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Risk Assessment of Introduced Species in the Aquaculture Areas of Pampanga, Philippines

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ABSTRACT

The intentional and unintentional introduction of new species can have significant ecological, social, and economic impacts at national, regional, and global scales. Due to the limited and scarce data on the impact of introduced species in the Philippines, this study was conducted to monitor, manage, and better understand the invasion strategies of these species. A total of six (6) species were assessed for potential invasiveness using the Aquatic Species Invasiveness Screening Kit (AS-ISK). Based on the outcomes of the Basic Risk Assessment (BRA) and BRA plus Climate Change Assessment (BRA+CCA) thresholds, all species were classified as "high risk" (score >30) for potential invasion. These species include the Thai catfish (*Clarias batrachus*), mudfish (*Channa striata*), softshell turtle (*Pelodiscus sinensis*), janitor fish (*Pterygoplichthys disjunctivus*), Rice eel (*Monopterus albus*), and blackchin tilapia (*Sarotherodon melanotheron*). Of the six species, four—*Clarias batrachus*, *Channa striata*, *Pelodiscus sinensis*, and *Pterygoplichthys disjunctivus*—were found to pose a high risk in both freshwater and brackish water areas of Pampanga. *Monopterus albus* was found to be a high-risk species in freshwater areas only, while *Sarotherodon melanotheron* posed a high risk in brackish water areas. This study successfully identified potentially invasive aquatic species in the aquaculture areas of Pampanga. The findings can be used to guide effective policy-making and informed decision-making for invasive species management.

INTRODUCTION

Invasive aquatic species (IAS) are defined by the **Convention on Biological Diversity (2014)** as species that spread beyond their native historical range. As a result, they are considered threats to biological diversity. Invasive species are often prolific and can easily establish populations in areas where they are introduced. Moreover, they have been linked to the endangerment of certain native species, as they can alter key ecological characteristics, including the dominant species within a community **(Bertness, 1984; Vitousek, 1990; Wilcove *et al.*, 1998)**.

Studies have shown that invasive aquatic species can also influence the evolution of native species. In some cases, uncontrolled hybridization between invasive and native species leads to genetic pollution, contributing to biodiversity loss **(Mooney & Cleland, 2001)**. This, in turn, has displaced natural habitats of indigenous species, degraded ecosystem function, and diminished the aesthetic value of natural environments **(Marbuah *et al.*, 2014)**.

In the Philippines, the spread of invasive species poses a serious threat to the fishery industry. **Guerrero (2014)** reported that a total of 60 freshwater fish species have been introduced, of which 8 are considered invasive and 4 have the potential to become invasive. These species have disrupted local fish communities and significantly impacted fish farmers across various regions. Notable invasive species affecting the country include the Chinese soft-shell turtle (*Pelodiscus sinensis*), blackchin tilapia (*Sarotherodon melanotheron*), knifefish (*Chitala ornata*), janitor fish (*Pterygoplichthys disjunctivus* and *P. pardalis*), and jaguar guapote (*Parachromis managuensis*).

In the province of Pampanga, no formal studies have yet been conducted on invasive aquatic species. As Pampanga has become a major center of aquaculture production—employing a polyculture system involving milkfish, shrimp, tilapia, and sometimes crabs—there is a high likelihood that invasive species have entered fishponds. Many fishpond owners and operators have reported the presence of introduced aquatic species that prey on the fry of cultured fingerlings, particularly tilapia and milkfish. Given this, there is a clear need to assess and document the presence of invasive aquatic species in the aquaculture areas of Pampanga.

MATERIALS AND METHODS

Study area

The study was performed in the major aquaculture areas of Pampanga. The criteria for site selection were based on two categories: Brackish water (Macabebe, Masantol, Minalin) and freshwater (Arayat, Candaba, Magalang). These areas are among the municipalities in the province with high production in aquaculture.

Sampling strategy and questionnaire design

The official list of fishpond owners was obtained from the Municipal Agriculture Office. Ten percent of the total population of fishpond operators in each municipality were selected as respondents. This resulted in a sample size of 404 respondents from various sites in the province of Pampanga, including Arayat, Candaba, Minalin, Macabebe, and Masantol. To accurately assess the impact of Invasive Aquatic Species (IAS) in these areas—regardless of whether the interviewee was positively or negatively affected by their introduction—the sample population included both fishpond owners and fishpond cooperators.

Respondents were randomly selected from the List of Aquaculture Farmers provided by the Municipal Agriculture Offices of each town. Data collection was conducted through face-to-face interviews using a structured questionnaire administered across the different municipalities of Pampanga.

The questionnaire consisted of two main sections: (1) a survey on the presence of invasive species in aquaculture ponds, and (2) a biological profile of these species, adapted from the Aquatic Species – Invasiveness Screening Tool.

Collection of samples

Specimens were collected with the assistance of local residents using various methods they commonly employ to capture invasive aquatic species (IAS). The collected potential IAS were then submitted to the National Museum of the Philippines for species identification.

Risk screening of invasive aquatic species

Risk screening of the identified invasive aquatic species was conducted using the Aquatic Species – Invasiveness Screening Kit (AS-ISK), accessible at http://www.cefas.co.uk/nns/Tools/. Experts in the field of fisheries served as assessors and were tasked with completing the risk screening process. The AS-ISK provided a total of 49 questions covering various aspects of the species being evaluated, including geographical distribution, biological characteristics, and economic impact. In addition, six questions addressed the potential effects of climate change to assess whether a species could become invasive under current and future climatic conditions.

Assessors were required to respond to every question in the toolkit, indicating their confidence level and providing justifications for each response based on existing literature and field survey data. This process ensured a comprehensive and evidence-based evaluation of each species' invasiveness risk. Confidence factors are derived from the confidence levels given to each response using this formula:

$$CF = \sum(CQi)/(4\times55) \quad (i=1,2\ldots55)$$

Where:

CF = confidence factor; and

CQi = confidence level for each question.

Assessors rated their confidence for each response on a scale from 1 to 4, with 1 representing the lowest confidence and 4 the highest. These ratings were then converted into a confidence factor ranging from 0.25 (lowest) to 1.0 (highest).

To interpret the results of the Basic Risk Assessment (BRA) and the combined Basic Risk Assessment and Climate Change Assessment (BRA+CCA), the interpretation framework developed by **Yu *et al*. (2024)** was adopted.

Table 1. Risk classification of invasive aquatic species based on the AS-ISK

	Basic risk assessment (BRA)	Basic risk assessment + Climate change assessment (BRA+CCA)
Low invasion risk	Below 26	Below 28.75
Medium invasion risk	Equal to 26	Equal to 28.75
High invasion risk	Above 26	Above 28.75

RESULTS AND DISCUSSION

1. Risk assessment area

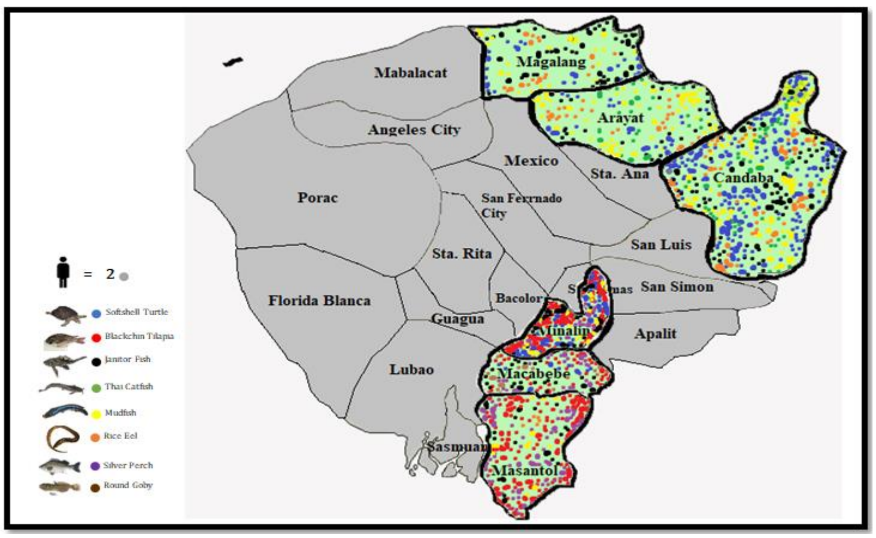

Fig. 1. Aquaculture areas of Minalin

Legend: Blue dot = Softshell Turtle, Red dot = Blackchin Tilapia, Black dot = Janitor Fish, Green dot = Thai Catfish, Yellow dot = Mudfish, Orange dot = Rice eel, Purple dot = Silver Perch, Brown dot = Round Goby. 1 fish farmer represents 2 species.

1.1. Brackish water environment (Macabebe, Masantol, and Minalin)

Fig. (1) shows that the most dominant species in the aquaculture areas of Macabebe, Pampanga is the blackchin tilapia followed by the janitor fish, silver perch, round goby, swamp eel and softshell turtle with a percentage of 53, 47, 40, 19, 13, and 13%, respectively. In the aquaculture areas of Minalin, Pampanga, the most dominant potential invasive species are the blackchin tilapia followed by softshell turtle, janitor fish, mudfish and silver perch with a percentage of 82, 69, 45, 36, and 24%, respectively. While in the aquaculture areas of Masantol, Pampanga, the most dominant potential invasive species are the blackchin tilapia with a percentage of 69%, followed by the silver perch (46%), janitor fish (4%), mudfish (3%) and rice eel (1%).

Sarotherodon melanotheron commonly known as the blackchin tilapia dominated the brackish water of Pampanga, as shown in Fig. (1). Though the species can thrive both in fresh and brackish water, the species is more abundant in brackish water which in this case, the aquaculture areas of Minalin, Macabebe and Masantol. This can possibly be linked by the geographical zones of the said brackish water areas in Pampanga. Manila Bay is connected to Pampanga River, while this river is also connected to Candaba swamp and Pasig-Potretro River which crosses the town of Minalin that links to Macabebe and Masantol waters. The occurrence of this species was already reported in 2013 thriving in the waters of Manila Bay and in Hagonoy, Bulacan **(Ordoñez, 2014)**. These connections of water could be the pathway of species in invading commercial aquaculture areas in Minalin, Masantol and Macabebe. The species is said to be confined to brackish water lagoon and estuaries **(Nico & Neilson, 2014)**.

1.2. Freshwater environment (Candaba, Arayat, and Magalang)

As indicated in Fig. (1), the most dominant potential invasive species in the aquaculture areas of Magalang, Pampanga are the janitor fish with a percentage of 87%, followed by the softshell turtle (73%), mudfish (67%), and rice eel (53%).

In the aquaculture areas of Candaba, the most dominant invasive aquatic species as seen in Fig. (1) are *Pelodiscus sinensis* which is locally known as softshell turtle with a percentage of 42%, followed by the janitor fish (34%), mudfish (30%), rice eel (29%) and the thai catfish (15%). The introduction of softshell turtle in the wetland may be the reason as to why the species is abundant in the Province of Pampanga. The ability of the species to tolerate harsh environment would most likely be the reason why they have already established their population in the aquaculture areas of Pampanga. In 2013, fishpond owners and operators from the province of Pampanga have filed complaints to the Department of Environment and Natural Resources (DENR) regarding the alarming increasing number of this species.

The most leading invasive species in aquaculture areas of Arayat, Pampanga are the mudfish with a percentage of 47%, followed by the janitor fish, rice eel, catfish with (37%), and softshell turtle (32%).

Two species which are *Channa striata* and *Pterydoplicthys* spp. are found both in the freshwater and brackish water areas of Pampanga (Fig. 1). These species can thrive in harsh environment and capable of surviving in dry season by burrowing. It was also reported that these species can survive in low-oxygenated environments. These species are widely distributed and are found in a wide range of aquatic habitats like lakes, rivers, swamps, marshes and even sewers.

According to the fisher folks both in the freshwater (Magalang, Candaba and Arayat) and brackish water (Minalin, Masantol) areas in Pampanga, these species invade fishponds through irrigation canals. These species are present in the Pasig-Potrero River which crosses the town of Minalin and Masantol and invades its commercial aquaculture areas. While, these species reside in the flood control component in Candaba, connected to Magalang and Arayat rivers, they enter the commercial aquaculture fishponds in the towns through irrigation canals, respectively.

2. List of potential invasive aquatic species in the risk assessment areas

Table (2) shows the complete list of potential invasive aquatic species found in the RA. As shown in the Table (1), four (4) species of finfishes were found at all study sites viz. the mudfish (*Channa striata*), janitor fish (*Pterygoplichthys disjunctivus*), and Thai catfish (*Clarias batrachus*). While, 2 species of aquatic macrophytes were both found in brackish and freshwater. Additionally, the golden apple snail (*Pomacea canaliculata*) under Gastropod family and the softshell turtle (*Pelodiscus sinensis*) under the family of reptile were both found in the risk assessment areas.

Moreover, *Labeo rohita* and *Gourami* were both found in the commercial aquaculture areas of Candaba. While, the *Leiopotherapon plumbeus* was abundant in three municipalities, which have the same type of water.

It can be presumed that the presence and absence of these species vary based on the type of habitat, the ability of the species to establish viable population, environmental factors, and even human interventions.

Table 2. List of potential invasive species found in the risk assessment areas

Species		Brackishwater			Freshwater		
English Name	**Scientific Name**	Minalin	Masantol	Macabebe	Candaba	Arayat	Magalang
Finfishes							
Rice eel	*Monopterus albus*	-	+	+	+	+	+
Mudfish	*Channa striata*	+	+	+	+	+	+
Black chin tilapia	*Sarotherodon melanotheron*	+	+	+	-	-	-
Janitor fish	*Pterygoplichthys disjunctivus*	+	+	+	+	+	+
Thai catfish	*Clarias batrachus*	+	+	+	+	+	+
Ayungin	*Leiopotherapon plumbeus*	+	+	+	+	+	+
Bidbid	*Elops hawaiensis*	+	+	+	-	-	-
Aquatic Macrophytes							
Water hyacinth	*Eichhornia crassipes*	+	+	+	+	+	+
Water lettuce	*Pistia stratiotes*	+	+	+	+	+	+
Reptile							
Softshell turtle	*Pelodiscus sinensis*	+	+	+	+	+	+

Legend: (+) present; (-) absent.

3. Risk screening result of potential invasive aquatic species using aquatic Screening – Invasive Scoring Kit (AS-ISK)

Six species were assessed for potential invasiveness using AS-ISK (Table 3). Based on the outcome of the BRA and BRA+CCA thresholds, all species were classified as “high risk” (>30) for potential invasion. Out of the 6, 4 species namely *Clarias batrachus*, *Channa striata*, *Pelodiscus sinensis* and *Pterygoplichthys disjunctivus* were found to be of high risk for both fresh water and brackish water areas of Pampanga, while *Monepterus albus* was found to impose high risk only in freshwater area and *Sarotherodon melanotheron* in brackish water.

Table 3. Risk screening of potential invasive aquatic species in the aquaculture areas of Pampanga, assessed with the aquatic species invasiveness screening kit (AS-ISK)

	Species		**Outcome**				**Confidence factor**		
	Common Name	**Scientific Name**	**BRA Score**	**Invasion Risk**	**BRA+ CCA Score**	**Invasion Risk**	**BRA**	**CCA**	**BRA+ CCA**
FRESHWATER	*Clarias batrachus*	Thai catfish	53	High	65	High	0.81	0.67	0.80
	Channa striata	Mudfish	62	High	58	High	0.68	0.58	0.67
	Pelodiscus sinensis	Softshell turtle	45	High	43	High	0.72	0.71	0.72
	Pterygoplichthys disjunctivus	Janitor fish	37	High	41	High	0.96	1	0.96
	Monopterus albus	Rice eel	47	High	57	High	0.82	0.67	0.8
BRACKISHWATER	*Clarias batrachus*	Thai catfish	53	High	65	High	0.81	0.67	0.80
	Channa striata	Mudfish	56	High	56	High	0.7	0.54	0.68
	Pelodiscus sinensis	Softshell turtle	45	High	43	High	0.72	0.71	0.72
	Pterygoplichthys disjunctivus	Janitor fish	37	High	39	High	0.95	0.96	0.95
	Sarotherodon melanotheron	Blackchin tilapia	58	High	70	High	0.65	0.38	0.62

DISCUSSION

The blackchin tilapia (*Sarotherodon melanotheron*)

The highest scoring species in this study in terms of BRA+CCA namely *S. melanotheron* has been considered as a pest in the nearby provinces of Pampanga. The fisherfolks in the municipality of Minalin (risk assessment area (RA)) believed that *S. melanotheron* came from the ponds of nearby provinces and has been brought to their ponds due to the flooding events. Given the location of the province, this scenario is possible since *S. melanotheron* has already been observed in the provinces of Bulacan and Bataan since 2011 and it is believed to have established its population in these areas **(Ordoñez *et al.*, 2014)**. According to the fisherfolks in the RA, the presence of *S. melanotheron* has caused the decrease in the volume of their production. The same scenario was observed in the province of Bataan where the appearance of *S. melanotheron* is regarded as the reason for the decline in fish catch of farmers. Local famers in Hagonoy, Bulacan also claimed that *S. melanotheron* feeds on the early stages of their farmed species which include the milkfish, tilapia and giant tiger shrimp **(Ordoñez *et al.*, 2014)**. This may be linked to the carnivorous nature of *S. melanotheron* which are reported to feed on eggs and larvae of smaller species **(Campbell, 1987)**. The "high" risk result of the study in terms of the of invasiveness of *S. melanotheron* is in conjunction with the risk assessment of the species conducted by the U.S. Fish and Wildlife Service, wherein they have noted a "high" risk of invasiveness in terms of its history, climate match and overall risk assessment category with a "medium" certainty of assessment.

Chinese softshell turtle (*Pelodiscus sinensis*)

Results of the study also revealed that *Pelodiscus sinensis* imposes a "high" risk of invasion in the aquaculture areas of Pampanga. *P. sinensis* is a native of China, Japan and Taiwan **(Turtle Taxonomy Working Group, 2014)**. The earliest record of this species in the Philippines was based on a single specimen collected from the Batanes Islands **(Sy *et al.*, 2004)** and is believed to be introduced via commercial farming for meat source. Although there were no studies conducted about its impact and literatures on its occurrences in the Philippines, this species has already been reported as a pest in the aquaculture and fisheries industry of Central Luzon and threatens the biodiversity of the area **(Cervantes, 2013)**. Fisherfolks in the RA noted a decrease in their production since the occurrence of *P. sinensis* in their ponds. They have observed that *P. sinensis* consumes other aquatic species in their ponds including their cultured species. *P. sinensis* is known to be a voracious feeder. They are predominantly carnivorous and feed on almost all kinds of species including zooplankton, insects, crayfish, crabs, fish, molluscs **(FAO, 2017)**. Though *P. sinensis* is included in the IUCN list as an endangered animal **(Baker, 2003)**, it was recorded to be an invasive species in the European Union having a "moderate" risk of invasion **(Kopecky *et al.*, 2013)**. It was reported to displace local species of turtles and other invasive species of turtle in many countries **(Cadi & Joly, 2004)**. Given this, it is likely that *P. sinensis* can impose a high risk of invasion in the aquaculture areas of Pampanga, as revealed by the AS-ISK analysis (Table 1).

The janitor fish (*Pterygoplichthys disjunctivus*)

Pterygoplichthys disjunctivus was also found to be of "high" risk based on the assessment conducted by the U.S. Fish and Wildlife Service. Several authors from the Philippines have claimed that *P. disjunctivus* is invasive **(Agasen, 2005; Joshi, undated; Guerero III, 2014)**. According to the U.S. Fish and Wildlife Service, this species is a native of South America. However, its presence is documented in the Philippines invading the waters of Laguna de Bay, Lake Paitan in Cuyapo, Marikina River, and Nueva Ecija

(Joshi, nd). High population of this species is also observed in the streams and rivers of Aparri, Cagayan and Zamboanga City **(Chavez *et al.*, 2006)**.

The wide distribution of *P. disjunctivu*s in Philippine waters may be related to the occurrence of this species in Pampanga specifically at six study sites (RA). Fisherfolks in the RA areas claimed that the large quantity of *P. disjunctivus* present in their ponds came from the riverine waters of Pampanga. Since the species is widely distributed in the Philippines, it is likely that the species has already reached the riverine waters of the area.

Another reason for the abundance of *P. disjunctivus* in the Philippine is the occurrence of Typhoon Rosing. It was documented that, during the disturbance to Typhoon Rosing, *P. disjunctivus* has escaped from commercial ponds and has established its population in natural waters. This scenario is possible since the species are reported to thrive in harsh environments explaining the presence of the species in both freshwater and brackish water environments in the RA. The species was also reported to compete with native fishes **(Mendoza *et al.*, 2009)** which was observed in Laguna de Bay where the decline of native and "more desirable fish" in the area was linked to its presence **(Chavez *et al.*, 2006)**.

Other problems brought by *P. disjunctivus* in the RA is the destruction of fishpond dikes and bank structures in their aquaculture areas. Researches revealed that in locations where *P. disjunctivus* is prevalent, siltation problems and dike erosion and instability are seen as a result of their burrowing activities.

Thai catfish (*Clarias batrachus*)

As shown in Table (3), *Clarias batrachus* also poses a "high" risk of invasiveness in the risk assessment areas. This supports the claim of **Guerrero (2014)** that the species have become invasive in the Philippines. The walking catfish is native in Southeast Asia and was introduced for cultivation purposes **(Guerrero, 2014)**. It serves as a food fish and is actively cultivated through commercial farming in its native range, however, when outside its native range, it has shown to be a destructive pest preying on farmed animals and causing genetic pollution which can cause significant economic and ecological damage **(Robins, nd)**.

In the RA, the fisher folks stated that the walking catfish enters their fishponds through irrigation canals and prey on the fingerlings of farmed species (tilapia), resulting in a decrease in fish catch and income loss. The fisher folks also revealed that the numbers of the waking catfish in their ponds increased during rainy season. This is possible since the species can easily migrate due to its ability to breathe atmospheric air for a period of time and to move short distances over land.

Clarias batrachus invasiveness can be linked to its behavior. This species is known for its resilience **(Kumar *et al*., 2012)** since it can thrive in harsh environments where many fish cannot **(Robins, nd)**. In addition, it was also seen as one of the reasons for the near extinction of *C. macroceohalus* (native catfish) in the Philippine waters. It was said to replace the native catfish in waters where it has been introduced **(Guerrero, 2014)**. The Philippine aquaculture supported the claims of **Guerrero (2014)** and stated that the introduction of *Clarias batrachus* in the Philippines contributed to the dwindling population of *Clarias macrocephalus*.

Rice eel (*Monopterus albus*)

Monopterus albus, commonly known as the rice eel, was assessed to pose a high risk of invasiveness based on the risk screening results (Table 3). Asian swamp eels are known to thrive in a wide range of aquatic environments, both within their native and introduced ranges. These habitats include lakes, rivers, ponds, marshes, swamps, sewage systems, and waste drains. In the Risk Assessment (RA) areas, *Monopterus albus* was found in five major aquaculture zones in Pampanga—except in Minalin.

Fisherfolk in Candaba reported that during the dry season, they convert their fishponds into farmland. This seasonal transformation may explain the higher presence of rice eels in the area, as the species is known to infest rice paddies **(Valencia, 2013)**.

The behavior of the rice eel may be a key factor contributing to its high invasiveness. According to **Matsumoto *et al*. (2010)**, the species is a nocturnal predator and a voracious feeder, especially when encountering prey such as small aquatic organisms **(Hill & Watson, 2007)**. It is classified as an opportunistic omnivore. In the RA areas, fisherfolk observed that *M. albus* preys on the eggs and fingerlings of cultured species, particularly tilapia. They also noted that the species likely enters fishponds via irrigation canals.

Guerrero (2014) reported that *M. albus* was originally introduced to the Philippines for cultivation but has since become invasive. Infestations have been observed in the rice paddies of the Cagayan Valley. The species is known to burrow into bunds, causing water loss **(Lazaro, 2013; Valencia, 2013)**.

The mudfish (*Channa striata*)

Channa striata was evaluated using the AS-ISK, and results indicated that the species poses a high risk of invasiveness (Table 3). It has been observed preying on the fry of commonly cultured fish such as tilapia and the milkfish **(Guerrero *et al.*, 1990)**. This supports local accounts from fisherfolk in the RA areas who reported that *C. striata* invades their ponds and feeds on the eggs and juveniles of their farmed species, particularly the Nile tilapia.

Locally known as *dalag*, *C. striata* is a solitary and territorial fish native to East and Southeast Asia **(Musikasinthorn, 2001)**. It primarily inhabits shallow, slow-moving freshwater environments such as rivers, lakes, ponds, canals, creeks, flooded rice fields, irrigation reservoirs, and swamps **(Cagauan, 2007)**. A significant factor in its high invasiveness is its ability to survive in low-oxygen and turbid conditions. Its feeding behavior, characterized by predation on any available food source, further increases its potential to disrupt aquaculture systems **(Cagauan, 2007)**.

The results of the risk screening indicate that invasive aquatic species have successfully established themselves in the aquaculture areas of Pampanga. Their presence is affecting the aquaculture sector and may lead to income losses for fish farmers in the risk assessment areas.

Moreover, the study revealed that many fisherfolks in these areas lack awareness of the ecological and economic impacts of invasive species. They also have limited knowledge of proper handling and control measures when these species intrude into their fishponds.

The findings of this study should be used to develop effective guidelines and management strategies aimed at preventing the further spread of identified high-risk invasive species.

CONCLUSION

Six fish species—*Sarotherodon melanotheron*, *Pelodiscus sinensis*, *Pterygoplichthys disjunctivus*, *Channa striata*, *Monopterus albus*, and *Clarias batrachus*—have been confirmed as invasive aquatic species in the risk assessment areas. Additionally, the risk screening conducted using the Aquatic Species – Invasiveness Screening Kit (AS-ISK) proved to be an effective tool for evaluating the potential risks and threats posed by these species in the six major aquaculture zones of Pampanga.

Observations revealed that many fish farmers in the risk assessment areas lack the knowledge and capacity to properly manage these invasive species. This gap in awareness and management skills poses significant risks not only to the aquaculture sector but also to the broader ecological stability of the province.

In this context, the findings from the risk screening are highly valuable for informing the development of more effective policies and management strategies. These would help aquaculture farmers mitigate income loss and equip them with the knowledge needed to respond appropriately to invasive species incursions.

Therefore, addressing the presence and spread of invasive aquatic species in Pampanga's aquaculture areas is imperative. There is a critical need to craft and implement new policies focused on the control, monitoring, and management of these species to safeguard both livelihoods and aquatic ecosystems.

REFERENCES

Agasen, E.V. (2005). Prawn fisheries of Lake Bato. In M.L. Cuvin-Aralar; R.S. Punongbayan; A. Santos-Borja; L.V. Castillo; E.V. Manalili, and M.M. Mendoza (Eds.), *Proceedings of the First National Congress on Philippine Lakes* (pp. 163-170). Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Baker, P.J. (2003). *Softshell Turtles* (Trionychidae). Gale Group, Inc., Thomson Learning, Inc.

Bertness, M.D. (1984). Habitat and community modification by an introduced herbivorous snail. *Ecology*, 65, 370-381.

Cagauan, A.G. (2007). Exotic Aquatic Species Introduction in the Philippines for Aquaculture - A threat to Biodiversity or A boon to the Economy.

Campbell, D. (1987). A review of the culture of Sarotherodon melanotheron in West Africa.

Casal, C.M.V. (2005). Documenting the presence and impact of introduced freshwater fishes for aquaculture in the Philippines, p. 145-154 In: Cuvin-Aralar, M.L.; Punongbayan, R.S.; Santos-Borja, A.; Castillo, L.V.; Manalili, E.V., and Mendoza, M.M. (eds.). *Proceedings of the First National Congress on Philippines Lakes*. Southeast Asian Regional Center for Graduate Study and Research in Agriculture; 5 June 1992. Los Banos, Laguna, Philippines: Convention on Biological Diversity. 1992. Convention on Biological Diversity. 29 p.

Cervantes, D. (2013, February 06). Invasive Chinese turtle species threatens fish in Central Luzon. *Philippine Star Global*.

Chavez, H.M.; Casao, E.A.; Villanueva, E.P.; Paras, M.P.; Guinto, M.C. and Mosqueda, M.B. (2006). Heavy metal and microbial analysis of janitor fish (Pterygoplichthys spp.) in Laguna de Bay, Philippines. *J Environ Sci Management*, 9(2), 31-40.

Copp, G.H.; Russell, I.C.; Peeler, E.J.; Gherardi, F.; Tricarico, E.; Macleod, A. and Britton, J.R. (2016). European non-native species in aquaculture risk analysis scheme - A summary of assessment protocols and decision making tools for use of alien species in aquaculture. *Fisheries Management and Ecology*, 23, 1-11.

Food and Agriculture Organization. (2014). Fisheries and Aquaculture Topics. Introduction of species. Topics Fact Sheets. In: *FAO Fisheries and Aquaculture Department*.

Food and Agriculture Organization. (2017). *DATABASE ON INVASIVE ALIEN SPECIES.*

Guerrero, R.D. (2014). Impacts of Introduced Freshwater Fishes in the Philippines (1905-2013): A Review and Recommendations.

Guerrero, R.D. III; Guerrero, L.A. and Garcia, L.L. (1990). Use of indigenous plants as sources of fish toxicants for pond management in the Philippines. *Philippine Technology Journal*, XV(2), 15-17.

Hill, J.E., and Watson, C.A. (2007). Diet of the nonindigenous Asian swamp eel in tropical ornamental aquaculture ponds in west-central Florida. *North American Journal of Aquaculture*, 69(2), 139-146.

Joshi, R.C. (n.d.). Invasive alien species (IAS): concerns and status in the Philippines.

Kumar, A.; Sharma, B. and Pandey, R.S. (2012). Alterations in nitrogen metabolism in freshwater fishes, Channa punctatus and Clarias batrachus, exposed to a commercial-grade k-cyhalothrin, REEVA-5. *Intel J of Exp Path*, 93(1), 34-45.

Kopecky et al. (2013). Establishment risk from pet-trade freshwater turtles in the European Union.

Lazaro, F.G. (2013). Farm pest now exported food. *Manila Bulletin* (August 31, 2013) p. 9.

Lawson Jr., L.L.; Hill, J.E.; Vilizzi, L.; Hardin, S. and Copp, G.H. (2013). Revisions of the Fish Invasiveness Screening Kit (FISK) for its application in warmer climatic zones, with particular reference to peninsular Florida. *Risk Analysis*, 33, 1414-1431.

Marbuah, G.; McKie, B. and Gren, I.M. (2014). Economics of Harmful Invasive Species: A Review.

Matsumoto, S.; Kon, T.; Yamaguchi, M. (2010). Cryptic diversification of the swamp eel Monopterus albus in East and Southeast Asia, with special reference to the Ryukyuan populations. *Ichthyol Res*, 57, 71-77.

Mendoza, R.E.; Cudmore, B.; Orr, R.; Balderas, S.C.; Courtenay, W.R.; Osorio, P.K.; Mandrak, N.; Torres, P.A.; Damian, M.A.; Gallardo, C.E.; Sanguines, A.G.; Greene, G.; Lee, D.; Orbe-Mendoza, A.; Martinez, C.R. and Arana, O.S. (2009). Trinational risk assessment guidelines for aquatic alien invasive species. *Commission for Environmental Cooperation* 393, rue St-Jacques Ouest, Bureau 200, Montreal (Quebec), Canada. ISBN 978-2-923358-48-1.

Mooney, H., and Cleland, E. (2001). The evolutionary impact of invasive species. *Proc Nat Acad Sci*, 98(10), 5446-5451.

Musikasinthorn, P. and Taki, Y. (2001). Channa siamensis (Günther, 1861), a junior synonym of Channa lucius (Cuvier, in Cuvier and Valenciennes, 1831): *Ichthyological Research*, v. 48, p. 319-324.

Nico, L. and Neilson, M. (2013). Sarotherodon melanotheron. *USGS Nonindigenous Aquatic Species Database*, Gainesville, FL.

Nico, L.G.; Jelks, H.L. and Tuten, T. (2009). Non-native suckermouth armored catfishes in Florida: description of nest burrows and burrow colonies with assessment of shoreline conditions. *Aquat. Nuisance Species Res. Bull.*, 9, 1-30.

Ordonez, J.F.; Asis, A.M.J.; Catacutan, B.J.; Dela Pena, J. and Santos, M.D. (2014). First report on the occurrence of invasive black-chin tilapia Sarotherodon melanotheron (Ruppell, 1852) in Manila Bay and of Mayan cichlid Cichlasoma urophthalmus (Gunther, 1892) in the Philippines.

Phen, C.; Thang, T.B.; Baran, E. and Vann, L.S. (2005). Biological Reviews of Important Cambodian Fish Species, Based on Fishbase 2004. *World Fish Center and Inland Fisheries Research and Development Institute*, Phnom Penh, Cambodia.

Robins, R. (n.d.). "Discover Fisheries: Walking Catfish." *Florida Museum*.

Roy, H.E.; Rabitsch, W.; Scalera, R.; Stewart, A.; Gallardo, B.; Genovesi, P.; Essl, F.; Adriaens, T.; Bacher, S.; Booy, O.; Branquart, E.; Brunel, S.; Copp, G.H.; Dean, H.; D'hondt, B.; Josefsson, M.; Kenis, M.; Kettunen, M.; Linnamagi, M.; Lucy, F.; Martinou, A.; Moore, N.; Nentwig, W.; Nieto, A.; Pergl, J.; Peyton, J.; Roques, A.; Schindler, S.; Schönrogge, K.; Solarz, W.; Stebbing, P.D.; Trichkova, T.; Vanderhoeven, S.; Van Valkenburg, J. and Zenetos, A. (2018). Developing a framework of minimum standards for the risk assessment of alien species. *Journal of Applied Ecology*, 55, 526-538.

Sy, E.; Farkas, B. and Buzas, B. (2004). The Chinese Sofshell Turtle Established in the Philippines. Turtle and Tortoise Newsletter, 7: 17-18

To, D.A.L.; Gomez, G.M.L.; Ramos, D.R.Y.; Palillo, C.D.V.; Go, N.K.C.; Gilles, Jr.; Briones, A.S.; Pavia, J.CA. and Jr., R.T.B. (2021). Invasive Risk Assessment of Non-native Freshwater Fish Species (Order: Siluriformes) for Lake Taal, Philippines. Philippine Journal of Science., 151 (3): 833-841

Van Dijk, P.P.; Iverson, J.B.; Rhodin, A.G.J.; Shaffer, H.B. and Bour, R. (2014). Turtles of the world, 7th edition: annotated checklist of taxonomy, synonymy, distribution with maps, and conservation status. Chelonian Research Monographs 5(7): 329-479

Uyan, U.; Oh CW.; Tarkan, AS.; Top, N.; Copp, GH. and Vilizzi, L. (2020). Risk screening of the potential invasiveness of non-native marine fishes for South Korean coastal waters. Accessed November 14, 2022 at https://www.sciencedirect.com/science/article/abs/pii/S0025326X20301363

Valencia, C. (2013). Pesky rice eel now an export commodity. Philippine Star (August 11, 2013) p. B-3.

Vitousek, P. M. (1990). Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. – Oikos 57: 7–13.

Wilcove, DS.; Rothstein, D.; Dubow, J.; Philips, A. and Losos E. (1998). Quantifying threats to Imperiled Species in the United States. Accessed at https://www.jstor.org/stable/1313420

Yu, R.; Wu, Q.; Li, F.; Zhan, A.; Zhou, J. and Li, S. (2024). Risk Screening of Invasive Aquatic Species and a Survey of Fish Diversity Using Environmental DNA Metabarcoding Analysis in Shanghai. Diversity, 16(1), 29. https://doi.org/10.3390/d16010029