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

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**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,<br>33 subtropical,<br>44 temperate, 3 others<br>62.4 (tropical and subtropical) | 24 tropical,<br>10 subtropical,<br>26 temperate, 6 others<br>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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