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# Conservation management initiatives for Philippine commercially important native freshwater fishes

**Mark Nell CORPUZ**

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Bataan Peninsula State University, Center for Research on Aquaculture and Aquatic Resources in Brackishwater Systems, Institute of Fisheries and Aquatic Sciences, Bayan, Orani, Bataan, 2112, Philippines

**ORCID IDs of the author(s):**
M.N.C. 0000-0002-2582-0772

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**Correspondence:**
**Mark Nell CORPUZ**
**E-mail:** mnccorpuz@bpsu.edu.ph

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## ABSTRACT

Native freshwater fishes in the Philippines are experiencing sustained population declines due to overexploitation, habitat degradation, invasive species, hydrological alteration, and weak regulatory enforcement. This review synthesized conservation management initiatives for commercially important indigenous taxa, including gobies (*Glossogobius* spp.), silver therapon (*Leiopotherapon plumbeus*), lobed river mullet (*Cestraeus plicatilis*), freshwater sardine (*Sardinella tawilis*), giant trevally (*Caranx ignobilis*) in Taal Lake, native catfish (*Clarias macrocephalus*), sinarapan (*Mistichthys luzonensis*), and tropical eels (*Anguilla* spp.). A structured literature synthesis of peer-reviewed publications and grey literature was conducted to evaluate current regulatory, habitat-based, and aquaculture-supported interventions. Existing measures include closed fishing seasons, gear restrictions, sanctuary establishment, export controls for eel juveniles, and hatchery-based conservation breeding for selected species. Although captive propagation has been technically achieved for silver therapon, giant trevally, and native catfish, most programs remain fragmented and weakly integrated with habitat restoration and stock assessment frameworks. Watershed degradation, aquaculture expansion, and invasive species continued to constrain the recovery of wild populations. The review identified critical gaps in long-term monitoring, population dynamics data, and implementation of fish-based indices of biotic integrity for ecological assessment. Strengthening inter- agency coordination, institutionalizing conservation-oriented breeding, enforcing harvest controls, and adopting watershed-scale habitat rehabilitation were essential to reverse population declines. The findings provided a scientific basis for refining national inland fisheries restoration programs and aligning conservation policy with biodiversity protection and food security objectives.

**Keywords:** Endemic fish, Fisheries management, *Silver therapon,* Sustainability*, Tawilis*

## Introduction

The Philippines is recognized as a global hotspot of biological diversity, ranking among the 17 megadiverse countries and exhibiting exceptionally high species endemism (Mittermeier & Mittermeier, 1997; Tanalgo et al., 2025). As an archipelagic nation, it is also a major center of freshwater biodiversity, characterized by a distinctive distribution of fish fauna across 211 lakes, 18 major river systems, and 22 marshlands. Among freshwater habitats, riverscapes and other lotic systems play a crucial role in supporting fish growth, survival, and migratory processes. The freshwater ichthyofauna in the Philippines has a total of 374 fish species within 29 orders and 78 families, and comprises native fish species (60.61%), endemic (22.73%), and introduced or non-native (17.11%) (Froese & Pauly, 2023; Jamandre, 2023).

Native or indigenous aquatic species, including freshwater fishes, are defined as organisms that historically occurred within rivers, streams, lakes, and other freshwater wetlands, excluding those introduced through anthropogenic activities (Mann, 2010). Native freshwater fishes constitute essential components of aquatic ecosystems, where they occupy key trophic positions and perform critical ecological functions such as energy transfer, nutrient cycling, and population regulation (Karr, 1981; Dudgeon et al., 2006; Gebrekiros, 2016). These assemblages are generally sensitive to environmental degradation and depend on suitable water quality and habitat conditions to maintain viable populations (Corpuz et al., 2016; Gonino et al., 2020). Consequently, native fish communities are widely recognized as reliable bioindicators of freshwater ecosystem health (Karr, 1981).

Freshwater ecosystems and watersheds in the Philippines are increasingly threatened by anthropogenic pressures, particularly pollution and land-use change that result in habitat degradation and hydrological alteration (Labajo-Villantes & Nuñeza, 2014; Martinico-Perez et al., 2015; Clemente, 2020; Corpuz & Espaldon, 2023). These pressures are exacerbated by limited public awareness, weak institutional support, and rapid industrialization, which collectively contribute to the progressive decline of freshwater ecosystem quality across the Asia-Pacific region (Bashir et al., 2020). In addition to habitat degradation, the proliferation of invasive alien species has significantly disrupted native biodiversity. Invasive fishes often exhibit broad environmental tolerances, enabling them to thrive under degraded and fluctuating conditions associated with pollution (Casal et al., 2007; Guerrero, 2014). Their rapid population growth and competitive dominance frequently lead to the displacement of native species through competition for food and habitat, ultimately causing population declines and localized extirpations (Havel et al., 2015). Numerous inland waters in the Philippines are now heavily colonized by invasive fishes, with their ecological impacts extensively documented (Cagauan, 2007; Guerrero, 2014; Corpuz, 2018). Despite this growing body of research, comprehensive review articles synthesizing the conservation status, threats, and management strategies for Philippine native freshwater fishes remain limited and are largely confined to grey literature and unpublished datasets.

Increasing demand for affordable and readily available food associated with rapid population growth has intensified pressure on fishery resources, making overexploitation a persistent threat to native fish species (Allen et al., 2005). Unsustainable fishing practices, coupled with escalating fishing effort, have contributed to the excessive extraction of indigenous fish with high commercial value from their natural habitats. In the Philippines, widespread poverty and limited livelihood alternatives compel many rural fishing communities to rely heavily on artisanal and communal fisheries for subsistence and household food security (Aya, 2019; Corpuz & Espaldon, 2023). Within this context, this review examined the conservation measures currently applied to Philippine indigenous freshwater fishes of commercial importance in aquaculture and capture fisheries. The study further synthesized evidence-based recommendations to strengthen conservation planning, policy formulation, and management frameworks for the sustainable use of native freshwater fishery resources.

## Methodology

This review examined selected native freshwater fishes and fish assemblages of conservation concern and fishery relevance in the Philippines, including goby fisheries locally known as *biya* (*Glossogobius* spp.), silver therapon or *ayungin* (*Leiopotherapon plumbeus* Kner, 1864), lobed river mullet or *ludong* (*Cestraeus plicatilis* Valenciennes, 1836), freshwater sardine or tawilis (*Sardinella tawilis* Herre, 1927), giant trevally or *maliputo* from Taal Lake (*Caranx ignobilis* Forsskål, 1775), native freshwater catfish (*Clarias macrocephalus* Günther, 1864), *sinarapan* (*Mistichthys luzonensis* Smith, 1902), and Philippine eels (*Anguilla* spp.) Species selection was guided by ecological importance, degree of endemism, documented population decline, and commercial significance in inland capture fisheries and prospective aquaculture systems. Widely studied species such as milkfish, non-native freshwater fishes, and secondary freshwater fishes were excluded to maintain analytical focus on indigenous taxa. In contrast, commercially important marine fishes were omitted due to the freshwater scope of the review.

The review followed a structured literature synthesis approach consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Literature searches were conducted across Web of Science, Zoological Record, SCOPUS, Google Scholar, FishBase, and other freshwater fisheries databases using combinations of scientific names, local names, and keywords related to native and introduced freshwater fishes, conservation status, production, exploitation, management, and legislation. Inclusion criteria comprised studies explicitly addressing Philippine freshwater systems, native fish species or assemblages, and information on population trends, threats, conservation status, or management interventions. Exclusion criteria included studies focused solely on marine environments, introduced species, experimental trials without conservation relevance, and publications lacking verifiable locality or taxonomic resolution. Grey literature, including technical manuals, terminal project reports, policy documents, and reputable national and regional electronic news sources, was incorporated to capture applied knowledge and locally relevant evidence not indexed in peer-reviewed databases.

All species names were standardized following the current taxonomic consensus adopted in the Catalog of Fishes (Froese & Pauly, 2023) and recent systematic revisions to ensure nomenclatural consistency across the manuscript. The final dataset consisted of no less than 100 publications selected from more than 300 retrieved records after title, abstract, and full-text screening. Synthesized information was organized within a conceptual framework linking fishery production status, major anthropogenic threats, ecological responses of native freshwater fishes, and existing conservation and management measures. This framework was used to identify knowledge gaps, assess the effectiveness of current interventions, and propose evidence-based directions for improved conservation management of Philippine native freshwater fishery resources.

## Results and Discussion

### *Philippine Commercially Important Native Freshwater Fishes*

Figure 1 illustrates multi-year (circa 2005-2025) fluctuations in inland capture fisheries production among the studied commercially important native freshwater fishes, highlighting overall declines in some taxa alongside episodic increases in others (e.g., catfishes and eels). The distribution of the studied native freshwater fishes in various inland aquatic habitats in the Philippines is shown in Figure 2.

Fishes belonging to the families Gobiidae and Eleotridae constitute the most species-rich and widely distributed components of native freshwater fish assemblages in the Philippines (Paller et al., 2011, 2013; Froese & Pauly, 2023; Jamandre, 2023). Their high abundance in streams and rivers connected to coastal waters makes gobioids a major component of artisanal and subsistence fisheries collectively known as *ipon* fisheries, which also include small shrimps and prawns. These fishery resources provide essential economic support to communities dependent on inland and estuarine resources (Corpuz et al., 2013, 2015). Fry of amphidromous gobies typically appear about nine days after the full moon between September and February (Agor-Balicanta, 1976) and are harvested in large numbers from estuarine areas using traditional fish traps. The *ipon* fisheries serve as an important livelihood and food source for small-scale fisherfolk. National inland fisheries production of gobies declined markedly from 5,335 metric tons in 2013 to 2,413 metric tons in 2025, indicating a substantial reduction in output (PSA, 2025). Despite this decline, gobies, particularly *Glossogobius giuris,* remain commercially valuable, with fresh fish selling for PhP 300–400 per kilogram (PhP 62 = 1.00 US$). However, goby production remains far lower than that of dominant aquaculture species (DA-BFAR, 2024).

The endemic silver therapon (*Leiopotherapon plumbeus*), locally known as *ayungin*, *lukaok*, or *bagaong*, is recognized as one of the most important fishery resources in Laguna de Bay, the Philippines' largest inland water body. The species has been translocated to various freshwater systems throughout the Philippines (Quilang et al., 2007) and also occurs in estuarine and mangrove habitats (Santos et al., 2020). Wild populations of silver therapon support subsistence fisheries and contribute significantly to the livelihoods of coastal fishing communities (Aya, 2021; Corpuz & Espaldon, 2023). In local markets, fresh and frozen individuals are sold at PhP 300–500 per kilogram, while dried products are priced at PhP 80–100 per 100 g. The International Union for Conservation of Nature classifies wild populations of silver therapon as *Vulnerable* (Torres et al., 2021).

The lobed river mullet (*Cestraeus plicatilis*), locally known as *ludong* or *purong*, has been classified as an endangered species by the Bureau of Fisheries and Aquatic Resources (BFAR) (Javier et al., 2016). This indigenous migratory mullet is primarily distributed in northern Philippine river systems, including the Cagayan and Agno rivers and their tributaries, and is popularly referred to as the "President's fish." Owing to limited ecological and population data, the species is categorized as *Data Deficient* in the IUCN Red List (Hoese et al., 2021). Among Philippine freshwater fishes, *ludong* commands exceptionally high market prices, reaching up to

PhP 6,000 per kilogram of fresh weight, making it a prized delicacy among Ilocanos, particularly in the Cagayan Valley region. Its high market value, coupled with limited availability, has incentivized illegal fishing and unsustainable harvesting practices within natural habitats (Agasen, 2007).

Taal Lake, the caldera lake, serves as the exclusive habitat of the world's only freshwater sardine, *tawilis* (*Sardinella tawilis*), which represents one of the most important fishery resources in the lake's artisanal capture fisheries (Mutia et al., 2020). The species is hypothesized to have originated from a marine ancestor that adapted to the freshwater conditions of the lake. Local artisanal and communal fisherfolk depend heavily on tawilis for both income and subsistence; however, recent fisheries production trends indicate a declining population within the lake (Muyot et al., 2021). Another ecologically and economically significant native species in Taal Lake is the giant trevally (*Caranx ignobilis*), locally known as *maliputo* or *talakitok*. Historically abundant, *maliputo* stocks have declined drastically, rendering the species increasingly rare and commanding high market prices (Mutia et al., 2020). The lake giant trevally exhibits a migratory life cycle, with adults spawning in estuarine waters near Balayan Bay and juveniles migrating upstream through the Pansipit River (the sole natural outlet of Taal Lake) into freshwater habitats as they grow (Mutia et al., 2015; Alaira et al., 2014). In 2022, the IUCN Red List classified *tawilis* as *Endangered*, while *maliputo* remains listed as *Least Concern* (Santos et al., 2019).

Native Asian freshwater catfish, *Clarias macrocephalus*, locally known as *hito* or *pantat*, is among the most economically valuable yet increasingly displaced freshwater fishes in the Philippines (Tan-Fermin, 2003; Aya, 2019). Historically, *C. macrocephalus* was widely distributed and abundant in ponds, floodplains, and river systems (Bombeo et al., 2002). The increase in captive catfish production shown in Figure 1 is largely attributed to the dominance and expanding culture of introduced freshwater catfish species, particularly the African catfish (*Clarias gariepinus*) and pangasiid catfishes (*Pangasius* spp.), which are favored for their rapid growth rates and larger body size compared with native clariids. The carnivorous *C. gariepinus* has established feral populations in multiple freshwater systems, where it competitively displaces native catfishes (Corpuz et al., 2025). Despite declining wild stocks, native catfishes remain highly sought in local markets due to superior flesh quality and strong consumer preference (Coniza et al., 2008). Regionally, *C. macrocephalus* has been assessed as *Near Threatened* because of widespread population declines across Southeast Asia (Vidthayanon & Allen, 2013), although the most recent IUCN assessment currently lists the species as *Data Deficient* (Ng et al., 2021).

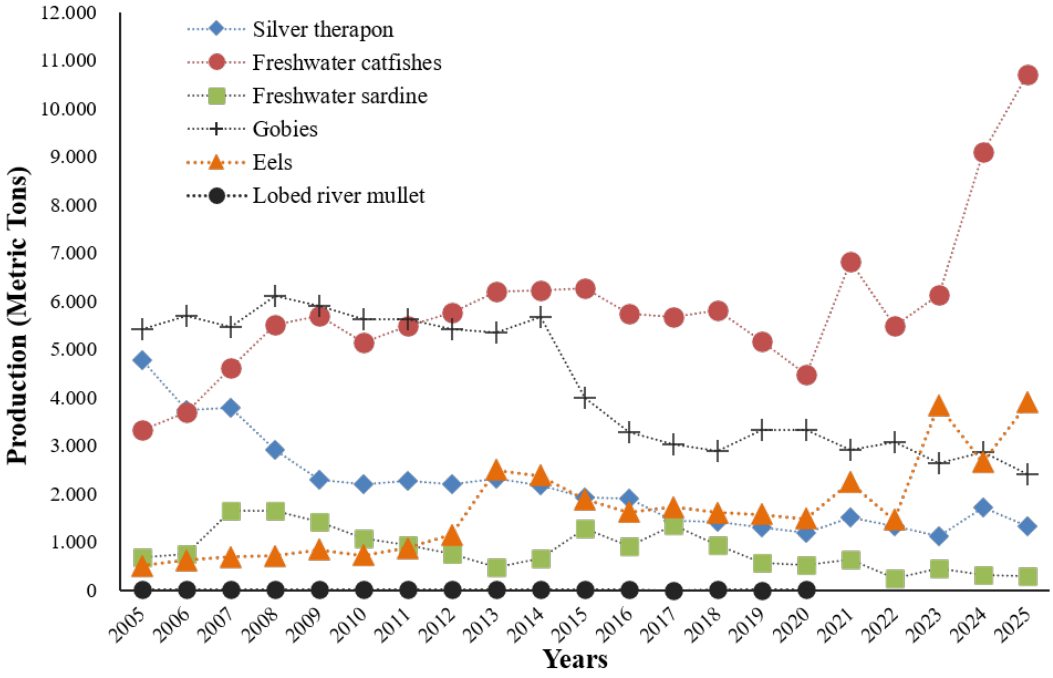


**Figure 1.** Annual inland capture fisheries production of selected commercially important Philippine native freshwater fishes (circa 2005–2025)

**Figure 2.** Map of the Philippines showing the geographic distribution of the studied commercially important Philippine native freshwater fishes and their associated aquatic habitats

The *sinarapan* (*Mistichthys luzonensis*) is a gobiid fish species inhabiting lacustrine ecosystems in the Bicol Region of southern Luzon, Philippines (Soliman, 1994). Adults attain a maximum length of only 1.2 cm, making it the smallest commercially harvested fish species in the world. The species is endemic to Philippine inland waters and is now largely restricted to selected water bodies in the Bicol Region, where it continues to persist after former populations in lakes such as Bato and Buhi declined. The *sinarapan* represents a vital fishery resource in Camarines Sur, where local fisherfolk rely on it as a primary source of income and sustenance. During the 1970s, daily catches using motorized fishing gear reportedly reached at least 100 kg per day (Gindelberger, 1981). Over the past four decades, however, sinarapan fishery production has declined markedly; by 2016, fisherfolk reported daily catches of only 2–5 kg. In local markets, fresh sinarapan is sold for PhP 150–200 per kilogram, while dried products are priced at approximately PhP 100 per 250 g (Escandor, 2017). This diminutive goby is currently classified as *Vulnerable* on the IUCN Red List (Soliman et al., 2021).

Freshwater eels of the genus *Anguilla* constitute culturally and economically important fishery resources in the Philippines, where these fish are locally known as *kasili*, *palos*, or *igat*. Several anguillid species recruit in Philippine river systems, including the giant mottled eel (*Anguilla marmorata*), Indonesian shortfin eel (*A. bicolour pacifica*), and Japanese eel (*A. japonica*), which have been documented among glass-eel catches in northern Luzon and tributaries of Lagonoy Gulf through morphological and molecular identification (Watanabe et al., 2009; Yoshinaga et al., 2014; Hilario et al., 2022). Studies in the Cagayan River (northern Luzon) confirmed the coexistence of multiple anguillid species, including *A. luzonensis*, A. marmorata, and *A. bicolour pacifica*, highlighting the Philippines as an important recruitment area for tropical anguillid eels (Yoshinaga et al., 2014). The Philippine mottled eel (*A. luzonensis*), first described from Luzon Island, has a restricted geographic distribution and is considered a conservation-priority species due to its limited range and vulnerability to exploitation and habitat degradation (Watanabe et al., 2009; Aoyama et al., 2015). Glass-eel fishing grounds have been reported in several regions, including northern Luzon (Cagayan River), the Bicol region, and parts of Mindanao, where *A. marmorata and A. bicolor pacifica* typically dominate catches (Yoshinaga et al., 2014; Hilario et al., 2022; Santos et al., 2023). At the national scale, eel fisheries contribute to export production; SEAFDEC (Monzon, 2025) reported that the Philippines exported approximately 23,019 metric tons of eel products in 2023 with an estimated value of USD 54.53 million. According to the IUCN global status reported by Pike and colleagues (2020), *A. marmorata* is classified as *Least Concern*, *A. bicolour* as Near Threatened, *A. luzonensis* as *Vulnerable*, and *A. japonica* as Endangered.

### *Problems and Challenges*

Most native freshwater and estuarine fishes in the Philippines are experiencing sustained population declines driven by a convergence of ecological, technological, and management

constraints (Bashir et al., 2020; Corpuz & Espaldon, 2023; Jamandre, 2023). For several taxa with potential for aquaculture and conservation value, such as gobies, research efforts have remained fragmented and limited largely to reproductive biology, morphology, and fisheries assessments (Vedra et al., 2013; Campang & Ocampo, 2015; Corpuz et al., 2015; Vedra et al., 2019). Attempts at captive breeding, including work on the white goby *Glossogobius giuris*, have demonstrated technical feasibility but consistently low survival rates, primarily due to unresolved constraints in seed production and the difficulty of replicating the physico-chemical and hydrodynamic conditions of natural lotic systems (DOST-PCAARRD, 2012b; Vedra & Ocampo, 2014). As previously reported, the biological and system-level limitations are compounded by water pollution, land reclamation, and weak environmental protection, which have contributed to the broader decline of freshwater fish assemblages, including gobioid assemblages

Several native fishes of high ecological and economic importance, such as silver therapon and lobed river mullet, exhibit marked declines associated with habitat degradation, fishing pressure, and biotic interactions. Silver therapon production has shown pronounced interannual variability and long-term reduction, with historical catches declining sharply from the mid-2000s onward (Corpuz, 2018; Aya, 2019; PSA, 2025). In major inland and brackish-water systems, declines have been linked to predation by invasive alien species such as *Chitala ornata*, loss of mangrove habitats, and intensified exploitation by small-scale fisheries (Corpuz, 2018; Corpuz & Espaldon, 2023). Similarly, lobed river mullet populations in northern Luzon have been severely affected by overfishing, river dredging, logging, and environmental degradation, with high market value further incentivizing illegal and unsustainable harvesting practices (Agasen, 2007; Visaya, 2020).

Anthropogenic pressures have intensified through the expansion of cage-based aquaculture, the introduction of exotic species, and increasing agrochemical runoff, all of which have altered aquatic habitats and disrupted native fish populations. In Taal Lake and the Pansipit River, fish cages and pens have degraded water quality, obstructed migratory pathways, and modified hydrological regimes, adversely affecting native migratory species (Estigoy et al., 2005). Furthermore, the widespread stocking of exotic fishes has further destabilized native communities through competition, predation, and habitat modification, contributing to the decline of indigenous catfishes (Gindelberger, 1981; Canonico et al., 2005; Quinn, 2011). These combined pressures are also exemplified by the collapse of the *sinarapan* fishery in Lakes Bato and Buhi, which has been attributed to logging, illegal fishing, hydrological alterations, and the introduction of Nile tilapia that degraded water quality through excess feed and effluents (Soliman, 1994; Pullin et al., 1997; Martin et al., 2010; Zengeya et al., 2013; Escandor, 2017; Champneys et al., 2021).

Eels are catadromous fishes, spawning in the ocean as leptocephalus larvae before migrating into freshwater systems where they mature. Their complex life cycles make them highly sensitive to environmental disruption. In the Philippines, the premature harvest of elvers (juvenile eels) driven by high market demand has been linked to localized depletion of eel populations in river systems, where eel catches once supported livelihoods but have since declined markedly (Santos et al., 2023). Apart from limited long-term biological data, major threats to Anguilids include overexploitation, habitat degradation, barriers to migration, and pollution (Gollock et al., 2018). Anguillids are experiencing a suite of pressures that include habitat loss/modification, migration barriers, pollution, parasitism, exploitation, and fluctuating oceanic conditions that likely have synergistic and regionally variable impacts, even within species (Jacoby et al., 2015; Gollock et al., 2018). Overharvesting of glass eels for both domestic consumption and export pressures natural stocks, while river modifications, pollution from agriculture and urban runoff, and loss of wetlands degrade critical habitats. Such pressures also mirror global conditions where habitat loss, river fragmentation, and pollution are primary drivers of eel decline (Arai, 2015).

### *Conservation Measures*

Inland capture fisheries from 2015–2025 showed predominantly declining production trends across several studied native freshwater fishes, including freshwater goby, silver therapon, lobed river mullet or *ludong*, Bombon sardine or *tawilis*, and freshwater eel, while freshwater catfishes exhibited a modest increase (Table 1). Species such as gobies and silver therapon remained small contributors to total inland municipal capture output, whereas catfishes accounted for the largest share. According to PSA (2025), the high contribution of freshwater catfish production in inland fisheries is largely associated with the presence and proliferation of feral populations of *Clarias gariepinus* (African catfish) in natural water bodies, which has driven the observed increase in inland capture fisheries production. The *ludong* and *tawilis* displayed the highest marked reductions among the studied native fishes. Fishing operations are characterized by diverse and often non-selective gear, including gill nets, push nets, traps, and electrofishing.

**Table 1.** Inland capture fisheries production and fishing gear utilization of the studied native freshwater fishes

| Native Freshwater Fishes | Average % Change in Production (2015-2025) | % Share in Inland Capture Fisheries Production | Fishing Gears Used by Fisherfolk |
|---|---|---|---|
| Freshwater gobies or *biya* | -7.86 | 1.281 | Manual or motorized push nets, gill nets, scoop nets, drag seine, cylindrical fish traps, fish corrals, hook-and-line fishing, electrofishing |
| Silver therapon or *ayungin* | -6.50 | 0.706 | Gill nets, manual or motorized push nets, beach seines, drive-in nets, fish corrals, brush shelters |
| Lobed river mullet or *ludong* | -29.44* | 0.69 | Bamboo fish pots, gillnets, filter nets, fish traps |
| Bombon sardine or *tawilis* | -15.70 | 0.157 | Mid-water gillnets, beach seines, motorized push nets, ring nets, beach nets |
| Giant trevally or *maliputo* | No data | 0.058** | Gill nets, ring nets, beach seines, hook-and-line, fry fine mesh net |
| Freshwater catfishes or *hito* | 2.79 | 5.69 | Fish traps, fish corrals, electro-fishing, bottom-set gill nets, conical bamboo cover pots, cylindrical fish traps |
| *Sinarapan* | No data | No data | Hand-operated scissor nets made of finely woven abaca cloth, motorized 'sakag', a collapsible Y-shaped push net. |
| Freshwater Eels | -2.34 | 2.067 | Modified fyke nets for glass eels, bamboo traps, pot gears, scoop nets, spear guns, hand gears, and electro-fishing |

* 2020 volume of production in capture fisheries reported by Mutia et al. (2020)
** from 2015-2020 PSA data (PSA, 2025)

In response to declining gobioid resources, the Philippine government enacted Republic Act No. 6145 in the 1970s, prohibiting the harvesting of *ipon* to protect gobioid stocks. In contrast, several local government units in Northern Luzon implemented seasonal fishing closures aligned with peak reproductive periods (Agor, 1976). Despite these regulatory measures, population recovery has remained limited, largely due to insufficient scientific understanding of stock enhancement feasibility and aquaculture-based interventions, as well as continued degradation of riverine habitats essential to gobioid life cycles and recruitment. Research on the aquaculture potential of Philippine gobies remains sparse and fragmented, with studies primarily addressing reproductive aspects, aquaculture studies, and morphological characterization (DOST-PCAARRD 2012b; Corpuz et al., 2013; Campang & Ocampo, 2015; Ramoran, 2023), and broader assessments focusing on capture fisheries, distribution, and conservation of gobioid assemblages (Vedra et al., 2013, 2014; Corpuz et al., 2015). Diminutive fishes such as gobies are subject to harvest regulation under RA 8550, as amended by Republic Act No. 10654, particularly through provisions governing the use of fine mesh nets to prevent the excessive capture of juvenile and small-bodied fish species (Philippine Fisheries Code of 1998, 1998/2015).

To address the decline of wild silver therapon populations, coordinated research efforts have focused on hatchery management (Añano et al., 2015), early ontogeny (Aya et al., 2017), reproductive biology (Denusta et al., 2014), population ecology (De Leon et al., 2017; Santos et al., 2020), and salinity tolerance (Corpuz & Manliclic, 2020), providing an integrated biological basis for culture and management interventions (Aya et al., 2014; Añano et al., 2015). Moreover, Aya (2021) and Consigna and his colleagues (2019) reported the successful development of captive breeding through hormonally induced spawning, demonstrating the technical feasibility of seed production and the species' suitability for aq-

uaculture applications. Similarly, hatchery protocol established by the University of the Philippines Los Baños has enabled the maintenance of backup populations to support conservation-oriented breeding and potential stock enhancement (DOST-PCAARRD 2012a). While these advances present clear opportunities for integrating aquaculture with conservation objectives, the effectiveness of complementary habitat-based interventions (e.g., mangrove rehabilitation) (Flores et al., 2016) remains poorly quantified due to the lack of empirical assessments linking restoration outcomes to silver therapon population recovery. Despite the availability of conservation breeding technologies, the absence of comprehensive regulatory frameworks, including enforceable ordinances, closed-season policies, and mandated minimum size limits, continues to undermine efforts to control fishing pressure and ensure the long-term sustainability of this fishery resource.

For lobed river mullet, the BFAR and the local government units (LGUs) have implemented biological investigations and fisheries assessments to inform conservation and management strategies (Dumlao, 2020). Regulatory interventions include the imposition of a closed fishing season under BFAR Administrative Circular No. 247 (2013), which prohibits the harvesting of mullet from October to 15 November to protect spawning populations and migratory runs (Agasen, 2007; Miele, 2011). In parallel, the DA-BFAR launched the OPLAN Sagip Ludong Project in collaboration with Isabela State University, the Zoological Society of London, and participating LGUs. This initiative established a Ludong Breeding and Research Center aimed at generating baseline ecological data, assessing population status, and evaluating the feasibility of induced breeding and ex situ conservation approaches (Martin, 2019; Dumlao, 2020). However, despite these institutional efforts, there are currently no peer-reviewed or technical reports documenting successful captive propagation, indicating persistent biological and technological constraints in the development of effective conservation breeding protocols. However, there are no national minimum length laws for catching *ludong.*

To enhance the conservation of freshwater sardines, the Taal Lake Protected Landscape established Tawilis Reserve Areas covering approximately 1,106 ha in strategic zones of the lake (Cabico, 2021). In 2008, all aquaculture structures along the 9-km Pansipit River were dismantled by a local task force to comply with environmental law and to facilitate the safe upstream migration of giant trevally and other migratory fish species (Estigoy et al., 2005; Luistro, 2008). Concurrently, NFRDI's National Fisheries Biological Center in Taal, Batangas, has been refining captive breeding protocols for giant trevally, with the goal of producing sustainable juveniles for both aquaculture and conservation purposes (Mutia et al., 2015, 2020, 2024). Apart from direct efforts, Republic Act No. 8550 (Philippine Fisheries Code of 1998, 1998/2015) limits the extent of aquaculture structures in lakes and rivers to no more than 10 per cent of the suitable water surface area, with stocking density and feeding practices governed by ecological carrying capacity to ensure sustainable resource use and environmental protection. In line with this mandate, the NFRDI conducted a comprehensive carrying capacity assessment of Taal Lake using water quality monitoring and biogeochemical modeling to characterize nutrient dynamics and to estimate maximum sustainable fish biomass and allowable cage density without exceeding critical thresholds for dissolved oxygen and phosphorus (Cabico, 2020). The resulting scientific evidence informed policy recommendations and regulatory guidelines for aquaculture licensing aimed at aligning cage culture intensity with the lake's assimilative capacity. To further reduce environmental loading and mitigate eutrophication associated with uneaten feeds and fecal wastes, NFRDI recommended the use of extruded floating feeds, which have been shown to improve feed conversion efficiency and reduce benthic organic accumulation compared with sinking or slow-sinking feeds (Muyot et al., 2018). Local conservation guidelines generally require fishers to catch *tawilis* above 11.66 cm (estimated size at first maturity) to allow them to reproduce. To minimize the capture of juvenile *tawilis*, the research team from NFRDI recommended the regulation of fishing gear, particularly the enforcement of a prescribed legal gill net mesh size of 3.05 cm to improve size selectivity and reduce juvenile exploitation (Alba et al., 2018).

For native freshwater catfishes, Section 92 of RA 10654 (Philippine Fisheries Code of 1998, 1998/2015) explicitly prohibits destructive fishing practices, including electrofishing and the use of noxious or poisonous substances, which can harm benthic and cryptic taxa such as clariid catfishes that inhabit muddy substrates and rock interstices. Despite these general regulatory safeguards, no species-specific conservation or management policy has been enacted to address the protection and recovery of native freshwater clariids in Philippine inland waters. Consequently, management interventions have largely relied on artificial propagation and stock enhancement programs implemented by local government units and fisheries stakeholders, with emphasis on *C. macrocephalus* as a priority species due to its ecological and economic importance (Lopez, 2006). In support of these efforts, the SEAFDEC has developed and disseminated standardized hatchery and larval rearing protocols that enable reliable captive breeding and juvenile production of native cat-

fishes, thereby providing seed material for both restocking initiatives and aquaculture development (Dagoon, 2000; Bombeo et al., 2002). There are currently no established legal-size limits or closed-season policies governing the harvest of wild native catfish in the Philippines.

To address the decline of *sinarapan*, LGUs enacted regulations prohibiting the use of motorized fishing gear to reduce overexploitation (Zoleta, 1987). Complementing these local measures, national government initiatives have prioritized the stocking of native species and the ecological rehabilitation of lakes to restore their intrinsic capacity to provide essential ecosystem services (Palma & Bartolome, 2016). In addition, *sinarapan* sanctuaries were established in adjacent minor lakes, including Manapao, Katugday, and Danao, to provide protected habitats and support population recovery. While aspects of the species' population biology have been characterized (Soliman, 1994), there remains a lack of peer-reviewed documentation on successful captive breeding for stock enhancement, highlighting a critical knowledge gap in conservation aquaculture and the development of evidence-based management strategies. Fisheries management and conservation initiatives aimed at protecting the remaining populations of *sinarapan* were comprehensively discussed by Soliman et al. (2021).

### *Recommended Mitigations*

Information on the conservation status, major threats, and conservation management initiatives for commercially important native freshwater fishes is summarized in Table 2.

### *Conservation-Oriented Breeding and Stock Enhancement Programs*

A national, conservation-oriented breeding program should be prioritized for threatened and declining Philippine native freshwater fishes, particularly species with proven or emerging captive propagation potential. Conservation aquaculture must move beyond purely production-driven objectives and explicitly integrate genetic management, population recovery, and ecosystem compatibility. Existing successes in hormonally induced spawning and hatchery rearing of species such as giant trevally, silver therapon, and native catfish demonstrate technical feasibility and provide a strong foundation for scaling up conservation breeding (Aya et al., 2014; Bombeo et al., 2002). Ecological risk assessments must precede stock enhancement initiatives to prevent density-dependent effects, disease transmission, and genetic introgression that could undermine wild populations. For migratory species such as gobies, lobed river mullet, and tropical eels, conservation breeding should be complemented by life-cycle research to resolve bottlenecks in larval survival and habitat requirements, particularly the transition between marine, estuarine, and freshwater environments. Importantly, conservation breeding programs should be institutionally anchored within state universities, national research agencies and LGUs to ensure long-term continuity, standardized protocols, and alignment with national biodiversity strategies. When integrated with habitat restoration and harvest controls, conservation breeding can function as a recovery tool rather than a substitute for ecosystem protection, contributing to both biodiversity conservation and livelihood resilience.

### *Habitat Protection and Watershed-Scale Management*

Habitat degradation remains the most pervasive threat to Philippine native freshwater fishes; therefore, effective mitigation must prioritize habitat protection at the watershed scale (Magbanua et al., 2017). Lotic and lacustrine ecosystems require intact riparian zones, stable hydrological regimes, and functional connectivity between rivers, floodplains, estuaries, and coastal waters to sustain life cycles of amphidromous and migratory species (Dudgeon et al., 2006; Deng & Demisse, 2023). Legal instruments such as the Philippine Fisheries Code (RA 8550 as amended by RA 10654) and the National Integrated Protected Areas System Act provide a framework for habitat protection, but enforcement remains uneven. Strengthening riparian buffer regulations, controlling sedimentation from logging and agriculture, and regulating aquaculture expansion within ecological carrying capacity limits are critical interventions (Estigoy et al., 2005; Cabico, 2020). Habitat connectivity should be explicitly incorporated into river basin management plans, including the removal or modification of migration barriers, protection of spawning and nursery grounds, and rehabilitation of estuarine transition zones (Felin et al., 2025). Successful examples such as the clearing of fish cages in the Pansipit River highlight the ecological benefits of restoring migratory corridors for giant trevally and freshwater sardines (Luistro, 2008; Mutia et al., 2020). Community-based habitat protection, supported by LGUs and co-management arrangements, can enhance environmental compliance and stewardship, particularly in river systems and lakes (Campos-Silva & Peres, 2016; Maliao et al., 2025). Mangrove and floodplain rehabilitation should also be recognized as fisheries conservation tools, given their role in supporting early life stages of many native fishes (Flores et al., 2016; Garcia et al., 2000). Moreover, habitat-based mitigation delivers long-term ecological benefits that no level of hatchery intervention for stock enhancement can replace, reinforcing the principle that conservation breeding must complement, not just compensate for, habitat loss.

**Table 2.** Commercially important native freshwater fishes, their conservation status and threats, and conservation management initiatives

| Native Fishes | IUCN Red List Status[1] | Major Threats | Conservation Management Initiatives | | | References for Conservation Measures |
|---|---|---|---|---|---|---|
| | | | Captive Breeding Program | Habitat Conservation | Fisheries Law, Policies, and Regulations | |
| Gobiids and Eleotrids, *in the* fishery | - | Overfishing | Semi-natural propagation of *Glossogobius giuris* | | Closed season in the Ilocos Region | Agor (1976); DOST-PCAARRD (2012b); Ramoran (2023) |
| Silver Therapon, *Leiopotherapon plumbeus* | VU | Overfishing, habitat loss, and alien invasive species | Hormonally induced breeding | Mangrove rehabilitation program in select areas in Luzon | | DOST-PCAARRD (2012a); Añano et al. (2015); Flores et al. (2016); Consigna et al. (2019); Aya (2021) |
| Lobed river mullet, *Cestraeus plicatilis*[2] | DD | Overfishing | Basic research, survey, and population biology studies | | Closed season for fishing in the Cagayan River, fish size, and catch limit | Miele (2011); BFAR Administrative Circular No. 247 (2013); Martin (2019); Dumlao (2020) |
| Bombon sardine, *Sardinella tawilis* | EN | Fish cage operation, overfishing, and pollution | Biological and population studies | Establishment of Taal Lake Reserve Areas | Closed season, regulation of fish cages, and mesh size limit | Mutia et al. (2015, 2020, 2024); Cabico (2021); Philippine Fisheries Code of 1998 (1998/2015) |
| Giant trevally, *Caranx ignobilis* | LC | Fish cages, overfishing, pollution, and obstruction to the migratory path | Hormonally induced breeding | Pansipit River rehabilitation | Prohibition of obstruction of the structure in the Pansipit River | Estigoy et al. (2005); Luistro (2008); Muyot et al. (2018) |
| Asian catfishes, *Clarias batrachus* | LC | Habitat loss, overfishing, and alien invasive species | Artificial fertilization | | Banning of electrofishing, noxious, and poisonous fishing | Bombeo et al. (2002); Philippine Fisheries Code of 1998 (1998/2015) |
| Bighead catfishes, *Clarias macrocephalus* | DD | Habitat loss, alien invasive species | Artificial fertilization | | Banning of electrofishing, noxious, and poisonous fishing | Bombeo et al. (2002); Philippine Fisheries Code of 1998 (1998/2015) |
| *Sinarapan, Mistichthys luzonensis* | VU | Overfishing, lake-based aquaculture, pollution, and exotic fishes | Biological and population studies | Dismantling of illegal fish cages, fish sanctuaries | Banning of motorized fishnets; use of lakelets as fish sanctuaries | Zoleta (1987); Soliman (1994); Palma & Bartolome (2016); Soliman et al. (2021) |
| Freshwater Eels | *A. marmorata* (LC), *A. bicolour* (NT), *A. luzonensis* (V), *A. japonica* (EN) | Over-exploitation, habitat degradation, migration barriers, and pollution | Molecular identification and feeding management studies | | Fishery regulation and resource management: export ban on eel fry and fingerlings below 15 cm | FAO (2012); Hilario et al. (2022); Aya et al. (2023, 2024); Huervana et al. (2024); Casco et al. (2025) |

[1] https://www.iucnredlist.org/
[2] is recognized as an endangered species by the DA-Bureau of Fisheries and Aquatic Resources

### *Fish-Based Indices for Monitoring of Habitat Ecological Health*

The adoption of fish-based indices of biotic integrity (IBI) is strongly recommended as a standardized, science-based approach for monitoring freshwater ecosystem health (Karr, 1981). Native fish assemblages integrate the cumulative effects of water quality, habitat condition, hydrological alteration, and biological interactions, making them reliable indicators of ecological integrity (Ergönül et al., 2018; Gonino et al., 2020). Despite their proven utility globally, fish-based indices remain underutilized in Philippine inland waters, where monitoring often relies on physicochemical parameters alone (Corpuz et al., 2025). Developing region-specific IBI using native freshwater fishes, including gobies, silver therapon, catfishes, and other endemic fish species, would allow managers and conservationists to detect ecological degradation, evaluate conservation outcomes, and prioritize restoration actions. Different metrics such as species richness, trophic structure, proportion of native versus invasive species, and abundance of sensitive taxa can be calibrated to Philippine River types and lake systems (Qadir & Malik, 2009; Corpuz et al., 2025). Integrating IBIs into routine monitoring by DENR, BFAR, and LGUs would strengthen evidence-based decision-making and enable adaptive management amidst changing environmental conditions. Moreover, fish-based indices can serve as performance indicators for conservation interventions, such as habitat rehabilitation or stock enhancement programs, linking biological responses directly to management actions (Cooper et al., 2018). Capacity-building initiatives are needed to train local agencies and academic partners in fish taxonomy, survey methods, and data analysis. When combined with community participation and long-term datasets, fish-based indices provide a cost-effective and ecologically meaningful tool for safeguarding freshwater biodiversity while supporting sustainable fisheries governance.

Government funding should expand to intensify research on the population dynamics of ecologically valuable native freshwater fishes. Quantitative data on their recruitment, growth, mortality, and exploitation rates are essential for accurate stock assessment and conservation classification. Several riverine and lacustrine fish species remain data-limited (Froese & Pauly, 2023), resulting in uncertain status evaluations and weak management calibration. Long-term monitoring, reproductive biology studies, and stock assessment modeling are necessary to generate evidence-based policies and sustainable harvest regulations.

### *Government Intervention and Policy Integration*

Effective mitigation is largely dependent on coherent and sustained government intervention that integrates conservation, fisheries management, and rural development objectives (Agbayani & Toledo, 2008; Perez et al., 2012). While the Philippines possesses a comprehensive legal framework for fisheries and environmental protection, fragmented implementation and limited enforcement capacity have constrained conservation outcomes (Guerrero, 2014; Lim, 2026). Strengthening inter-agency coordination among BFAR, DENR, NFRDI, LGUs, and academic institutions is essential to harmonize policies on fishing regulations, aquaculture zoning, habitat protection, and species conservation. Species-specific management plans should be developed for high-value and threatened native freshwater fishes, incorporating science-based harvest controls, closed seasons, and spatial protection measures, while also expanding existing conservation initiatives, such as the FishCoRe Project (Philippine Fisheries and Coastal Resiliency Project), to include native inland fish species that remain underrepresented despite their ecological and fisheries importance.

Government investment in long-term research, monitoring, and conservation hatcheries must be institutionalized rather than project-based to ensure continuity. Importantly, conservation policies should be socially inclusive, recognizing the dependence of small-scale fisherfolk on inland fisheries. Livelihood diversification, incentives for compliance, and community-based enforcement can enhance policy effectiveness while reducing economic displacement and fishing pressure.

The information generated from this research provides the scientific basis needed to refine the Program on *Balik Sigla sa Ilog at Lawa* (BASIL, English translation: “Revitalizing Rivers and Lakes”) interventions by BFAR (DA-BFAR, 2020). This study is hoped to strengthen evidence-based planning by identifying priority native species, assessing habitat requirements, and evaluating watershed-scale threats for improved rehabilitation of inland aquatic ecosystems to restore fisheries productivity, biodiversity, and ecological function (Manalili, 2022). The present findings support adaptive management, improve stocking protocols, and ensure that restoration efforts align with long-term biodiversity conservation objectives and mandates of the BASIL program.

Integration of native freshwater fish conservation into national food security (e.g., proposed SB 2674 or the Philippine Native Animal Development Act), climate adaptation, and biodiversity strategies (e.g., RA 9147 or the

evance and unlock sustained funding for indigenous and endemic fish assemblages. Strong government leadership anchored in science and ecosystem-based management is indispensable for reversing the decline of Philippine native freshwater fishes and ensuring sustainable fisheries production.

## Conclusion

This review demonstrated that commercially important native freshwater fishes in the Philippines are experiencing persistent population declines caused by overexploitation, habitat degradation, invasive species, hydrological alteration, pollution, and weak enforcement of fisheries regulations. Although the reviewed species differ in ecological characteristics and distribution, a common pattern emerged in which conservation interventions remain fragmented, species-specific, and insufficiently integrated within broader watershed and fisheries governance frameworks. Existing initiatives such as closed fishing seasons, sanctuary establishment, habitat rehabilitation, export restrictions for eel juveniles, and conservation-oriented captive breeding have provided important foundations for resource protection. However, the review also revealed a reduced number of institutions, particularly in the Visayas and Mindanao Islands, actively engaged in long-term native freshwater fish conservation, research, hatchery development, and ecological monitoring. Many conservation activities remain project-based, geographically isolated, and dependent on limited institutional support, resulting in weak continuity of monitoring and management programs. The diminishing participation of research institutions, local conservation centers, and fisheries agencies further constrains the generation of baseline ecological data and the implementation of sustained restoration strategies. Sustainable conservation, therefore, requires stronger institutional commitment and inter-agency collaboration, integrating science-based fisheries regulation, watershed-scale rehabilitation, conservation aquaculture with genetic safeguards, and fish-based ecological monitoring. Strengthening long-term government support, academic participation, and community-based stewardship is essential to ensure the persistence of Philippine native freshwater fishes while safeguarding biodiversity, ecosystem function, and food security for future generations.

**Compliance with Ethical Standards**

**Conflict of interest:** The author(s) declare no actual, potential, or perceived conflict of interest for this article.

**Ethics committee approval:** The methodology of the study was reviewed and approved by the Ethics Review Committee of the Bataan Peninsula State University.

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