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"Wild fish are a blessing": changes in fishing practices and folk fish cuisine around Laguna Lake, Northern Philippines

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Abstract

Several coastal communities rely heavily on wild-caught fish for personal consumption and their livelihoods, thus being sensitive to the rapid global change affecting fish availability. However, in the last century, aquaculture has been increasingly adopted. To understand the uses and changes of wild-caught fish, we conducted 30 semi-structured interviews with fishers of Laguna Lake, Philippines. Fishermen, with up to 60 years' experience, reported catching 31 fish species as a staple food. The taxa with the greatest variety of food uses were the farmed *Oreochromis aureus,* and the wild *Channa striata* and *Cyprinus carpio*. Fish was boiled, fried, grilled and dried, and over 20 different local dishes were reported. Fishers reported that local communities previously relied more on wild fish, while today a greater proportion of consumed fish comes from aquaculture fish species such as *Oreochromis aureus* and *Hypophthalmichthys nobilis*. Wild fish remains a crucial aspect of local gastronomic diversity, underpinning the biodiversity of the Laguna Lake, while also representing an important element for food sovereignty. The study stresses the need to sustain local ecological knowledge to ensure the ecological, social and economic sustainability of the communities.

Keywords: Ethnoichthyological knowledge, Freshwater fishes, Local ecological knowledge, Sustainable small-scale fisheries

Introduction

Fish are a crucial source of proteins and micronutrients contributing to the food security of much of the world's population [1]. For millennia, fish have been to a great extent captured from the wild, yet aquaculture has been increasingly adopted since the end of the twentieth century on a global scale [2]. In 2018, the farming of fish, shellfish and aquatic plants provided for the first time more fish than fisheries (52%), and its share is expected to further grow during this decade [2]. Aquaculture could improve the livelihoods of fishing-dependent communities by reducing risks and economic uncertainties (e.g., 3, 4]), yet it is also associated with several environmental concerns including habitat alteration, water pollution and the loss of biodiversity [5, 6]. Indeed, it is still unclear how aquaculture could affect to local biodiversity especially in the context of inland aquatic systems [7, 8]. However, it was found to contribute to the decline of wild fish populations [6] by introducing invasive species which harm native and endemic species [9, 10 and references within].

The shift from wild fish capturing to aquaculture took place in the last 70 years in several geographical contexts, especially in Asia [11]. Such a transition has been studied from an economic and ecological perspective. For instance, a country-based analysis revealed the positive economic impact of adopting aquaculture in rural

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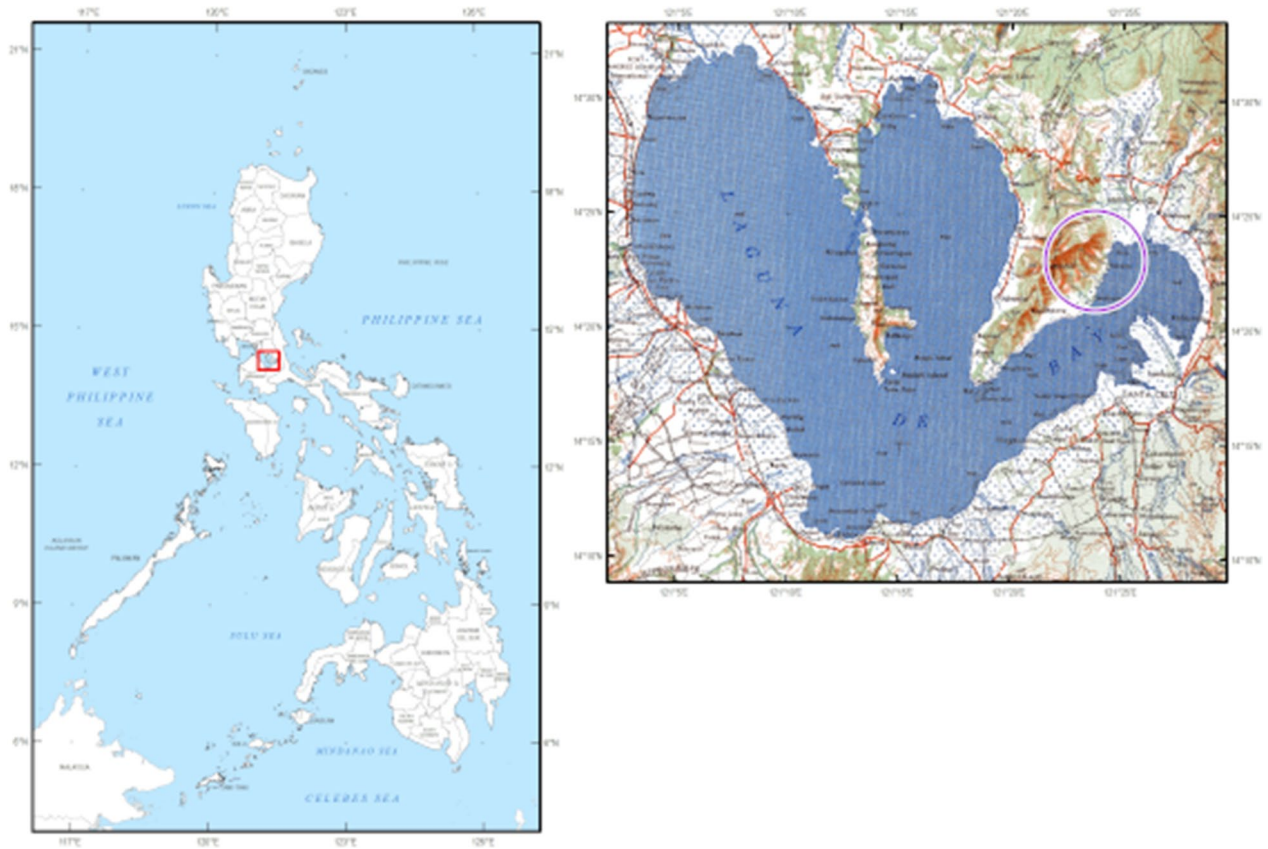

Fig. 1 Map of the study area. Mabato-Azufre Pangil, Laguna, Philippines. (*Source:* National Mapping and Resource Information Authority of the Department of Environment and Natural Resources, Philippines.)

contexts in Europe [12]. However, Hahn and Boonstra [13] underlined the socio-ecological trap, a negative loop of resource degradation and livelihood depletion in which many fishermen live in the Global South, and revealed that economic diversification is not always effective in overcoming it. From a nutritional perspective, the crucial role of aquaculture has recently been highlighted by Gephart et al. [1] as a potential contributor to a nutritionally secure future, yet Bené et al. [14] clarified that the contribution of aquaculture to poverty alleviation is still debated.

To date, no studies have focused on changes in food habits as a consequence of the transition from wild caught to aquaculture fish. This is a relevant issue as it addresses nutritional and cultural adaptation to the new ecological asset and can imply and reveal local impacts of those changes. Therefore, we aimed to analyze, from an ecogastronomic perspective, this shift from wild to farmed fish in a Filipino fishing community. Specifically, we focused our study on the local ecological knowledge regarding wild and farmed fish held by fishermen of Mabato-Azufre, a village on the northeastern side of Laguna Lake, Northern Philippines. The specific aims of the research were (a) to document from a diachronic perspective the wild and farmed fish species commonly caught by local fishers, (b) to analyze the current uses of wild and farmed fish, and (c) to explore the advantages and disadvantages of the use of wild and farmed fishes according to the fishers of Mabato-Azufre.

Materials and methods

Study area

We focused our study on Laguna Lake, located on Luzon Island, which is the largest freshwater lake in the Philippines and the third largest inland water body in Southeast Asia (Fig. 1). It is a eutrophic, extremely shallow lake (average depth 2.7 m) with an area of 900 km^2 and an elevation of approximately one meter above sea level. Laguna Lake represents a vital freshwater watershed for the communities living along its coast and the nearby city of Metro Manila [15, 16], and it is connected to the marine waters of Manila Bay via a single outlet, the Pasig River. The lake is a water resource supporting multiple uses, including various industries and agriculture,

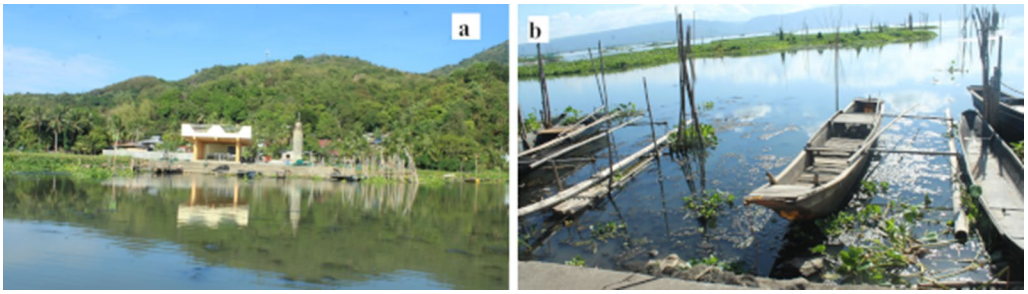

Fig. 2 Mabato-Azufre: (**a**, **b**) fish landing and tourism area

livestock and poultry production. Local people depend on traditional fishing for both commercial and nutritional purposes. There is a total of 11, 814 fishers (11,556 men and 258 women) on Laguna Lake and 318 pen and 3,002 fish cage structures (in 2018) [17]. The lake and its watershed also serve as a sanctuary for migratory birds and are rich in faunal biodiversity [16], including a number of endemic fish species [18].

Ecological studies have classified Laguna Lake as "critically endangered" [19] and in "need of restoration" [20]. Striking signs of Laguna Lake's ecological crisis include the loss of fish biodiversity, low water quality and changes in fish productivity. In the 1960s, the natural fish population of the lake consisted of 17–24 freshwater and migratory fish species [20]. Migratory fish populations have decreased, several native species have disappeared from the lake and non-native species have been introduced, so that now an important proportion of fish species are introduced, non-native fish taxa [18]. The catches of capture fisheries declined sharply from about 80 tons in the early 1960s to around 20 tons in the 1970s [21] and have been fluctuating between 15 and 30 tons ever since [20, 22]. Several scholars have agreed that the decline in wild fish stocks available to the fisheries of Laguna Lake happened as a result of a combination of different factors. Among these factors, overfishing in the past, increasing levels of pollution [23, 24] and invasive species [25, 26] stand out.

However, what was lost in the wild is now produced using aquaculture. Aquaculture is steadily growing at a global level [27], and this is also occurring in Laguna Lake. Aquaculture was introduced in the lake in the 1970s as a promising economic resource for the local population [27]. It started with milkfish (*Chanos chanos*) [28], but has developed rapidly, with other species, such as tilapia (*Oreochromis niloticus* and *Aristichthys nobilis*), being introduced into the lake [29]. At the national level, Laguna Lake and surrounding areas within the CALABARZON (Cavite, Laguna, Batangas, Rizal, Quezon) region are major producers of tilapia, milkfish and carp in fish pens and fish cages [30]. The expansion of fish pens and cages for fish was not regulated until the 1990s, leading to 40 years of controversy between fishers and pen operators [28, 31, 32]. Currently, the Fisheries Code of the Philippines limits aquaculture to 10% of the suitable water surface area, which compares to 30% at the peak of the industry [28, 31]. However, some fishers have also developed strong economic ties with the aquaculture sector and benefit occasionally from fish escaping from net enclosures [20, 33]

Mabato-Azufre is one of eight barangays, or primary administrative units in the Philippines, in the municipality of Pangil in the province of Laguna (Figs. 1, 2). The municipality of Pangil is inhabited by the Tagalog people, who speak the Tagalog language, one of the largest ethnolinguistic groups in the country [34]. In the studied village, fishing and rice cultivation, followed by handicrafts, are the main activities of the local inhabitants.

Data collection

Thirty semi-structured interviews with fishers of Mabato-Azufre were conducted between September and December 2019. First, the first author approached the head of the village of interest to whom the research project was explained and written approval obtained. Then, fishery managers and community leaders, such as the head of the village and the Barangay Fisheries and Aquatic Resources Management Council (BFARMC[1]) [35] were informed about the goals of the study. After an initial sampling of key informants among the most experienced fishermen indicated by community members, we followed the snowball method, selecting in total 30 local fishers (29 men and one woman). There is only one woman fisher in Mabato-Azufre and in the nearby villages. In the village

[1] Fisheries and Aquatic Resources Management Councils or FARMCs are created at the national to municipal level to formalize the main roles of resource users including fishermen in developing policies and in the conservation, management and sustainable development of aquatic resources including fisheries (BFAR, n.d); the BFARMC represents the one at the community level.

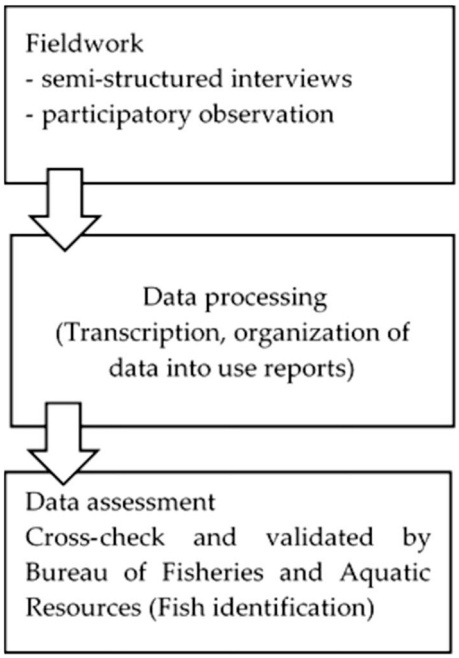

Fig. 3 Chart of the main methods employed in the study

Table 1 Profile of research participants from Mabato-Azufre

Profile	Categories	Number of interviewees (%)
Gender	Male	29 (97%)
	Female	1 (3%)
Age	20–40	3 (10%)
	41–60	13 (43%)
	61–80+	14 (47%)
Literacy	Illiterate	1 (3%)
	Primary education level	14 (47%)
	Elementary graduate	2 (7%)
	High school incomplete	11 (37%)
	Vocational undergraduate	1 (3%)
	College	1 (3%)
Fishing experience	0–20 years	11 (37%)
	21–40 years	9 (30%)
	41–60 years	10 (33%)
Inherited activity	Yes	20 (67%)
	No	10 (33%)
Fishing status	Active	23 (77%)
	Retired	7 (23%)

the role of women is to accompany their husbands when they go to the lake for fishing, helping their husband (the male fishers) in sorting the fish they captured, cooking it or selling what is captured by their husband. The only female fisher explained that she became a fisher, because her father was getting old and was going to need help with his fishing activity. Most of the fishers have been engaged in fishing activities for a long time, and some up to approximately 60 years (Table 1). Upon consent of the interviewee, field notes and voice recordings were taken. First, interviewees were asked to free-list the fish they caught at the time of the research and those they used to catch when they started professional practice. According to the fishers, wild fish are those that are captured in the lake using fishing gear such as "Baklad" or fish corrals (Fig. 9), while farmed fish such as *Hypophthalmichthys nobilis* and *Oreochromis aureus* are the ones raised in fish cages, which can sometimes be captured in the lake as well. Then we asked about the gastronomic or non-gastronomicuses of the species listed by the interviewees. The questions about catches, the methods of preparation and the changes in the fishery also served as points of reference for the fishers to reflect on related aspects such as socio-economic effects or taste preferences. Finally, we recorded the socio-economic profile (gender, age, literacy level, fishing experience, inherited activity, fishing status) of the interviewees. In addition, the first author carried out participatory observation by taking part in fishing trips and other fishing activities, as well as fish cooking sessions. During the entire study process, we strictly followed the Code of Ethics of the International Society of Ethnobiology [36]. All respondents provided written or oral informed consent to participate in this study. The data were anonymously processed and presented in order to secure participants' privacy. The applied methodology is summarized in Fig. 3.

Data analysis

The voice recordings and field notes were transcribed and translated into English by the first author.

Data regarding the fish caught were then extrapolated and organized on the basis of use records with the aim of providing a list of fish species and their food uses.

To include additional qualitative information that fishers provided during the interviews, the interviews were coded systematically by the first author with the help of the last author. The codes were grouped into thematic categories with specific attention paid to causal relationships between codes and their linkages to food uses.

The scientific names of fish species were identified according to local name and morphological characteristics. In order to assess the data obtained from the semi-structured interviews, the data was cross-checked

with that obtained by the local BFAR. Subsequently, the matches were validated by employees of that office. Nomenclature follows the Fishbase database [37].

The list of fish species and their food uses was based on the local names of dishes, and explanations of the meanings of local terms are provided at the end of Table 2. This was done in order to maintain, as much as possible, an emic approach.

Results

Wild and farmed species caught in Laguna lake

Fishers reported catching 31 fish and one shrimp ethnotaxa, which correspond to 31 fish species and one shrimp genus, for personal use as food over the course of their professional life (Table 2). The fish and shrimp taxa belong to 19 families. The most cited species include highly versatile taxa such as the farmed *Oreochromis*

Table 2 Reported fish species and their local uses

Scientific name (and family)	Wild or farmed	Local name	Local uses (n > 1)
Anabas testudineus B. (Anabantidae)	Wild	Tinikan/martiniko	Fried (2)
Arius dispar H. and *A. manillensis* V. (Ariidae)	Wild	Kanduli	Dried (6), fried (6), *adobo, ginataan*, *pinaksiw* (4), *sinigang* (3)
Barbonymus gonionotus B. (Cyprinidae)	Wild	Tawis	Fried (8)
Carassius auratus L. (Cyprinidae)	Wild	Karpita	Fried, grilled, *adobo*, *ginataan*
Chanos chanos F. (Chanidae)	Wild (farmed in other areas of the lake)	Bangus	Fried, grilled, *pinaksiw* (4), *relyeno* (2), *sarsiyado*, *sinigang*
Channa striata B. (Channidae)	Wild	Dalag	*sinigang* (4), fried (7), grilled (19), boiled (6), *ginataan* (2), *tinola* (19), *afritada*, *sarsiyado*
Chitala ornata G. (Notopteridae)	Wild	Knifefish	Fish ball (4), *lumpia*, animal feed, fish feed
Cichlasoma trimaculatum G. (Cichlidae)	Wild	Dugong, Duterte, Digong	Fried (2), *sarsiyado*
Clarias macrocephalus G. and *C. batrachus* L. (Clariidae)	Wild	Hito	Grilled (4), *adobo* (2), *adobo-paksiw*
Cyprinus carpio L. (Cyprinidae)	Wild	Karpa	*sinigang* (3), fried (14), grilled (2), *pinaksiw* (9), *adobo* (6), *ginataan* (11), *afritada*, *escabetche* (2), *ginisa sa kamatis*, *sarsiyado* (3), *pochero*
Elops hawaiensis R. (Elopidae)	Wild	Bidbid	Fried, *pinaksiw*
Giuris margaritacea V. (Eleotridae)	Wild	Palu-palo	*ginataan*, dried, *okoy*
Gobiopterus lacustris H. (Gobiidae)	Wild	Dulong	*adobo*, *ginataan*, *okoy*, fish omelet
Hypophthalmichthys nobilis R. (Cyprinidae)	Farmed	Bighead	*sinigang* (4), fried (12), grilled (15), *pinaksiw* (5), *lumpia* (2), *sarsiyado*, *puchero*
Labeo rohita H. (Cyprinidae)	Wild	Rohu	Fried, *puchero*
Leiopotherapon plumbeus K. (Terapontidae)	Wild	Ayungin	*sinigang* (7), grilled (2), *pinaksiw* (10), *ginataan* (6), dried (3)
Liza subviridis V. (Mugilidae)	Wild	Talilong	*sinigang* (3), *fried* (3), *pinaksiw* (4)
Ophisternon bengalense M. (Synbranchidae) and *Anguilla marmorata* Q. (Anguillidae)	Wild	Palos, Igat, Kiwit	Fried, *adobo* (3), *ginataan* (2)
Oreochromis aureus S. (Cichlidae)	Farmed	Tilapia	Bait (3), *sinigang* (24), fried (24), grilled (20), *pinaksiw* (6), boiled, *adobo*, *ginataan* (5), *afritada*, *sarsiyado* (2), dried (2), *adobo-paksiw*
Osphronemus goramy L. (Osphronemidae)	Wild	Gurami	Fried (7), grilled (2), *pinaksiw* (7), *ginataan*, *sarsiyado*, dried
Oxyeleotris marmorata B. (Eleotridae) and *Glossogobius giuris* H. (Gobiidae)	Wild	Biya	Fried (15), *pinaksiw* (6), *ginataan* (10), *escabetche* (2), *ginisa sa kamatis*, *sarsiyado* (4), *sinuam* (5), *adobo-paksiw* (2)
Oreochromis niloticus L. (Cichlidae)	Wild	Plapla	*sinigang* (7), fried (4), grilled (6), *adobo*, *pinaksiw*
Pterygoplichthys pardalis C. and *P. disjunctivus* W. (Loricariidae)	Wild	Janitor fish	Fertilizer (2)
Sarotherodon melanotheron R. (Cichlidae)	Wild	Arroyo	*sinigang*, fried (2), dried (2)
Tilapia zillii G. (Cichlidae)	Wild	Bruce lee	Dried (2), fried (4)
Zenarchopterus philippinus P. (Zenarchopteridae)	Wild	Kansusuwit	Dried
Macrobrachium spp. (Palaemonidae)**	Wild	Hipon	Fried (2), *sinigang* (5), *ginataan* (15), *ginataan sa pinya* (2), *ginataan sa kamias*, *okoy*

Wild or farmed—according to interviewees

aureus (90 use records) and the wild *Channa striata* (59 use records) and *Cyprinus carpio* (53 use records). Other important fish species that were mentioned by more than two thirds of the interviewees were the wild ethnotaxon "biya" *Oxyeleotris marmorata* and *Glossogobius giuris* (45 use records), and the farmed *Hypophthalmichthys nobilis* (40 use records).

Local food: *adobo*—marinated in soy sauce and vinegar; *afritada*—stewed with onions, tomatoes, bell peppers and potatoes; *escabetche*—sweet and sour dish; *ginataan*—cooked with coconut milk; *ginataan sa kamias*—cooked with coconut milk and sour fruit kamias (*Averrhoa bilimbi*); *ginataan sa pinya*—cooked with coconut milk and pineapple; *ginisa sa kamatis*—stir fried with tomatoes; *lumpia*—fish spring rolls; *okoy*—fried shrimp cake; *pinaksiw*—stewed in vinegar; *pochero*—stewed fish with vegetables and bananas; *relyeno*—stuffed milkfish; *sarsyado*—cooked with tomato sauce; *sinigang*—sour stew usually with tamarind as souring ingredient; *sinuam*—fish sautéed with garlic and ginger; *tinola*—stewed with either papaya or sayote; *adobaksiw* (*adobo-paksiw*) —cooked with both soy sauce and vinegar with ginger added. **—based on Laguna Lake Development Authority [38].

Fish as food: preparations and uses

Fish is commonly served as part of the main meal across most of the coastal areas of the Philippines. Fishers explained that boiled fish is usually made with tamarind (*Tamarindus indica*), while cooked fish is usually prepared with coconut milk and pineapple or any other sour fruits such as kamias (*Averrhoa bilimbi*), especially in the case of shrimp. Fish can also be cooked with soy sauce, vinegar and ginger or it can be stuffed with various ingredients and tomato sauce. On the other hand, when fish is dried and grilled it is usually cooked without the addition of other ingredients. However, when fish is marinated, most of the time it is infused with soy sauce and vinegar. When it comes to stewed fish, it is typically cooked with onions, tomatoes, bell peppers and potatoes as well as with papaya or chayote and other vegetables and bananas. It can also be cooked with vinegar. Finally, fish can also be prepared as spring rolls, omelets and fish balls, and, if stir-fried, it is cooked with tomatoes. It is important to add that a new type of preparation appeared along with the appearance of invasive species: fish balls made from *Chitala ornata* were reported as a new type of preparation in the village.

The only woman fisher in our study shared a new way of drying *Arius* spp. and *Oreochromis aureus* (Figs. 4, 5); that is, drying them in a "boneless" manner, unlike the usual way of using the whole fish. This type of dried fish could have greater value to consumers according to the interviewee. As mentioned during the interview, she had discovered the new drying technique when it was difficult to dry fish, which especially occurs during the rainy season. The authors anticipate that this new method of drying fish could become a way to diversify fishers' livelihoods to help improve the socio-economic conditions of the local community. According to the interviewee, she is the only person in the village and surrounding area employing this method. She said: "*I started in 2010 when it was frequently raining; it was difficult to dry fish, so I decided just to use the flesh of the fish, cut it in thin strips for easier drying. At this time, I am drying the fish manually in my house, and it would be a big help to further develop this activity if I had a solar dryer.*"

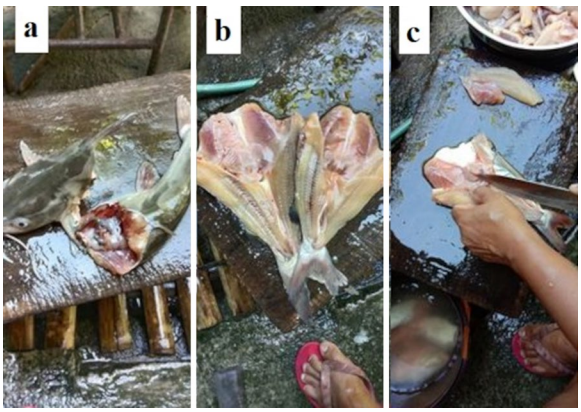

Fig. 4 The drying of *Arius* spp. [Kanduli]: **a** and **b** the old way; **c** the more recent method

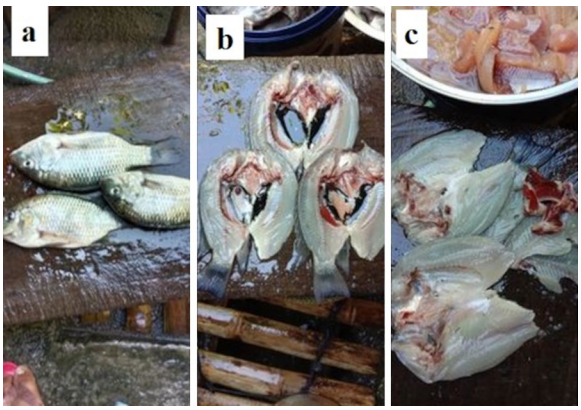

Fig. 5 The drying of *Oreochromis aureus* [Tilapia]: **a** and **b** the old way; **c** the more recent method

Figures 6 and 7 show the most common food preparations presented by some of the local residents.

To add, some non-food uses of fish species were reported, although by very few individuals (from 1 to 3

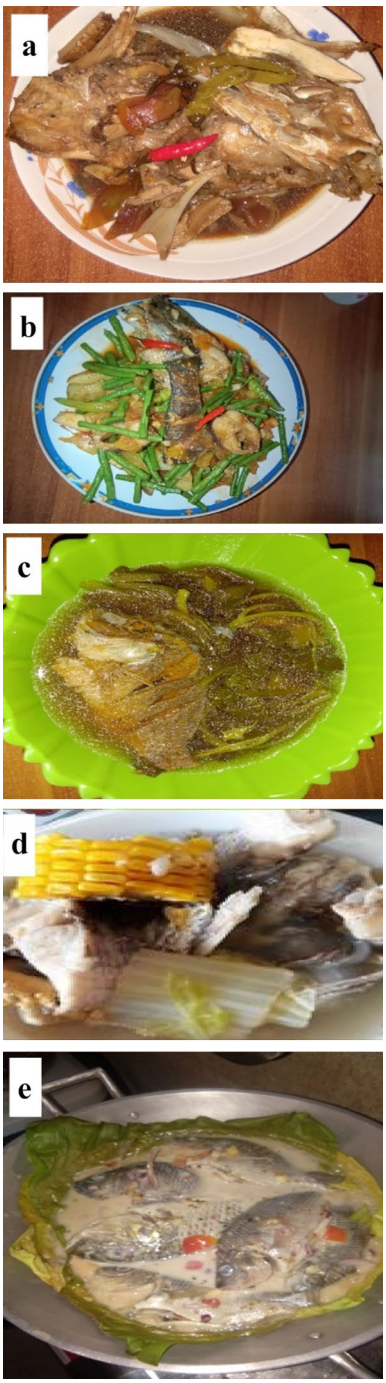

Fig. 6 The most common food preparations as described by the interviewees: **a** *Hypophthalmichthys nobilis* [bighead] cooked as "*Adobaksiw*"; **b** simple fish *Afritada* from a local person using Dalag [*Channa striata*]; **c** fish *Sinigang* using Tilapia [*Oreochromis aureus*] dishes; **d** "*Nilagang Dalag*" (boiled Dalag [*Channa striata*]) with corn and vegetables; **e** "*Ginataang Tilapia*" [*Oreochromis aureus*] cooked with coconut milk

Fig. 7 Additional dishes: **a** fried Kanduli [*Arius* spp.]; **b** grilled Tilapia [*Oreochromis aureus*]; **c** "*Ginataang hipon*" [*Macrobrachium* spp.] with coconut milk and pineapple; **d** *"Paksiw na Ayungin"* [*Leiopotherapon plumbeus*]

Fig. 8 Aquaculture practice in Mabato-Azufre

interviewees each, Table 2). *Pterygoplichthys pardalis* was used as fertilizer while *Chitala ornata* was also used for animal feed and fish feed. Neither of these species was present in Laguna Lake when most of the fishermen started their fishing activities. Furthermore, *Oreochromis aureus* was now being used as bait to capture the newly encountered *Chitala ornata*.

Wild or farmed fish? Advantages and disadvantages

The elder fishermen reported that at the beginning of their careers, aquaculture (Fig. 8) was not yet developed in the lake. One of them also mentioned that he tried to use fish pens for farming *Chanos chanos* but it did not work. Instead, most of the fishermen of Mabato-Azufre

Fig. 9 **a** One of the common fishing practices at Mabato-Azufre—using a "Baklad" or fish corral. **b** A fisherman catching fish inside the corral with the use of the scoop net

reported using fish cages for farming two species, namely *Hypophthalmichthys nobilis* and *Oreochromis aureus*. They argued that in the past local fishers engaged in aquaculture as an additional source of income because of its high profitability due to the fast growth rate of the fish. However, interviewees also reported that today aquaculture is no longer so profitable, as fish take longer to grow and the harvest is no longer so bountiful. Nonetheless, local fishers still perceive the partial advantage of aquaculture because the facilities for fish farming can be maintained using simpler boats (motorized or non-motorized) compared to wild fishing. Finally, fishers mentioned that typhoons are a major problem for aquaculture as they often destroy the poles and cages used.

However, fishers of Mabato-Azufre agreed that "wild fish are a blessing!" and this applies specifically to *Cyprinus carpio*, *Leiopotherapon plumbeus*, *Oxyeleotris marmorata* and *Glossogobius giuris*. These species are considered special because they are now becoming increasingly rare. They are also the most profitable as they can be sold for a good price in the market. Additionally, they are perceived to be tastier than other fish species. A local fisher also mentioned *Liza subviridis* as "one of the tastiest fish in the world" and added that is now almost extinct as saltwater is no longer entering Laguna Lake.

Finally, a fisher discussed with us and his wife the value of wild fish. While the woman underlined the profitability of those fish in the market, the husband asked her not to sell them because *Leiopotherapon plumbeus* and *Cyprinus carpio* are rare and extremely good for cooking *adobo* and *pochero*. Another fisherman added "The next generation should see these types of fish," expressing his concern for the persistence of wild fish in Laguna Lake (Fig. 9).

Discussion

Our results highlight the diversity and adaptability of food preparation among small-scale fishers. Fishers living in Mabato-Azufre recognized 31 fish ethnotaxa and one shrimp taxa in their catches, and prepared them in a variety of ways. With newly introduced species such as *Chitala ornata,* new preparations also appeared. In addition, fishermen reported that the community previously relied more on wild fish, while today a greater proportion of consumed fish comes from farmed fish. However, fish from aquaculture had limitedly profitability at the time of the study and were perceived to be not as tasty as some wild species. Fishers reported that several wild fish that are diminishing and becoming rare hold crucial value for food preparations, which in some cases was prevailing on its economic value (thus selling). Biological and gastronomic diversity, as an element of biocultural diversity, are inextricably linked [e.g., 39]; thus, a decrease in biodiversity will lead to a decrease in gastronomic diversity and related knowledge. Since aquaculture will increasingly be responsible for the global food supply of fish in the future, such economic and socio-cultural effects will play an important role in its further spread.

Of the 1 million fishers in the Philippines, over 25% lived below the poverty line in 2018 [40]. While this trend is negative, approximately 35% of fishers were classified as extremely poor in 2015 [40], wild-caught fish play a crucial role in ensuring local food security by introducing

nutrients into people's diets [41]. The Philippines still faces major social and environmental issues (e.g., [42–44] stemming from the high annual growth rates of both the general population (1.4%) and the urban population (1.9%) as of 2015 [45]). Fish is a key nutritional and cultural resource as a typical Filipino meal includes rice, fish and vegetables [46]. In the Philippines and other countries in Asia, freshwater fish species represent a significant portion of per capita fish consumption [47, 48]. The main component of the Filipino diet primarily comes from plant sources (72.8%) and animal sources (22.4%), and includes mostly carbohydrates (68.8%), then fats (18.8%) and a small percentage of protein (12.4%). Specifically, regarding household food consumption, fish and fish products, including dried fish, processed fish, fresh fish (such as tilapia) and molluscs and crustaceans, make up 11% of total food intake, or 392 g per day [49]. In Mabato-Azufre, as in most of the Philippines, fish is part of the daily diet, providing nutrition to the local people. Wuyun et al. [50] demonstrated that over 70% of the residents in the Laguna Lake watershed area consumed fishes such as *Oreochromis niloticus*, *Arius dispar* and *Chanos chanos.* This is true especially for residents living nearest to the lake due to the ease access to the freshwater resources. As the fish are not equally available throughout the year, their preservation may not only increase their market value, but also provide food security to the residents of the area. Yet, drying fish was among the uses that was least cited, despite its great potential to improve the livelihoods of local fishers if there is diversification with regard to the usual method of drying fish in the village. Our study showed that currently abundant fish species such as those considered invasive, like *Chitala ornata*, or the farmed species *Hypophtalmichthys nobilis* and *Oreochromis aureus*, could be processed into other food products to help diversify the livelihoods of local inhabitants by adding value to freshwater species. This could valorize the current biodiversity while ensuring economic stability.

It is worth noting that among our interviewees, the only woman was the one proposing some kind of innovation to the current system of fish production. In the village of Mabato-Azufre, women are commonly considered as contributors to the fishing activity, following their husbands and fathers, but not sufficiently independent, especially to drive the boat. Nevertheless, our study unexpectedly reported innovative processes promoted by a woman that could contribute to the resilience of the whole community. In relation to this, women play a major role throughout the chain of adding value to fish by serving as small-scale entrepreneurs, providing their services in commercial and artisanal fisheries [2]. Besides, the integration of gender and age concerns into policy making in agriculture, fisheries and forestry sectors is imperative in addressing economic disparity and enhancing women's access to resource governance, such as that seen in Nepal and India, where empowering women in decision-making with respect to the local conservation of fisheries and forests has led to better resource conservation and efficiency [51].

In addition, processing local fish to guarantee a longer shelf-life could contribute to the integrated management of local resources, including the fisheries in the region. For instance, in case of the nearby town of Pila, *Chitala ornata* is considered undesirable (many fishers said it causes problems to other species, e.g., *Chitala ornata* eats fingerlings of *Tilapia* and other native fishes), but it can be processed as sausages and dumplings, as well as fish balls, nuggets and burger patties [52]. In the same way, Tamayo and Brunal [53] explored the potential of utilizing the very popular but inexpensive *Chitala ornata* in developing value-added products, which could be used as input for sustainable food production. Similarly, fishers also adapted an application for the use of the invasive *Pterygoplichthys pardalis* as fertilizer. Other studies have shown the potential of using the skin of *Pterygoplichthys pardalis* to produce leather, which has been considered one way to address the issues of the deterioration of fish species and the degradation of local water sources in the Philippines [54].

Finally, our research found that aquaculture contributes to local livelihoods only to a limited extent as global challenges, including climate change, are threatening the profitability of this activity. Fishers of Mabato-Azufre also underlined the importance of wild fish to their culture in terms of taste and relevance to their gastronomic heritage. This underlines the importance of a holistic approach as the loss of some wild fish species (as part of biological diversity) will affect the local ecological knowledge regarding their gastronomic preparation (but also the fishing) as an expression of local identity and part of cultural diversity. In several areas of the world, freshwater lakes represent reservoirs of cultural and biological diversity (see [55]) and such richness should be regarded as a key element for ensuring the food security of communities living by lakes. In addition, fish populations not only ensure that communities receive the necessary nutrition but also fulfill ecosystem services which may not be replicable with technology, e.g., maintenance of genetic, species and ecosystem biodiversity [56]. While we are aware that it is extremely difficult to compare the ecosystem services generated by native species with those of non-native species [57], the ecological impacts of introduced species are often documented, but there is a lack of interdisciplinary studies that monetize these impacts and calculate the trade-offs between the ecosystem services of

non-native species [58]. This would allow management authorities to make informed decisions about whether fisheries and aquaculture should be based on native or introduced species [58].

The transmission of local ecological knowledge related to fishing appears to be endangered. Intergenerational knowledge transmission from father to son is challenged by the advancement of new fishing techniques and systems, but also by rural emigration which does not present the requisite conditions for inheriting local ecological knowledge. However, such local ecological knowledge could be valuable in providing fishers with diverse tools and copying strategies to face current ecological challenges and secure the supply of fish for food, which is a staple for communities living by Laguna Lake.

Conclusions

We documented the use of 31 fish species and one shrimp genus by the fishers of the Mabato-Azufre community of Laguna Lake, Philippines. The most commonly reported food preparations for fish species were frying, grilling, sour stew, stewing in vinegar and cooking with coconut milk. While food preparations such as drying and fish balls are among the least cited uses, these could become a source of livelihood diversification in the community. In addition, new (non-food) uses, such as bait, fertilizer, animal feed and fish feed, also deserve further attention. The fishers' knowledge about the food uses of fish species that has evolved, supported by the cultural practices of fishing communities, is vital for maintaining the food security of vulnerable lakeshore fishing communities in the Laguna Lake region. While farmed fish are considered an additional income opportunity, wild fish remain important for their sensorial and cultural characteristics. Wild fish is a crucial aspect of local gastronomic diversity, underpinning the biodiversity of the Laguna Lake, while also representing an important element for food sovereignty. Further, research should investigate the fishers' local ecological knowledge regarding the current challenges facing Laguna Lake and how this could contribute to bottom up approaches to sustain biological and gastronomic diversity of this aquatic ecosystem.

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Authors' contributions

JNM, BP, GM, RS involved in conceptualization; JNM, GM, BP, SK, RS participated in analysis; JNM and AC involved in data curation; JNM, RS, GM, BP, SK involved in writing—original draft preparation; RS and AP participated in writing—review and editing all the authors and supervision. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

The data that support the findings of this study are available on request from the first author, JNM.

Declarations

Competing interests

The authors declare that they have no competing interests.

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