Aquaculture Studies, 25(4), 206-211, AQUAST2178
http://doi.org/10.4194/AQUAST2178

AQUACULTURE STUDIES

RESEARCH PAPER

Economic Analysis of Invasive Aquatic Species in the Aquaculture Areas of Pampanga, Philippines

Walter Pacunana[1]

[1]Pampanga State Agricultural University, Department of Fisheries, Magalang, Pampanga, Philippines 2011.

How to Cite

Pacunana, W. (2025). Economic Analysis of Invasive Aquatic Species in the Aquaculture Areas of Pampanga, Philippines. *Aquaculture Studies*, *25(4), AQUAST2178*. http://doi.org/10.4194/AQUAST2178

Article History
Received 29 October 2024
Accepted 12 April 2025
First Online 30 April 2025

Corresponding Author
E-mail:
walter_pacunana@psau.edu.ph

Keywords
Aquaculture resources
Benefit-cost ratio (BCR)
Economic state
Livelihood fisheries

Abstract

Invasive aquatic species (IAS) are unintentionally released in natural habitats in bodies of water and pose a threat to native species. This disruption of the diversity of their habitat can result in social, biological, and economic damage. IAS often thrive because they have no natural competitors or predators. This study was conducted due to a lack of data on the impacts of IAS on the livelihood of the local fish farmers in the Philippines. Thus, it focused on six municipalities, which included three brackish water areas (Minalin, Masantol, Macabebe) and three freshwater areas (Candaba, Arayat, Magalang) in Pampanga. Data was gathered from fish owners and cooperators through surveys and interviews on the costs of control measures, types or practices of preventive measures, and any additional income from IAS as a raw material. The collected data were analyzed using cost-benefit analysis. The study found that the estimated costs associated with IAS were higher in brackish water areas (PhP19,486,477/ USD340,830) compared to freshwater areas (PhP15,388,491/ USD269,239). However, the estimated benefits totaled PhP 13,803,448 (USD 241,507) for both areas (freshwater: PhP7,164,400/ USD125,349); brackish water: PhP6,639,048/ USD116,157). The benefit-cost ratio (BCR) indicates that the costs associated with IAS outweigh the benefits, hence leading to a net economic loss. The study concludes that addressing IAS issues should be a priority for government intervention to control IAS populations, raise awareness about declining native species harvests, and mitigate the loss of livelihood for the local fish farmers.

Introduction

Invasive species are persistently altering the natural areas that are distinctively unique to the islands of the Philippines. By outcompeting native plants and animals, they devastate industries, communities, and native cultures that rely on the country's natural resources. These species also degrade waterways, thus, harming water quality and limiting recreational opportunities (NISAW, 2019). The impacts of invasive aquatic species (IAS) on native fishes in the Philippines are poorly understood because of the absence of comprehensive technical information. This knowledge gap is worsened by the poor implementation of laws on the introduction of exotic species and the unwillingness to interfere in their trade and commerce (Guerrero, 2014).

As the number of invasive species increases and control efforts become more complex, there is a need to prioritize control actions for IAS. Reports on the costs of invasive species control are inadequate, often found in gray literature, and limited in terms of the species considered and the geographical scope. Despite increased efficiencies in control efforts, the total costs of managing invasive species control are also most likely increasing due to control actions taking place in increasingly complex locations with multiple invasive species present.

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Türkiye.

Relevant to this, Hanley (2019) noted that the impacts of invasive species are associated with a range of costs and benefits, with many species having both positive and negative values depending on the context. Factors affecting the cost of controls include aggregated materials and labor costs. It is likewise manifested in potential income loss, which is indicated by the reduction in the volume of harvested cultured species. In estimating the costs associated with controls, the difference in production costs before and after the spread of IAS was used as a proxy. The estimated potential loss was determined by comparing the volume of cultivated species lost due to the presence of IAS during a specific period. Meanwhile, factors affecting the benefit are the economic value of IAS as fresh produce (price per kilogram) on the market and their potential as raw materials. The total volume of the marketable IAS was valued based on their current market price per kilogram to determine possible additional income. As these materials can only be acquired by purchasing IAS at their present market price, the same value was calculated for the potential raw materials derived from IAS.

The study used cost-benefit analysis to quantify the costs and benefits of IAS in selected aquaculture areas in Pampanga. To conduct the analysis, the following procedures are necessary:

(1) estimate the cost per invasive species;
(2) estimate the benefit per invasive species;
(3) estimate the cost per type or method of control;
(4) aggregate the total cost and total benefit; and
(5) determine the benefit-cost ratio.

Materials and Methods

Establishment of Baseline Information

Study Area

The study was conducted in the major aquaculture areas of Pampanga. The criteria for site selection were based on the amount of production and the type of environment, such as brackish water and freshwater, in each municipality. The selected brackish water areas include the municipalities of Macabebe, Masantol, and Minalin, while freshwater areas include the municipalities of Arayat, Candaba, and Magalang (Figure 1).

Sampling Strategy and Questionnaire Design

The respondents of the study were randomly selected from the lists of aquaculture farmers provided by the municipal agricultural offices of the six municipalities. The respondents were categorized as either: (1) fishpond owners and (2) fishpond cooperators. A total of 404 questionnaires were obtained from Arayat, Candaba, Minalin, Macabebe, Masantol, and Magalang. Specifically, 30% of the fish farmers from each municipality were interviewed for further information. However, as this study was conducted during the COVID-19 outbreak, the methodology used had certain limitations that affected the gathered data.

Computation for Cost and Benefit

Cost (K)

The costs represent the adverse effects brought by the spread of IAS. To compute the aggregate costs, represented by $\underline{K}$, the sum of the direct and indirect costs from the data retrieved from the two types of aquaculture areas were calculated using the following formula.

$$\underline{K} = \sum_{i=1}^{n} F_{it}^{Y} + \sum_{i=1}^{n} B_{it}^{Y} \qquad (1)$$

To estimate the costs associated with controls, the difference in value before and after the spread of IAS was used as a proxy to compare the value of production costs. The estimated potential income loss was determined by comparing the volume of cultivated species lost due to the presence of IAS during a specific time period.

Benefits (Y)

Benefits, represented by $\underline{Y}$, assess the favorable consequences of the situation. Its calculation is parallel with the process of how to compute the costs using the following formula.

$$\underline{Y} = \sum_{i=1}^{n} F_{it}^{Y} + \sum_{i=1}^{n} B_{it}^{Y} \qquad (2)$$

The total volume of marketable IAS was valued based on the current market price per kilogram to determine the additional income derived from IAS. As these materials can only be acquired by purchasing IAS species at their current market price, the same value was calculated for the potential raw materials derived from them.

Aggregate Net Present Value

Net present value (NPV) refers to the total economic value net of the computed economic costs. The computation of the aggregate NPV utilizes the result of the equation for benefit and cost using the following formula.

$$\underline{NPV} = \underline{Y} - \underline{K} \qquad (3)$$

Discounting

To account for the effect of inflation on the value of the benefits and costs accrued over five years, the computed values were converted into present values using the formula below.

$$PV = \frac{1}{(1+r)^t} \quad (4)$$

Benefit-Cost Ratio (BCR)

The negative NPV was validated by computing the ratio of benefits to costs using the computed present values of the costs and benefits. A BCR of less than 1 indicates that the cost outweighs the benefits of IAS, while a BCR greater than 1 indicates that the benefit of IAS outweighs the cost.

Results and Discussion

Estimation of Cost

The cost-benefit analysis (CBA) was based on the observed economic effects of invasive aquatic species (IAS) in identified aquaculture areas in Pampanga, particularly in the freshwater areas of Arayat, Magalang, and Candaba and the brackish water areas of Minalin, Masantol, and Macabebe. The study utilized a surveyed dataset, involving 92 aquaculture farm owners in freshwater areas and 313 in brackish areas, for a total of 405 aquaculture farm owners. Data for the cost include:

i) cost for controls – aggregated for materials and labor costs, and

ii) potential income loss – indicated by the reduction in the volume of harvested cultured species.

The maximum annual cost was reported to be PhP500,000 (USD8.723), while the largest annual income loss was computed to be PhP1,300,000 (USD22,679) in both freshwater and brackish water areas. On the other hand, the benefits considered were the economic value of IAS as fresh produce (priced per kilogram) on the market and their potential as raw material. The largest additional income in both research areas was PhP1,754,250 (USD30,603).

Table 1 shows the detailed computation of the annual economic costs in freshwater areas of Magalang, Arayat, and Candaba and in brackish water areas of Masantol, Macabebe, and Minalin. The cost imposed by the proliferation of IAS is the loss of potential income of fisherfolk due to the reduction in the volume of cultivated species harvested. This threat of reduced

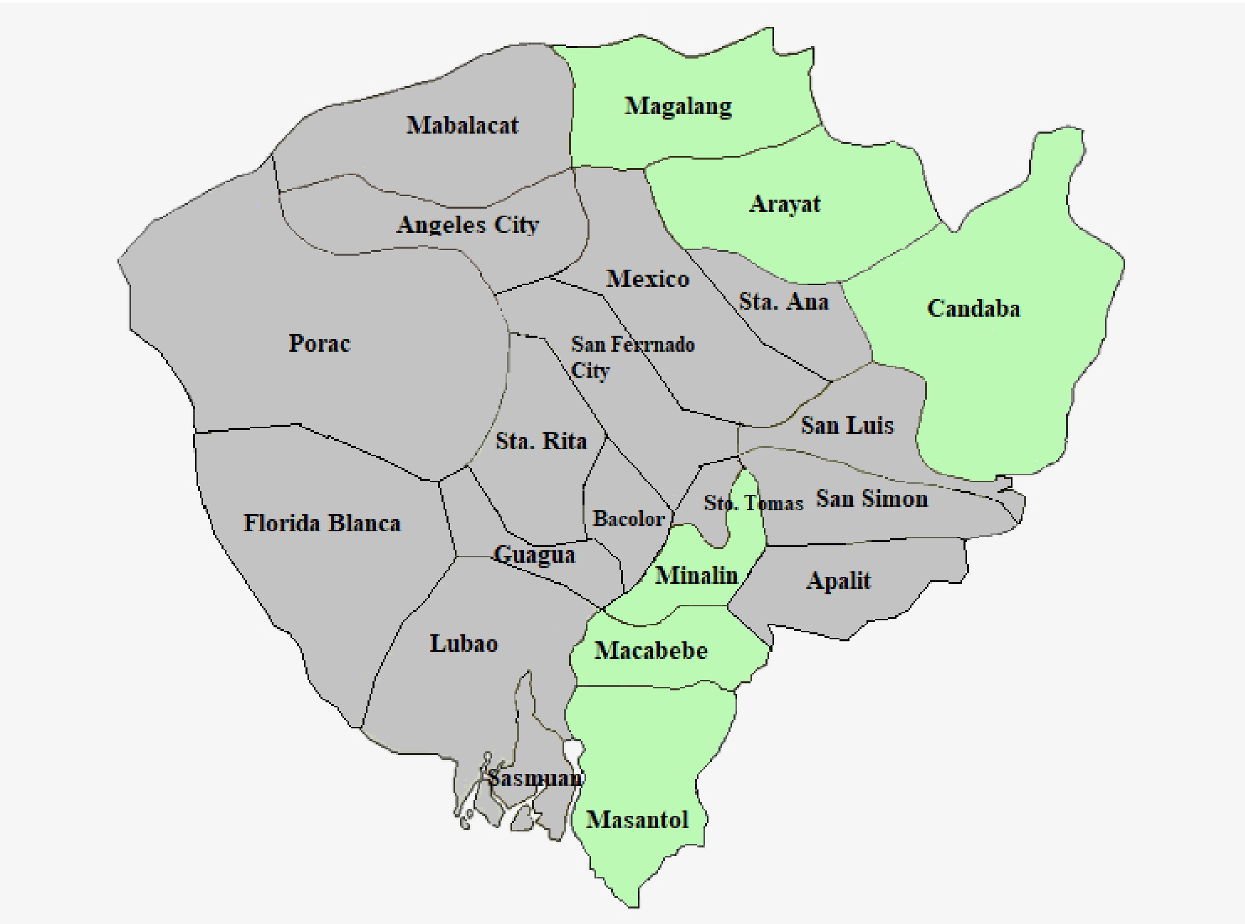

Figure 1. Graphical map of selected brackish water and freshwater areas.

volume forces fisherfolk to invest in IAS propagation controls, thereby increasing production costs. The use of traps, chemicals, and manual removal of IAS, which increases the labor and manpower, are some of the identified control measures.

Estimation of Cost per Method of Control

As shown in Table 2, gillnets, amounting to a total of PhP761,800.00 (USD13,324), represent the highest expense on net control measures in both brackish water and freshwater areas. In Pampanga, gillnets are locally known as *panti* or *kitig*. Most fish farmers use gillnets to manage the growing population of IAS in their culture areas. According to some of the fish farmers interviewed, gillnets are primarily used at the beginning of the culture period or until the cultured species reach a size larger than the mesh size of the net, after which the gillnet is removed. Meanwhile, *circulo* nets are only used in the brackish water areas, or southern part of the province, at the opening of ponds to control invasive species from entering the culture area. Additionally, *bukatot* nets and screens are widely used in brackish water areas, although these control measures are not documented in Magalang and Arayat.

In terms of control measures using chemical solutions, both study areas use sodium, costing a total of PhP989,200.00 (USD17,302). Sodium is applied after the harvest period and in preparation for the next cycle to ensure that IAS are not present in the culture area. Fish farmers also use tea seed after harvest if their culture species are crustaceans (e.g., mud crab, tiger prawn, white leg shrimp). However, the usage of tea seed in freshwater areas was not documented in the conducted survey and interviews.

Furthermore, other expenses include labor for pond draining, the application of sodium and tea seed in ponds, the fabrication of control measures, and the rental and gasoline used for the machinery needed in pond draining. Renting machinery for pond draining represented a significant capital expenditure, with the documented overall amount reaching PhP1,187,000.00 (USD20,761).

In the brackish water areas, a total of 14% of respondents reported not using any control measures in their culture areas. On the other hand, 29 out of 92 fish farmers in the freshwater areas reported not using any control measures to eradicate the increasing number of IAS in the culture areas.

This suggests that fisherfolk struggle on managing the IAS in their areas. It is evident that some choose not to use any control measures to avoid incurring production costs, as they face economic losses either way–on one hand, due to the costs required for control measures, and on the other because of the disruption caused by IAS to the cultured native species.

Estimation of Benefit

Despite the economic repercussions of IAS, they also hold market value comparable to farmed species and serve as a source of raw materials. Additional income from IAS was calculated by valuing the total volume of marketable IAS based on its current market price per kilogram. The same value was used to determine the value of potential raw materials, as these materials can only be accessed by purchasing the IAS at its current market price (Table 3). Examples of

Table 1. Value of cost for controls and potential income loss in Philippine Peso

Particulars	Value (PHP)		
	Freshwater	Brackish water	Aggregate
Costs for controls	5,832,000	14,523,400	20,355,400
Potential income loss	9,556,491	4,963,077	14,519,568
Total	15,388,491	19,486,477	34,874,968

Table 2. Expenses per control

Control	Brackish water Areas	Freshwater Areas	Total (PHP)
	CONTROL EXPENSES		
Gillnet (*Panti/Kitig*)	558,400	203,400	₱ 761,800
Circulo	136,600	-	₱ 136,600
Bukatot	297,280	20,000	₱ 317,280
Screen (*Patibong*)	174,800	19,500	₱ 194,300
	CHEMICAL CONTROL EXPENSES		
Sodium	755,100	234,100	₱989,200
Tea seed	265,830	-	₱265,830
	OTHER EXPENSES		
Labor	610,350	3,500	₱613,850
Gas	404,800	-	₱404,800
Rent (for draining)	1,187,000	-	₱1,187,000
	WITHOUT CONTROL MEASURES		
Fish farmers without control measures	43	29	

marketable IAS include mudfish (PhP200/ USD3.50), Chinese softshell turtle (PhP185/ USD3.24), catfish (PhP100/ USD1.75), silver perch (PhP120/ USD2.10), eels (PhP95/ USD1.66), and blackchin tilapia (PhP80/ USD1.40).

Total Net Present Value of IAS

As shown in Table 4, it is projected that a total economic loss of PhP 114, 752, 607 (USD2,007,517) NPV may be experienced in the coming years. Although the proposed National Invasive Aquatic Species Strategy and Action Plan (NISSAP) exists, additional interventions to control IAS are still necessary. It was observed that, five years after its implementation, at the time this study was conducted, local fish farmers, particularly those in the aquaculture areas of Pampanga, continue to suffer significant economic losses in their livelihood. This trend will likely persist unless IAS management measures are further strengthened.

Benefit-Cost Ratio

The net present value can be validated by calculating the ratio of benefits to costs using the computed present values. To determine the benefit-cost ratio (BCR), the aggregated present value of benefits was divided by the aggregated present value of costs. This resulted in a BCR of 0.31, which is less than 1, indicating that the aggregate costs (PhP167,078,535/ USD2,901,920) are higher than the aggregate benefits (PhP52,325,928/ USD908,828), demonstrating that the costs outweigh the benefits of the IAS (Table 5). In addition, the BCR highlights that the extent of economic loss is greater in brackish water areas compared to freshwater areas.

Conclusion

The findings revealed that IAS have diverse effects, causing both economic and environmental damages. Their impacts range from increasing control costs to disrupting the natural ecosystem of native fish species in selected municipalities. As the IAS population increases, so does the cost of controlling them. Consequently, harvesting declines, leading to income losses for fish farmers. Furthermore, IAS disrupt the natural ecosystem by threatening the populations of native species in these areas.

Despite the damage caused by IAS, they also offer certain benefits. IAS can serve as a source of raw materials for feed products and an alternative source of meat for food products. However, when weighing the data on costs and benefits, it is evident that the costs outweigh the benefits. This finding suggests that there can be significant opportunities to utilize IAS for other products that could benefit fish farmers. Nonetheless, the growing population of IAS must not be ignored. According to Cuthbert et al. (2021), cost reports on IAS are underrepresented, particularly in Asia, despite the region contributing 13% of the known global costs caused by aquatic invaders. Therefore, it is recommended to enhance IAS management cost reporting strategies to prevent and mitigate IAS-related damages in the affected countries.

Table 3. Income and potential value from IAS

Particulars	Value (PHP)		
	Freshwater	Brackish water	Aggregate
Additional income from IAS	3,582,200	3,319,524	6,901,724
Value of potential raw materials from IAS	3,582,200	3,319,524	6,901,724
Total	7,164,400	6,639,048	13,803,448

Table 4. Net Present Value (NPV) per year

Year	Freshwater	Brackish water	Aggregate
0	(15,388,491)	(19,486,477)	(34,874,968)
1	(7,476,446)	(11,679,481)	(19,155,927)
2	(6,796,769)	(10,617,710)	(17,414,479)
3	(6,178,881)	(9,652,464)	(15,831,345)
4	(5,617,165)	(8,774,967)	(14,392,132)
5	(5,106,513)	(7,977,243)	(13,083,756)
Total NPV	(46,564,266)	(68,188,342)	(114,752,607)

Table 5. Benefit-cost ratio per particulars

Particulars	SDR	PV of Benefits	PV of Costs	BCR
Aggregate	10%	52,325,928	167,078,535	0.31
Freshwater	10%	27,158,713	73,722,979	0.37
Brackish water	10%	25,167,215	93,355,556	0.27

Additionally, in a recent study conducted by Gilles et al. (2025), it is found that over 65.6% of 64 introduced freshwater fish species in the country are classified as very high-risk, and this figure is expected to increase to over 70.3% in the coming years. Hence, collaborative efforts are crucial in developing solutions to address this environmental challenge.

This study recommends various approaches to control and mitigate the issues of IAS, such as monitoring preventive practices and prioritizing the most effective ones. Conducting programs, events, and seminars to effectively disseminate information on IAS control management to the fish farmers, alongside training for effective implementation, may also be beneficial. Furthermore, Mr. Gregory Paul H. Yan, founder of the Best Alternatives campaign, suggests additional ways to upscale fisherfolk businesses, including farming high-value native fish species, such as *ludong*. These species adapt well to local conditions and are profitable for the farmers (Agribusiness, 2021). Lastly, documentation of IAS as a new food product through value-added processing could help further align its benefit for the fish farmers and consumers.

Ethical Statement

This study only documented information provided by human respondents (fisherfolks) regarding their respective economic background. Hence, the author did not request any approval from the Pampanga State Agricultural University's (PSAU) Institutional Animal Care and Use Committee (IACUC) as none of the species had undergone any experiments.

Funding Information

This study was funded by the Bureau of Agricultural Research: Department of Agriculture (DA-BAR).

Author Contribution

WPacunana: Conceptualization, Writing, Data curation, Formal analysis, Methodology, Visualization, Funding Acquisition, Project Administration, and Supervision.

Conflict of Interest

The author(s) declare that he has no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Acknowledgements

This author does not have any names, degrees, and affliations to mention under this section.

References

Cuthbert, R. N. (2021). Global economic costs of aquatic invasive alien species. Science of the Total Environment. Vol.775. ISSN 0048-9697. https://doi.org/10.1016/j.scitotenv.2021.145238

Gilles Jr, A. S. (2025) Current and future risk of invasion by nonnative freshwater fishes in a mega- biodiversity country: the Philippines. Management of Biological Invasions 16(1): 73–89. https://doi.org/10.3391/mbi.2025.16.1.05

Guerrero, R. D. (2014). Impacts of Introduced Freshwater in The Philippines (1905-2013): A Review and Recommendations. National Academy of Science and Technology, Philippines.

Hanley, N. (2019). The Economic Benefits of Invasive Species Management. People and Nature – British Ecological Society.

National Invasive Species Awareness Week – NISAW. (2019). The Economic Impact of Invasive Species in The United States – Regional Case Studies.

The Editors of the Agribusiness. (2021). PHL waters being taken over fish. Business World. https://www.bworldonline.com/agribusiness/2021/09/20/397595/phl-waters-being-taken-over-by-invasive-fish/