Investigating Fish Contamination Scenario and Community Willingness to Adopt Consumption Advice Proposing an Advisory Model

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Investigating fish contamination scenario and community willingness to adopt consumption advice proposing an advisory model

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Abstract: Consumption advice to ensure the health and safety of fish consumers remains urgent to handle the ever-increasing panic over heavy metal toxicity. Moreover, studies of fish consumption rarely focus on the perceptions and awareness of consumers. Considering this, the present study examines the knowledge and perceptions of the risks and benefits of fish consumption among consumers of Laguna de Bay to explore their willingness to follow fish consumption advice. The seasonal variation in selected types of heavy metal contamination in two commercially important fish species, tilapia and mudfish, was analysed and a vulnerability map based on the risk–benefit ratio was produced for Laguna de Bay. Furthermore, this study formulates fish consumption advice for consumers of fish in the area. Primary data on consumers' perceptions were collected through a questionnaire, whereas heavy metal contamination data were compiled from the best available literature. We concluded that people's willingness to adopt consumption advice is mostly dependent on their existing level of fish consumption. Moreover, consumption advice is formulated to indicate restrictions on consumption for the areas identified as vulnerable due to contamination. This empirical study can serve as a model for the future development of fish consumption advice in the region.

Keywords: Heavy metals, environmental pollution, risk–benefit ratio, vulnerability, health risk.

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Authors' contributions:

Lubna Aalam: Conceptualization, formal analysis, writing-original draft and funding acquisition.

U Rashid Sumaila: Validation and reviewing the draft;

Md Azizul Bari: Investigation, data curation, and statistical analysis.

Ibnu Rusydy: GIS Software and visualization.

Mohamed Saiyad Musthafa: Review and editing.

Mazlin Mokhtar: resources and project administration.

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1. Introduction

Fish are considered an important source of essential proteins, lipids, vitamins, minerals and unsaturated fatty acids, such as Omega-3 (Mohanty et al. 2019; Nordhagen et al. 2020; Balami et al. 2019). Therefore, fish consumption is highly recommended by nutrition experts worldwide, assuming a positive effect on the health of consumers. However, fish can pose a health risk due to contamination, especially by heavy metals (Costa et al. 2020; Alam and Mohamed 2011; Kim et al. 2020), which are well-known environmental pollutants because of their toxicity, persistence in the environment, and bioaccumulative nature (Ali et al. 2019). Several natural and anthropogenic processes, including volcanic eruptions, spring water, erosion, bacterial activity, fossil fuel combustion, industrial processes and agricultural activities, distribute heavy metals in the environment (Florea et al. 2004). Therefore, the contamination of aquatic systems with heavy metals has become a matter of concern over the last few decades (Canli et al. 1998; Javed and Usmani 2011; Hong et al. 2020). Exposure to heavy metals is known to cause adverse effects on human health, with an increased probability of respiratory problems, kidney pathology, neurological disorders and cancers (Mohammadi et al. 2019; Sall et al. 2020). Thus, consumer concerns have recently focused on the risk–benefit ratio of consuming fish and the safe consumption level. The risks and benefits of fish have been mentioned in the media and the literature (Alam et al. 2015a; Ricketts et al. 2019; Laird et al. 2018; Haque et al. 2019); however, much less attention has been devoted to safe consumption limits. Uncertainty remains regarding the level of risk and circumstantial factors that may impact consumers' health. At the same time, perceived public risks need to be acknowledged by policymakers to manage food safety risks; thus, many studies have been focused on informing and educating consumers about food safety (Rahmaniya and Sekharan 2018; Ahmed et al. 2020 b).

The Philippines has an enormous water area, encompassing about three-quarters of the country's geography, accelerating Filipinos' dependency on fish for their animal protein demand. The average per capita fish consumption of 41 kg in the Philippines is one of the highest in Southeast Asia and is considered comparatively high by world standards (Ahmad et al. 2003). As a result, the Philippines remains one of the top fish-producing countries in the world and over 1.6 million Filipinos depend on the fishing industry for their livelihood (WCPFC 2016). Laguna de Bay, which is the largest inland water body in the Philippines, contributes greatly to meeting the fish demand, producing about 80,000–90, 000 metric tons of fish in a year through aquaculture and open-water fisheries (LLDA 2020). However, Laguna de Bay's fisheries have been affected by human, industrial and environmental factors, threatening the fisheries' resources due to contamination (Tamayo-Zafaralla et al. 2002; Hallare et al. 2005). However, few studies have concentrated on the contamination of fish from Laguna de Bay (Molina 2012; Molina et al. 2011). Most studies failed to integrate evidence of contamination and consumers' perceptions to guide research on decision-making for the development of fish consumption advice. Many developed countries respond to the potential risk of contaminants in fish by issuing advice, but no proper initiatives have been undertaken to protect the consumers of the developing world. As a result, consumers are not well informed and are unable to make good decisions with regard to their fish consumption.

Therefore, in this study, the knowledge and perceptions of consumers of fish in the Laguna Lake area of the Philippines were examined to understand people's willingness to adopt fish consumption advice. The study also explored the contamination scenario of two commercially important fish species, tilapia (Oreochromis niloticus) and mudfish (Ophicephalus striatus), collected from Laguna Lake, conducting a risk–benefit analysis and producing a vulnerability map. Furthermore, safe consumption guidelines have been formulated for both species, which can serve as a model for future fish consumption advice in the region.

2. Materials and Methods

2.1. Data collection

This research used a self-administered survey questionnaire to collect primary data on the fish consumption of consumers in the Laguna de Bay area. The study area is located at the municipality of Los Baños in the province of Laguna, Philippines. Los Baños is politically subdivided into 14 barangays (villages). Of these 14 villages using random sampling method three nearest villages of University of the Philippines Los Baños have been selected for this study namely, Batong Malake, Anos and Tuntungin-Putho. A total 100 respondents participated in the survey and the sample size was calculated according to the following equation based on Bari (2015),

$$n = \frac{N_o}{1 + {N_o}/{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$N_o = t^2(p)(1-p)/d^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, n is the sample size, N is the size of the population, No is the sample size of a defined population, d is the error term that is estimated at 5%, p is the estimated frequency of the sample with size n, while t is the figure obtained from the t-student's table. With a 95% confidence level, the overall sample size was calculated to be 90 participants, with an additional 10 individuals questioned to rule out anomalous values.

The survey aimed to assess consumers' perceptions of fish consumption through open-ended questions on topics such as the risks and benefits of eating fish; their knowledge of fish contamination and water pollution; their fish consumption rate; the quality of fish; information needed for safe consumption, etc. Moreover, demographic information (age, occupation, education level, income, household size and number of children) was collected during the survey.

The information on heavy metal contamination in fish utilised in the study was based on the best available dataset in the literature for Laguna Lake (Molina 2012; Molina et al. 2011). Two popular and commercially important fish species, tilapia (*Oreochromis niloticus*) and mudfish (*Ophicephalus striatus*), were considered in the study for formulating consumption advice. The dataset comprises seasonal data on fish contamination collected from eight different locations within Laguna Lake.

2.2. Data Analysis

Nonparametric factor analysis, along with the multiple regression model, were performed using a statistical analysis system (SPSS) to explore consumers' perceptions of fish consumption and willingness to adopt consumption advice. Variance in the willingness to adopt fish consumption guidelines was regressed against the 12 independent variables, following the below equation:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + \beta_8 x_{8i} + \beta_9 x_{9i} + \beta_{10} x_{10i} + \beta_{11} x_{11i} + \beta_{12} x_{12i} + e_i, \quad (3)$$

where:

y_i = Response variable (willingness to adopt consumption advice)
β_0 = Constant variable
β_1 = Coefficient of first control variable, x_{1i}
β_2 = Coefficient of second control variable, x_{2i}
β_3 = Coefficient of third control variable, x_{3i}
β_4 = Coefficient of forth control variable, x_{4i}
β_5 = Coefficient of fifth control variable, x_{5i}
β_6 = Coefficient of sixth control variable, x_{6i}

x_{1i} = Controlled variable (fish consumption)
x_{2i} = Controlled variable (age)
x_{3i} = Controlled variable (occupation)
x_{4i} = Controlled variable (education)
x_{5i} = Controlled variable (income)
x_{6i} = Controlled variable (number of children)
x_{7i} = Controlled variable (risks of consuming fish)
x_{8i} = Controlled variable (benefits of consuming fish)
x_{9i} = Controlled variable (contamination in fish)
x_{10i} = Controlled variable (water pollution)
x_{11i} = Controlled variable (availability of information)
x_{12i} = Controlled variable (confusion about fish quality)
e_i = Error

The scenario of contamination in targeted fish species was analysed through seasonal variations, a risk–benefit assessment and a vulnerability map. The data were inputted into Microsoft Excel, including the coordinates (longitude and latitude) and the vulnerability data (risk–benefit ratio). Following this stage, ArcGIS software developed by ESRI was utilised to plot eight locations of vulnerability data into the map. The data were imported into ArcGIS and the coordinate system used in ArcGIS was set accordingly. For this research, we applied the geography coordinate system (GCS) and WGS (World Geodetic System) 84 as the datum reference. All data were represented in circles. The size of the circles illustrates the level of vulnerability, as shown in the map legend; the digital elevation dataset was taken from NASA (2017).

The formulation of consumption advice was carried out through the estimation of the safe dietary intake (CRlim) and maximum allowable fish consumption rate (CRmm), using the below equations (Gbogbo et al. 2018; Shakeri et al. 2015):

$$CR_{lim} = (RFD \times BW)/MC \quad \text{....(4)}$$

where:

CR_{lim} is the maximum amount of fish consumption in terms of the limiting consumption rate (kg/day).
Rfd = Oral reference dose (mg/kg) based on USEPA summary table (USEPA 2011).
Bw = Body weight (65 kg for adult and 35 kg for child).
MC = concentration of metal (mg/kg).
The number of acceptable fish meals per month (CR_{mm}), is calculated according to the formula below:
$CR_{mm} = (CR_{lim} \times Tap)/MS$.......(5)

Tap is the time average period (365.25 days/12 months = 30.44 days per month) and MS is the meal size (0.227 kg fish/meal for adults and 0.085 kg fish/meal for children under six years old). An advisory table was produced following the style of the Maryland Fish Consumption Advisories (MDE 2020).

3. Results

3.1. Community willingness to adopt consumption advice

The survey consisted of 72.2% of male and 27.8% of female respondents. The majority of the respondents were between 21 and 30 years old. Most respondents had higher levels of education (college/university). However, about 26% of participants had an education below secondary level. In terms of occupation, government/nongovernment workers comprised the highest proportion in terms of profession, comprising 35.6% of the total respondents; 24.4% were students, 23.3% were fishermen/farmers, and 16.7% were businessmen. In terms of income distribution, this study found that 43.3% of the respondents were middle-income individuals, followed by upper-middle (28.9%), lower (24.4%) and higher-income (3.3%) participants.

A factor analysis was carried out to reduce the large number of surveyed socioeconomic variables into fewer factors, extracting the maximum common variance from all variables and merging them into a common score that will be used for further analysis of multiple regressions. Table 1 demonstrates that, out of 15 variables, three variables were eliminated, leaving 12 variables that were distributed according to six components. All six components were later named as particular factors, such as social status, fish consumption behaviour, trust on fish quality, economic dependency, worry and risk.

In the attribute "sociodemographic", four items were identified: age, occupation, education and number of children. Factor 2 shows that all the variables were directly related to the consumption behaviour of participants, including the amount of fish consumption, participants' concern about contamination in the fish they eat, and intention to acquire information on the risks and benefits of consuming fish. Since the variables in factor 3 clearly describe the trust of the consumer in terms of the benefits of consuming fish and their confusion about the quality of the fish they consume, this factor was called "trust". Factor 4 represents variables related to economic dependency, namely the occupation and income of participants, whereas the fifth factor extracted information on worry, including the variables fish consumption benefit and water pollution. The last factor explained people's concerns about the risks of consuming fish.

A multiple linear regression analysis was used to predict the factors influencing consumers' willingness to adopt fish consumption guidelines as a health management measure in the Laguna de Bay area. Consumers' willingness to adopt fish consumption advice was the dependent variable, while the independent variables extracted from the factor analysis included sociodemographic factors (age, occupation, education and number of children), fish consumption behaviour (level of fish consumption, perceptions about fish contamination and availability of received information), perceived benefit (perceptions of the benefits of fish consumption and confusion about the quality of fish), economic dependency (occupation and income), worry (perceived benefits of fish consumption and perceptions of water pollution) and risk (perceived risks of fish consumption). Multivariate findings indicated that the level of fish consumption was the best predictor of consumers' willingness to adopt the consumption guidelines ($P = 0.000$), followed by respondents' perceived knowledge about fish contamination ($P = 0.003$) and respondents' self-reported age ($P = 0.044$), as presented in Table 2.

3.2. Seasonal variation of heavy metal contamination

For the statistical analysis, an independent sample t-test was applied to explore the statistical difference in heavy metal contents in fish samples collected during the dry and wet seasons. The null hypothesis (H0) and alternative hypothesis (H1) of the independent sample t-test are as follows:

H0: $\mu 1 - \mu 2 = 0$ ("the difference of the means is equal to zero")

H1: $\mu 1 - \mu 2 \neq 0$ ("the difference of the means is not equal to zero"),

where $\mu 1$ and $\mu 2$ are the population means for the dry and wet seasons, respectively.

Table 3 displays the results of the independent sample t-test, indicating the equality of means. In the case of arsenic (As), since $p < 0.0001$, we can reject the null hypothesis and conclude that the mean concentration of As during dry and wet season is significantly different ($t15.75 = 3.72$, $p < 0.001$). However, the null hypothesis was accepted for the rest of the heavy metals, finding no significant difference in the mean concentration in fish between the dry and wet seasons.

3.3. Risk–benefit assessment

The present study aims to estimate the risk–benefit ratio of consuming tilapia and mudfish from Laguna Lake, the Philippines, following the method presented by Gladyshev et al. (2009). It is well known that taking 1000 mg of EPA + DHA, which is prescribed by many organisations such as the World Health Organisation, the British Nutrition Foundation and the American Heart Association, is beneficial for maintaining good health by preventing mental, neural and cardiovascular diseases. A health benefit assessment was carried out, considering this recommended amount of EPA + DHA (EFA) in the human diet, using the below formula:

$$\mathrm{FP} = \frac{Refa}{C} \ \ldots\ldots. (6)$$

where:

Refa = the recommended dose of EFA for a person (mg/day).

FP = portion of fish one has to consume to obtain the recommended Refa (g/day)

C = content of EFA (EPA+DHA) in the target fish (mg/g).

In the current study, the EFA value of tilapia was 1.03 mg/g (Al-Souti and Claereboudt 2014) and, for mudfish, it was 0.5 mg/g (Muhamad and Mohamad 2012). Through consumption of the recommended amount of EFA, the consumer can also ingest a significant amount of the contaminant through the fish; this amount can be calculated using the formula below:

$$DM = FP \times CM \text{ ...... (7)}$$

where: CM = the contamination in fish (µg/g).

The following equation was utilized to measure the risk of consuming the dose of heavy metal:

$$\text{HQ} = \frac{DM}{RfD \times AW} \text{ ...... (8)}$$

where:

HQ = Hazard quotient (HQ < 1, indicates no possible risk)

RfD = maximum tolerable daily intake of a specific metal (µg/kg/day). RFD for As = 0.3, Pb = 0.003, Cd = 0.001, Cr = 0.003, Hg = 0.1. (Alam et al. 2015b; USEPA 2011).

AW = average adult weight (65 kg)

A hazard quotient (risk–benefit ratio) for fish consumption (HQefa) was calculated for consuming the portion of fish to achieve the recommended amount of EFA, estimated using the following equation:

$$HQefa = \frac{Refa \times CM}{C \times RfD \times AW} \text{ ...... (9)}$$

From the calculated risk–benefit ratio, it was found that HQefa was an order of magnitude higher among the samples of mudfish compared to the tilapia (Table 4). The HQefa values for mudfish ranged between 0.05 and 28.28, while the HQefa for tilapia was in the range of 0.04 to 16.02.

3.4. Vulnerability map

Cluster analysis is a statistical technique used to identify homogenous groups or clusters of similar sites based on similarities within a class and dissimilarities between different classes (Kannel et al. 2007). In this study, a hierarchical cluster analysis (HCA) was performed based on the calculated risk–benefit ratio to identify different groups in Laguna Lake by the location where the fish samples were collected. The result of this analysis is shown as a dendrogram (Figure 1), where the horizontal axis represents the distance or dissimilarity between clusters and the vertical axis represents the objects and clusters. The HCA conducted in this study explored three clusters, indicating high-, medium- and low-vulnerability zones. The first cluster comprised locations 1A and 1B (high), while the second cluster constituted 2A, 3A and 3B (medium). In the third cluster, locations 2B, 4 and 5 were linked with one another as low-vulnerability zones.

It is well known that vulnerability mapping helps to target vulnerable hotspots and recommend appropriate interventions (Gizachew and Shimelis 2014). Considering this, a vulnerability map of Laguna Lake was produced based on the risk–benefit ratio of contamination in fish (Figure 2). The vulnerability map clearly identified Binangonan and Taguig of the northern West Bay (1A and 1B) as the most vulnerable areas of Laguna Lake, signifying the necessity of further detailed research and risk assessments, as well as management.

3.5. Formulating fish consumption advice

In this study, we assessed the maximum number of servings of tilapia and mudfish from Laguna Lake that can be safely consumed over a month. Tables 5 and Table 6 show the maximum number of times the fish can be safely eaten in a month if the average meal contains 0.227 kg of fish for an adult and 0.085 kg of fish for a child (below six years) and a woman of childbearing age. Red indicates a "risk", where restrictions on consumption have been set. On the other hand, yellow reflects "moderate restrictions" and green is "no restrictions". Considering the safe consumption of more than 16 meals per month (USEPA 2000), in this study, the consumption advice was designed according to the CRmm values, with ≤ 10 as risk; 11 to 16 as moderate restriction and > 16 as no restrictions.

For tilapia, the lowest consumption limit was for the areas of the central West Bay and central bay at three meals per month for adults due to the As contamination during the dry season. Similarly, the lowest consumption limit was advised for children and women of childbearing age in the central West Bay. In general, As and Pb were found to be the elements responsible for the consumption restrictions on tilapia collected from different areas of Laguna Lake. However, no restrictions were set for the consumption of tilapia on Talim Island in the central West Bay and Cardona in the central bay. On the contrary, northern West Bay areas were identified as moderate-risk areas for tilapia consumption. Similar to tilapia, for mudfish. the areas with a high-risk advisory were identified as the northern West Bay and central bay, with a consumption limit of five meals in a month because of the considerable contamination with Hg. In general, the most important elements influencing the consumption advice for mudfish were Hg, As and Pb. However, the east bay, south bay and West Bay were denoted as comparatively safe zones for mudfish consumption, with moderate or no restrictions.

4. Discussion

The goal of this study was to evaluate the acceptability of consumption advice among fish consumers of the Laguna de Bay area and propose advice as a model for future development. The findings of the factor analysis, based on the community survey, revealed that factor 1 consists of four items linked with the sociodemographic data of consumers, which is similar to the previous study conducted by (Samoggia and Castellini 2018), reflecting the social influences on participants' fish consumption. Given the characteristics of the respondents in factor 2, it is likely that they are interested in having full information about fish contamination and the risks and benefits of the fish they consume, as the level of fish consumption is the most significant indicator of this factor. Conversely, respondents in factor 3 with a better perception of the benefits of fish consumption had a negative perception of fish quality, which implies that people who think fish consumption is beneficial are not confused about the quality of the fish they consume. It is assumed that the food preferences of a family can be influenced by family members' decisions to consume fish, as well as the frequency and the type of fish eaten (Myrland et al. 2000; Trondsen et al. 2004). The present study also extracted the number of children in the consumer's family as an important item of factor 1. The influence of children on food choices is not a new phenomenon, as studies from the last two decades also suggested that having children at home is the most significant factor in changing one's food consumption patterns (Reilly 1999; Tucker et al. 2006). Consumers with children in their household were more likely to seek out food safety information as well as to intend to increase their knowledge of food safety issues (Bennett 1999; Tucker et al. 2006). Another study reported that respondents with children had a significantly higher frequency of fish consumption and belief in the health benefits of fish consumption compared with families without children (Verbeke et al. 2005). However, a slightly unexpected finding was observed in another study (Tucker et al. 2006), in which respondents with children in their household perceived lower levels of risk than respondents with no children.

Education plays a major role in consuming fish because it positively impacts the belief that fish is important for health and influences the fish consumption frequency. This opinion has also been addressed by a previous study (Myrland et al. 2000). On the other hand, some studies confirmed that there was no difference in fish consumption based on educational status, and highly educated consumers thought of fish as a "difficult-to-prepare" food (Myrland et al. 2000; Danso et al. 2017). Furthermore, income can influence healthy eating practices and has an impact on fish consumption. Thus, the factor analysis in the present study also identified income as an important factor, with a loading value of 0.647. Previous studies reported that consumers with a high level of education and high income consume healthier food (Skuland 2015), and a positive relationship exists between fish consumption and income levels (Skuland 2015; Myrland et al. 2000; Trondsen et al. 2004). Likewise, the high price of fish is considered one of the most common perceived barriers to fish consumption, as fish is considered more expensive than other protein sources. A tendency toward a lower frequency of fish consumption was found for respondents with the lowest income levels in comparison with other income groups for consumers in Belgium (Verbeke et al. 2005).

Employing a multiple linear regression method to predict the willingness to adopt consumption guidelines was a good choice, as this method is widely used for similar kinds of predictions (F. Zhang and Li 2019). The main predictors of willingness were linked with the factor class of consumers' behaviour, such as the level of fish consumption, perceptions of fish contamination and the availability of information related to fish consumption. This clearly implies that consumers with a higher level of fish consumption are eager to receive information about the safety of fish consumption and are more likely/willing to adopt consumption advice. The present study shows that 34.4% of the respondents had been eating more than three servings of fish per week, whereas 33.3% of consumers reported consumption of 2–3 servings per week. It was further noted that 24.4% of the studied population said that they had been consuming 1–2 servings of fish per week, while only 7.8% reported no consumption of fish at all. The fish consumption pattern in the study area is much lower than that near Lake Victoria in Tanzania, where 1–2 servings of fish per day was reported for the majority of the surveyed consumers and considerably large proportions (85.2%) of household members were seriously thinking of increasing the number of daily servings of fish they consumed for the improvement of their health (Wenaty et al. 2018). This variation might be the reason that perceptions are different between high-income and low-income settings. Likewise, consumers' age has been identified as a significant variable for adopting fish consumption advice. It is well established fact that age has a significant impact on fish consumption. In general, older people are more health-oriented than younger people (Olsen 2003)) and, therefore, elderly people consume fish more often than younger people (Olsen 2003; Verbeke et al. 2005). As a result, the perception of fish as a healthy food increased with age (Verbeke et al. 2005). Moreover, Erdogan et al. (Erdoğan et al. 2011) reported a strong positive correlation between fish consumption and age. A more recent study found that fish was mostly consumed by adults aged over 45, compared to other age groups (Wenaty et al. 2018). There is no doubt that consumers' health concerns are a driver of increased fish consumption frequency (Danso et al. 2017). Concern about the safety of food has attracted consumer attention for many years and it was reported that a lack of access to high-quality fish leads to constraints on consumption (Myrland et al. 2000).

This study identified perceptions of fish consumption risks and benefits as important factors for the fish-consuming populace. We found that 35.6% of respondents expressed minimum levels of perceived risk related to fish consumption, whereas 32.2% of consumers reported a high level of risk. This finding is also in line with previous studies where a risk to safety was identified as a potential barrier to consuming fish more frequently (Verbeke et al. 2005). In another study, one-fifth of consumers claimed that fish was unsafe, with young respondents perceiving fish as less safe compared with other age groups. The same study also revealed that the perception of fish as safe tended to be stronger among families with children (Verbeke et al. 2005). Consumers' awareness of the perceived benefits of fish consumption was higher in the current study, with 47.8% of respondents reporting fish consumption as having health benefits compared to beef and pork consumption. Increased awareness of the health risks involved in the consumption of red meat has led many consumers to turn to fish consumption. In this study, consumers also confirmed their perception that fish consumption is beneficial, expressing moderate (47.8%) to high (37.8%) affirmation of the perceived benefits of consuming fish. This observed consumer perception is similar to other earlier observations reported for the fish-consuming population of Hanoi (Danso et al. 2017). Furthermore, the importance of consuming fish has been noted for people who live near Lake Victoria: 98.4% of the interviewed consumers indicated that the inclusion of fish in their diet provided health benefits (Wenaty et al. 2018). This study also found that availability of knowledge is an important factor determining fish consumption behaviour. It was also reported that consumers frequently eat fish if they believe that sustainable food is healthy (Danso et al. 2017). Therefore, making information available can play an important role in promoting the healthy consumption of fish. Overall, the most important factors adversely influencing fish consumption have been found to be the high price, low level of satiation, lack of trust in its safety, lack of knowledge on ways of judging the product's quality and in preparing the product, the presence of bones, the flavour and the perceived low availability of good fresh fish (Danso et al. 2017).

The present study found that most of the heavy metal concentration in the collected fish samples did not differ significantly according to the seasons, indicating the influence of an anthropogenic impact on Laguna Lake. A risk–benefit assessment has been defined as the weighing of the probability of an adverse health effect against the probability of a beneficial effect as a result of the intake of food (Berjia et al. 2012). Guidance on performing risk–benefit assessments of foods has been described in many studies (Berjia et al. 2012) (Du et al. 2012; D.-P. Zhang et al. 2012). In the present study, for mudfish and tilapia, the HQefa values of the contaminants were found in the order of Hg > As > Pb > Cd > Cr. HQefa values greater than 1 indicate the potential that the metal may possess noncarcinogenic effects (Ricketts et al. 2020, Thomsen et al. 2019). Notably, in the study, mean values of HQefa for all the metals, except Cr in mudfish and tilapia and Cd in tilapia, were higher than 1 in all of the study locations. In the case of mudfish, the mean HQefa for Hg and Pb was calculated as 17.91 and 11.67, respectively, which indicated deleterious health effects for the intake of such fish in order to obtain the recommended portion of EFA.

The cluster analysis and vulnerability map produced in the study indicated that northern West Bay was the most vulnerable area of Laguna Lake in terms of the contamination of fish. Many studies have proven that the concentration of pollutants in fish follows the concentration of pollutants in the ambient water (Alam and Mohamed 2011). In the case of Laguna Lake, it was observed that the polluted tributary rivers were located in the western and northern parts of West Bay, where most of the population and the industrial establishments are concentrated (LLDA 2012), indicating the reason for the higher contamination in fish sampled from the northern West Bay in the present study.

Dietary advice is identified as a tool in health management (van der Gaag et al. 2020). Considering the contamination of fish, the maximum amount of fish consumption that can be consumed safely during dry and wet seasons was estimated for adults, children and women of childbearing age. As with the higher contamination recorded in northern West Bay, stricter consumption restrictions have been advised for those areas where As, Pb and Hg were the most significant elements contributing to the health risks. Similar to the present study, considering 0.227 kg of fish per meal for an adult, the consumption advice for two commercially valuable species of fish from the fresh and coastal waters of Ghana was set to nine meals/month, which was linked with the contamination of Hg (Gbogbo et al. 2018). Moreover, fewer than 10 meals of fish in a month was suggested for the consumption of freshwater fish due to the contamination of Pb in the largest tributary of the Karoon River of Iran (Majlesi et al. 2018). Both Hg and As have been recognised as noteworthy contaminants limiting fish consumption in the Persian Gulf, with a maximum allowable limit of one meal per month for children under six and 6–8 meals per month for adults (Raissy and Ansari 2014). Considering the importance of Laguna Lake and consumers' willingness to receive information about safe consumption, fish species from different areas within the lake should be monitored to produce suitable fish consumption advice.

5. Conclusions

The findings presented in this study clearly indicate that fish consumers in the Laguna Lake area recognise the importance of consuming fish but have concerns about the risks. However, very limited information is available about the risks and benefits of fish consumption in the region. Moreover, consumers' willingness to adopt consumption guidelines was influenced by various socioeconomic factors. This study pointed out that consumers with higher levels of fish consumption are keen to receive information about the safety of fish consumption and are more interested in adopting consumption advice to ensure their health. Considering this, the contamination scenarios for two commercially important fish species collected from Laguna Lake were analysed based on the most suitable dataset of heavy metal contamination in fish available in the literature, with the aim of formulating fish consumption advice. Our study identified potential noncarcinogenic health risks due to the contamination of heavy metals in both tilapia and mudfish collected from Laguna Lake. The most polluted locations explored by the cluster analysis and a vulnerability map were areas of northern West Bay. Following research on the contamination level, fish consumption advice was formulated, setting a lower consumption limit for fish collected from those areas. The consumption advice produced in this study can be considered as a pioneering initiative in the region that can be used as the basis for the further development of consumption advice.

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Figures

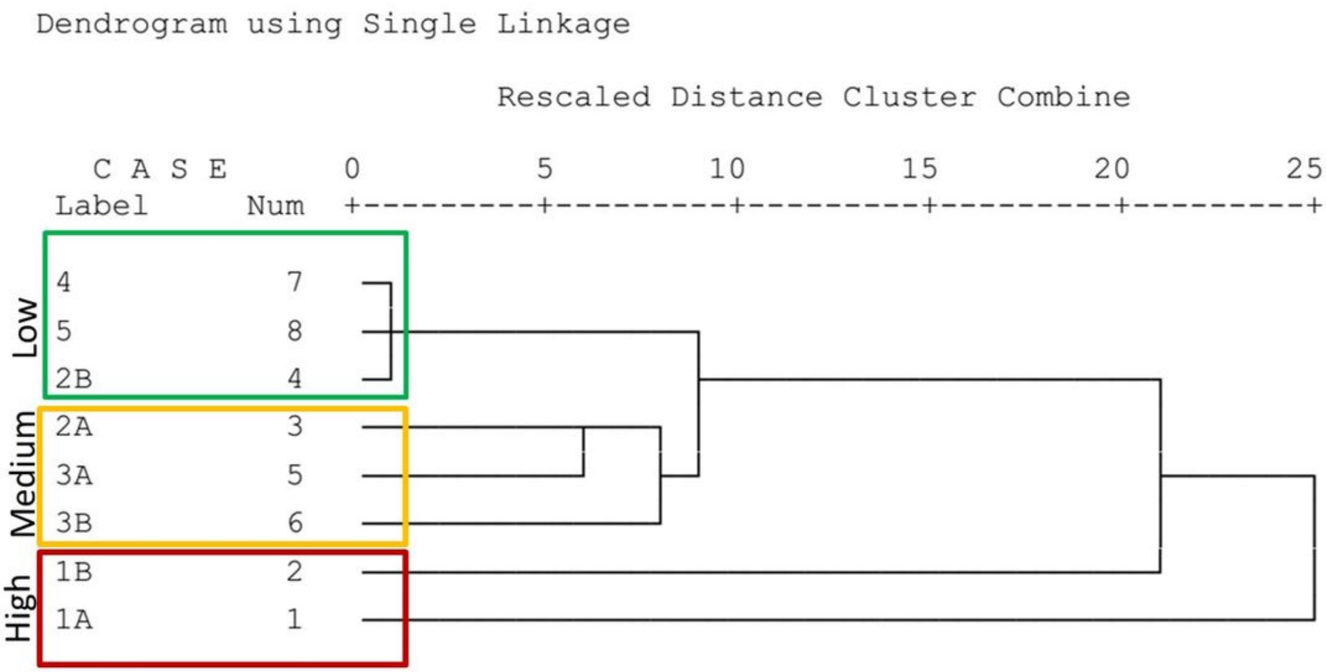

Figure 1

Hierarchical cluster analysis for heavy metal contamination in 8 stations in Laguna

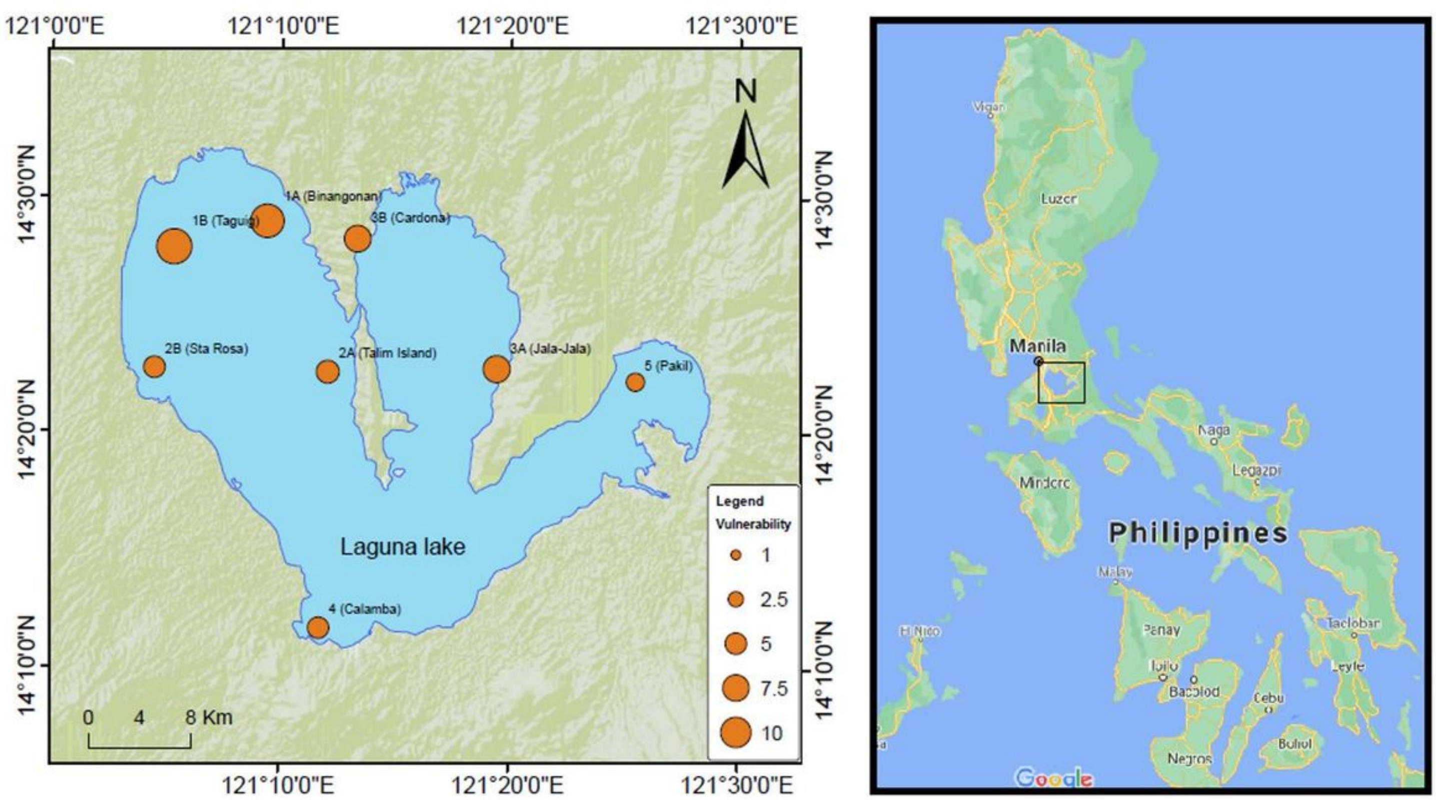

Figure 2

Vulnerability map of fish consumption risk at Laguna de Bay

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