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Biodiversity and Ecosystem Services – Impact on Fish and Fisheries

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Abstract

Fish and fisheries play a dual role in human society as a crucial food source and a driver of biodiversity change in aquatic ecosystems. This paper reviews the global state of fish fisheries and their multifaceted impacts on biodiversity. Wild fish captures have plateaued in recent decades while aquaculture has expanded rapidly to meet rising demand, now contributing roughly half of the world's fish supply. Unsustainable fishing practices, including overfishing and destructive gear use, have led to widespread declines in fish populations and degradation of marine habitats. Approximately one-third of assessed fish stocks are overexploited beyond biological sustainability, and intensive fishing pressure has driven severe reductions in the abundance of large predator species . The collateral impacts of fisheries—such as bycatch of non-target species and physical damage to seabed habitats—further erode aquatic biodiversity. Aquaculture, while alleviating some pressure on wild stocks, introduces its own environmental challenges including habitat conversion, pollution, and genetic and disease interactions with wild species. Many marine species, from commercially important fish to sharks, sea turtles, and marine mammals, are now endangered primarily due to fishing activities. We discuss how improved management, conservation policies, and the inclusion of indigenous knowledge are helping to counter these trends. Effective measures—such as sustainable catch limits, habitat protection, bycatch mitigation, and community-led stewardship—are essential to balance fisheries with the preservation of biodiversity. Strengthening these efforts globally will be critical to maintaining healthy, resilient aquatic ecosystems and the essential services they provide to humanity.

Keywords: Overfishing, Aquaculture, Biodiversity, Ecosystem services, Conservation, Endangered species, Fisheries management, Indigenous knowledge

Introduction

Fisheries provide food and livelihoods for millions of people worldwide, but they also exert significant pressure on aquatic biodiversity. Fish and other aquatic organisms constitute an important source of protein for over 3 billion people and support the incomes of around 60 million fishers globally (FAO, 2024). Over the past half-century, global fish production has increased substantially to meet growing demand. Wild capture fisheries yields rose dramatically in the 20th century but have largely stagnated since the 1990s, while aquaculture (fish farming) has grown exponentially and now accounts for about 50% of fish consumed (World Economic Forum, 2022; FAO, 2024). This trend is illustrated in **Figure 1**, which shows the relative contributions of wild capture and aquaculture to world fish production over recent decades. The expansion of fishing effort and aquaculture has raised concerns about impacts on species and ecosystems. The **Intergovernmental Science-Policy Platform on Biodiversity and**

Ecosystem Services (IPBES) reported that direct exploitation of organisms (mainly fishing) is one of the largest drivers of marine biodiversity loss globally (IPBES, 2019). Unsustainable fishing practices can reduce target fish populations, alter food webs, and damage habitats, leading to declines in biodiversity and ecosystem health. At the same time, fisheries are deeply embedded in economic, cultural, and subsistence contexts, meaning that solutions must reconcile human needs with conservation. This paper examines the multiple dimensions of how fish fisheries affect biodiversity on a global scale. It covers the consequences of overfishing, bycatch, and habitat destruction; the environmental challenges posed by aquaculture; the status of endangered species impacted by fisheries; the role of policy and management in mitigating harm; the importance of fish for ecosystem services; and the contributions of indigenous fisheries management to biodiversity conservation.

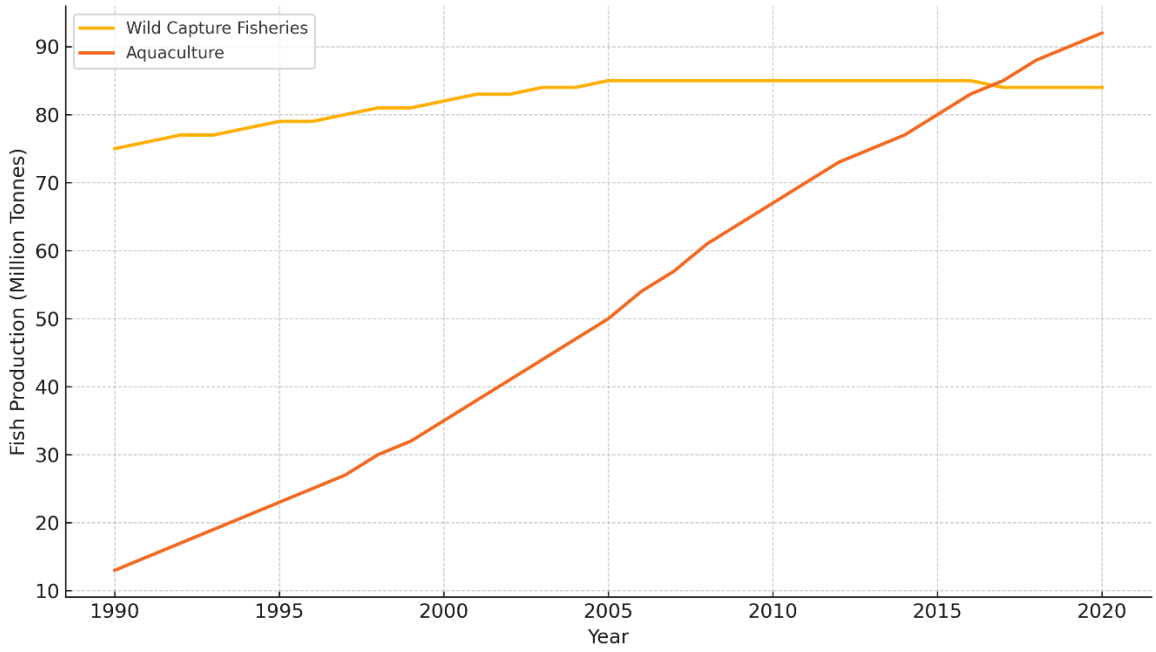

Figure 1. Global fish production by source (wild capture fisheries vs. aquaculture), 1990–2020. Wild capture yields leveled off in the 1990s while aquaculture output grew rapidly, overtaking wild catch in recent years. (Data source: FAO)

Overfishing and Ecosystem Impacts

Overfishing, the practice of harvesting fish faster than they can reproduce, has long been a major concern for marine biodiversity. According to the Food and Agriculture Organization (FAO), the number of overfished fish stocks worldwide has increased threefold since the 1970s (WWF, n.d.). As of 2019, about **34–35% of assessed fish stocks were classified as overfished**, up from only 10% in 1974 (FAO, 2022). By 2021, the proportion of overexploited stocks had risen further to roughly 37.5% (FAO, 2024). This means one in every three fish populations evaluated is being exploited beyond biologically sustainable limits. High fishing pressure has led to population collapses in some species; a well-known example is the Atlantic cod (*Gadus morhua*) off Newfoundland, which crashed in the early 1990s after decades of intense fishing, resulting in severe ecological and socio-economic consequences. When key species are depleted, there can be ripple effects throughout the food web. Predator-prey dynamics are disrupted as top predators decline, and smaller fish or invertebrate populations may irrupt or change in composition. Classic studies

have estimated that industrial fishing has **removed a large majority of large predatory fish** from the oceans – possibly up to 90% of the pre-industrial baseline for some species (Myers & Worm, 2003). Furthermore, fishers often shift to catching smaller, lower-trophic-level species once high-level predators become scarce, a phenomenon known as *"fishing down the food web"* (Pauly et al., 1998). This transition can fundamentally alter community structure, favoring fast-growing, short-lived species over slower, long-lived ones, and reducing overall marine biodiversity.

Bycatch – the incidental capture of non-target species – is another significant biodiversity impact of fisheries. Many fishing gears are non-selective, ensnaring marine wildlife such as dolphins, whales, sea turtles, seabirds, sharks, and non-target fish along with the intended catch. This unwanted catch is often discarded dead or dying back into the sea. Bycatch mortality has contributed to declines of numerous species. For instance, entanglement in gillnets and trawl nets kills hundreds of thousands of sea turtles and marine mammals each year (WWF, n.d.). Populations of seabirds like albatrosses and petrels have been severely reduced by longline fisheries, as the birds get hooked when diving for bait. Several small cetacean species have been pushed to the brink of extinction primarily due to fisheries bycatch – a prominent example is the vaquita (*Phocoena sinus*), a critically endangered porpoise in Mexico's Gulf of California, whose numbers have dwindled to fewer than 20 individuals as a result of entanglement in shrimp and totoaba gillnets. **Shark and ray populations** are also heavily impacted; beyond directed fishing for their fins and meat, millions of sharks are caught incidentally on longlines and nets. These fish are vulnerable to overexploitation due to slow growth and low reproduction rates. Overfishing and bycatch combined have driven **over one-third of all shark, ray, and chimaera species to become threatened with extinction** (Dulvy et al., 2021). Loss of such top and mid-level predators can cause mesopredator release (exploding populations of smaller predators) and altered competition dynamics, affecting the overall balance of marine ecosystems.

In addition to removing species, some fishing practices physically damage marine habitats, compounding the effects on biodiversity. **Destructive fishing methods** like bottom trawling and dredging scour and degrade seafloor communities. Trawl nets dragged along the seabed can destroy complex bottom structures such as coral reefs, seagrass meadows, and sponge gardens, which normally serve as important habitats for a variety of marine life. Repeated trawling in soft-bottom areas reduces habitat complexity and benthic biodiversity, analogous to clear-cutting a forest (Watling & Norse, 1998). For example, bottom trawling in the North Sea and other continental shelves has significantly reduced populations of bottom-dwelling organisms and reshaped benthic ecosystems. Likewise, **blast fishing** (using explosives) and cyanide fishing—illegal but still practiced in some regions—have obliterated sections of coral reef, one of the most species-rich marine ecosystems on the planet. The destruction of habitat not only directly kills resident organisms but also diminishes the ecosystem's capacity to support life, thereby lowering biodiversity in the long term. Overall, overfishing coupled with bycatch and habitat destruction has a devastating cumulative impact: it depletes populations of targeted and non-target species, erodes genetic diversity, and impairs the functioning of marine ecosystems.

Table 1. Major impacts of fisheries on biodiversity.

Impact Type	Description	Examples
Overexploitation of target species	Fish are harvested at unsustainable rates, causing	Atlantic cod collapse in the 1990s due to overfishing; 35% of fish stocks overfished globally.

	population declines and collapses.	
Bycatch of non-target species	Incidental capture and mortality of species not intended for catch.	Sea turtles and dolphins caught in tuna nets; seabirds hooked on longlines; sharks caught in trawls.
Destructive fishing practices	Use of gear or methods that physically destroy habitats and kill non-target organisms.	Bottom trawling damaging seafloor coral and sponges; blast fishing destroying coral reef habitat.
Trophic cascades and food-web shifts	Removal of key species alters predator-prey balance and community structure.	Decline of shark populations leading to increase in mesopredator rays, affecting shellfish populations; overfishing herbivorous fish causing algal overgrowth on reefs.
Illegal, unreported, and unregulated (IUU) fishing	Undocumented overfishing that undermines management and conservation efforts.	Poaching of high-value species like totoaba leading to vaquita bycatch; pirate fishing in high seas reducing fish stocks beyond quotas.

Aquaculture and Biodiversity

Aquaculture, the farming of fish and other aquatic organisms, has expanded dramatically and is now a cornerstone of global seafood supply. This rapid growth has helped meet the protein needs of a growing population and has the potential to relieve pressure on wild fish stocks (Naylor et al., 2000). In 1990, aquaculture contributed only around 13% of the world's fish production; by 2020 it accounted for roughly **49% of global fish, crustacean, and mollusk supply** (World Economic Forum, 2022). In absolute terms, aquaculture output rose from under 20 million tonnes in 1990 to over 100 million tonnes by the late 2010s (FAO, 2024). However, the expansion of aquaculture has introduced **new challenges for biodiversity and ecosystem health**. Fish farming interacts with the environment in ways that can negatively impact wild species and habitats if not managed sustainably.

One major concern is the **conversion of natural habitats** into aquaculture facilities. Coastal ecosystems such as mangrove forests, wetlands, and estuaries have been cleared and modified to create space for shrimp ponds, fish cages, and other farm infrastructure. Mangrove forests are particularly affected: these biodiverse coastal forests serve as nurseries for many marine species and protect coastlines, but large swaths have been destroyed for shrimp aquaculture in parts of Southeast Asia, Latin America, and other tropical regions. It is estimated that commercial shrimp farming has contributed to approximately 30–38% of historical global mangrove loss (Barbier et al., 2011). The loss of mangroves and wetlands means a loss of breeding and feeding habitat for countless species (fish, crustaceans, birds, etc.), thus reducing local biodiversity. Additionally, the clearing of mangroves removes the natural services they provide, such as water filtration, carbon sequestration, and coastal protection. Inland aquaculture can similarly lead to habitat modifications, for example the draining of wetlands or conversion of rice paddies to fish ponds, potentially threatening freshwater biodiversity.

Aquaculture's reliance on wild fish for feed has been another point of intersection with biodiversity. Many farmed species (notably carnivorous fish like salmon, trout, and shrimp) are fed with pellets containing fishmeal and fish oil derived from wild forage fish (e.g., anchovies, sardines, menhaden). In the past, a significant fraction of global wild catch – often lower-trophic, small pelagic fish – was reduced to

fishmeal/oil to support aquaculture. This raised the paradoxical concern that aquaculture could *increase* pressure on wild stocks if the feed input exceeded the farmed output (Naylor et al., 2000). However, there have been improvements in this area: feed conversion ratios have improved and alternative ingredients (plant proteins, algae, etc.) are increasingly used, resulting in a declining use of wild fish per unit of farmed fish produced (FAO, 2024). Today, roughly 10–15% of wild fish catch is diverted to aquaculture feed, and this percentage has stabilized or decreased over time with better practices (FAO, 2020). Nonetheless, localized depletion of forage fish for feed can occur, which may affect marine food webs and the predators (seabirds, larger fish, marine mammals) that rely on those small fish.

Finally, the physical and chemical outputs from aquaculture can impact local ecosystems. Fish farms often release **nutrient-rich waste**, including uneaten feed and excreta, into surrounding waters. In coastal areas or lakes with many farms, this can lead to nutrient loading, algal blooms, hypoxia, and other symptoms of eutrophication that harm water quality and wild organisms. Benthic communities beneath fish cages can be smothered by waste accumulation. Farm operations also sometimes involve intentional or accidental release of pollutants—such as antibiotics, pesticides (used to treat sea lice), and disinfectants—that can affect non-target species and contribute to issues like antibiotic resistance in environmental bacteria. Aquaculture of filter-feeding bivalves (oysters, mussels) or seaweed tends to have a lower negative footprint and can even provide some ecosystem benefits (filtering water, absorbing excess nutrients), whereas fed aquaculture of finfish tends to have higher environmental impacts if not carefully managed. In summary, **aquaculture can pose significant risks to biodiversity** through habitat modification, species invasions, disease spread, feed sourcing, and pollution. However, these impacts are not inevitable—best practices and new technologies can greatly mitigate them. For instance, integrated multi-trophic aquaculture (IMTA) systems combine species like fish, shellfish, and seaweed to recycle nutrients and reduce waste. Shifting feed composition away from wild fish, strengthening containment to prevent escapes, and siting farms in environmentally suitable locations are other strategies. As aquaculture continues to grow, implementing such sustainable practices is critical to ensure that the blue revolution complements rather than compromises biodiversity conservation (Diana, 2009).

Endangered Species and Fisheries

Intense fishing pressure has pushed many aquatic species to the brink of extinction, making overfishing a leading threat for numerous marine animals now listed as endangered or critically endangered. Unlike terrestrial fauna, relatively few marine fish species have gone completely extinct in modern times, but the **depletion in their populations** has been severe, and extinction risk is growing for certain groups. The **IUCN Red List** assessments show that fisheries exploitation is a primary threat for a large share of marine species that are considered threatened. For example, reef-building corals and seagrasses are threatened mostly by climate change and habitat impacts, but for marine fishes, overfishing is the dominant concern. Among the most imperiled are the **sharks and rays (Elasmobranchii)**. These species generally have life-history traits (slow growth, late maturity, few offspring) that make them exceptionally vulnerable to overexploitation. A comprehensive global study by Dulvy et al. (2021) revealed that **over one-third (approximately 37%) of all shark, ray, and chimaera species are now threatened with extinction**, primarily due to overfishing. This includes iconic species such as hammerhead sharks, manta rays, and sawfishes. Sawfishes, in particular, are one of the most endangered families of marine fish – all five species of sawfish are critically endangered, largely because they are easily entangled in nets (bycatch) and were historically over-harvested for their toothed rostra. Oceanic pelagic sharks like the oceanic whitetip and

various requiem sharks have seen population declines exceeding 70% in the past 50 years (Pacoureau et al., 2021). The **global abundance of oceanic sharks and rays has declined by an estimated 71% since 1970** due to an 18-fold increase in fishing pressure (Pacoureau et al., 2021). Such drastic reductions heighten the risk of these species becoming ecologically or even literally extinct. The collapse of shark populations can have cascading effects on marine ecosystems, as sharks often regulate the populations of mid-level predators and maintain healthy food web dynamics.

The endangered status of so many marine species underscores a key point: **biodiversity loss in the oceans is largely driven by fishing activities**. Unlike habitat loss or climate change – which are significant but often more diffuse or gradual in their effects – overfishing can rapidly reduce species abundances. The good news is that if fishing pressure is reduced in time, many marine species have the capacity to recover given their often high fecundity and dispersal. We have seen examples of partial recovery: humpback whale populations have rebounded after whaling ceased; some fish stocks like Atlantic swordfish and certain cod stocks have improved under strict quotas. However, the window for recovery closes once populations get too low or fragmented (as with the vaquita or some sawfish). Protecting endangered marine species thus requires urgent action to curtail unsustainable fishing and bycatch. Conservation tools include species-specific protections (e.g. bans on catching sawfish, shark finning bans, turtle protection laws), bycatch mitigation requirements, and the establishment of marine protected areas or fishing closures in critical habitats. International agreements, such as CITES listings for threatened sharks and rays or the newly signed high-seas biodiversity treaty, also aim to regulate exploitation of vulnerable species. In summary, **overfishing has brought many aquatic species to precarious status**, but through targeted conservation measures and better fishery management, it is possible to prevent extinctions and promote the recovery of these species in the wild.

Ecosystem Services and Ecological Roles of Fish

Beyond their direct economic value, fish and other aquatic organisms play critical **ecological roles and provide ecosystem services** that are fundamental to the health of the planet's waterways and oceans. Biodiversity in fish communities is closely linked to the delivery of these services. When fisheries diminish fish populations and alter community composition, there can be a loss or degradation of important ecosystem functions. Understanding these services highlights why conserving fish biodiversity is not only an ethical or aesthetic concern, but also a matter of maintaining the natural processes that support life (including human life).

One key ecosystem service provided by fish is the **regulation of food web dynamics**. Many fish are predators that keep populations of their prey in check, preventing any one species from monopolizing resources. For example, on coral reefs, predatory fish (like groupers and snappers) help control populations of smaller fish and invertebrates, maintaining a balance that supports coral health. If overfishing removes too many predators, prey species can overpopulate and overgraze or otherwise harm the ecosystem. Conversely, certain fish are herbivores that graze on algae; these fish (e.g., parrotfish, surgeonfish on reefs) are crucial for preventing algae from overgrowing and smothering corals. Overfishing of herbivorous fish in some regions has contributed to algal-dominated reefs and the decline of coral ecosystems.

Conclusion

Fish fisheries have a profound impact on global biodiversity, presenting one of the great conservation challenges and opportunities of our time. On the one hand, fisheries are indispensable for food security,

nutrition, and economic development – millions of people depend on fishing for their livelihood and billions rely on fish for animal protein. On the other hand, decades of overexploitation and unsustainable practices have led to significant biodiversity loss in the world's oceans and freshwaters. **Overfishing** has reduced the populations of numerous species, altering ecosystem structures and even driving some species toward extinction. We have seen how roughly a third of fish stocks are overfished and how cascades can occur when key species, such as apex predators or critical herbivores, are removed. Bycatch and habitat destruction associated with fishing further compound these effects, causing harm to non-target species (from sea turtles to corals) and degrading the environments that fish and other marine life require to thrive.

Yet, there is reason for cautious optimism. Fisheries, unlike some other threats to biodiversity, are something we can manage and improve with the right approaches. Cases of stock recovery and reduced impacts show that with science-based management, enforcement, and community engagement, it is possible to fish in a way that sustains both the resource and the broader ecosystem. Effective policy tools – such as catch limits aligned with scientific advice, protected areas, and bycatch reduction measures – have demonstrated success in various parts of the world. These successes need to be broadened and replicated, especially in regions where governance and resources for management are currently lacking. International cooperation will be key: fish do not respect political boundaries, so managing transboundary and high-seas fisheries requires collective agreements and compliance by all parties. The recent momentum in global policy (e.g., the 30x30 ocean protection goal, treaty agreements to curb harmful subsidies and manage high-seas biodiversity) indicates growing recognition of the urgency to protect marine life.

Aquaculture's rise offers both a relief and a cautionary tale. It has the potential to provide sustainable protein and reduce pressure on wild stocks if developed responsibly. However, as we discussed, aquaculture must be managed to avoid replacing one set of biodiversity problems with another. Continued innovation in feed, disease control, and farm siting – guided by principles of ecology – will be necessary to minimize aquaculture's footprint. Integrating aquaculture into an ecosystem perspective (for example, multi-trophic farming or restoration aquaculture for species like shellfish) could even help enhance biodiversity and ecosystem services in some contexts.

Finally, maintaining fish biodiversity is essential not only for nature's sake but for the myriad **ecosystem services** that underpin human well-being – from productive fisheries to coastal protection and cultural heritage. In a world facing climate change, resilient ecosystems will be crucial; diverse fish communities will help oceans and freshwater systems buffer against and adapt to changes such as warming temperatures and shifting currents. Thus, conserving biodiversity in fisheries is part of building climate resilience too.

In conclusion, fish fisheries and biodiversity need not be in conflict. With concerted effort, informed by science and tradition, we can move towards **sustainable fisheries that coexist with rich biodiversity**. This entails setting harvest limits that ecosystems can bear, protecting habitats, reducing wasteful bycatch, combating illegal fishing, and sharing governance with those on the frontlines of fishing. The challenge is immense, but the benefits of success – healthy oceans and rivers teeming with life, and fisheries that can provide for future generations – are well worth the effort. Achieving this balance is a critical component of global biodiversity conservation and of securing the benefits that nature provides to humanity.

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