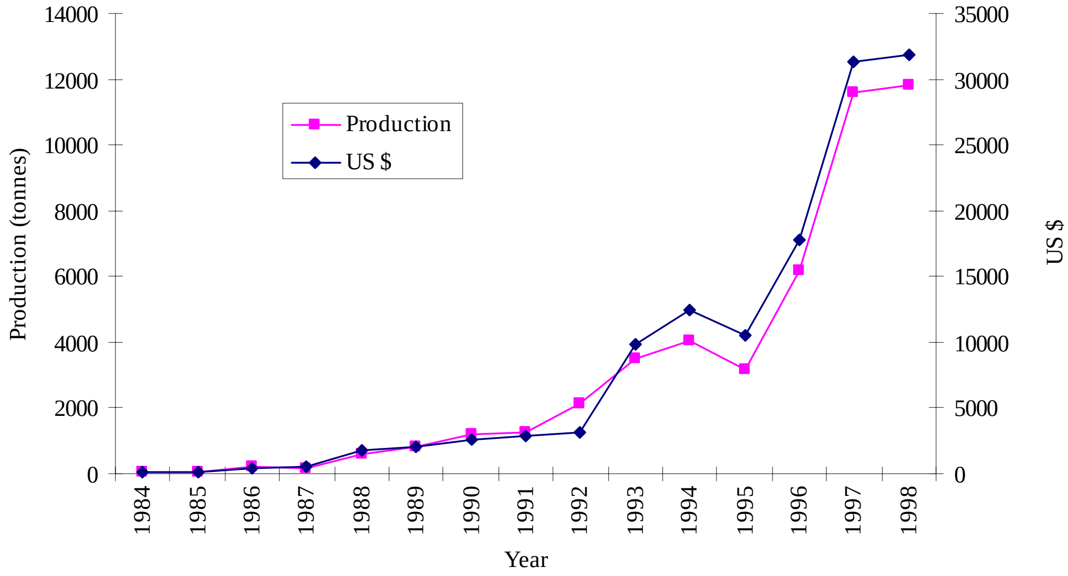

Figure 4. Annual aquaculture production of red-bellied pacu *Piaractus brachypomus* mainly in Colombia and Peru. (*FAO*)

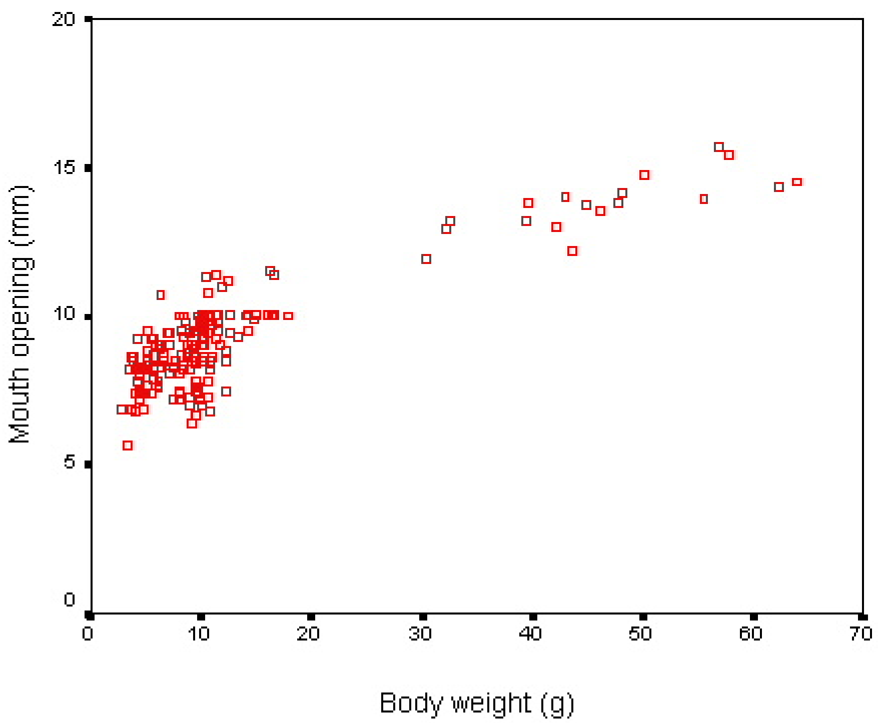

Figure 5. Relationship of red-bellied pacu body weight and mouth opening. (*Cagauan and Joshi, 2002*)

data show the production of *P. brachypomus* from capture fisheries and aquaculture (**Figures 3 and 4**, respectively). There is an increasing production data from capture fisheries and aquaculture from 1984 to 1998.

Case study on the use of red-bellied pacu as biological control for golden apple snails *Pomacea canaliculata*

The red-bellied pacu has been found to be a good biological control of the golden apple snail in simulated paddies planted to rice in screenhouse condition at the PhilRice, Munoz, Nueva Ecija. Cagauan and Joshi (*2002*) reported that the predation of red bellied pacu on golden apple snail depended on the fish's mouth size, as a function of body size (**Fig. 5**), that is suitable to the size of GAS. However, large sized pacu (42-49 g) and densities of 2-3 fish m^{-2} caused damage (i.e. 2-3 hills $plot^{-1}$) to 20-day old rice plants from transplanting. The damage caused by this fish mimics that of the damage caused by rats. Pacu with size: <10 g with densities of 1-3 fish m^{-2} did not damage the rice plants.

Potential invasive impacts of red-bellied pacu

Pacu has existed in the Philippines almost two decades now. It occurs in Laguna and Pampanga in freshwater ponds for the production of ornamental fishes. The establishment of this fish in natural waters is unknown.

Presently, red-bellied pacu is not an invasive fish but may have potentials to become invasive when it gets loose and establish in natural waters. Being an aggressive aquatic plant eater, the fish may be advantageous as a biological control for aquatic weeds and golden apple snail. On the other hand, large pacu can be disadvantageous to the rice plants as it was proven by Cagauan and Joshi (*2002*) to damage young rice plants. The molluscivorous feeding habit of pacu may have a negative impact on the native snails particularly those with edible and economic value such as *Corbicula manilensis*, *Pila conica*, *Thiara* sp. and *Vivipara* sp., hence, it is necessary to investigate this through research.

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ACKNOWLEDGEMENT

The authors wish to thank the enumerators namely: Virginita Lamano, Maria Liza de Roxas, Eilene Mendoza, Adoracion Bajar, Andre Vhon Villanueva and Pamfilo de Villa. We appreciate the cooperation and patience of Rejie O. Salavaria in typing the reports and manuscript and the technical assistance rendered by Maribeth Ramos and Esmeralda Mendoza. Monitoring would be difficult without the BFAR-IFRS Fish Health Monitoring Team composed of Catalino R. Tizon, Erwin P. Gorospe, Raymond M. Calvelo, Rejie O. Salavaria and Macario M. Terrible for assisting in the survey. We are thankful to Director Rosa F. Macas for her moral support, which has greatly inspired us to continue doing timely and significant researches in Taal Lake. Most of all, we praise the Lord Almighty for guiding and giving us enough strength to accomplish this piece of work.

Journal of Environmental Science and Management 10(1): 48–62 (June 2007)
ISSN 0119-1144

REVIEW PAPER

Exotic Aquatic Species Introduction in the Philippines for Aquaculture – A Threat to Biodiversity or A Boon to the Economy?

Arsenia G. Cagauan

ABSTRACT

An updated list of exotic aquatic species shows that there are 181 organisms (28 families) introduced in the Philippines since the 1900s; however, 40 organism have unknown records of introductions in the country. Based from the records of the year of introduction, the highest number of exotic aquatic introductions was in the 1970s, which was coincidentally the green revolution years of the Philippines. About 93% of these exotic species are fishes, 2.67% mollusks and the rest are crustaceans, frogs and turtles. These exotic organisms are primarily used as ornamental species (76%), as food (21%) and as biological control (2%).

There are twelve organisms reported to be invasive with negative impact on native species and the environment. However, they are also useful as food or ornamental species. Nine species with no known record of establishment in the natural waters may potentially become invasive when loosed into water bodies, creating a negative impact on biodiversity and environment. While invasive exotic aquatic organisms are usually perceived from a negative point of view and the general management approach is to control or eradicate, these organisms may also be managed as food and ornamental species, which seem to be an appropriate approach in the Philippines. They can also be sources of livelihood and income. Exotic aquatic organisms in the Philippines have played a major role in aquaculture, one of the fastest food producing sectors. These experiences show that exotic species can be both a bane and boon to the country depending on the species and manner of introduction. For truly invasive species, measures to prevent their entry in the Philippines may be avoided by employing import risk analysis and the hazard analysis critical control point (HACCP) approach is suggested.

Keywords: *Philippines exotic aquatic species, invasive aquatic alien species (IAAS), aquaculture, tilapias, HACCP*

INTRODUCTION

An exotic organism or a non-native organism is a plant or animal that has been transplanted by humans; they are usually perceived from a negative point of view (*Morton 1997*). The issue of exotic species transfer is of international concern because of the high risk of diseases introduction, disruptive effects on aquatic communities and environment as well as the degradation of the genetic quality of host stocks (*de Silva 1989*). There is a tendency for an introduced aquatic organism to adopt a niche that differs completely from that occupied in its native range. Exotic species are generally regarded as invasive alien species (IAS) that causes or has the potential to cause harm to the environment, economies and human health.

Most progressive agriculture worldwide is based on exotic animal organisms, subjected to modern husbandry, contributing to animal protein production and source of livelihood and income. Aquatic organism introductions in many countries have played a major role in aquaculture, one of the world’s fastest growing food production sectors. The significance of aquaculture lies in the fact that fish plays a major role in the diet, particularly of many Asian countries, where over one-half of animal protein intake comes from fish (*Welcomme 1998*). This paper discusses the status of exotic aquatic organisms in the Philippines and their utilization particularly in aquaculture; species that became invasive and have potentials to become invasive; and their positive and negative impacts on the environment and economy. The context of what is truly an invasive aquatic alien species (IAAS) to the experiences of the Philippines is discussed Measures to prevent truly IAAS in the country are suggested which includes the application of hazard analysis critical control point (HACCP) approach.

Status of exotic aquatic organisms in the Philippines

Information presented in this paper on the updated list of exotic species introduced in the Philippines came from different sources. The Bureau of Fisheries and Aquatic Resources, a government agency responsible for the fisheries in the country, provides information particularly on exotic fishes use for food. The Aquarium Science of the Philippines in 1996 listed 145 aquarium fishes introduced in the Philippines, which can be found in Fishbase (2000). The information on the year of introduction and biology, including native ranges and morphology for most of the fishes reported here is based mainly from Fishbase (2000). Information from the personal observations of the author from field visits of aquaculture farms and other water bodies is included particularly on the impact of exotic introductions.

An updated list of exotic introduced aquatic species in the country shows that there are 181 organisms which are composed mainly of fishes (169 species; 93.4%), mollusks (5 species; 2.8%), crustaceans (3 species; 1.7%), frogs (2 species; 1.10%) and turtles (2 species; 1.10%) (**Fig. 1**). Of the total number of exotic aquatic species introduced in the country, 40 species have an unknown record of the year of introduction and most of these are ornamental species. Fishes introduced belong to 28 families and majority come from Cichlidae (48 species), Cyprinidae (31 species) and Characidae (29 species) (**Table 1**).

Earliest records of the first introduction of exotic fishes in the Philippines was in 1905 when mosquito fish (*Gambusia affinis),* guppy (*Poecilia reticulate)* and mummichog (*Fundulus heteroclitus)* were introduced. This was followed by the largemouth bass (*Micropterus salmoides)* in 1907 and snakehead fish (*Channa striata) Channa striata (=Ophicephalus striatus)* in 1908. *G. affinis* and *P. reticulata* were introduced for mosquito control while *Channa striata* for food. The common carp *Cyprinus carpio* was introduced in 1910. Majority of these species (49 organisms) were introduced in the 1970s (**Fig. 2**), the period of green revolution and agriculture boon in the Philippines. In fact, the popular freshwater food fish from the Southeastern United States channel catfish (*Ictalurus punctatus)* was introduced as an ornamental fish in 1974, but records of its establishment in natural waters in the country is unknown. In the 1980s, 31 species were introduced which include the herbivorous gastropod *Pomacea canaliculata*, a major rice pest. In the 1990s, 32 species were introduced and these were mostly ornamental species.

Exotic aquatic organisms in the Philippines are utilized as food (21%), biological control (2.2%) and ornamental species (76.2%). One species unintentionally introduced in the Philippines via ship is the black striped mussel *Mytilopsis sallei* which is considered a serious pest in some marine areas causing massive fouling problems (*GISP*, *2004*). A summary of fish families and number of species show that there 31 species utilize as food, 3 species as biological control and 135 as ornamental species (**Table 1**). Among the introduced exotic species contributing to aquaculture production in the country as food fishes are tilapia, major carps, catfishes, snakehead fish and gourami. Tilapia is the most successfully introduced alien species for aquaculture with high consumer acceptance. Major carps industry can be found in Laguna province and acceptance of this fish is only in selected places in the Philippines. There is an increasing demand for catfishes and mudfish but the supply is low. For biocontrol, the introduction of the mosquito fish (*G. affinis)* from Hawaii in 1905 was the earliest introduction of alien aquatic species in the country. This was re-introduced in the country in 1913 and 1920 (*Fishbase 2000*). The blackfin pearlfish (*Austrolebias nigripinnis)* (Regan, 1912) introduced in 1996 has been used for research in mosquito control.

Freshwater ornamental fish. The freshwater ornamental fish, all of which are exotic species can provide livelihood opportunity to many poor families because it does not require high capitalization. Even if aimed primarily at the local

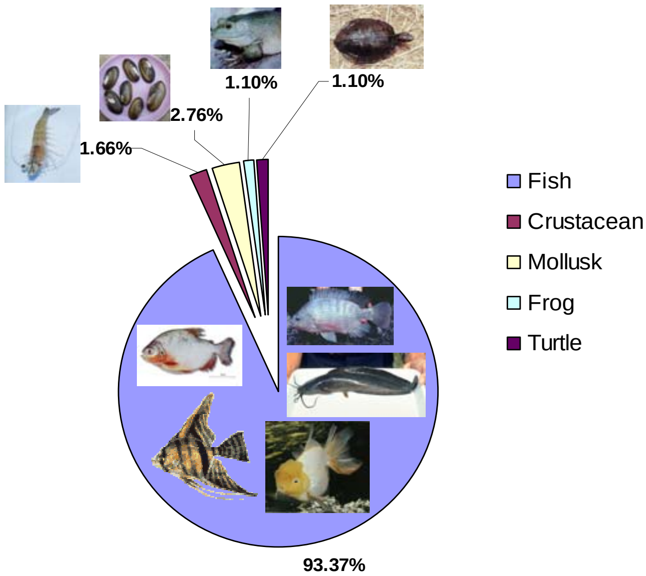

Fig. 1. Percent distribution of various groups of introduced exotic organisms in the Philippines.

Table 1. Fish families and number of species utilize for food, biocontrol and ornamental in the Philippines.

Fish families	Number of species utilized as			Total
	Food	Biocontrol	Ornamental	
1. Anabantidae	1			1
2. Alestiidae			2	2
3. Ambassidae			1	1
4. Anostomidae			1	1
5. Aplochaelidei		1	1	2
6. Belontidae	2		2	4
7. Callichthyidei			6	6
8. Centrarchidae	3		1	4
9. Channidae	1		1	2
10. Characidae			29	29
11. Cichlidae	8		40	48
12. Clariidae	2			2
13. Cobitidae	1		6	7
14. Cyprinidae	9	1	21	31
15. Eleotridae			1	1
16. Fundulidae			1	1
17. Helostomatidae			1	1
18. Hemirampidae			1	1
19. Ictaluridae	1		1	2
20. Loricariidae			3	3
21. Melanotaeniidae			4	4
22. Mochokidae			1	1
23. Osphronemidae	1			1
24. Osteoglossidae			7	7
25. Pangasiidae	1			1
26. Poeciliidae		1	2	3
27. Syngnathidae			1	1
28. Terapontidae	1		1	2
Total	**31**	**3**	**135**	**169**

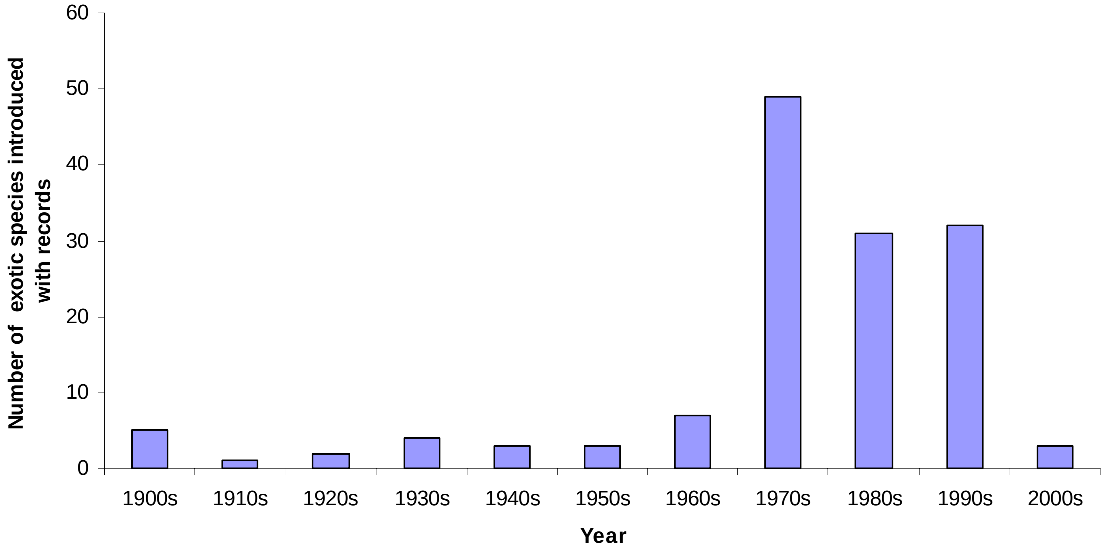

Fig. 2. Number of introduced exotic species from the 1900s to 2000s in the Philippines.

market, it can still help the country save valuable foreign exchange since it will minimize imports.

Invasive aquatic alien species (IAAS) in the Philippines and their impacts

In the Philippines, there are twelve exotic aquatic species with invasive reports and their impacts are summarized in **Table 2**.

Golden apple snail *Pomacea cananiculata*. This South American freshwater gastropod was introduced illegally in the 1980s in the country through the private sector. The golden apple snail (GAS) was marketed as an aquaculture species in aquaria as a source of food. It escaped through waterways and eventually to rice fields. A few years after its introduction, the damage to rice farming particularly to newly transplanted rice plants have been known. The snail has given rise to the use of an additional pesticide (molluscicide) in rice farming, an added cost to farmers. The first pesticides in the group of organotin compounds used to eradicate the GAS were banned because of its unregistered use as molluscicide and its harmful health effects to farmers. The snail reproduces very fast and in great quantity but utilization level as food is low. GAS has been implicated in the decline of the population of the native freshwater snail *Pila conica*. A separate Paper on GAS is presented in this conference-workshop (see Golden apple snail in the Philippines, Cagauan and Joshi in this proceeding).

Tilapias. Worldwide, tilapias ranked as the most introduced species, second to salmonids, among the major aquatic species groups introduced during each decade since 1900 (*Welcomme 1988*). The two tilapia species frequently introduced are *O. mossambicus* and *Oreochromis niloticus* for aquaculture purposes. The distribution of tilapias in the Philippines is widespread in freshwater and brackishwater environments.

Reports on the impacts of tilapias in the country are both positive and negative. The first tilapia species introduced in the country in 1950 was Mozambique tilapia (*O. mossambicus)* which came from Thailand (*Welcomme 1988; Tech. Com. for tilapia 1985*) (**Table 4**). However, this species did not attract much approval for culture in freshwater because of its poor growth and early sexual maturity resulting in overpopulation. It is also considered as pest in brackishwater.

Over several decades, the story of tilapia introductions in the country has brought about beneficial impact on food production. Tilapias are now one of the major aquaculture species in the country, second to milkfish. About 51% of tilapias in the country are produced in freshwater fishponds, 37% from freshwater fish cages, 8% from

Table 2. Invasive exotic species in the Philippines and their impacts

Common name/ Scientific name	Distribution	Feeding ecology	Impacts	
			Positive	Negative
1. Mosquito fish *Gambusia affinis*	Widespread. Found in canals, creeks, swamps, ponds, shallow areas of lakes.	Feeds on zooplankton, small insects and detritus.	Very effective for mosquito control Used as ornamental fish and sold for income	Predate on the eggs & hatchlings of cyprinid loach *Misgurnus anguillicaudatus* Competes with indigenous fish
2. Snakehead *Channa striata* (*Ophicephalus striatus*)	Widespread. Found in canals, creeks, swamps, ponds, shallow areas of lakes	Carnivore. Feeds on fish, frogs, snakes, insects, earthworms, tadpoles & crustaceans.	A food fish with high aquaculture value & commands a good price in the market. Major source of income for fishermen.	Predate on native species
3. Common carp *Cyprinus carpio*	Widespread. Found in canals, creeks, swamps, ponds, lakes	Omnivore. Feeding mainly on aquatic insects, crustaceans, annelids, mollusks, weed and tree seeds, wild rice, aquatic plants & algae; mainly by grubbing in sediments	Food species that easily reproduces in ponds, lakes, canals & swamps. Source of food & income but there is low consumers acceptability. Popular only in few selected areas of the Philippines. Good for weed control	Compete with indigenous fish Adults uproot & destroy submerged aquatic vegetation.
4. Mossambique tilapia *Oreochromis mossambicus*	Found in ponds, rivers, swamps and rice fields throughout the country & brackish water areas	Omnivore	A saline-tolerant species suitable for brackish water aquaculture. Source of food & income from brackish water aquaculture. Bred with Nile tilapia *O. niloticus* to develop a better saline tolerant tilapia species good for brackish water aquaculture	Considered a pest in brackish water ponds as it competes with the natural food (*lab-lab*) of milkfish A highly inbred population occurs and has hybridized with the Nile tilapia both in the wild & in captivity

5. Nile tilapia *Oreochromis niloticus*	Widespread in all freshwater bodies	Omnivore	Commercial aquaculture species. The second most important freshwater species contributing to national fish production. Species for export. Source of genetic material for breeding	Cage culture of this fish in open waters has caused pollution of major lakes & reservoirs. In natural water, it is a competitor of native species. The introduction of new strains might have brought new species of parasites into the country (Yambot & Lopez, 1997)
6. Crucian carp *Carassius carassius*	Found in shallow ponds, lakes rich in vegetation & slow moving rivers.	Feeds on plants, insect larvae & plankton.	Source of food fish from local fishery but has a low consumers acceptability.	A competitor of native fishes in fresh water.
7. Freshwater mussel *Cristaria plicata*	Found in shallow bodies of water like canals, creeks, swamps, ponds, shallow pools of rivers & littoral areas of lakes & reservoirs	Filter feeder	Source of food and income. Biological filter. Can be polycultured with tilapia	Can be a nuisance in ponds as the sharp shells can injure workers when they step on it, hence, poses an occupational hazard.
8. Janitor fish (*Liposarcus disjunctivus*; *Pterygoplichthys disjunctivus*}Weber, 1991 (*Liposarcus pardalis; Pterygoplichthys pardalis*) Castelnau, 1855	Established in Laguna de Bay, Philippines Founf in Marikina river and Lake Paitan		Fish can be processed to fish meal. Fish skin can be dried and used for handicrafts.	Adverse competitor of indigenous fishes. Destroy nets of fish pens and cages
10. Thai catfish *Clarias batrachus*	Widespread. Inhabits swamps, ponds, ditches, rice paddies, & shallow pools after rivers have been flooded	Carnivore	Major source of food. Source of income and livelihood from local fishery	Dominated natural populations in lakes & rivers and the indigenous *Clarias macrocephalus*. Considered as pest in tilapia ponds
11. Golden apple snail *Pomacea cananiculata*	Widespread. Found in rice paddies, swamps, ponds, ditches, other bodies of freshwater & brackish water ponds.	Herbivore	Source of human food. Processed as organic fertilizer. Food of ducks and other animals.	Major pest of rice. Resulted in the decline of rice production in the 1980s as it damaged newly transplanted rice Resulted in the use of pesticide such as molluscicide.
12. Guapote tigre *Parachromis managuensis*	Ornamental fish established now in Lake Taal	Feeds on small fishes & macro-invertebrates	Ornamental fish Food fish	Predator of indigenous fishes in Lake Taal.

Table 3. Production of tilapia from different culture systems/types of aquafarms 1995-2004.

Culture Systems	Production (mt)									Total	Percent of total
	1996	1997	1998	1999	2000	2001	2002	2003	2004		
FW fishponds	38,410	39,005	32,780	36,705	43,174	54,312	65,942	68,056	71,831	450,215	50.84
FW fish pens	4,876	4,272[1]	3,748	4,059	3,688	2,147	1,713	8,207	11,769	40,207	4.54
FW fish cages	32,579	42,615[2]	29,544	35,207	37,622	40,779	46,330	50,179	53,010	325,250	36.73
BW fishponds	5,317	5,939	5,949	7,828	8,033	9,388	8,266	9,367	9,046	69,128	7.81
BW fish cages					9	71	74	134	116	404	0.05
BW fish pens					49	45	53	36	97	280	0.03
MW (cages, pens)			2	33	4	9	12	16	0	76	0.01
TOTAL	81,182	91,831	72,023	83,832	92,579	106,746	122,390	135,995	145,868	885,559	

FW: Fresh Water BW: Brackish Water MW: Marine Water
Sources: BFAR, 1996, 1997, 2003, 2004; Bureau of Agricultural Statistics (BAS) 1998-2002
[1]includes Marine fish pens [2]includes marine fish cages

brackishwater fishponds, 5% from freshwater fish pens, and less than 1% from brackishwater and marine fish cages and pens (**Table 3, Fig. 3**). The tilapia production by major type of culture environment in top producing provinces from 2001 to 2003 shows that Pampanga tops the production in fishponds, Batangas in freshwater fish cages, Rizal for freshwater fish pens and Pampanga for brackishwater fishponds, cages and pens. Based on the Bureau of Agricultural Statistics (BAS), the tilapia harvest area from 1998 to 2002 showed an average of 16,256 ha for freshwater fishponds, 10,135 has for brackishwater ponds, 2,373 ha for freshwater fish cages and 1,413 ha for freshwater fish pens. The trend of tilapia harvest areas is increasing for freshwater fishponds but declining for brackishwater ponds.

Most of the introductions of other species of tilapia occurred in the 1970s and 1980s. In 1972, the first Nile tilapia *O. niloticus* (Uganda strain) from Israel was received by the Laguna Lake Development Authority. The introduction of Egypt and Ghana strains of *O. niloticus* followed, with recipients mainly the government sector. In 1977, the blue tilapia *O. aureus* (Israel strain) coming from the United States was introduced to CLSU and BFAR. In the succeeding years, the introduction of this species also followed, received by SEAFDEC, CLSU and the private sector.

The red tilapia hybrid *O. hornorum* x *O. mossambicus* coming from Singapore introduced by the private sector in 1971; followed by the red tilapia *O. niloticus* x *O. mossambicus* from Taiwan in 1981. Lastly, the herbivorous tilapia Zill's tilapia *Tilapia zillii* from Taiwan was introduced in 1978 with unknown recipient in the country.

Different strains of *O. niloticus* are present in the country today. Strain refers to the country where the species has established its population. These strains were brought about by different government and international agencies responsible for the genetic improvement of *O. niloticus*, the preferred species for commercial production.

There were also reports on the negative environmental impact of tilapia introduction in the country. The introduction of *O. mossambicus* resulted in the competition for food with *Chanos chanos* in brackishwater aquaculture (*Juliano et al 1989*). The indiscriminate introduction of tilapia caused the reduction of the population of native fishes *Mistichthys luzonensis* (*Soliman, 1993; Mercene, 1995*) and *Sardinella tawilis* (*Mercene 1995*). In a survey of parasites of fishes imported into the Philippines, Albaladejo and Arthur (*1989*) and Lumanlan *et al* (*1990*) provided evidence that fish entering the Philippines carried with them a myriad of potentially pathogenic parasites. Yambot and Lopez (*1997*) reported the occurrence of a new gill parasite *Lamproglena monody* Capart in Nile tilapia *O. niloticus* unreported in surveys of parasites of the same fish by Bondad-Reantaso and Arthur (*1990*). The researchers reported further that *L. monody*, known previously only in Africa, could have been introduced in the country along with the importation of Nile tilapia on or before 1992. The widespread culture of Nile tilapia, commercial tilapia species, in lakes and reservoirs resulted in the pollution of major lakes in the

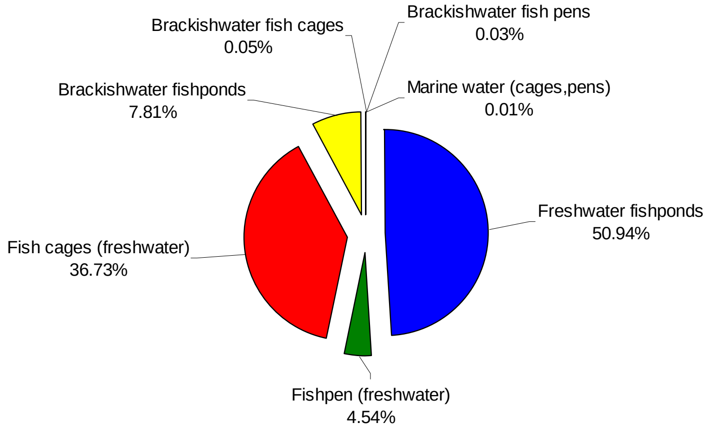

Figure 3. Tilapia production in different culture environments/types of aquafarms, Philippines, 1996-2004.

Table 4. Estimated carp production from fish ponds based from farmers' records in different regions of the Philippines, 2003-2004. (Source: BFAR Tanay, Rizal)

Region	Production	% Share
I	108,304.20	12.44
II	40,751.40	4.65
III	128,019.00	14.71
IV	541,797.20	62.24
V	8,160.00	0.94
VI	1,800.00	0.21
VII	606.00	0.07
VIII	-	-
IX	1,230.00	0.14
X	1,500	0.17
XI	-	-
XII	-	-
XIII	-	-
CAR	31,091.00	3.57
NCR	7,224.00	0.83
Total	**870,482.80**	**100**

Philippines. Feed wastes from cages are sources of organic nutrients causing eutrophication of lakes and reservoirs. Poor water quality as a result of excessive fish feeding leading to eutrophication in ponds, lakes and reservoirs has brought massive mortality of tilapia. This brought about economic losses to the farmers. Cagauan and Tayamen (*2005*) reported the occurrence of *Streptococcus* in Santiago, Isabela last September-October 2005 resulting in significant mortality of cultured stocks which were about ready for the market. The yearly occurrence of the parasitic isopod *Alitropus typus* Milne-Edwards locally known as "*timud*" in Taal lake has also brought significant losses of tilapia in cages. This parasite is macroscopic, parasitizing the head gills, fins and caudal peduncle. It can be found in water with high organic loading and high stocking density system.

Eutrophication of inland bodies of water brought about by excess nutrients particularly feed wastes, disposed from aquaculture culture environments is one of the negative impacts of tilapia culture. This poor environmental condition is often felt in cage culture areas such as Magat Dam and Taal Lake. Increased conversion of productive rice farms to tilapia ponds because of better economic returns from the latter in some parts

Table 5. Estimated carp production from 2000-2004 in Laguna de Bay

Year	Culture	Increase (%)	Capture[2]	Increase (%)
2000	5,977.24	-	798.99	1
2001	1,431.70	-317.49	920.27	13.18
2002	8,411.80	82.98	1,531.17	39.9
2003	3,286.08	-155.98	1,781.02	14.03
2004	5,914.26	44.44	2,850.14	37.51
Total	**25,021.08**		**5,031.45**	

Source: Palma, A. 2005. BFAR, Tanay Carp Station

of Central Luzon is increasing. This will have an implication to the rice industry.

Carps. The first carp species introduced in 1910 is the common carp *Cyprinus carpio* from Hongkong, China. The crucian carp *Carassius carassius* and the major carps (catla *Catla catla*, bighead carp *Aristichthys nobilis*, grass carp *Ctenopharyngodon idellus*, mrigal *Cirrhinus cirrhosus*, silver carp *Hypophthalmichthys molitrix* and rohu *Labeo rohita*) were introduced in the 1960s. Common carp can be found in ponds and natural waters. While the major carps are primarily cultured in ponds, they are also stocked in open waters such as lakes and reservoirs.

Based from the records of the BFAR Tanay Station in Rizal, estimated carp production based from farmers' records in 2003-2004 amounted to 870,483 kg. The major producer was Region IV contributing to about 62% of the total production. This was followed by Regions 3 and 1 contributing 15% and 12%, respectively (**Table 4**).

While several countries report adverse ecological impact after introduction (*Fishbase 2000*), the common carp has not been reported to adversely affect the aquatic biodiversity and the environment in the Philippines. However, it could be a fact that the common carp is a competitor of native species. Common carp can also serve as biological control for aquatic weeds by uprooting submerged weeds as a result of its benthic feeding habit. The turbid condition the fish creates when it scours the bottom during feeding limits light penetration, preventing the growth of submerged weeds. Whether the common carp could cause adverse impact on native aquatic plants is unknown.

The common carps and the major carps are cultured in freshwater fishponds, cages and pens mainly in Laguna province. The estimated production of common carp in Laguna de Bay from capture fisheries and aquaculture from 2000 to 2004 show increases of 37.51% and 44.44%, respectively (**Table 5**). About 67% of the carp production from 2000 to 2004 was contributed by common carp and 33% by major carps (**Table 6**). During the period 2000-2004, 2,300,976 common carp fingerlings were dispersed from the BFAR Tanay Station and about 44% of this was dispersed in open water for capture fisheries. About 56% were sold for culture in fishponds, cages and pens (*Palma per. com.*). Moreover, 650,421 major carp fingerlings were dispersed, 33% of which were introduced to open waters and 67% for culture. The low consumer acceptability of carps is a limiting factor to the demand of this fish in the market. The industry of bighead carp in Laguna province is becoming popular and now marketed in Central Luzon at a market price of PhP 35/kg.

Catfish. Introduced alien catfish species are the Thai catfish/walking catfish (*Clarias batrachus)* introduced in 1972 from Thailand and African catfish (*Clarias gariepinus)* introduced in 1985 from Taiwan, China and re-introduced in 1987 from Taiwan, China and Thailand. Thai catfish has reproduced extensively in natural waters and has been attributed to the decline of the population of the Asian catfish/native catfish (*Clarias macrocephalus)*. However, hard data to confirm this observation is lacking. SEAFDEC and FAC, CLSU conducted studies on the propagation of the Asian catfish and presently, fingerlings for culture are available.

Catfish production in 2003 from fishponds was 2163 MT, 56% of which comes from Region 3 and 13% from Region 12 (*BFAR Fisheries Profile*

Table 6. Carp production by species from 2000-2004 in Laguna de Bay

Year	Common carp	Major carp
2000	79.99	108.66
2001	92.03	125.16
2002	1,531.12	208.24
2003	178.1	242.22
2004	285.01	387.62
Total	2,166.25	1,071.90

Source: Palma, A. 2005. BFAR, Tanay Carp Station

2003). This also includes the production of African catfish *Clarias gariepinus*.

Mudfish. The mudfish *Channa striata* is one of the earliest species introduced in 1908 from Malaysia. It is a highly carnivorous fish which can be found widespread in natural waters. It is able to survive adverse condition because it has an accessory breathing organ. It is a pest in tilapia ponds and commonly eradicated by the use of piscicides. The burrowing ability of this fish in moist soil makes it difficult to eradicate.

While the fish has an impact on native fish species because of its carnivorous feeding habit, it is a valuable component of capture fisheries catch and aquaculture species. The estimated production of mudfish in 2003 from the different regions of the country was 1,388 MT, with Region 3 as the major producer. The fish commands a good price in the market and there is high demand but with low supply.

Gourami. The snakeskinned gourami (*Trichogaster pestoralis)* and three spotted gourami (*Trichogaster trichopterus)* were introduced from Thailand to the Philippines in 1938. These species abound in the natural waters and serve as competitors of the indigenous fishes. The giant gourami (*Osphronemus gouramy)* was introduced from Java, Indonesia in 1927 and re-introduced in the 1990s from Thailand. The gouramis abound in rice fields, creeks and canals in the 1960s but decreased in population during the green revolution years in the 1970s. They were affected by agro-pesticides used in the intensification of rice farming. The giant gouramy was primarily affected during the green revolution years resulting to its re-introduction in the 1990s. With the integrated pest management approach in rice farming, the rice field environment is now becoming a friendly place for aquatic fauna such as fishes, crustaceans and mollusks.

Gourami species such as *Trichogaster pectoralis* production in 2003 was about 49 MT (*BFAR Fisheries profile 2003*). Presently, the production of giant gourami *Osphronemus gouramy* in ponds can be found at BFAR-CLSU, FAC-CLSU, Llamas's Farm in Pampanga and Mercado's Farm in Bulacan but supply of fingerlings of this fish is still limited. The culture technologies of gouramis are still not much developed in the country. In Thailand, it was observed that female giant gourami grows faster than male.

Production of catfish, mudfish and gourami. Freshwater fishpond production from 1995-2003 showed that mudfish production was 14.7 t followed by catfish production (12.4 t) and gouramis (0.89 t) (**Table 7**). These fishes are valuable food for Filipinos.

Janitor fish. The janitor fish or armored catfish species in the Philippines are reported as *Pterygoplichthys disjunctivus* and *P. pardalis* by PCAMRD but the Fishbase valid name is *Liposarcus pardalis* and *L. disjunctivus*. This was first reported by BFAR as *Hypostomus plecostomus*. This fish with unknown origin was introduced in 1970-1979 as an ornamental species. The *L. disjunctivus* is established in Laguna de Bay while *L. pardalis* in Marikina river and Lake Paitan. It is an adverse competitor of indigenous fishes and destroys nets and cages in Laguna de Bay. Data on the janitor fish population in Laguna de Bay, Marikina River and Paitan Lake are lacking. Janitor fish is the major component of fish catch in those waters mentioned but the fish has very little value as food fish since the flesh tastes bitter. It may be used, however, as a source of fish meal. The demand for this fish as ornamental is low.

Guapote tigre. Jaguar guapote or guapote tigre (*Parachromis managuensis)*, a South American fish introduced in 1990 as an ornamental fish. It was found in Lake Taal, Batangas in 2003 where it is now established. The carnivorous feeding habit of this fish makes it a predator to indigenous

Table 7. Productions of catfish, mudfish and gourami from 1995-2003 in freshwater fishponds.

Year	Catfish	Mudfish	Gourami
1995	1,300	2,433	216
1996	1,075	2,076	199
1997	1,052	2,144	132
1998	743	1,343	43
2000	1,090	1,273	86
2001	1,523	1,439	44
2002	2,634	1,344	41
2003	2,163	1,388	49
Total	12,419	14,718	887

(Source: BFAR Fisheries Profile)

fishes of Lake Taal including small fishes and invertebrates. Presently, guapote tigre is now a major fish catch by gillnet in Lake Taal. It is a food fish for the locals.

Potential invaders. Exotic species with potential invasive impacts are summarized in **Table 8**. These species are Java barb or tawes (*Barbodes gonionotus)*, red piranha (*Pygocentrus nattereri*), African catfish (*Clarias gariepinus)*, giant snakehead (*Channa micropeltes)*, arapaima *(Arapaima gigas)*, red-bellied pacu (*Piaractus brachypomus)* white shrimp (*Litopenaeus vannamei),* Australian redclaw (*Cherax quadricarinatus)* and Lousiana crayfish (*Procambarus clarkia).* They are now found in the country but records of their establishment and distribution in natural waters are not known. Most of these are popularly sold as ornamental fishes in pet shops.

The riverine African catfish reproduces using artificial spawning and has high fecundity. This fish is allowed for culture in ponds but not in open waters. The African catfish is now an aquaculture species and the market size is 200-300 grams. Since this fish is very carnivorous, it may be a threat to indigenous fishes if established in open waters. The red piranha introduced in 1970-1990 as an ornamental fish may already be established in ponds in the Philippines and may become a threat to indigenous fishes and to humans if it has escaped to natural waters. Red piranha can be bought in few ornamental aquarium fish shops. The giant snakehead and arapaima are also both carnivorous and may serve as predators of indigenous fishes. The Java barb or tawes may serve as a competitor of native fishes and could serve as a good biological control for weeds.

The red bellied pacu (*Piaractus brachypomus)* looks like a piranha but the former is primarily an herbivore and molluscivore. Piranha has a longer lower jaw with prominent sharp teeth while the red bellied pacu has relatively uniform length of lower and upper jaws and small teeth. A riverine species from South America introduced to the Philippines in the 1990s, it reproduces in ponds using artificial spawning. This fish may be threat to native mollusks in the Philippines. (*see paper by Cagauan in this proceeding*).

The Australian redclaw introduced in the Philippines in early 2000 is now mass produced in the Visayas. This freshwater crustacean has been reported to burrow, but this was not observed in simulated rice paddies (*Bolivar et al 2003*), hence, it may not be threat to the rice plants when this crustacean escapes to the rice fields. However, it may be a potential competitor of the native shrimps *Macrobachium idella*, *M. lanchesterii* and *M. lanceifrons* which are abundant in rice fields and other natural waters.

The Louisiana crayfish, native of Southern United States and northern Mexico, was introduced as an ornamental species in the late 1990s. It may become a truly invasive species if it escapes to natural waters. A very herbivorous species, it is known to consume aquatic plants, rice plants, and a variety of food such as insects, worms, snails, crustaceans, amphibians and small fish, including eggs and fry. In Spain, this North American species became invasive in rice fields and is controlled using pesticides. The disappearances of some species of snails in African wetlands and amphibians in the United States have been blamed on Louisiana crayfish (*Matthew 2004*). Its highly territorial behavior frequently outcompetes and excludes other predators, further reducing biodiversity.

According to the GISP, the Louisiana crayfish is a vector of crayfish plague *Aphanomyces astaci* which caused the collapse of crayfish industry in Europe after it was introduced with the American red signal crayfish in the 1860s (*Matthew 2004*). It is also a vector for harmful human parasites,

Table 8. Exotic species in the Philippines with potential invasive impacts.

Common name/Sc. name	Environmental occurrence/distribution	Feeding ecology	Benefits	Potential invasive impact
1. Java barb/Tawes *Barbodes gonionotus* (Bleeker, 1850) *(= Puntius gonionotus=Puntius javanicus)*	Well established in rivers and lakes, where it reproduces naturally. Found also in aquaculture ponds	Feeds on plants, insects and detritus.	Source of food and income from local fishery (capture). Can be used as pituitary donor for artificial propagation in aquaculture. Useful as biological weed control for submerged vegetation in lakes and reservoirs.	May consume native aquatic submerged weeds. Competitor of native species.
2. Red piranha *Pygocentrus nattereri*	Common in creeks.	Carnivore. Feeds on insects, worms and fish. Adults feed mainly at dusk and dawn. Medium-sized to large individuals (15-24 cm length) forage mainly at dawn, late afternoon and night up to about 2200H, whereas smaller fish (8-11 cm) are active mainly during the day. Teeth replacement on alternating sides of jaw allows continuous feeding. (Fishbase, 2000)	Ornamental fish and commands high price.	Since its introduction in 1970-1979, no available information on its establishment and invasive impacts. However, this fish is available occasionally in ornamental fish shops. Its powerful dentition can inflict serious bites. A threat to native species.
3. African catfish *Clarias gariepinus*	Found in aquaculture ponds. Accidentally released into the rivers due to overflowing of ponds. Widely tolerant of extreme environmental conditions. The presence of an accessory breathing organ enables this species to breath air when very active or under very dry conditions.	Highly carnivorous. Bottom feeder which occasionally feeds at the surface.	Source of food and income through aquaculture. Highly priced fish.	The introduction of the African catfish to inland waters is proved to have negatively affected the natural stock and indigenous population. Boon in production led to the rapid decrease of prices of other catfish species.

4. Giant snake-head *Channa micropeltes*	Usually associated with deep water bodies. Found in large streams and canals with standing or slowly flowing water.	Carnivore. Preys mainly on fish but also feeds on some crustaceans.	Utilized as a food fish	The establishment of this fish in natural waters is unknown but if release in open waters may become a threat to the native population.
5. Arapaima *Arapaima gigas*	Often referred to as the largest freshwater fish. Its present culture condition is in ponds and tanks, No report on its occurrence in natural waters bodies.	Carnivore. Builds a nest of about 15 cm depth and 50 cm width in sandy bottoms. Spawns in April and May and guards the eggs and the young. Obli-gate air breather.	Expensive ornamental fish	Threat to native population
6. Red-bellied pacu *Piaractus brachypomus*	Reproduced in freshwater ponds using artificial spawning.	Feed mainly on aquatic plants and detritus. Has been proven to predate on small sizes of golden apple snail (Cagauan and Joshi, 2002)	Commercial culture in ponds as ornamental fish. It is a food fish in South Amer-ica	Its ability to predate on small mollusks such as the golden apple snail is an indication that the fish can be explored as a biological control for the GAS and this may also be threat to other native mollusks.
7. White shrimp *Litopeneaus vannamei*	Found in brackishwater ponds	Detritivore	Commercial aquaculture species for food	Competitor of tiger shrimp *Peneaus monodon* Feared to become a Source of disease-causing pathogens that might affect the tiger shrimp *Penaeus monodon*
8. Australian redclaw *Cherax quad-ricarinatus*	Found in freshwater aquaculture ponds	Omnivore	Commercial aquaculture species for food	Competitor of the native shrimps Its burrowing behavior may be detrimental to dikes of fishponds and ricefields
9. Louisiana crayfish *Procambarus clarkii*	Since this species is introduced through the aquarium ornamental fish trade, the present occurrence of this may be in controlled aquarium condition. Occurrence in natural waters unknown.	Herbivore	Food and ornamental species	Potential pest of rice plants Competitor of native shrimps

including the lungworm *Paragonimus westermani* and the rat lungworm *Angiostrongylus cantonensis*, which are passed to humans when crayfish is eaten raw (*Matthew 2004*). The burrowing behavior of the Louisiana crayfish could create leaks and erosion of aquaculture pond dikes.

In other parts of the world, Louisiana crayfish is farmed with rice in China, is a popular family pet in Japan; traded as an aquarium and garden pond pet in Europe; is released in Africa to control the snail host of schistosomiasis; and stocked outside its native range as a source of food for game fishes in the United States (*Matthew 2004*).

A threat to biodiversity or a boon to the economy?

The Philippine's experiences on exotic aquatic species in the country are not always viewed in the context of being truly invasive. These experiences showed that exotic species can be both a bane and boon to the country depending on the species and manner of introduction. The utilization of these exotic species as aquaculture species for food and as ornamental fishes as source of livelihood and income may alter the context of what is an invasive species. A species could truly become invasive if its utilization is less than the demand. The golden apple snail is a truly invasive aquatic alien species as its utilization as food is less than its population in natural waters. While there are some species that have been reported to have affected the population of indigenous fishes, there is a greater economic benefit derived from these exotic aquatic species.

Well-defined and strong markets whether local or export, is a driving force to make an introduced alien aquatic species (IAAS) become a boon. IAAS with no or low market while it may prove to be a bane, can still be a boon by turning their disadvantages to the advantage of the environment and people. For example, tawes and common carp can be used as biological control for aquatic weeds in lakes and reservoirs. The post harvest technology of fishes with low market value can be developed in order to increase their marketability.

The usual approach to manage the invasive alien species by eradication in developed countries may not be appropriate to the Philippine condition. It would be more relevant to improve and strengthen risk analysis, including quarantine measures of the government to prevent the entry of truly invasive species. Management of invasive species by utilization for those with food and economic value would be more appropriate in the Philippines. Integrated approach can be employed to manage invasive species with no economic value.

Suggested measures for exotic aquatic species to prevent invasive impacts

For any IAAS, it is essential to conduct an import risk analysis to compare the benefits to be gained against the risks involved. IAAS with very high benefits should also be subject to standard quarantine procedures to minimize the incidental introduction of possible unwanted "hitchhiker" organisms as well as exotic diseases that may be disastrous to local species. As part of the risk analysis, the application of Hazard Analysis Critical Control Point (HACCP) starting from introduction, production/hatchery, to marketing can be of help. The application of the HACCP may serve to avoid the accidental release to the natural environment of IAAS so as not to contaminate the local gene pool, especially for species which are also found locally. The HACCP approach concentrates on points that are critical to product safety and also to the environment. It also aims to minimize risks and increase communications between decision-makers, regulators and the aquaculture and ornamental fish industry in general.

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ACKNOWLEDGEMENT

The authors wish to thank all those who had contributed, in one way or another, to the completion of this study. To Director Malcolm I. Sarmiento, Jr., Westly R. Rosario, DFT; Rosa F. Macas and Francisco F. Santos, for their invaluable support. Likewise, sincere thanks is also extended to Ms. Leah Villanueva, Center Chief of IFRS, Josephine dela Vega and Libertad Briones, research staff of IFRS, and Ms. Karen Boots Briagas for their help in fecundity studies, and most of all to Almighty Father for his wisdom and guidance.

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