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RESEARCH

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Fishery and ecology-related knowledge about plants among fishing communities along Laguna Lake, Philippines

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Abstract

Background Ethnobotanical knowledge about plant roles in fisheries is crucial for sustainable resource management. Local ecological knowledge helps understand dynamics of the lake ecosystem. Fishers use plants based on availability and characteristics while adapting to the changes in the environment. Studying fishery related uses of plants and algae and the challenges interconnected with them from local perspectives can provide insights into their beneficial uses and impacts to the ecosystem.

Methods The study investigates the botanical knowledge of three fishing villages in Laguna Lake or Laguna de Bay (LB), Philippines, including Buhangin, Sampiruhan, and Mabato-Azufre, each with varying degrees of industrialization. The ethnobotanical study, which gathered 27 interviews between June 2022 and July 2024, included plant collection with the help of local collaborators, including local fishers as research guides.

Results Fishers in LB highlighted positive and negative plant-fishing interactions. The most frequently mentioned plant applications were fish habitat and fish hiding places. Fish food, spawning sites, conservation, and a number of challenges such as navigational concerns and aquaculture fish deaths had been previously reported in local use reports. The remaining observations provide new insights into plant-fishing interactions, including indicators of food quality and food sources for fish, the decrease in the action of waves, and how plants help in improving the quality of the water.

Conclusion These results highlight that the knowledge of fishers regarding the ecosystem in which they conduct their fishing activities provides baseline information about the positive and negative relationships between plants and fishing activities in the region, which is vital for further understanding its biodiversity and ecosystem interactions. It is crucial to consider fisher knowledge and involve them as equal partners in conservation efforts of LB.

Keywords Local ecological knowledge, Local fishers knowledge, Traditional ecological knowledge, Traditional fisheries knowledge, Ethnobiology, Ethnobotany, Laguna Lake

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Introduction

Local ecological knowledge (LEK) is essential to understanding and protecting crucial ecosystems, such as wetlands, and the species which inhabit them [1]. Studies on LEK have provided new biological information and helped develop management and conservation measures in many areas, including fish ecology and fisheries, and biotic/abiotic variables influencing fish growth [2–9].

Subsistence strategies of coastal fishing communities are closely linked to the coastal environment on which they depend. For instance, on the north coast of Peru, the main economic activity is fishing, but botanical resources have also helped local inhabitants to survive by aiding their economic and cultural activities [10]. In the Southeastern region of the Brazilian Atlantic Forest, Caiçara fishers and farmers frequently utilize native plants despite external economic shifts affecting their livelihood resulting from seasonal availability, market acceptability, and knowledge dynamism [11]. Tng et al. [12] demonstrated a rich collective knowledge of plant use in an artisanal fishing community in Northeastern Brazil, providing a framework for ethnobotanical research in nearby communities and examining social and demographic factors influencing traditional plant use knowledge. Fishers use various plants depending on their individual qualities and ability to meet different needs and situations [13], and their traditional ecological knowledge mediates these decisions. Fishers' knowledge on plant use, notably in the coastal Brazilian Atlantic Forest, has been studied [14–20], which has included fishing ecology [15]. More globally, Peroni et al. [11] reported that ethnobiological resources may help achieve sustainable fishing management while retaining the knowledge of local people. Silvano et al. [21] investigated ethnobiological case studies that might improve ecological research and engage local people in forest-stream ecosystem protection.

Hanazaki et al. [22] found that ethnobotanical research on people, fish, and plants in coastal habitats is scarce and that fishing activities with regard to plants and their involvement in ethnobotanical knowledge are very poorly documented in fishing communities, particularly in the Philippines, Italy, and South America [13, 23, 24].

Considering that several investigations have shown that LEK is essential for sustainable environmental management and socioecological transformation [25, 26], it is vital to document the LEK of local resource users including fishing communities.

This study focuses on the fishing-related plant knowledge held by three fishing communities living along Laguna Lake (Luzon, Philippines): the most distant to the industrialized centers (Mabato-Asufre) situated in East Bay, the highly populated, industrialized and tourist areas along South Bay (Sampiruhan), and an island fishing village (Buhangin) located in the middle of West and Central Bay, near the capital city of Manila [27]. Provided that Laguna Lake faces ecological issues [28–30] and the knowledge of fishers is crucial to its conservation [23], we aim to document the fishers' knowledge on plants related to fishing activities and factors that affect these plants, compare this knowledge among the three selected communities, and evaluate the social, ecological, and economic reasons behind possible differences in knowledge.

Methods

Study areas

Laguna Lake or Laguna de Bay (LB) (Fig. 1) is the Philippines' largest lake and one of the biggest lakes in Southeast Asia [31]. The lake has a surface area of approximately 900 km^2, with an average depth of 2.5 m and an elevation of one meter above sea level. The lake supports several industries, agriculture, and cattle and poultry farming. Local residents rely on traditional fishing as well as fish cage and pen aquaculture for sustenance and income. Migratory birds and biodiversity thrive in the lake and watershed ([27] The Laguna de Bay Ecosystem Health Report Card, 2016). According to Tamayo-Zafaralla et al. [32], the lake is currently surrounded by impoverished communities of fishers in semi-urban and rural cities and municipalities of the province of Laguna.

Laguna Lake provides ecological services to central Luzon, including Manila residents. Unsustainable aquaculture and overexploitation have reduced production, biodiversity, and water quality [32, 33]. The 2018 Policy Brief Series of Lake Ecosystem Assessment in the Philippines found fish catch declines, native fish reductions, alien species introductions such as knifefish (*Chitala ornata*) and janitor fish (*Pterygoplichthys* spp.), and Laguna de Bay fish kills. These factors degraded regional water quality and quantity [34]. Cuvin-Aralar et al. [35] found that 60% of Laguna Lake's mass fish fatalities were caused by low dissolved oxygen, mostly from hazardous algal blooms caused by industrial and agricultural pollutants and fish infections. Lasco et al. [36] raised various questions concerning Laguna Lake and its dynamics, including how to encourage local communities to maintain natural resources and manage the lake basin.

We have selected 3 areas of study (Fig. 1), and differences in their degree of industrialization [37–39] are presented in Table 1.

Map

See Figs. 2, 3, 4, 5, 6, 7.

Data collection

Ethnobotanical field work took place between June 2022 and July 2024. Initial contact with communities

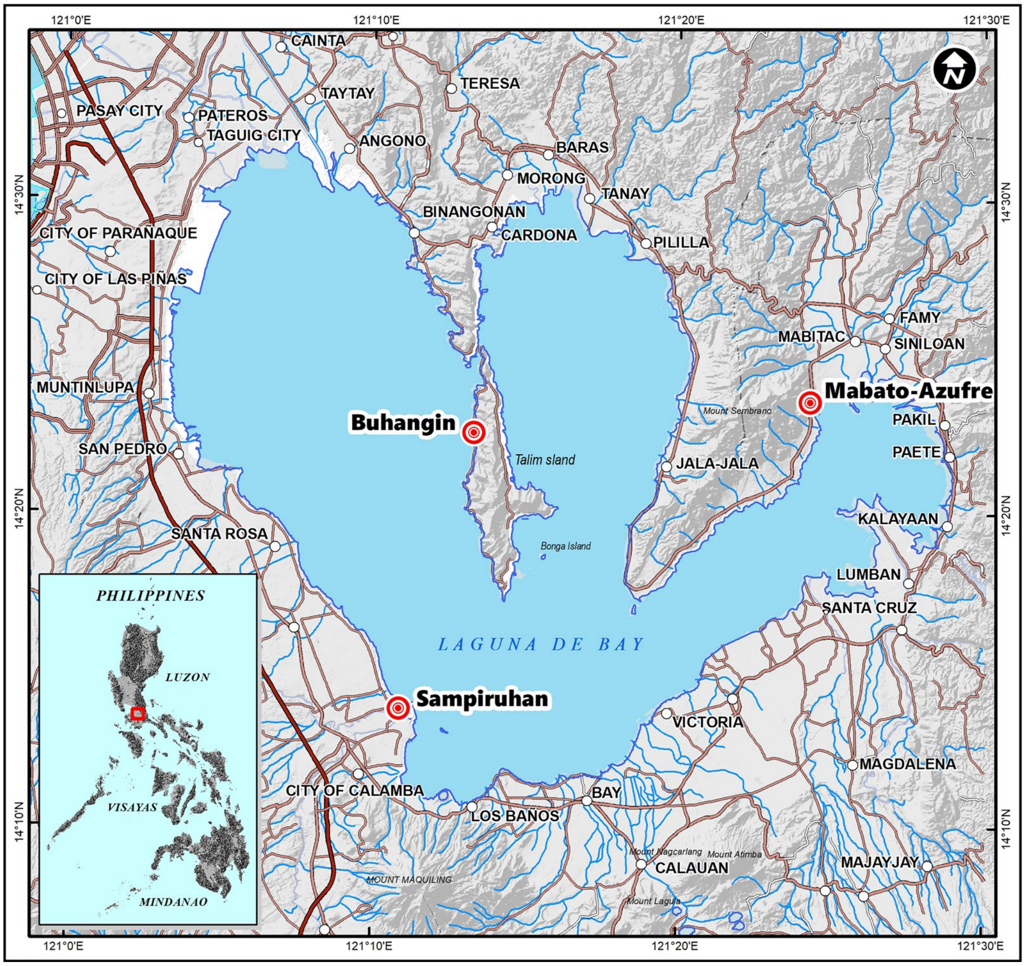

Fig. 1 Map of the three study areas. *Source*: National mapping and resource information authority of the department of environment and natural resources, Philippines

Table 1 Description of study areas

	Mabato-Azufre	Buhangin	Sampiruhan
Coordinates	14.3852, 121.4052 (14° 23′ North, 121° 24′ East)	14.3628, 121.2213 (14° 22′ North, 121° 13′ East)	14.2173, 121.1823 (14° 13′ North, 121° 11′ East)
Population (no. of habitants)	1654	2000	9466
Households (no.)	393	440	2167
Elevation above sea level (m)	9.5	14.1	8.4
Government unit	Pangil municipality	Binangonan municipality	Calamba city

was made by presenting the study goals and process to the fisheries' managers and community leaders. Key informants were initially identified by community members, and additional participants were then selected through the snowball technique. The selected participants were local experts in the fishery––local fishers and resource users who were recognized by the team as having substantial knowledge on this topic. The interviewees were asked about their knowledge of the plant species affecting their fishery activities and the challenges associated with them and about everyday life in the fishing village. Field notes were taken, and interviews were voice-recorded. A total of 50 people were interviewed (Table 2).

Fig. 2 Mabato-Azufre, Pangil, Laguna fish landing site. Credit: First author (June 2022)

Fig. 3 Identification of local names with local fishers and collaborators in Mabato-Azufre. Credit: First author (July 2022)

Fig. 5 Fishing activity in the village for catching "ayungin" [*Leiopotherapon plumbeus*], Buhangin, Binangonan, Rizal. Credit: First author (June 2022)

Fig. 4 Buhangin, Binangonan, Rizal lakeshore. Credit: First author (July 2022)

Fig. 6 Fishing gear entangled by water hyacinths near Sampiruhan, Calamba, Laguna. Credit: First author (September 2022)

Fig. 7 Part of Laguna Lake near Sampiruhan, close to the industrial area (left) and the tourist area (right). Credit: First author (September 2022)

Table 2 Profile of research participants from Laguna Lake, Philippines

Characteristics	Mabato-Azufre (M)	Sampiruhan (S)	Buhangin (B)
Age range	18–23 to > 56–61	24–29 to > 56–61	40–45 to > 56–61
No. of people in the sample	21	15	14
Gender	11 men/10 women	15 men	11 men/3 women
Education	Primary school to university level	Primary school to university level	Primary school to high school
Occupations other than fishing (if they exist)	Making paper boxes, farmer	Driver, painting works, welder, construction worker	Making bamboo sticks
Range of years of experience (mean)	3–53 yrs	5–57 yrs	Up to 56 yrs
Types of fishing activities	*Baklad*, catching *dulong*, fish vendor, *takibo*, *roborat*, *talabog*, *pante*, *kitang*, fish cage	*Pante*, *baklad*	*Pante*, *skylab*, fish vendor

Baklad, fish corrals; *takibo*, encircling gillnet; *roborat,* screen fish trap; *talabog,* fish trap; *pante,* gillnet fishing; *kitang,* long line fishing gear; *skylab,* skylab fish trap

Interviews, lasting from 30 min to three hours, were conducted in the Filipino language and took place either in the fishers' house or near the lakeshore while they met with other fishers or engaged in fishing activities, such as catching fish and repairing fishing gear. Six boat trips were arranged for plant collection and participant observation with local fishers and collaborators as guides. All interviewees provided written informed consent to participate in this study. The study was approved by the Ethics Committee of Ca' Foscari University of Venice.

Collection of botanical specimens

The reported plants and macroalgal taxa were identified by botanist JP. The samples are stored dried in the Ca' Foscari herbarium (Code ETBOTLV01-09) and the samples available in Mabato-Azufre are deposited at the department museum of Isabela State University in the Philippines (LBBOT01-26).

The plant and algae nomenclature follows Plants of the World Online (https://powo.science.kew.org/) [40], AlgaeBase [41], and previous taxa reports and LEK studies in the Philippines. When a plant sample was not available, it was identified on the basis of the combination of description and local name provided by local fishers, as often done in ethnobotanical research [42, 43]. Some taxa remain unidentified either because they have disappeared or were not available for sampling and neither name nor description was enough to identify them at least to the genus level.

Data analysis

The interviews were transcribed and translated into English before being coded in a codebook generated using Atlas.ti 23 software. The analyses followed an inductive (data-driven) approach as outlined by Bernard and Ryan [44]. The exported codebook from the software had an organizing table that contained codes derived from the categories and subcategories identified in the transcripts. Every segment of the encoded transcripts was meticulously examined to ascertain the categories. Results were then analyzed, and Venn diagrams were used for data visualization.

Results

Fisheries and ecology knowledge about plants known to fishers

We recorded a total of 544 use reports (UR) for 25 plant taxa (see Additional file 1). These taxa were mainly related to positive plant-fisheries interactions and, to a lesser extent, problematic aspects. A total of 25 taxa were identified (23 to species level and 2 to genus level), which consisted of 24 genera and 17 families (Table 3, Fig. 8). Two taxa were not identified.

Positive relationships between plants and fishing activities known to fishers

For positive relationships between plants and fishing activities, *Hydrilla verticillata* (103 UR), *Vallisneria natans* (73 UR), *Pontederia crassipes* (57 UR), and *Nymphaea pubescens* (33 UR) were the most cited taxa. The most frequently recorded families in this category were Hydrocharitaceae, Pontederiaceae, Fabaceae, Microcystaceae, and Nymphaeaceae.

Role of plants in the LB ecosystem based on fishers' knowledge

The crucial roles of plants in LB, Philippines, were emphasized by fishers and mainly focused on their benefits to humans and animals, and their function as ecosystem and natural climate buffers.

Benefits to humans and other animals

Fishers highlighted the importance of plants as food for fishes and habitats for birds. For example, a fisher from Mabato-Azufre remembered, "Fishes eat *lumot* [*Ulva* sp.] in *baino* [*Nymphaea pubescens*]. Birds will have lots of nesting grounds, there are lots of them in the parts of the lake where *digman* [*Hydrilla verticillata*], *tikiw* [*Actinoscirpus grossus*], *baino* [*Nymphaea pubescens*] are found, birds can lay eggs in those areas" (MAF21).

Another fisher from Mabato-Azufre added,

> *Plants also serve as habitat for ayungin [Leiopotherapon plumbeus], they love to stay in areas where there are plants because they can find many shrimp there, and because it feeds on shrimp (Fig. 9). Branches of trees such as sampalok [Tamarindus indica], bamboo [Bambusa sp.], callos, himbabao [Allaeanthus luzonicus], star apple [Chrysophyllum cainito], when you put them together, they serve as habitat for the fishes. Baino [Nymphaea pubescens], tilapia [Oreochromis aureus], dalag [Channa striata], karpa [Cyprinus carpio], knifefish [Chitala ornata]; it is like a forest in the lake. After about two weeks, the fisher puts nets around the area where they put the branches, then all of them are removed, and both sides of the nets are collected to catch all the fishes inside. They can use this method for up to 2 years. As habitat, they will live or lay eggs as they will not be easily disturbed by humans. They can also serve as hiding places from predators… (PA MAF01).*

Ecosystem buffer

Fishers described how plants could aid fish conservation in the region. In fact, one fisher mentioned that tree branches are also used for community-based fish conservation in the fishing village of Sampiruhan.

"Our project is for our fish sanctuary, it is called Yangkaw Fish Garden. It has boundary markers, and it is prohibited to catch fish there. We bring the yangkaw with branches of *kamatsile* [*Pithecellobium dulce*] there" (CAF09). With regard to other particular plants being used for yangkaw, another fisher in the same community added, "Mostly water hyacinths [*Pontederia crassipes*] are placed above (considering the tree branches are under water), when time passes then *lumot* [*Ulva* sp.] develop" (CAF12).

Natural climate buffer

In addition to the above function, fishers from Mabato-Azufre shared their thoughts on the role of plants in maintaining clean water.

One fisher explained, "If there are lots of plants, it can make the lake water clean because the lake is not affected by the action of waves due to the presence of plants such as *digman* [*Hydrilla verticillata*]" (MAF21).

Likewise, the wife of a fisher shared her thoughts on the impact of wave action on fishing gear, especially boats, "The water becomes clearer because of plants, when there is a typhoon coming, boats are parked on top of where there is abundant *digman* [*Hydrilla verticillata*] and *baino* [*Nymphaea pubescens*]. This occurred in the 1970s when plants kept the boats safe from the action of waves." (MAF32).

Negative plant-fisheries interactions highlighted by fishers

The most recorded families for this category are Microcystaceae, Hydrocharitaceae, Pontederiaceae, and Convolvulaceae (Fig. 11). Among the most cited taxa were *Microcystis aeruginosa* (21 UR) and *Pontederia crassipes* (14 UR) (Table 4).

Fishers from Talim Island and Sampiruhan noticed problems caused by *Microcystis aeruginosa* (Fig. 10),

Table 3 Traditional plant uses related to fisheries and ecology along Laguna Lake, Philippines

Latin name, family, herbarium number	Local name	Plant part(s)	Fisheries and ecology-related	Mabato-Asufre	Sampiruhan	Buhangin
Actinoscirpus grossus (L.f.) Goetgh. & D.A.Simpson, Cyperaceae, ETBOTLV03	Tikiw	Whole plant	Reduces waves	1	1	
			Indicates good water	6		
			Fish habitat	7		
			Hiding place	1		
			Nesting area	1	1	
			Spawning area	1	1	
Allaeanthus luzonicus (Blanco) Fern.-Vill., Moraceae, LBBOT25	Himbabao	Flowers, leaves	Catching fish	1		
			Fish habitat	1		
			Hiding place	1		
			Spawning area	1		
Bambusa sp., Poaceae, LBBOT19	Bamboo	Body	Catching fish	5		
		Body	Fish habitat	5		
		Body, leaves	Hiding place	1		
		Body	Spawning area	1	1	
Chrysophyllum cainito L., Sapotaceae, LBBOT24	Starapple	Fruits	Catching fish	1		
			Fish habitat	1		
			Hiding place	1		
			Spawning area	1		
Hydrilla verticillata (L.f.) Royle, Hydrocharitaceae, ETBOTLV04	Digman	Whole plant	Filters water	2		
			Reduces waves	6		
			Indicates good water	9	6	3
			Fish food	4	1	7
			Catching fish	2		
			Fish habitat	20	13	10
			Hiding place	1	1	
			Spawning area	6	4	2
			Staying area	1		
			Food source	5		
Ipomoea aquatica Forssk., Convolvulaceae, ETBOTLV09	Kangkong	Leaves, body	Indicates good water	2		
		Whole plant	Fish food	4		
			Nesting area		1	
			Fish habitat	7		1
			Hiding place	6		
			Spawning area	4		
Mangifera indica L., Anacardiaceae, LBBOT06	Mango	Fruits, leaves	Catching fish	6		4
Microcystis aeruginosa (Kützing) Kützing 1846, Microcystaceae	Liya	Whole plant	Fish food	8	1	7
Nymphaea pubescens Willd., Nymphaeaceae, LBBOT10	Lawas or baino	Whole plant	Indicates good water	6	1	1
			Reduces waves	3		
			Fish habitat	15		1
			Hiding place	2		
			Nesting area	1		
			Spawning area	1	1	1
Ottelia alismoides (L.) Pers., Hydrocharitaceae, ETBOTLV01	Kulut-kulotan	Whole plant	Indicates good water	2		
			Spawning area	2		
Phragmites australis (Cav.) Trin. ex Steud., Poaceae, LBBOT20	Tambo	Flowers	Nesting area		1	

Table 3 (continued)

Latin name, family, herbarium number	Local name	Plant part(s)	Fisheries and ecology-related	Mabato-Asufre	Sampiruhan	Buhangin
Physalis angulata L., Solanaceae, LBBOT22	Putok-putokan	Whole plant	Catching fish			9
			Fish habitat	1		
Pistia stratiotes L., Araceae, ETBOTLV06	Kyapo	Whole plant	Indicates good water		2	
			Fish habitat	5	2	
Pithecellobium dulce (Roxb.) Benth., Fabaceae, ETBOTLV08	Kamatsile	Fruits	Fish conservation		11	
			Catching fish		8	
			Spawning area		1	
			Fish habitat		1	
Pontederia crassipes Mart., Pontederiaceae, LBBOT14	Water hyacinths	Whole plant	Indicates good water	2		
			Floating aids	1		
			Fish food	1		9
			Catching fish		2	2
			Fish habitat	7		10
			Hiding place	1	1	2
			Spawning area	6		4
			Nesting area	4	1	4
Pontederia hastata L., Pontederiaceae, LBBOT18	Gabi-gabihan	Whole plant	Staying area			1
Portulaca granulatostellulata (Poelln.) Ricceri & Arrigoni, Portulacaceae, LBBOT23	Kulasiman	Whole plant	Hiding place	1		
Psidium guajava L., Myrtaceae, LBBOT07	Bayabas	Fruits	Catching fish	5		
		Whole plant	Fish habitat	6		
Saribus rotundifolius (Lam.) Blume, Arecaceae, LBBOT21	Anahaw	Leaves	Catching fish	1		
		Leaves	Hiding place	1		
Sesbania sesban (L.) Merr., Fabaceae, ETBOTLV02	Balakbak	Whole plant	Hiding place			5
Streblus asper Lour., Moraceae, LBBOT17	Callos	Leaves, stem	Catching fish	8		2
			Fish habitat	1		
			Hiding place	1		
		Fruits	Spawning area	1		
Syzygium cumini (L.) Skeels, Myrtaceae, ETBOTLV07	Duhat	Leaves, stem	Catching fish		1	
Tamarindus indica L., Fabaceae, LBBOT26	Sampalok	Branches, leaves, stem	Catching fish	13	1	
			Fish habitat	5		
			Hiding place	3		
			Spawning area	1		
Ulva sp., Ulvaceae	Lumot	Whole plant	Indicates good water	3	1	8
			Fish food	2	2	
			Fish habitat	3		4
			Spawning area			2
Vallisneria natans (Lour.) H.Hara, Hydrocharitaceae, ETBOTLV05	Hinlalabiw, prinsa prinsahan, sintas	Whole plant	Filters water	1		
			Indicates good water	9	3	1
			Reduces waves	4		
			Fish habitat	17	12	8
			Hiding place	2		
			Spawning area	5	11	

Fig. 8 Traditional plants reported in fishing communities along Laguna Lake, Philippines. Credit: First author, AC, AM, and HC (2022)

Fig. 9 *Hydrilla verticillata* with shrimp clinging to it. Credit: First author (June 2022)

Fig. 10 Liya [*Microcystis aeruginosa*] proliferation near the fish port going to Talim Island. Credit: First author (July 2022)

including how they not only cause fish kills, but also affect the taste of the fish, thus reducing its selling price in the market. One fisher from Calamba observed, "Right now the fishes have a bad taste due to *liya* [*Microcystis aeruginosa*], which is also our problem, as no one wants to buy our catch" (CAF14). Additionally, fishers from the island experienced fish kills, "Fishes died from overeating *liya* [*Microcystis aeruginosa*]" (TAF27 and TAF28).

Fishers in LB shared the problems caused by excessive plants to their fishing activities (see Figs. 11, 12, 13, 14 and 15).With regard to water hyacinths [*Pontederia crassipes*], fishers from Talim Island explained the problems they experienced, "In the 1980s, due to typhoons, we had to clear them to create a passable route. Also, around

Fig. 11 Fish cages close to Talim Island entangled by excessive water hyacinths growth in 2022. Credit: First author

Table 4 Problems associated with plants and algae in fishing communities along Laguna Lake, Philippines

Latin name, family, herbarium number	Local name	Plant parts	Problem caused by plant	Mabato-Asufre	Sampiruhan	Buhangin
Hydrilla verticillata (L.f.) Royle, Hydrocharitaceae	Digman	Whole plant	Damages gear	3	1	4
Ipomoea aquatica Forssk., Convolvulaceae	Kangkong	Whole plant	Damages gear	1		
			Fish kills	5		
Microcystis aeruginosa (Kützing) Kützing 1846, Microcystaceae	Liya	Whole plant	Damages gear	2		
			Cheaper cost	4		
			Has disgusting taste	4	2	
			Fish kills	6		3
Pontederia crassipes Mart., Pontederiaceae	Water hyacinths	Whole plant	Damages gear	1		3
			Fish kills	7		
			Navigation problem	1	1	1
Sesbania sesban (L.) Merr., Fabaceae	Balakbak	Whole plant	Damages gear			5
Ulva sp., Ulvaceae	Lumot	Whole plant	Damages gear			1
Vallisneria natans (Lour.) H.Hara, Hydrocharitaceae	Hinlalabiw, prinsa prinsahan, sintas	Whole plant	Damages gear	3		
			Navigation problem			1

Fig. 12 An excessive amount of water hyacinth growth along the Mabato-Asufre lakeshore in 2018. Credit: First author

Fig. 13 The problem of *Hydrilla verticillata* entangling fishing nets used in "*pamamante*" or gillnet fishing in Mabato-Azufre. Credit: First author (June 2022)

Fig. 14 The problem of tree branches entangling fishing gear used in "*pamamante*" or gillnet fishing in Mabato-Azufre. Credit: First author (June 2022)

2017 or 2018, there were lots of them on the other side of the lake; in Pangil, fishes in cages died, due to around three months of overabundant water hyacinths [*Pontederia crassipes*]..." (TAF26). Two fishers added, "and our fishing gear was carried away by them [*Pontederia crassipes*]" (TAF27 and TAF28).

Fishers in Mabato-Azufre experienced problems with water hyacinths [*Pontederia crassipes*] and *kangkong* [*Ipomoea aquatica*] affecting their fishing activities. Specifically, one fisher wife explained, "water hyacinths [*Pontederia crassipes*] cause massive fish kills due to the lack of oxygen. This happened from Mabato-Azufre to nearby towns such as Siniloan, Pakil, and Paete in 2018. The fishers were stranded in the middle of the lake" (MAF02 and MAF32).

Another old fisher in the village commented on his experiences with excessive water hyacinths [*Pontederia crassipes*], "They attached themselves to the bamboo [*Bambusa* sp.], breaking the bamboo poles of our fishing gear and cages. When there is too much growth of waterlilies [*Pontederia crassipes*] (Figs. 11 and 12), they cover our fish cages, fishing nets, and boats from the shore cannot pass through when fishers are going to the lake. They are our main problem, as they disturb our fishing activities, the plants get entangled in our fishing gear" (PA MAF01).

Aside from the abovementioned plants, *digman* [*Hydrilla verticillata*], *sintas* [*Vallisneria natans*], and *hinlalabiw* [*Vallisneria natans*] also cause problems in Laguna Lake when they get entangled in fishing gear. One young fisher from Mabato-Azufre shared, "I saw plants such as *digman* [*Hydrilla verticillata*], *sintas*, or *hinlalabiw* [*Vallisneria natans*] near Mabato-Azufre, from Mabitac up to Lumban town, close to the shore, because these plants were entangled in my fishing gear" (MAF33).

Comparison of fishery and ecology-related knowledge among the study areas

Fishers from Mabato-Azufre, which is located in the least industrialized area of LB, reported most of the taxa associated with positive relationships between plants and fishing activities, while negative plant- fisheries interactions were cited most in the fishing village of Buhangin, near the capital city of the Philippines (Figs. 16 and 17). All three groups shared 28% of the taxa mentioned for positive plant-fishing interactions (Fig. 16) and 50% of all species with negative interactions (Fig. 17).

Comparing the three study areas, fishers from Mabato-Azufre reported most of the emic uses regarding positive and negative plant-fisheries interactions (Figs. 18 and 19). Seven out of 13 emic uses reported for positive interactions were common among the three studied fishing

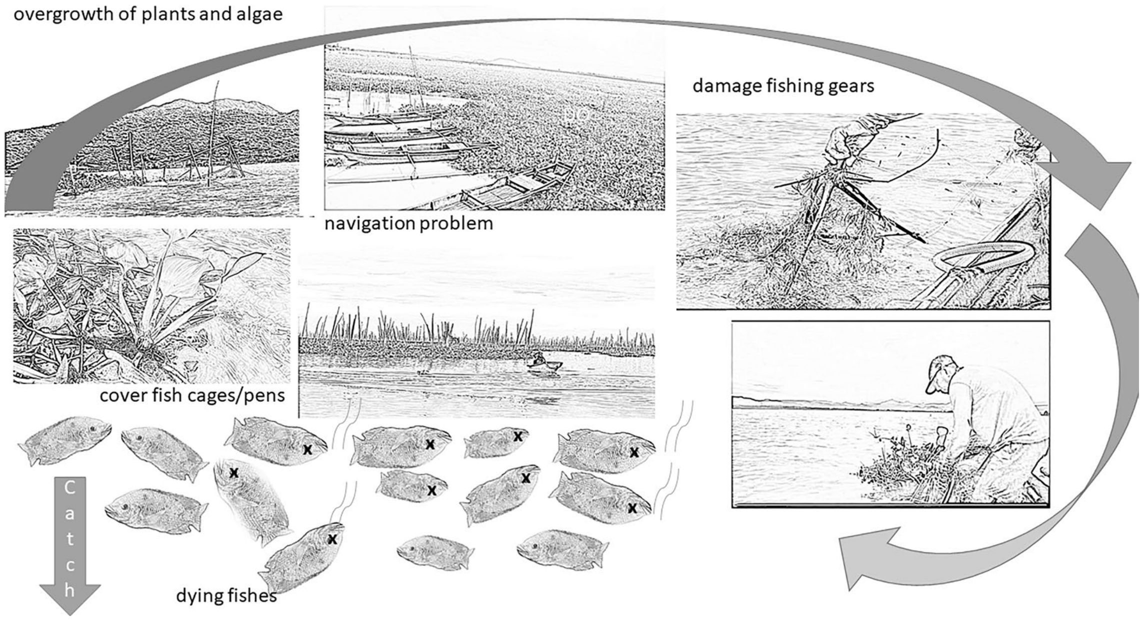

Fig. 15 Fishers' knowledge on negative plant-fisheries interactions and their impacts in LB, Philippines

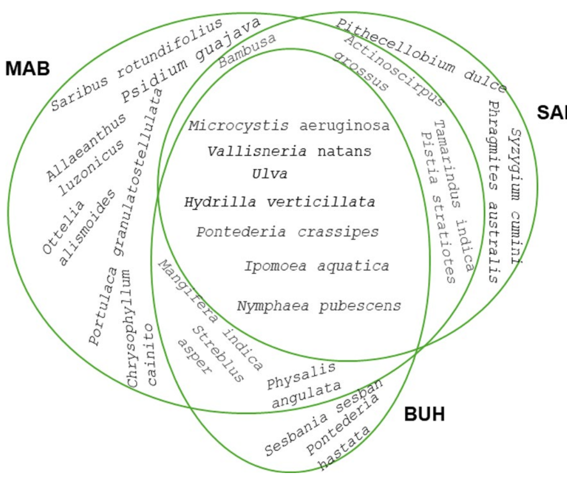

Fig. 16 Venn diagram comparing the taxa associated with positive relationships between plants and fishing activities as reported by the interviewees. MAB—Mabato-Azufre, BUH—Buhangin, SAM—Sampiruhan

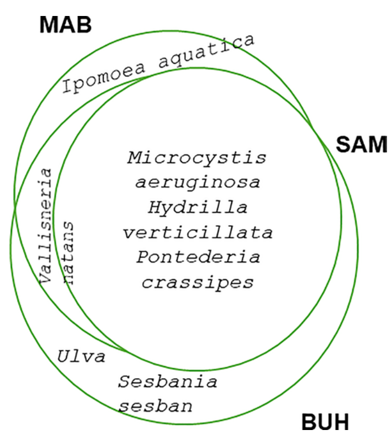

Fig. 17 Venn diagram comparing the taxa associated with negative plant-fisheries interactions as reported by the interviewees

communities (53.85%). Of the five negative interactions, only two uses (40%) were shared (Fig. 19).

Factors affecting plants in the Laguna Lake environment

Aquatic plants are threatened by three main environmental issues–hydropower plant pipe cleaning activities, sedimentation, and less saltwater intrusion reducing the quality of water in LB. Therefore, the decline in fish in the region is connected to the decrease in these submerged macrophytes in relation to the abovementioned environmental problems.

For example, an elderly fisher from Mabato-Azufre said, "Plants also serve as habitat for *ayungin* [*Leiopotherapon plumbeus*], they love to stay in areas where there are plants because they can find many shrimp there, because it feeds on shrimp. So, when the plants decline, *ayungin* [*Leiopotherapon plumbeus*] also declines. For instance, *digman* [*Hydrilla verticillata*] and *hinlalabiw*, many *ayungin* [*Leiopotherapon plumbeus*], almost a thousand, were present in that area

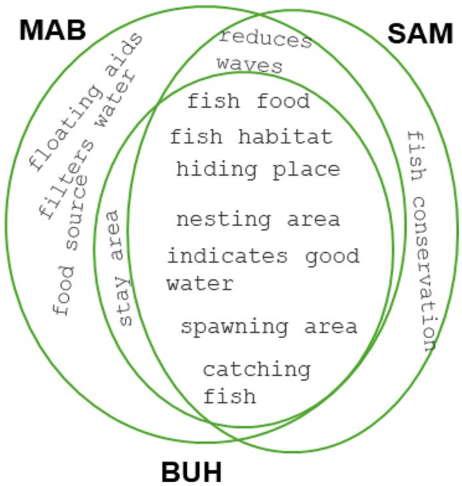

Fig. 18 Venn diagram comparing the emic uses associated with positive plant-fisheries interactions

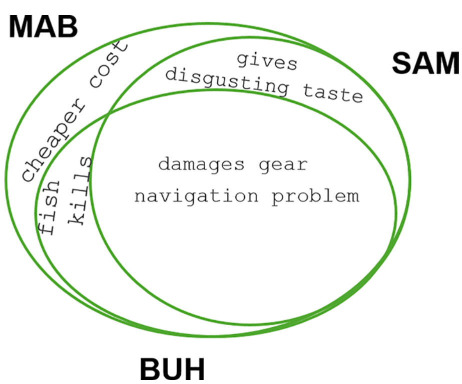

Fig. 19 Venn diagram comparing the emic uses associated with negative plant-fisheries interactions

before, you can witness with your own eyes how abundant they were in the past" (MAF01).

Fishers from all three study areas also shared their long-term observations, "…these plants died because of the hydropower plant. That is why water quality decreases when these plants are not present. The water becomes dirty as there are no plants to filter the water" (PA MAF01).

Another fisher commented on the sedimentation problem, "Tree branches can be used in the Calamba area; it is not advisable in our area (East Bay) because the depth of the water in this part is shallow, and it is muddy. Unlike in the Talim Island area (near Central and West Bay) which is deeper" (MAF30).

Several fishers noticed that plants in LB are also affected by less saltwater intrusion into the lake. An old fisher in Mabato-Azufre observed, "…even though there are power plants around, if only Napindan channel opens again, the lake will improve again, because saltwater or "*tapsing*" can kill bacteria in the water" (MAF01).

Therefore, according to the fishers, the low quality of the Laguna Lake water impacts the growth of plants, "… In relation to the status of the water quality, when the water is dirty there's no *digman* [*Hydrilla verticillata*], it grows when the water is clean" (MAF30).

Moreover, a couple of interviewees (TAF27 and TAF28) added "…around the 1970s, the 1980s, the *Lawin* [*Haliastus indus intermedius*] ate fish as the water was very clear, therefore those birds were able to see the fish, but at present this bird is also rare."

According to the interviewees, the abovementioned factors result in the reduction of important plant species, which then affects the bird species and contributes to the decline of important fish species in the LB region, together with the impacts of invasive species such as knifefish.

Discussion

The current study revealed rich fisheries and ecology-related knowledge about plants across the fishing communities of LB, Philippines, including positive plant-fisheries (with the beneficial roles of plants) interactions as well as negative ones. Local fishers in the studied areas shared abundant novel information on the uses of plants and related algae and their interconnectivity with the local environmental challenges affecting the entire LB ecosystem.

Positive plant-fisheries interactions

The important ecological functions of plants, which mainly focus on their benefits to humans and animals and as ecosystem and natural climate buffers, were highlighted by interviewees. In the previous studies on plant usage data from around the world, uses such as catching fish, habitat, and hiding places have been reported [9, 45–47]. Moreover, an earlier study found that *Actinoscirpus grossus* is used as fish habitat in the Philippines [48], which is directly in line with the findings of this study. A similar observation was reported in India [49]. In Brazil, *Pontederia crassipes* serves as a hiding place for fish, while *Pontederia rotundifolia* helps maintain a steady temperature [9]. Numerous fishers underlined the value of aquatic plants like *Vallisneria natans* as fish hideouts in severe weather conditions [48].

Our fishers shared that the plants of LB produce a variety of microhabitats that provide organisms, such as fish and birds, with habitat, hiding places, and nesting and spawning areas, making such places ideal for fish conservation as well. The reported uses of tree branches for fish conservation are consistent with the observation of Buen et al. [50] who reported that Laguna Lake's traditional fish aggregating device, the "yangkaw," is constructed from *Tamarindus indica* or *Pithecellobium dulce* branches to shelter and protect fish, which is a part of their community-based fisheries resource management. One explanation for this finding is that the tannins and flavonoids from traditional fishing gear, such as the "yangkaw", as per Concepcion [51], increase water quality for aquatic plants like *Hydrilla verticillata*, creating an area for fish reproduction.

According to LB fishers in Mabato-Azufre and Talim Island, plants serve as a food source for fish, demonstrating their important role in the food web dynamics of LB. The present finding corresponds well with previous studies in that fish feed on *Hydrilla verticillata* in India [1], and thus it is used to catch fish in both the Philippines and India [47, 50]. Similarly, *Pontederia crassipes* and *Pontederia rotundifolia* are used to feed fish in Brazil [9] as well as harvest fish in India [52]. Another fish food source found in a previous study of Laguna Lake is the cyanobacteria *Microcystis aeruginosa* [48]. One possible explanation for this finding is that microalgae and cyanobacteria linked with aquatic macrophytes feed tiny fish and invertebrates even close to the shore of the LB ecosystem. Aquatic animals also reproduce well on aquatic macrophytes because of the complex coexistence of algal periphyton [53]. This result is also due to the fact that in aquatic environments algae are widely distributed and are in charge of primary production and lay the groundwork for aquatic food webs [54]. Thus, because of its global spread and quick growth, sea lettuce (*Ulva* spp.), which is still currently underutilized, can become a source of food, medicine, and biofuel, and can be exploited by bioremediation industries [55]. *Ulva* biomass is mostly fed to abalone, shrimp, and aquaculture fish [56–60] Therefore, integrating *Ulva* spp. into livestock monocultures, including that of shrimp, urchin, and abalone, provides several benefits, such as reducing effluent nutrient loads, decreasing feed requirements, and potentially increasing the economic value of the final product [61–63].

Furthermore, according to interviewees, plants filter the water naturally and reduce the action of waves. These reveal the ecological significance of aquatic plants and algae in preserving water quality in the LB ecosystem.

Negative plant-fisheries interactions

Pontederia crassipes, together with *Vallisneria natans*, *Ipomoea aquatica*, and *Microcystis aeruginosa*, caused the Laguna Lake aquaculture fish kills. According to fishers, fish kills in this region were a problem for many fish cage operators and caused difficulties in local fishing activities. The former also damages fishing gear, as do *Hydrilla verticillata* and *Ulva* spp., and causes navigation problems in the LB region. In the Philippines, local fishers say that *Pontederia crassipes* and *Microcystis aeruginosa* overgrowth, shallow water depth, a decrease in oxygen, solid waste, polluted water from agriculture, and chemical substances from hydroelectric power plants cause fish kills [48]. Additionally, eutrophication, which is caused by nutrient pollution from wastewater discharges and agricultural runoff, can result in hazardous algal blooms that lower oxygen levels and endanger aquatic life [64].

In the present study, fishers reported issues related to the presence of water hyacinths and *Ipomoea aquatica* in Laguna Lake. Similarly, in Africa, *Pontederia crassipes* is invasive, increasing other plant taxa such as *Pistia stratiotes*, and its overgrowth may hinder transportation and mobility in the Lake Victoria Basin (see [46]). Semi-aquatic tropical *Ipomoea aquatica* grows abundantly as floating herbs in canals, rivers, lakes, and ponds, or as creepers in marshy plains in India and Asia [65]. The plant grows quickly and encroaches over most of a water body, causing irrigation, navigation, fisheries management, and other ecological issues in aquatic environments in Texas in the United States [66].

Social, economic, and ecological reasons for differences in plant-related fishery knowledge in the three fishing communities

Of the three study areas, fishers in Mabato-Azufre, which is situated in the least industrialized part of the region, reported the majority of the uses related to positive and negative plant-fisheries interactions. This could be due to several interconnected social, economic, and ecological factors. Mabato-Azufre is located in the East part of the lake where water quality is the highest, but the area scored the lowest in fisheries indicators, with a high concentration of fishers, invasive species, and smaller fishing grounds ([27] The Laguna de Bay Ecosystem Health Report Card, 2016). However, taxa associated with negative plant-fisheries interactions were cited most in the island fishing village of Buhangin. This could be due to the fact that this island fishing village has been vulnerable to cyclonic storms, and it has issues with population growth, waste management, and erosion [67]. Moreover, all of the study areas share nearly half of the reported plant uses, which is probably the result of similar fishing activities and local environmental challenges. Given the proximity of the entire LB ecosystem to Metro Manila and the highly populated communities in nearby Rizal and Laguna provinces, the lake is being used as a waste repository because of the temporary retention of floodwaters to alleviate inundation in the lower areas of Manila, to supply irrigation water, potable water, and electricity, for water transport to and from Talim Island and neighboring lakeshore communities, as well as for recreational and tourism activities [68]. Sampiruhan, on the other hand, is a barangay in the city of Calamba, which is a premier industrial hub near Metro Manila, boasting more than ten industrial parks and the highest income in Region 4A [69]. Another reason for the recorded differences in knowledge is that the study of the utilization of plants associated with traditional practices, as noted by Savo et al. [13] in Italy, indicates that a significant number of plants and their applications have disappeared, complicating the assessment of whether the reported uses within a specific fishing community are exclusive to that region or have diminished elsewhere.

The study of these communities, which range in their level of industrialization from the least to the most industrialized in the area, reveals the understanding of local resource users including fishers regarding the effects of waste from domestic and agricultural discharges and effluents from the chemical and tourism industries, such as the decline of submerged macrophytes occurring in different parts of this region, thus affecting their crucial ecological functions and how they impact fishing activities in LB, Philippines. This finding contributes to advancing our understanding of crucial positive and negative interactions concerning plants, humans, fishes, and other species threatened by interconnected social, economic, and ecological factors. This demonstrates the importance of fishers' perspectives for freshwater resource conservation, which is essential to fisheries management in the LB ecosystem.

Factors affecting plants in the Laguna Lake environment

Fishers explained that the aquatic plants are impacted by three main environmental factors in different parts of the LB region namely hydropower plant pipe cleaning activities, sedimentation, and less saltwater intrusion reducing the quality of water. The decline in fish in the region is connected to the decrease in submerged macrophytes resulting from the above-mentioned issues. In this regard, fishers linked the loss of aquatic plant species in Laguna Lake, including *Pontederia crassipes*, *Actinoscirpus grossus*, *Scirpus grossus*, *Vallisneria natans*, and *Hydrilla verticillata*, to hydropower plant operations, such as chemically cleaning pipes of moss using chlorine [48], as chlorine can have an impact on aquatic ecosystems [70, 71]. For example, Watkins and Hammerschlag [72] found that "high-level chlorine discharges from wastewater facilities and electric generating plants could be a contributing factor impacting nearby submerged aquatic vegetation."

In the present study, fishers also noted that while plants in LB provide fish with spawning areas and places to live and hide from predators, they are also negatively impacted by the low quality of the water in the region and invasive species like knifefish (*Chitala ornata*). Given these local environmental challenges, they are also directly tied to the decline in native fish populations such as ayungin (*Leiopotherapon plumbeus*). This is concerning because aquatic plants are vital to the survival of other aquatic species and provide a variety of ecosystem services including habitat, spawning sites, and nursery areas for several important fish species [73].

In regard to the sedimentation problems of LB waters, in the present study, fishers from the east side of LB stated that putting tree branches in the lake is not advisable in that area because the water is shallow and muddy, unlike in the Talim Island area (or Central Bay area) where the lake is deeper. In relation to this, the LB ecosystem, and specifically the Central Bay area, is impacted by natural disasters, pollution, and anthropogenic constructions. Central Bay, a municipal water body, is used by industries for waste discharge, which exceeds acceptable limits for the preservation of aquatic life. Waste from domestic activities, fertilizers, pesticides, and animal industries also contribute to the pollution. The use of insecticides has increased by 20–25% since 1976, and the lake's sedimentation and siltation resulting from forest denudation contribute to the lake's shallowness, raising turbidity levels and reducing production [67]. Furthermore, the erosion in LB is a result of improper agricultural practices, quarrying, deforestation, landfills, and land conversion [32].

In addition to the above issues, fishers also reported less saltwater coming into LB. A possible explanation for this might be that the lake environment is affected by man-made structures, as in Napindan Channel, which block entry of saltwater from Manila Bay. Therefore, biotic-abiotic connections could be slightly affected by thermal pollution resulting from the more than 1000 companies that use lake water as a cooling agent and then release it as heated water [67]. Human-caused pressures such as pollution (e.g., Häder et al. [74]), invasive species [75], and overfishing [76] are crucial and might affect people who depend on aquatic ecosystems.

Conclusion

Fishing, hiding places, and habitat were among the most important observations related to plants highlighted by fishers regarding positive plant-fisheries interactions. In addition, fish food, spawning sites, conservation, and issues involving navigation concerns and aquaculture fish deaths had all been previously reported in local use reports. Observations such as indicators of water quality and food sources for fish, the decrease in the action of waves, and the filtering of water provide novel insights, together with important ecosystem functions to other animals, such as birds for their nesting and staying areas, which were also noted. In contrast, with regard to negative plant-fisheries interactions, fishers specified adverse changes in the taste of fish and the resulting decrease in the their selling price, as well as damage to fishing gear. Fishers in LB highlighted crucial ecological observations and their interconnections with each other and to the local environment in general. Factors including hydropower plant pipe cleaning activities, sedimentation, and reduced entry of saltwater pose significant threats to the growth of plants and other species in LB. It is generally recognized that the decline in fish populations in the region can attributed to these conditions, as fish rely on submerged macrophytes for their survival, thus causing harm to plants. These results highlight the crucial knowledge of fishers from fishing communities under different levels of industrialization regarding positive and negative interactions involving plants, humans, fishes, and other species threatened by interrelated social, economic, and ecological issues. This illustrates the significance of fishers' perspectives for the conservation of freshwater resources essential to fisheries management of the LB ecosystem. Therefore, in future actions it is crucial to consider wider fisher knowledge and involve them in co-creating conservation efforts and policies as equal partners.

Abbreviations

LB	Laguna Lake or Laguna de Bay Philippines
LEK	Local ecological knowledge
CALABARZON	Cavite, Laguna, Batangas, Rizal, and Quezon

Supplementary Information

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Additional file1. Fishing and ecology, Mendoza et al

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Author contributions
J.N.M., R.S., B.P., G.M., and A.C. designed the study. J.N.M., A.C., A.M., and H.C conducted fieldwork with the help of local fishers and C.B. as research guides, especially in Sampiruhan Calamba Laguna, Philippines. J.N.M., R.S., and F.P. analyzed the data. J.N.M., A.C., A.M., and H.C. collected samples with the help of local collaborators and prepared the herbarium specimens. J.N.M. drafted the manuscript with contribution from all authors. R.S. supervised the study. All authors read and approved the final version of the manuscript.

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Availability of data and materials
All data used in this study can be found in the additional files.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Ca' Foscari University of Venice, Italy.

Consent for publication
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Competing interests
The authors declare no competing interests.

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References
1. Bhatta K, Patra HK. Economically important macrophytes of Chilika lagoon, Odisha. India Int J Adv Sci Technol. 2020;29(3):5131–73.
2. Poizat G, Baran E. Fishermen's knowledge as background information in tropical fish ecology: a quantitative comparison with fish sampling results. Environ Biol Fishes. 1997;50(4):435–49.
3. Johannes RE. The case for data-less marine resource management: examples from tropical near shore fin fisheries. Trends Ecol Evol. 1998;13(6):243–6.
4. Johannes RE, Freeman MM, Hamilton RJ. Ignore fishers' knowledge and miss the boat. Fish Fish. 2000;1(3):257–71.
5. Valbo-Jørgensen J, Poulsen AF. Using local knowledge as a research tool in the study of river fish biology: experiences from the Mekong. Environ Dev Sustain. 2000;2:253–376.
6. Silvano RA, Begossi A. Ethnoichthyology and fish conservation in the Piracicaba River (Brazil). J Ethnobiol. 2002;22(2):285–306.
7. Silvano RA, Begossi A. Local knowledge on a cosmopolitan fish: ethnoecology of Pomatomus saltatrix (Pomatomidae) in Brazil and Australia. Fish Res. 2005;71(1):43–59.
8. Drew JA. Use of traditional ecological knowledge in marine conservation. Conserv Biol. 2005;19(4):1286–93.
9. de Freitas CT, Shepard GH Jr, Piedade MT. The floating forest: traditional knowledge and use of matupá vegetation islands by riverine peoples of the Central Amazon. PLoS One. 2015;10(4): e0122542.
10. Paredes R, Hopkins AL, Villanueva F. Ethnobotany in the north coast of Peru: use of plants in the fishing community of huanchaco for subsistence. Econ Bot. 2020;74:32–45.
11. Peroni N, Begossi A, Hanazaki N. Artisanal fishers' ethnobotany: from plant diversity use to agrobiodiversity management. Environ Dev Sustain. 2008;10:623–37.

12. Tng DY, Apgaua DM, Lisboa MD, El-Hani CN. Plant uses in a traditional fisherman community in northeastern Brazil. bioRxiv. 2019;620542.
13. Savo V, La Rocca A, Caneva G, Rapallo F, Cornara L. Plants used in artisanal fisheries on the Western Mediterranean coasts of Italy. J Ethnobiol Ethnomed. 2013;9:1–4.
14. Rossato SC, Leitão-Filho HD, Begossi A. Ethnobotany of caiçaras of the Atlantic Forest coast (Brazil). Econ Bot. 1999;1:387–95.
15. Hanazaki N, Begossi A. Fishing and niche dimension for food consumption of caiçaras from Ponta do Almada (Brazil). Hum Ecol Rev. 2000;1:52–62.
16. Fonseca-Kruel VS, Peixoto AL. Etnobotânica na reserva extrativista marinha de Arraial do Cabo, RJ. Brasil Acta Botanica Brasilica. 2004;18:177–90.
17. Miranda TM, Hanazaki N. Conhecimento e uso de recursos vegetais de restinga por comunidades das ilhas do Cardoso (SP) e de Santa Catarina (SC). Brasil Acta botanica brasílica. 2008;22:203–15.
18. Baldauf C, Kubo RR, Silva F, Irgang BE. Ferveu, queimou o ser da erva: conhecimentos de especialistas locais sobre plantas medicinais na região Sul do Brasil. Revista Bras Plantas Med. 2009;11:282–91.
19. Borges R, Peixoto AL. Conhecimento e uso de plantas em uma comunidade caiçara do litoral sul do Estado do Rio de Janeiro Brasil. Acta Botanica brasílica. 2009;23:769–79.
20. Carneiro DB, Barboza MS, Menezes MP. Plantas nativas úteis na vila dos pescadores da reserva extrativista marinha Caeté-Taperaçu, Pará. Brasil Acta Bot Brasilica. 2010;24:1027–33.
21. Silvano RA, Silva AL, Ceroni M, Begossi A. Contributions of ethnobiology to the conservation of tropical rivers and streams. Aquat Conserv Mar Freshwat Ecosyst. 2008;18(3):241–60.
22. Hanazaki NA, Oliveira FC, Miranda TM, Peroni NI. Ethnobotany of artisanal fishers. Curr Trends Human Ecol. 2009;101(124):101–24.
23. Mendoza JN, Hanazaki N, Prūse B, Martini A, Bittner MV, Kochalski S, Macusi E, Ciriaco A, Mattalia G, Sõukand R. Ethnobotanical contributions to global fishing communities: a review. J Ethnobiol Ethnomed. 2023;19(1):57.
24. Galeano G. Forest use at the Pacific Coast of Chocó, Colômbia: a quantitative approach. Econ Bot. 2000;1:358–76.
25. Adger WN, Hughes TP, Folke C, Carpenter SR, Rockstrom J. Social-ecological resilience to coastal disasters. Science. 2005;309(5737):1036–9.
26. Johnson LM, Hunn ES, editors. Landscape ethnoecology: concepts of biotic and physical space. Berghahn Books; 2010.
27. The Laguna de Bay Ecosystem Health Report Card. 2016. Retrieved from http://pemsea.org/publications/reports/laguna-de-bay-2013-ecosystem-health-report-card.
28. LLDA. Annual Report 2019a. https:// llda. gov. ph/ wp-content/uploa ds/dox/ ar/ ar19. pdf.
29. UPLB. Science and policy forum pushes for Laguna de Bay restoration. 2018. https://uplb.edu.ph/research/science-and-policyforum-pushes-for-laguna- de-bay-restoration.
30. Caballero I, Navarro G. Monitoring cyanoHABs and water quality in Laguna Lake (Philippines) with Sentinel-2 satellites during the 2020 Pacific typhoon season. Sci Total Environ. 2021;788:147700. https://doi.org/10.1016/j.scitotenv.2021.147700.
31. Laguna lake development authority. Laguna de bay basin master plan. Laguna de bay basin master plan: 2016 and beyond towards climate-resilience final report.2015.
32. Tamayo-Zafaralla M, Santos RA, Orozco RP, Elegado GC. The ecological status of lake Laguna de Bay, Philippines. Aquat Ecosyst Health Manag. 2002;5(2):127–38.
33. Santos-Borja A, Nepomuceno DN. Laguna de bay: institutional development and change for lake basin management. Lakes Reserv Res Manag. 2006;11(4):257–69.
34. LEAP forum focused on science and policies for a sustainable Laguna Lake.2018. (2018, April 17). Retrieved from https://sesam.uplb.edu.ph/news/leap-forum-2018-focused-on-science-and-policies-for-a-sustainable-laguna-lake/.
35. Cuvin-Aralar ML, Santiago AE, Gonzal AC, Santiago CB, Romana-Eguia MR, Baldia SF, Palisoc Jr F. Incidence and causes of mass fish kill in a shallow tropical eutrophic lake (Laguna de Bay, Philippines). In 9th international conference on the conservation and management of lakes. Conference proceedings 2001 (pp. 233–236). Shiga Prefectural Government.
36. Lasco, Rodel., Espaldon, Ma. Victoria. Ecosystems and people: The Philippine millenium ecosystem assessment (MA) sub-global assessment. environmental forestry programme, college of forestry and natural resources university of the Philippines, Los Baños. In collaboration with department of environment and natural resources and Laguna Lake development authority. 2005.Retrieved from https://www.millenniumassessment.org/documents_sga/Philippine%20SGA%20Report.pdf.
37. Mabato-Azufre, Pangil, Laguna Profile–PhilAtlas [Internet]. Philatlas.com. Available from: https://www.philatlas.com/luzon/r04a/laguna/pangil/mabato-azufre.html.
38. Buhangin, Binangonan, Rizal Profile – PhilAtlas [Internet]. www.philatlas.com. Available from: https://www.philatlas.com/luzon/r04a/rizal/binangonan/buhangin.html.
39. Sampiruhan, Calamba, Laguna Profile – PhilAtlas [Internet]. www.philatlas.com. Available from: https://www.philatlas.com/luzon/r04a/laguna/calamba/sampiruhan.html
40. Royal Botanic Gardens, Kew. Plants of the World Online | Kew Science [Internet]. Plants of the World Online. 2024. Available from: https://powo.science.kew.org/.
41. Guiry MD and Guiry GM. 2024 (http://www.algaebase.org).
42. Zocchi DM, Sulaiman N, Prakofjewa J, Sõukand R, Pieroni A. Local wild food plants and food products in a multi-cultural region: an exploratory study among diverse ethnic groups in Bessarabia, Southern Moldova. Sustainability. 2024;16(5):1968. https://doi.org/10.3390/su16051968.
43. Alrhmoun M, Sulaiman N, Haq SM, Abidullah S, Prakofjewa J, Krigas N, Pieroni A, Sõukand R. Is Boiling bitter greens a legacy of ancient crete? Contemporary foraging in the Minoan Refugium of the Lasithi Plateau. Foods. 2024;13(22):3588. https://doi.org/10.3390/foods13223588.
44. Bernard HR, Wutich A, Ryan GW. Analyzing qualitative data: systematic approaches. SAGE publications; 2016 Jun 23.
45. Saha RK, Nath D. Indigenous technical knowledge (ITK) of fish farmers at Dhalai district of Tripura, NE India.2013.
46. Sayer CA, Akwany LO, Kishe-Machumu MA, Natugonza V, Omondi R, Kabuye CS. The importance of freshwater species to livelihoods in the Lake Victoria Basin. IUCN Global Species Programme.2018.
47. Devi BN, Mishra SK, Pawar NA, Das L, Das S. Traditional fish aggregating wisdom of Manipur, Northeastern India. 2013.
48. Mendoza JN, Prūse B, Mattalia G, Kochalski S, Ciriaco A, Sõukand R. Fishers' perspectives: the drivers behind the decline in fish catch in Laguna Lake Philippines. Maritime Stud. 2022;21(4):569–85.
49. Dominic R, Ramanujam SN. Traditional knowledge and ethnobotanical uses of piscicidal plants of Nagaland, North east India.2012.
50. Buen CC, Guerreo EJ, Espino T. MATH for Yaman ng Lawa: Strategies for sustainable development of the wealth of the lake the case of Laguna De Bay, Calamba City Philippines. Aquaculture. 2018;80:4–7.
51. Concepcion RN. Yaman ng Lawa Social action agenda: the Yankaw fish garden sanctuary. In research institute for humanity & nature. RIHN-LakeHEAD Community Forum 2013: Proceedings 2013 (pp. 272–293).
52. Kalita B, Dutta A, Bhagabati SK, Sharma A. Indigenous technical knowledge for fish harvesting in Karbi-Anglong district of Assam.2010.
53. Manna S, Ghosh R, Sen Sarkar N, Roy A. Diversity and association analysis of algal periphyton community on hydrilla verticillata, vallisneria spiralis, and ceratophyllum demersum. Res J Pharm Biol Chem Sci. 2017;8(2):1232–40.
54. Pradhan P. Aquatic plants and algae in protected bodies of freshwater: understanding biodiversity and ecological importance. J Agric. 2023. https://doi.org/10.37532/jagri.2023.6(4).106-108.
55. Simon C, McHale M, Sulpice R. Applications of Ulva biomass and strategies to improve its yield and composition: a perspective for Ulva aquaculture. Biology. 2022;11(11):1593.
56. Guerreiro I, Magalhães R, Coutinho F, Couto A, Sousa S, Delerue-Matos C, Domingues VF, Oliva-Teles A, Peres H. Evaluation of the seaweeds Chondrus crispus and Ulva lactuca as functional ingredients in gilthead seabream (Sparus aurata). J Appl Phycol. 2019;15(31):2115–24.
57. Qiu X, Neori A, Kim JK, Yarish C, Shpigel M, Guttman L, Ben Ezra D, Odintsov V, Davis DA. Green seaweed Ulva sp. as an alternative ingredient in plant-based practical diets for Pacific white shrimp, Litopenaeus vannamei. J Appl Phycol. 2018;30:1317–33.
58. Santizo-Taan R, Bautista-Teruel M, Maquirang JR. Enriched Ulva pertusa as partial replacement of the combined fish and soybean meals in juvenile abalone Haliotis asinina (Linnaeus) diet. J Appl Phycol. 2020;32:741–9.

59. Wassef EA, El-Sayed AF, Sakr EM. Pterocladia (Rhodophyta) and Ulva (Chlorophyta) as feed supplements for European seabass, *Dicentrarchus labrax* L., fry. J Appl Phycol. 2013;25:1369–76.
60. Valente LM, Gouveia A, Rema P, Matos J, Gomes EF, Pinto IS. Evaluation of three seaweeds Gracilaria bursa-pastoris, Ulva rigida and Gracilaria cornea as dietary ingredients in European sea bass (Dicentrarchus labrax) juveniles. Aquaculture. 2006;252(1):85–91.
61. Cruz-Suárez LE, León A, Peña-Rodríguez A, Rodríguez-Peña G, Moll B, Ricque-Marie D. Shrimp/Ulva co-culture: a sustainable alternative to diminish the need for artificial feed and improve shrimp quality. Aquaculture. 2010;301(1–4):64–8.
62. Bolton JJ, Robertson-Andersson DV, Shuuluka D, Kandjengo L. Growing Ulva (Chlorophyta) in integrated systems as a commercial crop for abalone feed in South Africa: a SWOT analysis. J Appl Phycol. 2009;21:575–83.
63. Shpigel M, Shauli L, Odintsov V, Ashkenazi N, Ben-Ezra D. Ulva lactuca biofilter from a land-based integrated multi trophic aquaculture (IMTA) system as a sole food source for the tropical sea urchin Tripneustes gratilla elatensis. Aquaculture. 2018;1(496):221–31.
64. Bhagowati B, Talukdar B, Ahamad KU. Lake eutrophication: causes, concerns and remedial measures. Emerging issues in the water environment during anthropocene: a South East Asian perspective. 2020;211–22.
65. Austin DF. Water spinach (Ipomoea aquatica, Convolvulaceae): A food gone wild. 2007.
66. Chilton EW. Risk assessment for water spinach (Ipomoea aquatica) in Texas. J Aquat Plant Manage. 2017;1(55):96–102.
67. Binangonan Rizal [Internet]. 50webs.com. 2024 [cited 2024 Dec 4]. Available from: http://binangonan.50webs.com/geography.html.
68. Lasco RD, Javier EQ. Laguna de Bay: a case study for sustainable fisheries development. Trans NAST PHL. 2017;39(2):2.
69. Commission on Audit, Philippines. Annual Audit Report 2014. Quezon City, Philippines.
70. Sedlak DL, von Gunten U. The chlorine dilemma. Science. 2011;331(6013):42–3.
71. Da Costa JB, Rodgher S, Daniel LA, Espíndola EL. Toxicity on aquatic organisms exposed to secondary effluent disinfected with chlorine, peracetic acid, ozone and UV radiation. Ecotoxicology. 2014;23:1803–13.
72. Watkins CH, Hammerschlag RS. The toxicity of chlorine to a common vascular aquatic plant. Water Res. 1984;18(8):1037–43.
73. FAO. Aquatic plants. Their uses and risks. A review of the global status of aquatic plants. 2012. http://www.fao.org/3/ca905 1en/CA9051EN. pdf.
74. Häder DP, Banaszak AT, Villafañe VE, Narvarte MA, González RA, Helbling EW. Anthropogenic pollution of aquatic ecosystems: emerging problems with global implications. Sci Total Environ. 2020;15(713): 136586.
75. Gallardo B, Clavero M, Sánchez MI, Vilà M. Global ecological impacts of invasive species in aquatic ecosystems. Glob Change Biol. 2016;22(1):151–63.
76. FAO. The state of world fisheries and aquaculture 2020. Rome: in brief. Sustainability in action. 2020.

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