Review Article

# A Systematic Review on the Bacterial Infestation of Aquaculture Farms in Selected Regions of the Philippines and its Impact on the Fisheries Industry and Public Health

**Aleczandra Marie T. Cid, Shaira B. Sarapuddin, Rolando M. Santos Jr., Jeizelle S. Fernandez, Angel Marie L. Divinagracia, Christian Jocel S. Garcia, Alyssa Claire L. Untalan, Princess B. Albelda and Earl Adriane A. Cano**

Department of Medical Technology, Institute of Arts and Sciences, Far Eastern University, Manila, PHILIPPINES.

Submission Date: 26-05-2022; Revision Date: 13-06-2022; Accepted Date: 21-07-2022.

## ABSTRACT

**Background:** Regions III and IV-A of the Philippines, with their vast natural water bodies and myriad marine resources, have been among the country's leading fish producers. However, having situated near the infamously known "dirty" Manila Bay, aquaculture farms in these provinces are vulnerable to various potential contaminants. **Methods:** A systematic search was conducted to gather current reports and studies from JSTOR, Google Scholar, PubMed, ResearchGate, ScienceDirect, and other outside sources regarding possible bacterial infestations in aquaculture farms within these regions, including their implications on their respective fisheries sector. After removing duplicates and screening for eligibility, 40 studies were considered amongst 415 publications from five databases and 58 records from external sources. **Results:** The results of this systematic review demonstrated that aquaculture farms in Central Luzon and Calabarzon have a significant economic impact on the Philippine fisheries industry and a diversity of resources is evident despite natural disasters. The results also revealed that bacterial infestations seem to be observable in some provinces in the regions, which can be linked to managerial and environmental concerns in these areas, despite having very few reports denoting the existence of the issue in aquaculture facilities of both regions. **Conclusion:** Prompt investigations into the aquaculture farms' water conditions and contamination must be conducted to provide appropriate and cost-effective solutions to respond to this public health emergency. Other specific biosecurity concerns that were also presented can be further clarified to aid in the provision of resolutions.

**Keywords:** Aquaculture Farming, Bacterial Infestation, Fisheries, Philippines, Public Health.

**Correspondence:**
***Mr. Santos Jr,***
Department of Medical Technology, Institute of Arts and Sciences, Far Eastern University, Manila, PHILIPPINES.

Email: 2019122971@feu.edu.ph

## INTRODUCTION

In the Philippines, aquaculture is one of the three major fishing sectors of the country, alongside municipal and commercial fisheries. It is the most developed sector and the most significant contributor to the country's fish and other seafood products, producing 53% of the total seafood production in 2018 alone.[1] However, one of the central concerns in this sector is the evolution of antibiotic-resistant bacteria in cultivated fishes found in agricultural waters such as in aquaculture farms.[2] In urban farms found within Metro Manila, Philippines it is revealed that antimicrobial resistance was greatest amongst the *E. coli* isolates obtained from agricultural water systems, having a total percentage of 67.3%, as compared to those gathered from soil and vegetables.[3] Furthermore, tetracycline resistance and multidrug resistance were likewise most widespread in water isolates, with 45.6% and 25.3%, respectively, in total.[3] ESBL genes were also detected in 13 of the

SCAN QR CODE TO VIEW ONLINE

www.ajbls.com

DOI: 10.5530/ajbls.2022.11.35

212 isolates studied in the same investigation. The outcomes of the previously stated study demonstrate that surface waters, such as those used for cultivation on aquaculture farms, might very well harbor antibiotic-resistant and multi-drug resistant pathogens which can accidentally be introduced to the major food production setting and induce foodborne gastro-intestinal diseases.[3] Consumption of contaminated farmed fishes from waterways containing bacterial isolates with antibiotic resistance genes presents health and safety apprehensions, as well as consumer health skepticisms.

Given the global impact of microbial colonization on marine resources consumed by the public, this systematic review intends to discuss bacterial infestations in Region III and Region IV-A aquaculture farms, along with its ramifications on their respective fishing industries.

This systematic review intends to address the following concerns (1) How widespread is the bacterial infection in the aquaculture farms of the regions; (2) What are the implications of the bacterial infestation in these aquaculture farms; and lastly, (3) What are the risk factors for the emergence of various bacterial species?

As the researchers write this systematic review, it aims to (1) determine the present status of aquaculture farms in Regions III and IV-A relating to the presence of bacterial infestation in such economic areas; (2) gather and summarize recent reports to fill in the gaps of the current knowledge about this situation in the Philippines; and ultimately, (3) assess the situation to make necessary recommendations.

This systematic review shall be beneficial not only for the Fisheries industry of the Philippines but for other sectors and localities as well. For the rural communities, in which aquaculture farms are mostly situated, can benefit from gaining knowledge not only about the possible occurrence of pathogenic bacteria within their fishery farms but also their implications – both in health and agriculture. For government agencies like the Bureau of Fisheries and Aquatic Resources (BFAR), this systematic review will provide them with valuable statistics to help them implement more stringent countermeasures against prevailing water contamination problems. For future researchers and colleagues, as they continue to expand education through research, this shall provide relevant, valuable, and up-to-date data as the study of Microbiology, Aquatics, and other relevant fields further develop.

## MATERIALS AND METHODS

### PRISMA Protocol

The researchers employed the PRISMA Protocol as this study's systematic foundation where it utilizes the reporting of different reviews that evaluate the effects of various interventions. The planned methodology, rationale, and hypothesis are prepared prior, serving as the backbone of the review. A 27-item checklist is provided where the parts of the study are broken down to keep track of articles that fall under each row criteria (PRISMA, 2020).

The PRISMA Flow Diagram was also used by the researchers where the systematic review is plotted as a flow chart showing the phases of the study. The number of articles, studies, and publications sourced, included, excluded, and the reasons for exclusion are noted in this diagram.

### Inclusion and Exclusion Criteria

For the researchers to achieve more meaningful and accurate results, they decided to include an Inclusion and Exclusion Criteria to set specific boundaries for the study. Studies were eligible for inclusionif they reported Philippine aquaculture farms that were associated with bacterial infestation. The researchers only decided to include aquaculture farms located in Central Luzon and Calabarzon as they have access to coastlines and direct linkages to Manila Bay. Existing aquafarms in other regions were not considered. Moreover, this review only included articles that were published in English and were written between the years 2012 and 2022. Articles older than 10 years and written in foreign languages were excluded regardless of their relevance to this systematic review. Additionally, articles with incomplete data were ruled out.

### Search Strategy and Library Databases

Following the PRISMA protocol, the authors conducted a systematic literature search of journals and articles in five different online databases: JSTOR, Google Scholar, PubMed, ResearchGate, and ScienceDirect. The search terms used in these online databases were the following keywords: "aquaculture", "bacteria", "Philippines", and "aquaculture farms in the Philippines". Furthermore, the results were limited to articles written in English with publication dates between the years 2015 to 2022. Upon the deliberate analyses of the reviewers, only a total of 22, 2, 0, 8, and 49 related articles, studies, and publications were gathered from ResearchGate, ScienceDirect, PubMed, JSTOR, and Google Scholar, respectively. Figure 1 presents the schematic diagram of the review procedure used in this systematic review.

### Data Collection and Extraction

The researchers organized the sourced articles, studies, and publications using Zotero, an online tool used to store and manage various academic materials. The articles have been analyzed using the established Inclusion and Exclusion criteria to filter the relevant data which later was assessed to see if it could (1) answer the questions established in the Statement of the Problem, (2) fit within the range of the scope of the study and (3) align with the focus of this systematic review. Relevant outside sources not foundin these databases were also utilized.

### Data Analysis

A meta-analysis of the gathered data was deemed infeasible by the researchers due to the scope of this systematic review. Alternatively, descriptive analysis was performed on the data extracted from the research material included. The results were presented as a collective summary of all the research studies' findings following the Descriptive Analysis. The data were analyzed as such to ensure that the topic of this systematic review was of common interest between the research articles and journals used.

### Risk of Bias and Quality Assessment

For the risk of bias and quality assessment of the included studies, six (6) independent reviewers (AU, AD, CG, JF, PA, RS) carefully selected and extracted studies and articles based on their relevance to the research topic beginning with the screening of its title, abstract, and full text. The six reviewers utilized the CASP Systematic Review Checklist to eliminate the risk of bias andensure study quality. Using this checklist, the studies, as well as articles, have been assessed for their results, validity, and significance. Additionally, in line with this systematic review's primary focus, the reviewers assessed the publications for the following variables: (1) location, (2) bacteria present, and (3) timeframe of the research studies included. Two (2) other reviewers (AC, SS) validated the data and resolved any conflict or discrepancy during data collection and extraction.

### Systematic Review Flowchart

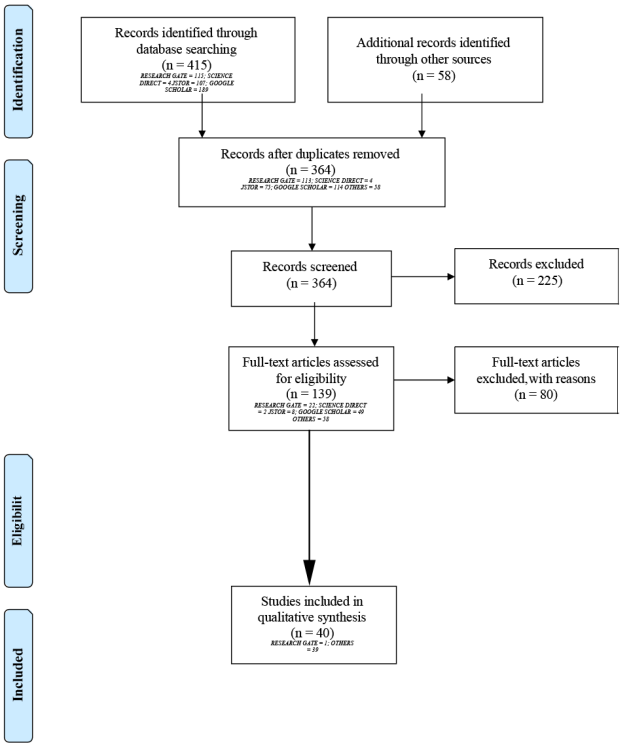


**Figure 1: Systematic Review Flowchart.**

## RESULTS

### Central Luzon (Region III)

Region III or Central Luzon encompasses a space of approximately 2,147,035 hectares.[4] Agricultural production takes up around 30% of the overall land mass, which is approximated to be 644,475 hectares.[4] Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales are the seven provinces that make up Central Luzon. This region is also among the top three localities with the biggest inhabitants in May 2000, accounting for about 10% of the national population of 76.5 million people, or 8,204,742.[5] Central Luzon is considered a significant agrarian and manufacturing hotspot as it is closely located on the northern side of Metro Manila,[5] therefore, making it an evolving sector in the Philippines that provides a remarkable contribution to the country's economic development.[6]

### Fisheries

Central Luzon has one of the country's largest aquaculture zones, with an estimated fishfarming vicinity of 37,352.78 hectares,[7] contributing significantly to the region's annual accumulated fish production since a significant proportion of the area's fish stocks come from their commercial, municipal, and aquaculture farms (Table 1).[8] The region's overall quantity of fishery output climbed by 7.5% in the first quarter of 2021, starting from 89.1 thousand metric tons in 2020 to reach 95.7 thousand metric tons in 2021, this is owing to developments in their aquaculture and inland fishery resources.[9]

The province of Aurora holds one of the widest coasts in the Philippines and serves as a key aquatic environment for reef fish species and uncommon cetaceans.[10] The Pacific Ocean, Casiguran Sound, Baler Bay, Casapsapan

**Table 1: Central Luzon Cumulative Fishing Output, 2021.[9]**

| Sub-sector | 2021 | 2020 | Percent Change (%) |
|---|---|---|---|
| | 1st Quarter | 1st Quarter | |
| Total | 95,746.8 | 89,100.8 | 7.5 |
| Commercial | 639.7 | 826.1 | (22.6) |
| Municipal | 15,756.5 | 16,834 | 13.9 |
| Marine | 8,662.1 | 10,420.9 | (16.9) |
| Inland | 7,094.4 | 3,413.9 | 107.8 |
| Aquaculture | 79,350.6 | 74,440.0 | 6.6 |

bay, Dibut bay, and Dingalan bay are among Aurora's main fishing areas. It also possesses three main types of fishing resources: marine, inland or aquaculture, and municipal fisheries, with aquaculture occupying 111 hectares of its land area. Freshwater fishponds occupy 36.46 hectares, brackish water fishponds comprise 81.93 hectares, and hatcheries take up 0.40 hectares of the province's aquaculture facilities.[11] On the other hand, the province of Bataan has two kinds of fish farming facilities: brackish water fish farming, with 4,266 hectares of fishing zone, and freshwater ponds having 115.72 hectares of the remaining land area.[12] As for Bulacan, one of its major aquatic resources comes from the Bustos-Angat Dam. Approximately 88 hectares of freshwater ponds and 15,059 hectares of brackish water fishponds are provided for aquaculture in this province.[13] While in Nueva Ecija, Singgalat, Pantabangan and Aulo dam are the major fishing grounds in this province.[14] Additionally, there are four main farming facilities in this province including freshwater fishponds, fish cages, hatcheries, and rice fish.[14] Freshwater fishponds have the largest zone with a total area of 1,480 hectares and are operated by 3,005 operators. Followed by hatcheries which occupy a total of 66 hectares with 17 operators, fish cage with 2 hectares, and finally, rice-fish having 1 hectare only.[14]

As for the province of Pampanga, one of the province's major fishing grounds is the Manila Bay as this province is mainly found on its northern shore. Its freshwater ponds have a total pond area of about 4,812 hectares with 3,685 operators, while its brackish water fishponds occupy a larger area of 11,678 hectares and are operated by 1,609 operators.[15] Fisheries production in Tarlac relies mostly on inland or communal bodies of water.[16] Because of this, the province mainly utilizes freshwater fishponds, devoting 1,089 hectares for industry and 3,263 aquafarm operators.[16] Lastly, the province of Zambales has direct access to the West Philippine Sea for aquatic resources as well as inland sources, including 153.18 hectares of freshwater fishponds and 1,552.99 hectares of brackish water fishponds.[17] Zambales also has 12.06 hectares for hatcheries and grow-out farms, 18.50 hectares for seaweeds, and other inland sources such as rivers and lakes.[17]

## Resources

Central Luzon is quickly becoming among of the Philippines' dominating areas that generate the highest quantity and worth of fishery products, continuing to make it one of the country's most commercially advantageous fish-producing sectors.[8] In 2020, Pampanga appears to be the largest contributing member to the region's collective fishery production, followed by Bulacan, Zambales, Bataan, Tarlac, Nueva Ecija, and, finally, Aurora (Table 2).[8]

For Aurora, their cumulative fishing output during the final quarter of 2021 was 12.01% higher than when it was in the 4th quarter of 2020 (Table 3).[18] With 25.39 metric tons, its aquaculture subsector contributed the most to the province's overall fishing production in the fourth quarter of 2021, preceded by its municipal marine subsector. Its aquaculture sector is dominated by freshwater aquaculture farms which produced 18.23 metric tons in 2021, most of it is cultivating *Tilapia*, accounting for 7.14 metric tons, and the rest would be Milkfish (*Bangus*) with only 0.02 metric tons.[18]

**Table 2: Volume of Fishery Production in Region 3.[8]**

| | 2018 | 2019 | 2020 |
|---|---|---|---|
| Central Luzon | 309,582.19 | 322,164.34 | 346,631.03 |
| Aurora | 3,038.39 | 2,946.88 | 2,474.12 |
| Bataan | 29,788.26 | 35,165.31 | 33,116.16 |
| Bulacan | 42,574.09 | 46,705.65 | 58,927.33 |
| Nueva Ecija | 6,348.77 | 5,930.31 | 5,795.63 |
| Pampanga | 174,993.02 | 176,967.69 | 189,127.78 |
| Tarlac | 9,215.63 | 7,340.73 | 7,439.47 |
| Zambales | 43,642.03 | 47,107.78 | 49,750.54 |

**Table 3: Aurora Cumulative Fishing Output, 2020-2021.[18]**

| Sub-sector | 2018 | 2019 | Percent Change (%) |
|---|---|---|---|
| | 2020, 4th Quarter | 2021, 4th Quarter | |
| Commercial Marine | 15.83 | 16.82 | 6.25 |
| Municipal Marine | 230.55 | 260.08 | 12.81 |
| Aquaculture | 22.15 | 25.39 | 14.62 |
| Municipal Inland | 12.97 | 13.03 | 0.46 |
| Total | 281.50 | 315.32 | 12.01 |

As for Bataan, the major aquatic resources grown are shrimps, milkfish, crabs, and bivalves.[19] Bataan's overall production in 2014 reached 26,098.27 metric tons, improving significantly from the previous year's 23,000 metric tons.[12] Bulacan, on the other hand, is one of the leading producers of Milkfish in the country.[13] In addition to this, they are also a major harvester of aquatic resources like *tilapia*, prawns, and catfish. The municipal subsector produces the most in their aquaculture sector – 706.1 metric tons, while the commercial sector only produces 47.4 metric tons.[13]

The most common aquatic resources in Tarlac are *tilapia*, catfish, carp, *dalag*, and gourami.[16] In 2015, their aquaculture sector contributed the most for fishery production, – which was 91% (7,415.75 metric tons) of total production in the province.[16] Lastly, Zambales' major inland aquatic resources are *tilapia*, milkfish, and shrimp, while the marine resources harvested are tuna, mackerel, scad, and mollusks.[17] The total harvested fish from 2015 is 27,765 metric tons, 53% of whichwas from aquaculture farms.[17]

*Bacterial Infestation.* Notwithstanding the region's abundance of aquaculture farms, there is still a scarcity of research studies concerning the quality of the water they utilize. Waterscape contamination concerns have already been noted across Aurora's shoreline by both fishermen and sports surfers, but these problems have hardly been examined methodically by professionals or even addressed by municipal authorities.[10] Aside from that, there seems to be limited information available involving microbial infestations throughout the region, as well as any observations indicating the occurrence of microbial species within their valuable natural assets.[10] 135 soil and water samples were acquired across the provinces of Central Luzon for the identification of pathogenic *leptospires* within their region.[20] 77 of the 135 specimens were confirmed to be infected with *Leptospira spp.*, with 53 of the 77 identified to be from the water samples they obtained.[20] Additionally, pathogenic strains of *Leptospira* were also found in soils contaminated by livestock feces, which can be washed off to inland bodies of water such as lakes due to rain and flood, implying that weather variations have a significant impact on the presence of bacterial infestation in this province.[20]

Another incidence of bacterial infestation has been reported in the province of Bataan. Bacterial infestation in this province is greatly linked to shrimp farming, since shrimp is one of the major aquatic resources grown in this province.[19] Biosecurity was investigated in this province and the lack of protective boundaries between people and the farms was noted.[19] Additionally, unhealthy facilities and traffic, lack of seed stock testing, improper disposal, and lack of water treatment was also observed.[19] These instances have been indirectly correlated to the presence of bacterial infestation within their shrimp farming zones. On the other hand, in Bulacan, the presence of *Escherichia coli* was reported to be present in the aquaculture farms located in this province last 2015.[21] Bacterial infestation in this province is generally linked to seasonal changes and pollution.[21] It was observed that these bacteria usually increase in the dry seasons of February and April and decrease as the wet season approaches.[21] Pollution is also linked to the infestation of bacteria within the province due to poor and bad water quality observed by fishpond operators in the province and other nearby provinces like Pampanga.[21] Prawn production is greatly affected by the pollution of water flowing through the province's major waterways.[22]

As for Nueva Ecija, several water samples in Nabao Lake, Nueva Ecija, were taken to determine the total coliform and bacterial count in the flesh of the fishes.[23] The results showed a significantly increased total bacteria count and total coliform count, exceeding the acceptable limit.[23] *Mycobacterium* spp., *Aeromonas* spp., *Staphylococcus aureus* and *Escherichia coli* were identified through Mueller Hinton Agar and McConkey Agar.[23] This suggests that fishes in Nabao Lake and other connected lakes are not safe for human consumption when not properly cooked and eaten raw. Lastly, *Pseudomonas aeruginosa* caused an outbreak in tilapia particularly in Milanin, Pangasinan.[24] The fish collected in the lake showed various signs of bacterial infections like abnormal body coloration, eye opacity and skin rotting.[24] The presence of pathogenic organisms and contamination were seen as risk factors for the development of this bacteria. Hence, continued dumping of wastewater from aquaculture in river systems without being treated may aggravate this problem if left unresolved.

## CALABARZON (Region IV-A)

Region IV-A or Calabarzon, is in the south-western part of the Luzon islands and is made up of five provinces: Cavite, Laguna, Batangas, Rizal, and Quezon. Its cumulative land surface area of 16,560 square kilometers is home to more than 16 million Filipinos, making it the second most populated region in Luzon next to Manila.[25] Calabarzon is known for its vast natural resources from land to marine that are ideal for its agribusiness and ecotourism sites. Additionally, the region of Calabarzon is home to major bodies of water such as Taal lake, Laguna Bay, and Tayabas Bay. These waters encompassing the region are an integral part of the region's livelihood, mainly of its marine industry.

**Table 4: Aquaculture Production by the (Top 7) Regions and Culture Environment, in Metric Tons (MT).[1]**

| Region | Brackish Water | Fresh Water | Marine Water | Mariculture | SFR | Rice Fish | Total |
|---|---|---|---|---|---|---|---|
| BARMM | 6,258.12 | 11,461.90 | 1.12 | 711,141.33 | 37.16 | - | 728,899.63 |
| IV-B | 1,887.45 | 188.02 | 1.76 | 320,947.02 | 0.06 | - | 323,024.31 |
| III | 89,413.55 | 132,844.11 | 27,005.92 | 39,784.85 | 2.58 | 0.53 | 289,051.54 |
| IX | 8,170.98 | 122.65 | 128.16 | 203,040.62 | 0.25 | 0.15 | 211,462.81 |
| VI | 103,971.02 | 4,187.30 | 690.99 | 101,701.98 | 1.51 | 0.45 | 210,553.25 |
| I | 28,807.67 | 14,188.10 | 102,294.57 | 1,095.84 | 7.28 | 2.21 | 146,395.67 |
| IV-A | 30,006.04 | 91,673.66 | 363.21 | 5,800.26 | - | - | 127,843.17 |

## Fisheries

The Aquaculture sub-sector of the fishery industry, together with commercial and municipal fisheries, are among the significant contributors to the region's fishery production. According to the Philippine Fisheries Profile of 2020, the region's main Aquaculture products also include Tiger prawns, Tilapia, Mud crab, Mussels, Seaweeds, and Oysters harvested from fishponds, fish pens, fish cages, and small farm reservoirs from its Brackish water, Freshwater, and Marine waters. With this diversity, Region 4-A places 7$^{th}$ out of 17 regions, with almost 128,000 metric tons of Aquaculture Production by Region and Culture Environment (Table 4).[1]

## SFR, Small Farm Reservoir

The region's provinces contribute largely to its fishery industry, as these 5 provinces have a large quantity of water sources. Laguna Lake or the Laguna de Bay in Laguna is considered the largest freshwater lake in the Philippines, and its large water area of 292,000 hectares is a significant aquaculture contribution both to its region and the whole country.[26] The lake also branches off to rivers and streams, including the Tanay River of the Rizal. Another lake in the region is the Taal Lake in Batangas with 236.9 square kilometers of aquatic area.[26] It is also a large freshwater lake ranking 3$^{rd}$ in the country.[26] Likewise, this aquatic environment supports many resource-based activities, including Aquaculture.[26] On the other hand, Quezon province's Ragay Gulf, Tayabas Bay, and Lamon Bay are known to provide abundant fishing grounds including the Padre Burgos Mariculture Zone along Tayabas Bay, which is a major fish farming site.[27]

Aquaculture, together with Municipal and Commercial Capture fisheries, makes up the 3 sub-sectors of the fisheries Industry. Among the 3, Aquaculture leads with 52.79% of shares in total fisheries production in the country. Of this 52.79%, Calabarzon contributes 5.52% among the country's regions (Table 5).[1] In Calabarzon, there are 6 registered Aquaculture farms located in Quezon and Batangas of which 3 cultures species of Shrimp, 2 of Milkfish, and 1 of Milkfish and Pompano.[28]

**Table 5: Fisheries Production Volume by Sub-sector, in Metric Tons (MT).[1]**

| Sub-sector | Volume | Total % Share |
|---|---|---|
| Aquaculture | 2,322,905.55 | 52.79% |
| Municipal Capture Fisheries | 975,205.08 | 22.16% |
| Commercial Capture Fisheries | 1,102,262.36 | 25.05% |

In the year 2020, the region's fisheries output recorded a 19.10% decline from 300,391.66 MT in 2019 to 243,008.54 MT. Of this 19.10%, the Batangas contributed the biggest with a decline of 29.25%, followed by Rizal, Quezon, Cavite, and Laguna with 18.21%, 17.93%, 15.98%, and 4.10% decline respectively.[29] This decline is attributed to the calamities and problems encountered during 2019-2020 such as the COVID-19 pandemic, Taal eruption, and typhoons.[29]

Due to the eruption Taal Volcano, the Aquaculture sub-sector experienced a halt in the fishing business in the lake. This eruption disrupted the fish stocks in aqua farms resulting in a major loss of stocks and fish production.[29] Other challenges also posed risks to the Aquaculture of the region such as issues on the waters' quality brought about by volcanic eruption, excessive fish farming, and several human activities.

## Resources

The major aquatic products of the region come mainly from fishponds, fish pens, and fish cages of its Brackish water, Freshwater, and Marine waters. Production from the region's mariculture such as mussels, oysters, and seaweeds also contribute significantly. Milkfish, Tilapia, and Carp are the top aquatic products of the 3 types of bodies of water in this region, while mussels, oysters, and seaweeds are the top products in its mariculture.

In Cavite, fishing serves as its main livelihood and is responsible for the production of certain fish products

such as fish sauce (*patis*), dried fish (*tinapa* and *daing*), and fish paste (*bagoong*). The province is also known for its green mussel algae, a mariculture product. However, this production faced a decline over 3 years due to a phenomenon called 'Alig' or '*masamang tubig*' which happens after heavy downpours or typhoons. These calamities and others such as overfishing and climate change also affected the province's commercial and municipal fishery.[30] Similar to Cavite, Laguna's aquatic resources also include fish, mollusks, and crustaceans.[26] In terms of Aquaculture, Laguna also grew and cultivated non-native fish species that further developed and boosted its fishery industry.

The Taal Lake in Batangas sustains the province's aquaculture and non-aquaculture activities. Their main aquatic resources include reptiles, mollusks, crustaceans, and finishes. Their aquaculture farms culture species of Tawilis (*Sardinella tawilis*), Milkfish (*Chanos chanos*), and Tilapia (*Oreochromis niloticus*). Although widely known for their Tawilis that are endemic to the Lake, the province has seen a decline in catch of this species since 1998.[31] Rizal also cultivates species of Bangus and Tilapia, White catfish (*Hito*), Apple snails (*Kuhol*), Clams, and Shrimps. On the otherhand, Brakishwater Fishpond Milkfish and mud crab (*Alimango*) dominate Quezon's aquaculture production while commercial and municipal fisheries are dominated by the *Galunggong* (Roundscad), *Alumahan* (Indian mackerel), *Tulingan* (Frigate Tuna), *Tamban* (Bali sardinella), *Tunsoy* (Frimbriated sardines), and *Bisugo* (Threadfin bream).[8]

Region IV-A recorded a 5.52% share of the total Fisheries Production Volume adding up to 243,008.54 metric tons.[1] Compared to the Commercial and Municipal Fisheries, the Aquaculture sub-sector contributed largely and most significantly to the Fisheries production of the region (Table 6).[1]

### Bacterial Infestation

Minimal data have been published suggesting that Cavite's waterways suffer bacterial infestation or the presence of bacteria. No evidence is also available that documents any case of the bacterial or viral disease being linked to its waters or any aquatic products. On the other hand, *Escherichia coli* were isolated in Laguna Lake.[32] It was also discovered that these isolates included *E. coli* with genes for Extended-spectrum B-lactamases (ESBL) of which 95.69% of these thermotolerant *E. coli* isolates were resistant to 6 antibiotics.[32] Evidence also showed that several *E. coli* isolates (37%) were multi-drug resistant (MDR) with most being resistant to ampicillin.[32] In Batangas, evidence showed that the Aquaculture farms were pre-dominated by the bacteria of the genus Proteobacteria and Firmicutes.[32] *E. coli* was also isolated from Tilapia delivered from Batangas and sold at wet markets in Manila.[33] These *E. coli* isolates were also found to be ESBL-producing and consequently resistant to beta-lactam antibiotics and at least one antimicrobial.[33]

Apart from common *E. coli* isolates, Free Living Amoebas (FLAs) infect freshwater fish that may induce public health threats following their possible human consumption.[34] In a study conducted using 75 Tilapia samples from Taal Lake, it was discovered that FLAs were found in fish gills of 18 fish samples and fish intestines of 19 fish samples.[34] Additionally, *Vermamoeba vermiformis*, *Colpoda steinii,* and Eocercomonas were also identified.[34] Total Fecal Coliforms were also identified as a concern in the quality of certain water bodies, most notably the Tanay River of Rizal. In 2014, the downstream portion of Tanay River has a high total fecal coliform which was responsible for the re-classification of the water into Class D from Class C.[35] This change in the aquatic situation of Tanay River is significant since it is a major Tributary of Laguna Lake that can ultimately affect the aqua fisheries of the lake. The fecal coliform parameter also showed discrepancies in the waters of Quezon, however, this does not warrant public health concerns.

## DISCUSSION

### Economic Impact of Aquaculture Farming in Regions III and IV-A

The results show that Central Luzon and its provinces possess an extensive aquaculture system, owing to its access to vast fishing sources and continuous development. Even landlocked provinces such as Tarlac contribute to the production of fish in the region through aquaculture. In the Calabarzon region, aquaculture is the major contributor to fish and fish products. The major river systems found in the region provide the water source for fisheries and aquaculture farms. However, recent natural disasters have negatively affected the performance of the region, most notably

**Table 6: Fisheries Production Volume by Sub-sector in Metric tons, 2020.[1]**

| Region | Commercial | Municipal | Aquaculture | Total | % Share to total |
|---|---|---|---|---|---|
| IV-A | 28,060.25 | 87,105.13 | 127,843.16 | 243,008.54 | 5.52 |

the recent eruption of the Taal volcano. Due to the presence of powerful mineral acids like hydrochloric acid, hydrofluoric acid, and sulfuric acid, even small quantities of ashfall can reduce the pH of aquaculture farm waters.[36] Because of this, careful monitoring of the water conditions of aquaculture farms is essential to maintain the health of fish resources.

### Bacterial Infestation

Based on the results, bacterial load comprising *Mycobacterium* spp., *Aeromonas* spp.,*Staphylococcus aureus*, and *Leptospira* spp. are seen in Central Luzon while *Escherichia coli* is present in both regions. They are a grave threat to fish production because bacterial infection constitutes the largest economic loss in aquaculture farms.[37] Due to the advancements made in the aquaculture industry, seasonal changes such as the occurrence of rainfall, and pollution, there have been ecological implications that resulted in impaired sustainability of the water in fisheries. The results showed that these bacterial infestations directly affect the aquatic environment fish production and water quality. The normal process of fish reproduction might be disrupted by the severity of bacterial infestation.[38] In addition, indirect effects such as decreased fish growth, increased fish mortality, and fish farmers' perceptions of safe aquaculture can also be impacts incurred.[38]

### Public Health Situation

The presence of other pathogenic microorganisms such as bacteria in aquatic farms may pose risks not only to the farm-cultured species but also to the communities nearby and consumers of the aquaculture products.[39] Upon evaluation and analyses, the prevalence of microorganisms in aquaculture farms in both regions may cause varying health implications to humans: (1) typical *E. coli* isolates, including ESBL-producing isolates and in high concentrations, may cause diarrhea and/or abdominal pain, and certain *E. coli* strain or Enterovirulent classes may severely infect humans;[21] (2) presence of non-pathogenic free-living protozoa (e.g. *Vermamoeba vermiformis*, *Colpoda steinii*, and *Eocercomonas*) from fish samples in Taal Lake in Batangas may harbor certain bacterial pathogens resulting in further diseases like legionnaires disease;[34] and (3) other similar microorganisms like *Salmonella*-infected aquaculture products may cause gastroenteritis, and other severe food poisonings.[40] At present, little to no data directly relating to the bacterial infestation on the aquaculture farms in the specified locations to its health effects on the surrounding communities are yet to be established.

## CONCLUSION AND RECOMMENDATION

The breeding, raising, and harvesting of fish is a practice much valued in the Philippines since the archipelago is surrounded by rich waters and abundant resources. Such practice has been an important benefactor to the country's food security and the growing economy. In this review paper, the researchers looked at the contributions of Central Luzon and Calabarzon to the Aquaculture sub-sector of the fisheries industry in the Philippines and presented updates on the status of bacterial infestation in their waters while further highlighting its impact on public health. The results of this review paper emphasize a major concern in the fisheries industry which is a bacterial infestation. Notable bacteria have been documented together with their risk of inflicting serious health problems to consumers.

Environmental preventative measures must be strictly enforced to prevent further water contamination and to maintain an appropriate aquatic environment. Hence, lawmakers must be given every viable managerial alternative founded on factual data to formulate suitable strategies for strengthened environmental monitoring. This systematic review then recommends that a community-based investigation and training initiatives be developed, with an emphasis on forming partnerships among fishermen, NGOs, local governments, and scientific experts, to act toward reducing fisheries' frailty to hazard and shifting market situations through the establishment of aquaculture water quality criteria that are suitable to tropical environments, as well as the pronouncement of aquaculture special economic areas equipped with suitable technological innovation.

## ACKNOWLEDGEMENT

We, the proponents of this study, extend our heartfelt gratitude to the people who have significantly contributed to the success of this review paper. First and foremost, to Mr. Earl Adriane Abella Cano, our research adviser, we offer endless thanks for his constant patience, encouragement, and advice that were essential to the completion of our study. To fellow peer reviewers and research professors from Far Eastern University, for the learning opportunities, inputs, and insights they have provided for us and our paper. Finally, to our friends and family, for their unwavering support and encouragement throughout the research process.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## Authors' Contributions

Rolando M. Santos Jr. led the systematic review and conceptualization headed by Aleczandra Marie T. Cid, and Shairra B. Sarapuddin. This was also discussed with Princess B. Albelda, Angel Mae L. Divinagracia., Jeizelle S. Fernandez, Christian Jocel S. Garcia., Mr. Santos and Alyssa Claire L. Untalan In the introduction, Ms. Cid wrote the background of the systematic review, Mr. Garcia determined the statement of the problem, Ms. Untalan defined the objectives, and the significance was prepared by Mr. Santos In the methodology, Ms. Albelda. stated the PRISMA protocol and summarized the data collection and extraction process; Ms. Fernandez. made the inclusion and exclusion criteria with the help of Ms. Divinagracia for the search strategy and library databases. The risk of bias and quality assessment was written by Ms. Sarapuddin. together with the remaining six authors who selected and screened the articles. The systematic review flowchart was made by Mr. Santos

In the results. Ms. Cid. tallied the results for Central Luzon regarding the fisheries, resources, and bacterial infestations with the helpful contributions of Mr. Garcia, Mr. Santos, and Ms. Untalan. On the other hand, Ms. Sarapuddin managed the results for Calabarzon with the individual data provided by Ms. Albelda, Ms. Divinagracia, and Ms. Fernandez. The discussion for the systematic review was made by Mr. Garcia, Ms. Fernandez, and Ms. Divinagracia. After which, the conclusion and recommendations was presented by Ms. Cid and Ms. Sarapuddin. Finally, after careful review and checking, all the authors read and approved the final manuscript. Earl Adrianne A. Cano served as our mentor and adviser as we accomplish this paper.

## SUMMARY

The regions of Central Luzon and Calabarzon are crucial to the Philippines' fishing industry, however their proximity to Manila Bay, which is heavily polluted and known to harbor a multitude of pathogens, leaves them particularly vulnerable to infestation. Given that aquaculture farms in Central Luzon and Calabarzon are the primary providers of marine commodities marketed to consumers, consumption of compromised cultivated fishes from waterways harboring pathogenic bacterial populations generates health and security concerns, as well as public healthcare skepticism. As a result, considering the global consequences of pathogenic microbes on public-access aquatic resources, this systematic review intends to provide insights concerning bacterial infestations in Region III and Region IV-A aquaculture farms, as well as the implications for their respective fishing industries. Utilizing the PRISMA protocol as the basis, a total of 40 articles sourced from Google Scholar, JSTOR, PubMed, ResearchGate and ScienceDirect were reviewed. An additional 58 articles from external sources were screened and used. Aquaculture facilities in both regions support and enhance the Philippines' fishing output. Central Luzon alone had a cumulative fishing output of 95,746.8 metric tons in the first quarter of 2021, growing significantly by 7.5% from 2020s 89,100.8 metric tons, a growth mostly owing to developments in their aquaculture and inland fishery resources. As a result, Central Luzon is increasingly becoming one of the Philippines' prevailing regions in terms of the number and value of aquatic products, further cementing its position as one of the country's most commercially advantageous fish-producing sectors. Calabarzon, on the other hand, came in the seventh position out of 17 regions in the 2019 Aquaculture Production by Region and Culture Environment, with nearly 128,000 metric tons of aquatic goods contributed. The aquaculture sub-sector of the fishery industry, together with commercial and municipal fisheries, are major contributors to the region's aquatic productivity. Both regions are home to a plethora of aquatic commodities, the majority of which are widely consumed by the general public. The primary aquatic resources cultivated in Central Luzon are tilapia, shrimp, and milkfish, whereas the principal aquaculture products in Calabarzon include tiger prawns, tilapia, mud crab, mussels, seaweeds, and oysters. Knowing this, bacterial infections not only threaten the livelihood of inhabitants in those localities but also their wellbeing and safety. Samples taken from lakes in Nueva Ecija had shown an increase in the total bacteria and coliform count that exceeded the acceptable limits. *Mycobacterium spp., Aeromonas spp., and Staphylococcus aureus* were identified in samples collected from Central Luzon, and *Escherichia coli* was found in both regions. Moreover, samples taken from lakes in Nueva Ecija had shown an increase in the total bacteria and coliform count that exceeded the acceptable limits. In Laguna Lake, ESBL-producing *E. coli* were isolated were 95.69% of isolates were resistant to 6 antibiotics and most isolates were resistant to ampicillin. Free Living Amoebas (FLAs) were observed in 75 Tilapia samples from Taal lake where FLAs were found in 18 gills and 19 fish intestines. Additionally, *Vermamoeba vermiformis, Colpoda steinii, and Eocercomonas* were also identified. The study highlights the growing problem of the rise of bacteria in aquatic settings in the Philippines that poses a health hazard to

citizens and raises awareness about the growing numbers of drug-resistant bacteria. A thorough investigation must be carried out to address and create a solution to this emerging problem.

## REFERENCES


1. Bureau of Fisheries and Aquatic Resource. Philippine fisheries Profile 2019 [internet]. Philippines: Depatment of Agriculture; 2019. Publications [cited Mar 3 2022]. Available from: https://www.bfar.da.gov.ph/publication.jsp?id=2375#post.
2. Preena PG, Swaminathan TR, Kumar VJR, Singh ISB. Antimicrobial resistance in Aquaculture: A crisis for concern. Biologia. 2020 Feb 27;75(9):1497-517. doi: 10.2478/s11756-020-00456-4.
3. Vital P, Zara E, Paraoan C, Dimasupil M, Abello J, Santos I, *et al*. Antibiotic resistance and extended-spectrum beta-lactamase production of *Escherichia coli* isolated from irrigation waters in selected urban farms in Metro Manila, Philippines. Water. 2018;10(5):548doi. doi: 10.3390/w10050548.
4. National Nutrition Council. NNC region. Philippines. Profile: ~:text=It%20is%20bestowed%20with%20a,Rice%20Granary%20of%20the%20Philippines. Vol. III; 2015 [updated 2020 Aug 17.
5. Environmental Management Bureau, International Center for Environmental Technology Transfer (EMB and ICETT). Green framework of innovative strategy (GFIS) for sustainable consumption and production report [internet]. [place unknown]; 2008 [cited Apr 14 2022]. Available from: http://119.92.161.2/icettgfis/downloads/GFIS%20on%20Sustainable%20Consumption%20and%20Productivity%20(GFIS).pdf.
6. Department of Trade and Industry. Profile of region 3 [internet]. Philippines [cited Apr 14 2022]. Available from: https://www.dti.gov.ph/regions/region-3/profile/.
7. Bureau of Fisheries and Aquatic Resources III. Fisheries profile: Central Luzon [PDF] [internet]. Philippines; 2015 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/1f120244-37d0-4565-8ca8-c602f886c3db.pdf.
8. Philippine Statistics Authority (PSA). Fisheries statistics of the Philippines 2018-2020 volume 29 [internet]. Philippines; 2021 [cited Apr 14 2022]. Available from: https://psa.gov.ph/sites/default/files/Fisheries%20Statistics%20of%20the%20Philippines%2C%202018-2020.pdf.
9. Philippine Statistics Authority. RSSO 03. Volume of fisheries production in Central Luzon first Quarter. Philippines. Vol. 2021(Jun 24); 2021 [internet] [cited Apr 14 2022]. Available from: http://rsso03.psa.gov.ph/article/volume-fisheries-production-central-luzon-first-quarter-2021.
10. Alejos SF, Pajaro M, Raquino M, Stuart A, Watts P. Agricultural biodiversity and coastal food systems: A socio-ecological and trans-ecosystem case study in Aurora Province, Philippines. Asian J Agric Dev. 2021;18(2):73-84. doi: 10.37801/ajad2021.18.2.5.
11. Bureau of Fisheries and Aquatic Resources III. Aurora fisheries profile [internet]. Philippines; 2016 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/341d092f-0869-4126-913d-0ddfa91d0d6a.pdf.
12. Bureau of Fisheries and Aquatic Resources III. Bataan fisheries profile [internet]. Philippines; 2014 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/1760af26-1257-4626-a00c-72f1e830040a.pdf.
13. Provincial Government of Bulacan. Aquaculture, food and food processing [internet]. Bulacan, Philippines: Business: Aquaculture, Meat and Meat Products; 2007 [cited Apr 14 2022]. Available from: https://www.bulacan.gov.ph/business/aquaculture.php.
14. Bureau of Fisheries and Aquatic Resources III. Nueva Ecija fisheries profile [internet]. Philippines; 2016 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/d3cccb67-7a21-40b5-93d5-01b39aeb2b56.pdf.
15. Bureau of Fisheries and Aquatic Resources III. Pampanga fisheries profile [internet]. Philippines; 2015 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/7f141b9c-54ef-472f-bb26-fa1efe739274.pdf.
16. Bureau of Fisheries and Aquatic Resources III. Tarlac fisheries profile [internet]. Philippines; 2015 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/7037850d-59ca-4d97-88ee-1fbd5aae061f.pdf.
17. Bureau of Fisheries and Aquatic Resources III. Zambales fisheries profile [internet]. Philippines; 2015 [cited Apr 14 2022] [cited 1-24-2017]. Available from: https://region3.bfar.da.gov.ph/cmsFiles/region3/fisheriesprofile/pdf/17a62cef-c45d-40c2-9e1e-e0def5e4766f.pdf.
18. Philippine Statistics Authority. RSSO 03. Aurora fishery situation October to December 2021 [internet]. Philippines: Philippine Statistics Authority; 2022 [cited Apr 14 2022]. Available from: http://rsso03.psa.gov.ph/article/aurora-fishery-situation-october-december-2021.
19. Corpuz MNC, Flores R, Tungol FE, Villafuerte AA, Antonio AS. Assessment of aquaculture biosecurity measures in Bataan, Philippines. Int J Life Sci Biotechnol Pharm Res. 2015 Oct;4(4):189-92.
20. Tantengco OAG, Gloriani NG. Isolation and genetic detection of pathogenic Leptospira spp. from environmental soils and water in Central Luzon, Philippines. Asian Pac J Trop Dis. 2017;7(12):748-52. doi: 10.12980/apjtd.7.2017D7-220.
21. Raña J, Domingo J, Opinion AG, Cambia F. Contamination of Coliform Bacteria in Water and Fishery Resources in Manila Bay Aquaculture Farms. TPJF. 2017;24(2):98-126. doi: 10.31398/tpjf/24.2.2016A0015.
22. The fish site. Pollution threatens Bulacan Aquaculture Industry [internet]. Philippines; 2007 [cited Apr 14 2022]. Available from: https://thefishsite.com/articles/pollution-threatens-bulacan-aquaculture-industry.
23. Habal SPE. Assessment of flesh and gut bacteria in fishes collected from Nabao Lake in Cabiao, Nueva Ecija, Philippines [internet]. Nueva Ecija, Philippines: Muñoz. Central Luzon State University; 2016. Academia.edu [cited Apr 14 2022]. Available from: https://www.academia.edu/30985995/ASSESSMENT_OF_FLESH_AND_GUT_BACTERIA_IN_FISHES_COLLECTED_FROM_NABAO_LAKE_IN_CABIAO_NUEVA_ECIJA_PHILIPPINES?email_work_card=view-paper.
24. Reyes AT. Outbreak investigation of Pseudomonas aeruginosa in tilapia grow-out farms in Minalin, Pampanga, Philippines. Int J Fish Aquat Stud. 2019;7(4):428-34.
25. Population, health, and environment issues in the Philippines: A profile of Calabarzon region [internet]. Washington, DC: PRB; 2008 [cited Apr 14 2022]. Available from: https://www.prb.org/resources/population-health-and-environment-issues-in-the-philippines-a-profile-of-calabarzon-region/.
26. Cuvin-Aralar MLA. Impacts of aquaculture on fish biodiversity in the Freshwater Lake Laguna de Bay, Philippines. Lakes and Reservoirs. 2016 Apr 26;21(1):31-9. doi: 10.1111/lre.12118.
27. Provincial information and communications. Quezon, Province: Technology Office [internet]. Philippines: The Official Website of the Province of Quezon; 2022 [cited Apr 14 2022]. Available from: https://www.quezon.gov.ph/general-information/about.
28. Bureau of Fisheries and Aquatic Resources. Registered aquaculture. Farms [internet]. Philippines; 2022 [cited Apr 14 2022]. Available from: https://www.bfar.da.gov.ph/BFAR_INDUSTRY?id=202#post.
29. Regional Development Council. Calabarzon regional development report [internet]. Philippines: Gov; 2020 [cited 8-7-2022].ph. National Economic Development Authority, Region IV-A; 2020 [cited Apr 14 2022]. Available from: https://calabarzon.neda.gov.ph/wp-content/uploads/2021/10/Final-2020-RDR-10.4.pdf.
30. Cavite provincial planning and development. Cavite ecological Profile 2016 [internet]. Philippines; 2016 [cited Apr 14 2022]. Available from: https://cavite.gov.ph/home/wp-content/uploads/2018/01/Cavite-Ecological-Profile-2016.pdf.
31. Santos M, Munroe TA, Di Dario F, Hata H, Quilang JP. Sardinella tawilis, Bombon sardine. IUCN Red List of threatened Species. 2018. doi: 10.2305/IUCN.UK.2018-%202.RLTS.T98836352A98886655.en.
32. Salvador-Membreve DM, Rivera WL. Predominance of blaTEM and tetA genes in antibiotic-resistant *Escherichia coli* isolates from Laguna Lake, Philippines. J Water Sanit Hyg Dev. 2021;11(5):814-23. doi: 10.2166/washdev.2021.067.

33. Kang, T., Oyong, G. G., Cabrera, E. C. High prevalence of carbapenem and extended spectrum β-lactam resistant *Escherichia coli* from tilapia (*Oreochromis niloticus*) from two wet markets in Metro Manila, Philippines. Malays J Microbiol. 2020;16(2):88-96. doi: 10.21161/mjm.180304.
34. Milanez GD, Masangkay FR, Thomas RC, Ordona MOGO, Bernales GQ, Corpuz VCM, *et al*. Molecular identification of vermamoeba vermiformis from freshwater fish in Lake Taal, Philippines. Exp Parasitol. 2017;183:201-6. doi: 10.1016/j.exppara.2017.09.009, PMID 28917710.
35. Environmental Laboratory, Research Division (ELRD). Laguna Lake development authority. Laguna de bay monthly water quality status report [internet]. Philippines; 2014 [cited Apr 14 2022]. Available from: https://llda.gov.ph/wp-content/uploads/2019/09/LLDA_WMR_2018.pdf.
36. Sonone SS, Jadhav S, Sankhla MS, Kumar R. Water contamination by heavy metals and their toxic effect on aquaculture and human health through Food Chain. Letters in Applied NanoBioScience. 2020;10(2):2148-66. doi: 10.33263/lianbs102.21482166.
37. Ikpi G, Offem B. Bacterial infection of mudfish *Clarias gariepinus* (Siluriformes: Clariidae) fingerlings in Tropical Nursery Ponds. Rev Biol Trop. 2011;59(2):751-9. doi: 10.15517/RBT.V0I0.3137, PMID 21717856.
38. Ss M. Present status of fish disease management in freshwater aquaculture in India: State-of-the-art-review. Aquacult Fish. 2017;1(1):1-9. doi: 10.24966/AAF-5523/100003.
39. Magcale-Macandog DB, Briones RM, Calub AD, Saludes RB, Cuvin-Aralar MA, Salvacion AR *et al*. V. An overview of agricultural pollution in the Philippines summary report. DC, WA: Word Express, Inc; 2016 [internet] [cited Apr 14 2022]. Available from: https://openknowledge.worldbank.org/bitstream/10986/29245/5/122931-WP-P153343-PUBLIC-Philippines-Summary.pdf.
40. Tanyag B, Quiambao JJ, Ko AA, Singh A, Cambia F, Montojo U. Prevalence of INVA gene of salmonella spp. in fish and fishery resources from Manila Bay Aquaculture Farms using real-time PCR. Appl Microbiol. 2021;1(3):510-9. doi: 10.3390/applmicrobiol1030033.

**Cite this article:** Cid, AMT, Sarapuddin, SB, Santos Jr., RM, Fernandez, JS, Divinagracia, AML, Garcia, JS Untalan, ACL, Albelda, PB, and Cano, EAA. A Systematic Review on the Bacterial Infestation of Aquaculture Farms in Selected Regions of the Philippines and Its Impact on the Fisheries Industry and Public Health. Asian J Biol Life Sci. 2022;11(2):256-66.