*Turk. J. Fish.& Aquat. Sci. 25(11), TRJFAS27643*
https://doi.org/10.4194/TRJFAS27643

Turkish Journal of FISHERIES and AQUATIC SCIENCES

RESEARCH PAPER

# Farm-Raised Versus Wild Caught Fish: Which is Better?

**Erkan Can[1], Esin Özçiçek[2], Nida Demirtaş Erol[3], Brian Austin[4,*]**

[1]Fisheries Faculty, Department of Aquaculture, İzmir Katip Çelebi University, İzmir, Türkiye.
[2]Fisheries Faculty, Department of Aquaculture, Munzur University, 62000 Tunceli, Türkiye.
[3]Fisheries Faculty, Department of Fish Processing, Munzur University, 62000 Tunceli, Türkiye.
[4]Institute of Aquaculture, University of Stirling, Stirling, FK9 4LA, Scotland, U.K.

**How to Cite**

Can, E., Özçiçek, E., Erol, N.D., Austin, B. (2025). Farm-Raised Versus Wild Caught Fish: Which is Better? *Turkish Journal of Fisheries and Aquatic Sciences*, *25(11)*, *TRJFAS27643.* https://doi.org/10.4194/TRJFAS27643

**Article History**
Received 30 December 2024
Accepted 29 April 2025
First Online 13 May 2025

**Corresponding Author**
E-mail: baustin5851@gmail.com

**Keywords**
Aquaculture
Sustainability
Health
Freshness
Nutrition
Fisheries

## Abstract

There has been much discussion about which is better, farmed (= aquaculture) or wild-caught fish (= capture-fisheries), with supporters and opponents of both approaches. On balance, aquaculture should be the better option because of the ability to control all aspects of production. The result is that farmed products are often cheaper than wild-caught equivalents. However, there are negative aspects to aquaculture, including habitat destruction, for example the removal of mangroves for the construction of shrimp farms, the effect of escapees on native fish populations, and the possible negative impact of pollution from organic material, pathogens and antimicrobial compounds. The use of wild-caught "trash" fish as a source of protein and oil for the diets of carnivorous fish species in aquaculture is unsustainable. In contrast with wild-caught fish, there is greater variability in supply because of overfishing, quotas imposed by governments, and the effects of adverse weather. Moreover, fishing in distant waters is expensive and hazardous. Certainly, the quality of the product is more difficult to control because the history of the catch is largely unknown. However, there are concerns about illegal fishing activities, and the capture of undersized specimens which impacts negatively on future stocking levels. For the forseeable future, there will be roles for both aquaculture and capture-fisheries to meet the increasing global demand for aquatic food.

## Introduction

Fish farming, i.e. aquaculture, developed 4000 years ago in China when common carp (*Cyprinus carpio*) were raised in earthen ponds (Fan Lei 475 BCE. The Classic of Fish Culture; Nash, 2011). Since then, aquaculture increased steadily, such that according to the Food and Agriculture Organization (FAO) in 2022, aquaculture production worldwide actually exceeded production from fisheries for the first time, reaching a production volume of 130.9 million tonnes. The transformation strategy presented by FAO under the name of "Blue Transformation" focuses on the growth of aquaculture, sustainable fisheries and the strengthening of aquatic product value chains, and aims to provide solutions to global problems, such as food security and poverty alleviation (FAO, 2024).

Fish consumption is considered an essential part of a healthy diet, and stands out as a rich source of omega-3 fatty acids, protein, vitamins and minerals. However, the increasing demand for aquatic foods and the decreasing natural resources raise questions about the supply, both from an individual and environmental perspective. Currently, consumers are forced to choose between farm-raised fish (FRF) and wild-caught fish (WCF = capture-fisheries) obtained from seas, rivers and lakes. By way of clarification, a fish species that inhabits the natural aquatic environment throughout its whole life is regarded as wild (Dunham & Su, 2020; Dvoretsky & Dvoretsky, 2024). Each of the options for aquaculture

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Türkiye

and capture-fisheries has advantages and disadvantages, including nutritional value, environmental impacts, sustainability and cost.

It is apparent that there is not universal support for aquaculture, with criticism from tourist organizations and capture fisheries (Cao et al., 2013; Melikh et al., 2019). This begs the question, which is better aquaculture or capture-fisheries? This report aims to provide guidance for consumers to make more informed choices by addressing the different strengths and weakness of farmed and wild fish production, including aspects of health, sustainability and effects on the environment.

**Nutritional Profile**

Fish is an important source of nutrients, and has been accepted as a healthy component of any well-rounded diet, promoting longevity and an anti-inflammatory state (Grigorakis et al., 2002; Orban et al., 2003; Özçiçek, 2018; Yerlikaya & Yatmaz, 2025). Moreover, wild-caught and farmed aquatic foods tend to be superior to terrestrial products for human nutrition and health in terms of the higher more readily digestible protein content reflecting the essential amino acid content, especially lysine and methionine, and less saturated fat but more long-chain omega-3 polyunsaturated fatty acids. In addition, aquatic animal foods are excellent sources of essential minerals and trace elements, including calcium, copper, iron, magnesium, manganese, phosphorus, selenium, sodium and zinc. Also, there are superior levels of vitamins, namely vitamin A, $B_3$-niacin, $B_3$-nicotinamide, $B_5$-pantothenic acid, $B_6$-pyridoxal $B_{12}$, C, D, E, choline and folic acid (Grigorakis et al., 2002; Orban et al., 2003; Tacon & Metian, 2013; Özçiçek, 2018; Mohanty et al., 2019; Yerlikaya & Yatmaz, 2025). However, as a consumer, it may be difficult to understand the differences and to make informed choices about which foods are best especially as there may be a seasonal effect on the precise nutritional content of the fish. In the case of wild-captured and farmed gilthead sea bream there were minimum and maximum amounts of muscle and total fat in late spring and late summer, respectively (Grigorakis et al., 2002). This is an important aspect as the differences in type and quality of fish have the ability to affect health. Often, health experts recommend choosing WCF because of its alleged superior health benefits to farmed products (Wang et al., 2024). However, many fish markets now promote sustainably FRF as a healthier alternative (URL-1, 2024).

Fish is an excellent source of poly unsaturated fatty acids (PUFA). Oily fish, such as trout, sardines and salmon, are better sources of PUFAs than leaner fish, namely catfish, halibut and cod (Chen et al., 2022). When comparing different types of fish, the risk of coronary heart disease appears to be more strongly associated with consumption of oily than with lean fish (Oomen et al., 2000; Mozaffarian et al., 2003). Arguably, increasing the consumption of fish and their products that are rich in n-3 PUFA and poor in n-6 PUFA series is important for human health (Burr, 1989; Sargent, 1997). Eicosapentanoic acid (EPA) and docosahexenoic acid (DHA) belong to the family of n-3 fatty acids, whose beneficial effects on human health are well known; they have protective effects on coronary heart disease, cardiovascular disease, inflammatory and autoimmune disorders, and have important roles in the development of the nervous, photoreceptor and reproductive systems (Simopoulos, 2006; Amoussou et al., 2019).

Fish provide an important source of protein, which is a basic component of all animal tissues. These proteins are essential for growth, and are also important sources of energy (NRC, 1993).

However, there is insufficient evidence to support that either FRF or WCF are better in terms of nutrient density, and thus, it is the consumers who determine preferences (Verbeke et al., 2007).

**Wild-caught Fish**

Wild fish are chasing food in order to survive, they have to move constantly in order not to become prey for larger creatures (Adriaenssens & Johnsson, 2011). Adverse environmental conditions during hunting of wild fish may cause increases in stress levels, which reduces meat quality (Johnston et al., 2006). Yet, wild fish have some advantages over farmed species. Thus, the food groups that these fish consume are unlimited, and depending on the nutrient content of the water, may contain higher levels of important fatty acids than cultured species (Aslan et al., 2007).

**Farm-raised Fish**

Intensively farmed fish will be fed with artificially prepared feeds according to their species and external development conditions (URL-2, 2024). In particular, cultured fish are fed with higher energy feeds compared to wild fish in order to develop faster, and be delivered to the market as quickly as possible (Yüngül & Özdemir, 2017). Thus, FRF will develop faster and be larger than their counterparts in nature.

However, whereas cultured fish live in a limited fimite area within aquaculture facilities, wild fish have the opportunity to move in extensive geographical areas. For this reason, FRF will develop faster and be fatter than the counterparts in natüre. This situation is viewed as a negative aspect of aquaculture during the sales and storage phase. In particular, the shelf life of farmed fish is inevitably shorter because of their high oil content compared to animals obtained from the wild (Navarro-Segura et al., 2020).

In aquaculture, feeding is stopped prior to sale ensuring that the stomach is empty and therefore digestive enzymes are unable to perform their full function, and the meat quality does not deteriorate (URL-2, 2024). The presence of key nutrients in the feed, such as omega-3 fatty acids, give farmed fish an advantage over wild specimens. Thus, farmed fish are generally richer in monosatuated/unsaturated fatty acids than those from the wild (Özçiçek, 2018). Certainly, most farmed fish have been found to contain higher levels of lipids than wild-caught individuals (Hossain, 2011). However, when fatty acid differences are examined, total PUFA and n-3 PUFA contents are usually higher in wild compared to farmed fish. Yet in terms of n-6 PUFAs, the difference between farmed and wild fish is unclear. Possibly, this difference in n-3 PUFA composition in lipids of farmed and wild fish may reflect the actual fatty acid composition in their respective diets (Hossain, 2011). Commercial feed using high levels of fish meal and fish oil generally contain higher levels of n-3 PUFA and lower amounts of n-6 PUFA. Therefore, feeding such commercial diets will lead to higher levels of n-3 PUFA in fish muscle (Hossain, 2011). In particular, farmed trout has been recommended as "a good source of PUFA, vitamins D and K, and essential amino acids for humans" (Özçiçek, 2018).

It has been suggested that the n-3/n-6 ratio is a better index for comparing the relative nutritional values of different species (Piggot & Tucker, 1990). Thus, a high n-3/n-6 ratio plays an important role in reducing cardiovascular diseases (Cahu et al., 2004). Generally, the higher the n-3/n-6 ratio, the better that the body may use n-3 fats. Fish with a high n-3/n-6 ratio should be recommended for consumption (Hossain, 2011). Fish species, sex, age, body size, seasonal changes, presence in different tissues and organs, water temperature, nutrition and environmental conditions, are the factors affecting fatty acid composition (Özçiçek et al., 2022).

Farmed fish generally have lower levels of EPA and DHA than wild individuals (Hossain, 2011). Research has shown that protein and cholesterol levels are similar in wild and farmed fish, whereas some vitamin levels may be higher in the latter (Hossain, 2011). Overall, it has been concluded that farmed fish are better in terms of nutritional value than wild-caught specimens (Özçiçek, 2018). In a direct comparison of farmed and wild-caught sea bass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*), Orban et al. (2003) reported that farmed animals had significantly higher lipid content. Furthermore, Fuentes et al. (2010) compared wild and farmed seabass, and determined that the latter had higher levels of alanine, glutamic acid, glycine and histidine, and less arginine, methionine, serine and taurine than wild-caught specimens. Certainly, farmed fish have the advantage of being raised and harvested under controlled conditions, making it easier to detect and control the dangers associated with fish consumption (Fuentes et al., 2010). It may be concluded that farmed fish raised under appropriate conditions and dietary regimens, provide consumers with a nutritional composition that is as good, if not better, than that provided by wild-caught animals (Hossain, 2011).

**Sensory Properties of Wild and Farmed Fish**

Sensory characteristics, including flavor, consistency and other properties perceived by the senses, play a significant role in food products (Mihafu et al., 2020). When it comes to fish, these sensory characteristics offer further insight into the species and the habitat in which it resided. Additionally, the sensory characteristics could potentially impact consumer behavior, influencing their willingness to purchase a product (Krešić et al., 2022).

The sensory attributes of fish are crucial for both experts and consumers when selecting recipes. Generally, WCF possess a harder/firmer texture than farmed specimens because of their natural diets and superior muscle quality. Often, farmed fish have a softer texture (Chen et al., 2022). Indeed, diet and muscle composition influence flavor and texture. Also, the cooking method and color affect texture (Du et al., 2022). It is accepted that overcooking compromises quality of the meal (Stormo & Skåra, 2023). Altering physical attributes of the fish is crucial for enhancing attractiveness. For example, grilling leads to superior texture than fried or steamed fish. Also, flakiness influences the consumption experience (Nishinari, 2020).

The flavor profile of wild and farmed fish is the primary sensory attribute recognized by most individuals. Wild adult fish that grow slowly typically possess a more intricate and powerful flavor than their farmed counterparts (Bøhn et al., 2024). Elements influencing flavor comprise feed, physical activity, salinity, phenolic chemicals, water temperature and seasonality (Ma et al., 2023). Commonly, wild fish consume plankton, crustaceans and smaller fish, such as herring, hake or whiting (Kumar et al., 2021). Undoubtedly, diet influences the flavor of both wild and farmed fish. The former receive a varied diet and have highly developed senses. Indeed, research has indicated that wild fish are favored in blind studies (Ma et al., 2023).

A variety of environmental components may affect the flavor of fish. These components, such as algae, invertebrates, nutrients, metal ions and dissolved gases present in the fish's surroundings, may impact the overall taste (Zhang et al., 2023). Typically, wild fish have a more intricate aroma profile than farmed fish, which is attributed to their natural habitats. In terms of taste perception, wild fish are often described as having a richer flavor profile compared to farmed fish. This is due to the varied diet and natural environment of wild fish (López-Mas et al., 2021). Also, the flavor is influenced by the chemical composition, oral physiology and environmental background of the consumer. Even fish raised in similar conditions may have varying taste profiles (Du et al., 2022). Moreover, cultural influences may also exert a role in how fish flavor is perceived, making it essential to consider these factors when comparing the taste of wild versus farmed fish

(Wang et al., 2022).

Variations in the flavor of wild and cultivated fish stem from the distinct ecological conditions present in their respective habitats. When examining the flavor of fish, one should not disregard the nutritional worth and health advantages of fish lipids, which, for wild populations, vary depending on the season and diet. The operational attributes, dietary worth and muscle composition are variables that affect the flavor assessed by a trained taste panel, consumer or instrumental approach. Distinctions in taste are evident in the most sought-after fish species globally, and include salmon, trout, and eel. This prompts the question: what influences these differing tastes? (Bekhit, 2022) What are the causes for the variations in taste among these fish categories, and which factors should be considered as the benchmark for comparison? Additionally, the effects of dietary alterations and the selection of superior-tasting fish for future aquaculture are under scrutiny (López-Mas et al., 2021).

The gustatory perception of fish is a crucial factor in determining its nutritional value, with taste and aroma being highly subjective to individual preferences (Pu et al*.,* 2024). Trained panels utilize a standardized approach to evaluate the taste of fish, which may be impacted by pigments and compounds with potential health benefits (Monteiro & Almeida Costa, 2024). These taste-shaping compounds encompass fatty acid composition, myofibrillar and sarcoplasmic proteins, aroma compounds, nucleotide breakdown products and collagen content. The amalgamation of these variations collectively contributes to the overall taste of the fish. Research has predominantly focused on salmon, rainbow trout, and eel, which are the primary species in aquaculture, and with a focus on traits, such as fishy taste and aroma. Notably, these species possess distinctive nutritional and sensory attributes, including variations in lipid content and color properties, which influence their taste (Wang et al., 2022).

**Environmental Impact**

Aquaculture may be environmentally problematic if not managed well. Issues including water pollution, habitat destruction, disease spread to wild fish populations and antibiotic use may arise. Typically, there may be use of substances that may be regarded as contaminants, such as phosphorus and nitrogen, which are used in feed and chemicals destined for aquaculture (Jeanson et al., 2022). Integrated Multitrophic Aquaculture (IMTA) is an environmentally friendly approach that may be used for mitigation of the harmful environmental compounds from the aquatic ecosystem (Azhar & Memis (2023). Otherwise, these chemicals may overstimulate algal growth when released into the environment, resulting in blooms. In addition to reducing the oxygen concentrations that fish tolerate, some micro-organisms (e.g. cyanobacteria) release toxins into the water that may harm fish (Brooks et al., 2016). However, there are some positive developments concerning fish nutrition in aquaculture. Thus, complementary protein feedstuffs of various origins have been identified, and are now regularly included in aquafeeds to lessen dependence on fishmeal. As such, feedstuffs of marine origin have become strategic ingredients, typically used at lower inclusion levels, to extend their availability and used in aquafeeds to support increased aquaculture production. Traditional as well as novel protein feedstuffs will continue to be developed and used in aquafeeds to support expanded production of seafood by aquaculture to meet the demands of a growing world population (Gatlin, 2024). Natural components are added to feed, such as insects, in addition to vegetable protein sources. Besides, advancements in sustainable aquaculture practices are improving, and some farms are regarded as eco-friendly (Austin et al., 2022).

The phenomenon of overfishing is a major concern for wild populations, and was first documented in the 19th century when it was discovered that whale fat could be used to make lamp oil. This led to a huge increase in whaling, bringing the species to the brink of extinction (URL 3). Shortly thereafter, in the middle of the 20th century, some of the most common fish, such as herring, sardines and cod, were overfished almost to extinction (Du et al*.,* 2021). Bycatch and discards are also significant issues for global fisheries, with the latter considered as causing unnecessary mortalities and wasted fishing opportunities (Lively & McKenzie, 2023). Certain fishing methods may damage ecosystems. A topic example is trawling that harms the ocean floor and thus bottom dwellers. However, sustainable wild fisheries do exist and use responsible fishing practices (Boyd et al., 2020).

Another issue concerns escapees from farms to waterways, which leads to competition for food, predation pressure, hybridization effects, and the spread of farm-originating diseases to natural stocks, such as has been reported for salmon stocks (Naylor et al., 2005). Clearly, attention is needed to minimize the risk of escapees, which could have a detrimental effect on wild stocks.

In addition to the more obvious environmental concerns, increased harvesting of small fish from marine and inland waters often as a source of fish meal [= protein] to feed the growing aquaculture industry is placing additional pressure on capture fisheries. Thus, there is a conflict of interest in fisheries (= hunting) versus aquaculture. There is an argument that if small fish, e.g. *Sardina*, are not used in aquaculture, big fish will consume them in natüre. So, who will get the added value? Of course, the answer is "fishermen". As a result, small fish, which comprise the diets of big fish in the natural environment, are given to cultured fish. This raises the question about who has the right? Which is more economical? If there are not any cultured fish, will the fishing pressure not increase? These are still ongoing discussion topics. Consequently, both aquaculture and wild-capture fisheries have environmental impacts, but with proper management and sustainable practices, both approaches may be less damaging to the environment. However, both approaches have their own challenges, given the environmental impacts of overfishing of wild fish and the high-intensity production processes of farmed fish.

**Sustainability**

**Farm-raised Fish**

Are aquaculture and capture fisheries sustainable? Overall, the goal of aquaculture is continued expansion, although this is likely to be focused particularly in Asia, North Africa and South America. However, aquaculture requires the availability of suitable sites, which for the future may well focus on offshore and deep water. This has particular relevance for offsetting the effects of global warming. Moreover, sites need to be chosen after consideration of the needs of other uses, including tourism, sports fishermen and energy generation (Galparsoro et al., 2020). In short, aquaculture must function as an integral part of food production, and reflect all societal needs. Certainly, the establishment of coastal sites needs to consider the effects on the environment. For example, the destruction of mangroves for the location of shrimp farms has ecological implications insofar as important habitats/breeding grounds for many species would be removed impacting adversely on native aquatic populations and biodiversity (Hasan et al., 2024). However, aquaculture has a fundamental need for adequate quantities of clean water, free of pollutants including sewage discharges and run off from the land. Of note, in one study, it was reported that mariculture was not significantly affected by industrial wastewater. Instead, urban domestic sewage had a more pronounced effect (Yuan et al., 2021). It is clear that sites need to be well separated from others otherwise the effluent from one is effectively the inflow for another, thus spreading possible pathogens and parasites, and bioactive molecules, e.g. antibiotics (e.g. Asche et al., 2022). A recent concern is the occurrence of microplastics in aquaculture systems, and the impact on human health (Su et al., 2024). In short, aquaculture should not be a polluter of the aquatic environment. Then, there is the largely unknown effect of environment/climate change, specifically oceanic warming and acidification, which may adversely affect the survival of species in aquaculture operations (Baag & Mandal, 2022). Interestingly, winter warming in Tasmanian waters may be beneficial for Atlantic salmon production/growth but not so hotter summers that would be too warm for optimal growth, leading to mortalities among the fish populations (Meng et al., 2022). Thus, warmer water temperatures may have advantages but also disadvantages for aquaculture. Yet, it is concluded that offshore sites may have less temperature variatons/extremes than coastal zones. Clearly, there needs to be careful planning to ensure the future success of aquaculture (Mengual et al., 2021). Fortunately, site selection is now aided by computer software that assist with decision making particularly with view to reducing the impact of aquaculture sites on the vicinity (Puniwai et al., 2014; Falconer et al., 2020). It is encouraging to note that recirculation offers a solution for when water is scarce (Ahmed & Turchini, 2021).

To be sustainable, aquaculture needs to be self-sufficient in terms of the total production regime from adults to eggs to hatchlings to marketable product, as happens with salmonids, for example pikeperch (*Sander lucioperca;* Wuertz et al., 2023). There should not be reliance on sourcing broodstock and/or eggs from the waterways as has happened with shrimp production, previously (Hoang et al., 2024). Indeed, there are advantages in relying on domesticated stock as data from Vietnam showed that postlarval tiger shrimp (*Penaeus monodon*) from farmed individuals produced larger adults with higher sales value than those derived from wild-caught broodstock (Hoang et al*.,* 2024).

The provision of high-quality food is a constraint particularly for carnivorous fish when the source of protein and oil is derived mostly from trash fish that are plundered from the oceans and seas. This practice is clearly not sustainable and poses a major challenge for aquaculture, although there is progress with using plant-based protein and oil (Boissy et al*.,* 2011; Mugwanya et al., 2023). İn addition, there is interest in using land-based insects as protein for fish feeds although there could be issues with acceptability by consumers (Goglio et al., 2022; Roccatello et al., 2024). These approaches would help improve the sustainability of fish feed destined for carnivorous species.

Aquaculture is useful for restocking waterways, and for seeding with juveniles for ongrowing as a source of food (obtained by capture fisheries) and for sporting activities, i.e. sports fishermen (e.g. Aura et al., 2023).

The message is that aquaculture can be sustainable, and reduces the strain on capture fisheries. Certainly, some species are farmed more sustainably than others. For example, molluscan farming tends to have a lower environmental impact, is considered as a "green" industry and is extremely sustainable (Tamburini et al., 2020). Yet for this example, it is apparent that there are issues with the disposal of shell waste although effective remedial measures, e.g. the use of shells for creation of artificial bio-reefs, are under consideration (Corbau et al*.,* 2023). Also, aquaculture has generated concerns about the adverse effects of water quality, and possible genetic interactions between farmed and wild stock (Asche et al*.,* 2022). Fortunately to date there is minimal evidence for disease transmission from aquaculture to wild fish stocks in northern and Arctic regions attributable to the low numbers of fish farms in these areas. However, the situation may well change as aquaculture develops in the north (Vollset et al*.,* 2021).

**Capture Fisheries**

There is ongoing concern about the effects of overfishing and the collapse of fish stocks (e.g. Asche et al., 2022; Pham et al., 2023). This is particularly troublesome for local communities that rely on small scale fishing operations where the issues are not only overfishing but the capture of immature individuals before reaching maturity and thus reducing the opportunity to breed (Gough et al., 2020). Fortunately, there is evidence that reducing overfishing lead to stock recovery (Villasante et al*.,* 2022). However, it is apparent that the only solution is well managed fisheries where realistic fishing limits are set and enforced, such as occur in European waters (Arias et al., 2022). Also, regulation of net size and the periods when fishing is allowed should serve to conserve stocks although there is evidence that the legal codend (= narrow end of a tapered trawl net) is not always successful in allowing juveniles to escape capture. For example, Yu et al. (2023) reported that the legal codend retained >75% of undersized juvenile croaker in the Yellow Sea, China. These workers recommended that increasing the mesh size would enable better selectivity for the desired size range; i.e. smaller fish would escape and have the opportunity to grow to marketable size and breed. Moreover, Maynou et al. (2021) commented on the capture of large quantities of sub-legally-sized fish and shrimp using bottom trawls in the Mediterranean Sea, and noted that modifications could reduce the retention of small specimens. Another concern reflects the mechanical damage/habitat destruction caused by lobster pots and abandoned/discarded fishing nets particularly to structures on the sea bed, including coral, submerged vegetation and sponges (Amjad et al., 2021; Stevens, 2021). Unfortunately, lost fishing lines/nets may entangle marine inhabitants, including whales, leading to injury and death (Stevens, 2021). Also, abandoned/discarded nets may trap target and nontarget species, the so called "ghost fishing" (Nguyen, 2024). Yet, in many areas, there are not any controls on fishing activities, and fish populations suffer.

Capture fisheries are at the mercy of aquatic pollution and global warming, specifically warming and acidification of the oceans and seas, a rise in sea levels and altered precipitation patterns (Simionov et al*.,* 2021; Baag & Mandal, 2022). Certainly, oceanic warming will affect species distribution and fishing patterns. For example, cold water species may migrate towards the poles necessitating more lengthy and difficult fishing operations.

So, which is better? Aquaculture should be better because there is the opportunity to control all aspects of production but there are concerns about the possible dissemination of harmful micro-organisms in discharges. Also, there are issues with the protein and oil component of diets for carnivorous species. The advantage over capture fisheries is that illegal fishing and the capture of undersized specimens in not problematic. However, if fish are caught from well-managed, sustainable fisheries, then this would be a good option. Unfortunately, not all WCF come from sustainable practices, making it important to verify the source. Certainly, the source and possible exposure to potentially harmful pollutants of fish from capture fisheries is largely unknown. Thus, aquaculture and capture fisheries have advantages and disadvantages, but for the future the former will dominant in the production of aquatic food.

**Availability**

Fish consumption is a popular source of protein worldwide, and has been increasing because of the rapid world population growth and increased awareness of the health benefits of consuming seafood (APROMAR, 2018; Austin et al*.,* 2022). However, the rising demand cannot be met by WCF alone, mainly because the world's fish stocks are limited, and wild fish are becoming scarcer (Atalah & Sánchez-Jerez, 2020). There are ongoing debates about the source of fish. In particular, the perceived differences between farm-raised and WCF affect consumer decisions (Özçiçek et al., 2022). What is the evidence?

Fermed fish are raised under controlled conditions, such as in cages or ponds. These fish are commonly available, and include salmon, trout and sea bass (Can et al., 2023). The advantage of aquaculture is that the production processes are planned and controlled resulting in a stable supply to consumers throughout the year. In addition, their availability at more economically affordable prices makes them more popular in comparison with the wild caught alternatives (Cantillo et al., 2023). Thanks to the continuous production capacity, farmed fish and shellfish may be found more often and consistently in markets, restaurants and fishmongers.

The source of WCF is the aquatic environment where the animals live freely in their natural habitats and are obtained with less human intervention. However, WCF are sometimes in reduced quantities due to seasonal restrictions, environmental factors and fishing quotas (Silva et al., 2024). WCF may be more abundant in certain seasons, but their overall supply is more variable, i.e. unpredictable and limited. In addition, WCF are subject to environmental regulations, which affect production processes. For example, fishing restrictions may be imposed in some areas, or environmental factors (e.g. climate change) may affect catch efficiency (de Carvalho et al., 2023).

In conclusion, if the goal is to simply consume esily accessible fish aquaculture is the more practical option. However, if the consumer wants to make more unique environmental and health choices, the choice may be WCF, although the availability may be more variable.

## Freshness

The freshness of fish is crucial to produce valuable products preferred by consumers, as well as to preserve the nutritive, health and taste qualities of consumed fish (Ali et al., 2022). Variability in the freshness and subsequent storage time of fish is associated not only with postmortem processes but also with factors such as seasonal availability, size and sex of the fish, geographical area of catch, fish feeding habits, species of fish, and environmental factors such as water temperature, salinity and pollution (Prabhakar et al., 2020). Among these, water temperature is acknowledged as the main, and sometimes the only, significant factor contributing to fish freshness. Physiological differences between individuals of the same fish species also have to be taken into account, as fish are poikilothermic organisms and their metabolism changes in response to available feed, physiological condition, water temperature and activity. These external factors result in the need for post-capture and handling care (Zhang et al*.,* 2022).

The time that elapses between the death of fish and the appropriate catching ritual is a critical step leading to the final storage time and the subsequent deterioration of the fish product (Bai et al., 2023). In wild fish harvesting, catching practices are particularly important as fishing begins with the catch, and only after processing can fish and fish products be regarded as "fresh fish." All fish begin to deteriorate rapidly after death due to the action of intrinsic enzymes. By not cooling fish immediately post-capture will lead to a reduction in flesh quality due to autolysis or a build-up of bacterial contamination. (Singh et al., 2022). The question now is how long fish remain in the best possible condition after being processed from factory fishing vessels, and under what storage conditions and for how long will this freshness be maintained? The condition of fish sold in the markets may also be influenced by factors in the supply chain that occur after catch, such as temperature abuse during transportation, grading and packaging (Chu et al., 2023).

Farmed fish are often subject to different factors affecting their freshness, such as water quality, feed and handling practices. Appropriate nourishment, veterinary attention and water quality are essential for the optimal development of farmed fish. Certainly, the aim of fish farming is to yield top-quality produce with perfect flavor and texture. Customers seek uniform taste, aroma and texture in their food, so preserving a healthy environment for the produce is crucial for a fresh final product (Freitas et al., 2020).

The taste of fish is intricately tied to its environment, diet and species. The texture of the fish is shaped by its surroundings, whereas its flavor is influenced by the marine oils and other compounds within it. The overall quality of fish is affected by a combination of natural elements and factors related to capture and handling (Arechavala-Lopez *et al.,* 2022). Fish that are farmed in a controlled environment, with carefully managed food sources, generally possess superior flavor, shorter transportation times, reduced processing expenses and a lower risk of harboring parasites and pathogens in comparison to their wild-caught counterparts (López-Mas et al., 2021).

## Microbial Health Risks

### Farm-raised Fish

Most of the microbiology issues concerning aquatic foods centre on health of which there is an extensive literature with the greatest emphasis on aquaculture, i.e. organisms that are owned by individuals, consortia or industry. In contrast, there is a more restricted literature dealing with macro-organisms in their natural environment, and which are the focus for WCF. The list of pathogens/parasites includes bacteria, viruses and eukaryotic parasites. New pathogens are regularly reported, such as a distro-like virus associated with “Black May disease” of red swamp crayfish/Louisiana crawfish (*Procambarus clarkia;* Huang et al., 2020). Also, well recognized pathogens become associated with new conditions, e.g. *Vibrio parahaemolyticus* and acute hepatopancreatic necrosis disease (AHPND) of shrimp in Asia (Ahmed et al., 2022). With the latter condition, the pathogen acquired plasmids encoding lethal toxins, PirA/PirB. The outcome was a rapidly developing disease and high levels of mortality (Ahmed et al., 2022). Overall, large scale losses have occurred in farmed populations due to a wide range of diseases leading to severe financial losses, job losses and the complex issues of dealing with large numbers of corpses. Examples of these diseases include:

- Atlantic salmon (*Salmo salar*) production in Scotland suffered a 10% loss in 1991 with the cause attributed to *Aeromonas salmonicida* and *Lepeophtheirus salmonis,* which are the causal agents of furunculosis and sea lice, respectively (Munro & Gauld, 1996).
- Infectious salmon anaemia (ISA) led to losses of approximately third of total salmonid production in Chile during 2008-2010 (Asche et al., 2009; Lagno et al*.,* 2019).
- Salmon rickettsial syndrome (SRS) caused losses valued at US$700 million in Chilean salmon production (Flores-Kossack et al., 2020).
- AHPND was responsible for an estimated >US$44 billion loss to shrimp production in Asia and Mexico in 2010-2016 (Tang & Bonda-Reantaso, 2019).

It is extremely likely that the many diseases recorded in aquaculture originate from the surrounding aquatic environment and its fauna and flora (e.g. Murray & Peeler, 2005; Johansen et al., 2011). Transmission is especially troublesome when a non-indigenous species is introduced into an area for use in aquaculture; resistance to the local pathogens is likely to be lacking with the resulting development of clinical disease. This could explain the high mortalities attributed to ISA and SRS resulting in the non-native Atlantic salmon aquaculture in Chile.

There is a literature discussing the impact of aquaculture on wild populations, notably regarding the transmission of pathogens and parasites, including sea lice and piscine orthoreovirus-1, particular if health management on farms is not ideal (e.g. Kurath & Winton, 2011; Bouwmeester et al., 2021; Mordecai et al., 2021). This will be easier than in the terrestrial environment because of the ability for pathogens/parasites to move through the aqueous medium. Also, there may well be a role of escapees in the movement of disease from farmed to wild populations. Of relevance, Krkosek et al. (2006) discussed the spread of sea lice to migratory chum- (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) leading to increases in the rates of infection and mortalities of 9-95%.

**Wild Fish**

There is less information dealing with diseases of commercially-important fish species in natural waterways, including ocean/seas, rivers and lakes/ponds. Examples of these diseases include:

- Ulcerate dermal necrosis (UDN), which is a chronic skin disease, has been reported in mature salmonids particularly Atlantic salmon and sea trout (*Salmo trutta*) that were returning to rivers for spawning (Johansson et al*.,* 1982; Henard et al*.,* 2022).
- Mycobacteriosis has been diagnosed repeatedly as a low-level infection in striped bass of the eastern seaboard of the USA, including Chesapeake Bay (e.g. Jacobs et al., 2009; Matsche et al*.,* 2010).
- Viral nervous necrosis virus has been identified in subclinically diseased wild marine fish species off the southern coast of Korea. These fish could therefore be a source of virus for other susceptible fish species (Gomez et al*.,* 2008).

The reasons for diseases in natural waterways may reflect the impact of chemical pollution (Martínez-Gómez & Vethaak, 2019) compounded by the stresses of high population densities (Wootton et al., 2012), ultraviolet radiation in sunlight in the case of UDN (Henard et al., 2022), and proximity to the large numbers of individuals in aquaculture sites whereby there is the possibility for the transfer of disease from farmed to wild fish/shellfish populations through water.

**Health Risks to Consumers**

Unfortunately, some micro-organisms from farmed and wild species may cause disease in human beings. Some parasites may be acquired from raw, undercooked or poorly preserved WCF, and sometimes farmed products, and include *Anisakis, Capillaria* and *Diphyllobothrium* (dos Santos & Howgate, 2011; Hajipour et al., 2023). Intestinal capillariasis, which is caused by *Capillaria philippinensis* and in many cases was linked with the consumption of raw or undercooked fish*,* was first recognized in the Philippines and subsequently in Egypt, Iran, Japan, Taiwan and Thailand (Saichua et al., 2008). This diarrheal disease may have a fatal outcome (Prasongdee et al., 2022). Moreover, there is evidence that shellfish, notably raw oysters, have been associated with serious (sometimes fatal) disease after their consumption. In particular, *Vibrio vulnificus* has been determined to be the cause of rapidly developing septicemia especially in immunocompromised individuals or those who have liver disease (Morris, 2003; Hernández-Cabanyero & Aandmaro, 2020).

Consideration needs to be given to the microbiology issues associated with aquatic foods as they are processed through wholesale businesses/markets to retailers including supermarkets, and thence to the final customer. However, the origin of the aquatic foods is not always clear, and could be either aquaculture or capture from the wild. The microbiological standard is certainly important for those organisms that will be consumed raw, with examples including oysters, sashimi and sushi. In addition, there are problems of spoilage, which will adversely affect or completely negate sales potential. Specific examples include:

- Bacterial pathogens have been detected in farmed *Macrobrachium rosenbergii* and *Penaeus monodon* in Bangladesh with reasons reflecting unhygienic conditions on the farms, post-harvesting procedures and poor market hygiene (Khan et al., 2024).
- Toxigenic *Clostridioides difficile* was recovered from smoked and dried freshwater fish in Cambodia (Rodriguez et al*.,* 2021)
- Potentially pathogenic, antibiotic-resistant taxa, including diarrheagenic *Escherichia coli, Salmonella and V. cholerae*, have been associated with pangas (*Pangasius pangasius*) and tilapia from retail markets more so than supermarkets in Bangladesh (Amin et al., 2024).
- Fish and fish products from markets in Kenya harboured *S. enterica* and *E. coli* (Kyule et al., 2022).
- Enteropathogenic *E. coli* O157:H7 has been recovered from fish farms and retail markets in Turkey (Onmaz et al., 2020).
- Methicillin resistant *Staphylococcus aureus* was recovered from mullet (*Mugil cephalus*), washing water and knives in Egyptian retail markets (Attia et al., 2024).
- Antibiotic resistant *V. cholerae* and *S. enterica* serovar Paratyphi B, Escanaba and Saint Paul were recovered from Nile tilapia obtained from fresh markets and supermarkets in Bangkok, Thailand (Sripradite et al., 2024).

- Sushi, which is mostly prepared from WCF species has been linked with the food borne pathogen, *S. enterica* (da Silva et al., 2020).
- Spoilage organisms, namely *Pseudomonas putida* and *Shewanella putrefaciens* with high adhesion properties, have been reported from fish, including grass carp and tilapia, leading to the deterioration of proteins especially collagens producing putrescine during refrigerated storage, and the development of unpleasant fishy smells (Zhuang et al., 2022).

**Which İs Better – Aquaculture or Capture Fisheries?**

The question to be resolved is which is better in terms of health? The answer should be aquaculture because the history of the farmed species is known, including any health issues. Moreover, a wealth of prophylactic procedures, including vaccines, probiotics, plant products and nonspecific immunostimulants, are available to manage health in aquaculture. However, there are concerns about the widespread use of antibiotics and other inhibitory compounds, particularly macrolides, quinolones, sulfonamides and tetracyclines, in aquaculture in many countries. The administration of these antimicrobial agents permits the development and spread of transferable resistance genes, and contributes to the development of antibiotic resistance (Lu et al., 2021), which may impact negatively on human health (e.g. Heberer, 2009). Also, the use of antimicrobial agents may leads to residues in tissues, and these may have serious consequences for consumers including those with allergies (Xiao et al., 2022). In contrast, little is known about the history of capture fisheries, in terms of exposure to potential pollutants, toxic compounds and disease agents. Therefore, aquaculture produce should be better, but with concern about antibiotic use and its potential effect on the consumer.

**Toxic Substances**

There has been an increasing focus on the presence of harmful substances in fish, which serve as effective filters of environmental toxins and have a significant impact on both the ecosystem and human health (Fulke et al., 2024). The consumption of contaminated fish poses a potential risk to consumers because of the accumulation of toxic substances. These include heavy metals, mining waste, toxins from algae, mycotoxins, organo-halogens, pesticides and gaseous atmospheric pollutants. The toxic compounds build up in fish through a process known as bioaccumulation or biomagnification. Global regulatory agencies have established guidelines to monitor and control the levels of mercury, cadmium and algal toxins found in fish. Certainly, environmental pollution is a significant factor in the presence of toxic substances in fish (Abbas et al., 2024).

Harmful substances pose a significant threat to both farmed and wild fish, and originate from a wide range of sources, such as natural processes, industrial activities and even everyday human actions. It is crucial to recognize that wild fish, in particular, are highly susceptible to environmental changes and habitat destruction, which may result ultimately in a rapid decline in their populations and an unfortunate disruption in the delicate balance of ecosystems (Simukoko et al., 2022). Within the realm of aquaculture, it is essential to acknowledge that rearing practices themselves represent the primary risk factor for exposing fish to harmful toxins. Despite the existence of legal regulations, the potential dangers are still quite prevalent (Custodio et al., 2022).

This multifaceted challenge demands collaborative efforts from all stakeholders involved to effectively address the presence of harmful substances in fish. Safeguarding human health and protecting the environment for both present and future generations necessitate a unified approach that incorporates scientific expertise, governmental regulations, industry initiatives, consumer awareness and support for sustainable practices (Jensen et al., 2020). Fish represent a higher link in the aquatic food chain, and their tissues frequently contain low amounts of potentially hazardous chemicals (Huang et al., 2021). It has been reported that toxic compounds are more prevalent in certain wild fish compared to farmed fish, which are cultivated in controlled environments that provide better management of the types and levels of toxic substances (Jensen et al., 2020). Clearly, wild fish become contaminated with environmental contaminants and natural substances. Unfortunately, the environment is all too often polluted due to human activities, leading to increased contamination of habitats and of wild fish populations (Habib et al., 2024). To date, no substantial disparities in the profiles of hazardous chemicals have been identified between certain cultivated and wild fish. This is significant because it is generally assumed that the individual toxicological profiles of wild and farmed fish are similar because animals that consume the same diet tend to have similar toxicological profiles. For example, similar quantities of dioxins and polybrominated biphenyls congeners were identified in the liver and muscle of both wild and farmed turbot (López-Mas et al., 2021). In certain species, farmed fish become contaminated due to inadequate emphasis on maintaining environmental quality in the holding facilities, the use of reduced fishmeal quantities, and insufficient scrutiny of the quality of inflow water (Fulke et al., 2024). Wild fish may exhibit lower levels of contamination with potentially harmful compounds compared to high-quality farmed fish, because they regulate the presence of these substances in their environment, ensuring their absence in water or food sources (Simukoko et al., 2022).

**Price**

Price is one of the most important criterion for consumers when buying aquatic food (Claret *et al.,* 2012; Conte et al., 2014), with the cost depending on many factors, for example hunting or production methods, season and the weather (López-Mas et al., 2021). Generally, farmed animals are more affordable than WCF (when compared with the same species). The reasons for these differences are:

- Farmed animals are produced in controlled situations, and on a large scale (Can et al., 2023). This large-scale production reduces per-unit costs because aquaculture produces stock throughout the year, and thus a constant supply is ensured, which is essential for marketing.
- Farmed fish are supplied continuously and are available throughout the year without any restrictions imposed by fishing seasons. This leads to constant availability in the market and thus leads to lower prices (Engle et al., 2016).
- Farmed fish are not the focus of high labor and energy costs that result in fishing activities, which inevitably require the use of ships, crews and effective refrigeration to ensure the freshness of the catch during long periods away from harbor. As the majority of aquaculture facilities are on land or close to the coast, there is less logistics and transportation costs.
- WCF involves expensive fishing equipment, fishing permits, catching processes, transportation and processing costs. Procuring wild fish is more laborious and time-consuming. In addition, because these fish may be caught only in certain seasons and places, there may be a limitation to the supply (López-Mas et al., 2021). This may cause the supply to decrease, and prices to increase.
- The risks of overfishing wild stocks have led to fewer animals being caught, which results in price increases. In addition, factors, such as sustainable fishing policies and fishing quotas (Silva et al., 2024), may lead to some species becoming more expensive, i.e., the economics of supply and demand. Because the availability of wild-caught stock may be seasonal, there will be fluctuations in price. Thus, the availability of these stocks will decrease at certain times of the year, which leads to higher prices (Engle et al., 2016).

Which option is cheaper? Generally, aquaculture has enabled the availability of cheaper products than their wild-caught counterparts (URL 4, URL 5). Aquaculture production is more controlled, continuous and less labor intensive. This leads to more affordable prices for consumers. In addition, farmed fish are generally more abundant and more widely available on the market. Conversely, wild-caught stock tend to be more expensive in terms of supply continuity, and costs involved with their capture and transportation. Therefore, aquaculture products are considered to be more suitable for consumers, especially those looking for a budget-friendly option although farmed fish often have a less positive image than their respective wild-caught equivalents. Of course, price depends on economic purchasing power, and there may be significant differences in various regions around the World (Cantillo et al., 2023). Some examples concern prices in fishmongers in Norway, in which the cost of wild-caught Atlantic cod was ~25% more than the farmed product (Pettersen et al., 2023). A similar price differential was observed in Scotland for Atlantic salmon. In the USA, several years ago a supermarket chain, Costco, was selling fresh farmed salmon at \$11.99/lb, whereas the wild-caught product was retailing at \$12.99/lb, a difference of 9% in favor of aquaculture. However, aquaculture products may enjoy a competitive advantage as a result of governmental subsidies (Kim, 2019). For example from 2000-2014 and 2014-2020, the European Union spent Euro 1.17 billion, and Euro 1.72 billion on aquaculture although the investment was not matched by an increase in production (Guillen et al., 2019). The topic of subsidies is emotive insofar as they may be considered to confer an unfair economic advantage for products entering the international marketplace.

## Conclusions

Which is better, aquaculture or capture-fisheries? Clearly, there are strong proponents and opponents reflecting local politics and personal biases. Aquaculture should be the better option because there is the ability to control all aspects of production, and produce a regular, sustainable supply to the marketplace at an affordable price for consumers. Moreover, farmed fish are regarded as superior for the consumer in terms of nutritional value than wild-caught products (Özçiçek, 2018). However, there are negative aspects to aquaculture including competition with other users, including tourism, and habitat destruction, such as mangroves for the development of shrimp farms. Also, there are concerns about aquaculture sites exerting a negative environmental impact by polluting the surrounding waters with organic material, e.g. uneaten feed and fecal material, pathogens and antimicrobial compounds. In turn, the fixed aquaculture sites may be at the mercy of biological and chemical pollution carried in from the surrounding environment, and storm damage. Then, there is a concern that escapees from aquaculture facilities could interfere with native stocks by outcompeting or interbreeding with them (Glover et al., 2020). Arguably, the current activity of using wild-caught “trash” fish as a source of protein and oil for the diets of carnivorous fish species in aquaculture is unsustainable. Indeed, research is aiming to replace these WCF products with alternatives, including plant- and insect-based products. In short, there is ingenuity and willingness to develop aquaculture, and overcome difficulties to enable continued expansion to meet the need for aquatic protein for the rapidly expanding human population.

What about capture-fisheries? There is greater variability in supply because of overfishing, quotas imposed by governments, and the weather. Fishing in distant waters is expensive in terms of the need for specialized equipment, such as boats and associated fishing gear, i.e. nets and lines, the latter of which may damage the seabed and entrap/drown wildlife, such as turtles (Alfaro-Shigueto et al., 2011). All these matters will impact on cost ultimately to the consumer. Certainly, quality is more difficult to ascertain because the history of the catch is largely unknown. However, there are concerns about illegal fishing activities, such as for the highly prized shark fin (e.g. Ferrette et al., 2019; Nijman, 2023), and the capture of undersized specimens of commercially important species the latter of which impacts negatively on future stocking levels. Moreover, unwanted species will be simply discarded. By itself, capture-fisheries is unable to meet the global demand for aquatic food. Hence, there is a real need for aquaculture, which must be the better option for the supply of aquatic products.

WCF exhibit a firmer texture than farmed counterparts due to their natural diets and enhanced muscle quality. In contrast, farmed fish frequently possess a softer texture (Chen et al., 2022). Diet and muscle composition indeed affect flavor and texture (Du et al., 2022). Indeed, the flavor profile of wild and farmed fish is the predominant sensory characteristic acknowledged by the majority of humans. Wild adult fish that exhibit sluggish growth generally have a more complex and robust flavor compared to their farmed equivalents (Bøhn et al., 2024). The differences in flavor between wild and cultured fish arise from the unique ecological conditions of their habitats (Bekhit, 2022).

In wild fish harvesting, capturing procedures are crucial, as the process commences with the catch, and only subsequent to processing can fish and fish products be classified as "fresh fish." Farmed fish are frequently influenced by several factors impacting their freshness, including water quality, diet and handling procedures. Farmed fish, cultivated in regulated settings with meticulously managed feed, typically exhibit enhanced flavor, diminished transportation durations, lower processing costs, and a reduced likelihood of harboring parasites and diseases compared to WCF (López-Mas et al., 2021).

Hazardous chemicals are more common in wild than in farmed fish, the latter of which are raised in regulated circumstances that allow for superior management of dangersous substance types and levels (Jensen et al., 2020). Wild fish become polluted with environmental toxins and natural compounds. Human activities frequently result in environmental pollution, causing heightened contamination of ecosystems and wild fish populations (Habib et al., 2024).

**Recommendations**

**Farm-raised Fish**

- Aquaculture must strive for sustainability in all aspects of production from broodstock to eggs to adults, and in nutrition, i.e. there must be move away from the use of trash fish as a source of protein and lipids in feeds for carnivorous fish. Thus, cultivation of omnivorous and herbivorous rather than carnivorous species should be encouraged by local, national and international policy makers. Certainly, feeds must meet the full needs of the farmed stock to ensure the best possible quality of product for consumers.
- Aquaculture needs to be cognizant of the needs of other users of aquatic sites, and must not destroy pristine habits, e.g. mangroves, for the development of new sites.
- Attention needs to be given to minimize the risk of escapees, which could interact/interbreed with native stock.
- Aquaculture facilities should be mindful of the need to minimize or preferably eliminate pollution of the surrounding waterways with organic material, principally feces and uneaten feed (such as by embracing IMTA) and bioactive compounds, namely antibiotics.
- Where water is scarce or of poor quality or suitable sites are not available, attention should be given to the use of recirculation, aquaponics, integrated multitrophic systems and biofloc technologies.
- To meet the future needs of marine products, focus needs to be given to the development of offshore/deep water aquaculture.
- Disease needs to be carefully managed preferably by prophylactic means to reduce or preferably eliminate the risk of potentially pathogenic organisms entering the receiving waters and posing as a risk to native stock.

Capture Fisheries

- Comprehensive strategies are needed to ensure the sustainability of fisheries, protecting the environment and other aquatic species, e.g. turtles, and dealing with the risks associated with illegal fishing.
- Efficient capture systems need to be developed that recover only market-sized stock, allowing the escape of small/juveniles and other species, e.g. dolphins, turtles and whales, that could be caught by mistake.
- Nursery sites need to be protected from fishing activities to allow replenishment of stock.
- Fishing practices that harm the ecosystem, such as dynamite, poison and methods that scrape the seabed, must be avoided.
- Real-time monitoring of fishing activities is needed using technology would be effective in preventing overfishing.

- Fishermen need to be trained on sustainable methods and legal regulations.
- Fishing policies need to be address the impact of environmental (= climate) change.

## Ethical Statement

This study does not require any ethics committee approval.

## Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for profit sectors.

## Author Contribution

EC: Conceptualization; Writing -original draft, review & editing; EÖ: Writing -original draft, Writing – review; NDE: Writing -original draft; Writing –review; BA: Validation, conceptualization; Writing -original draft, review & editing.

## Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

## References

Abbas, M. M. M., El-Sharkawy, S. M., Mohamed, H. R., Elaraby, B. E., Shaban, W. M., Metwally, M. G., & Farrag, D. M. (2024). Heavy metals assessment and health risk to consumers of two commercial fish species from polyculture fishponds in El-Sharkia and Kafr El-Sheikh, Egypt: Physiological and biochemical study. Biological Trace Element Research, 202(10), 4735–4750.

Adriaenssens, B., & Johnsson, J. I. (2011). Shy trout grow faster: exploring links between personality and fitness-related traits in the wild. Behavioral Ecology, 22(1), 135-143. https://doi.org/10.1093/beheco/arq185.

Ahmed, J., Khan, M. H., Unnikrishnan, S., & Ramalingam, K. (2022). Acute hepatopancreases necrosis diseases (AHPND) as challenging threat in shrimp. Biointerface Research in Applied Chemistry,12(1), 978-991. https://doi.org/1cahu0.33263/briac121.978991121.978991

Ahmed, N., & Turchini, G. M. (2021). Recirculating aquaculture systems (RAS): Environmental solution and climate change adaptation. Journal of Cleaner Production, 297, Article 126604. https://doi.org/10.1016/j.jclepro.2021.126604

Alfaro-Shigueto, J., Mangel, J. C., Bernedo, F., Dutton, P. H., Seminoff, J. A., & Godley, B. J. (2011). Small-scale fisheries of Peru: a major sink for marine turtles in the Pacific. Journal of Applied Ecology, 48(6), 1432-1440.

Ali, A., Wei, S., Ali, A., Khan, I., Sun, Q., Xia, Q., Wang, Z., Han, Z., Liu, Y., & Liu, S. (2022). Research progress on nutritional value, preservation, and processing of fish: A review. Foods, 11(22), 3669.

Amin, M. B., Talukdar, P. K., Sraboni, A. S., Islam, M. R., Mahmud, Z. H., Berendes, D., Narrod, C., Parveen, S., & Islam, M. A. (2024). Prevalence and antimicrobial resistance of major foodborne pathogens isolated from pangas and tilapia fish sold in retail markets of Dhaka city, Bangladesh. International Journal of Food Microbiology,418, 110717.

Amjad, A., Siddiqui, P. J. A., & Burhan, Z. U. N. (2021). Ecology of fish communities in coral habitats along the coast of Pakistan: Potential threats and conservation strategies. Pakistan Journal of Zoology, 53, 1341–1351.

Amoussou, N., Marengo, M., Durieux, E. D. H., Douny, C., Scippo, M.-L., & Gobert, S. (2019). Trace elements and fatty acid profile of *Argyrosomus regius* (Asso, 1801) from Mediterranean aquaculture. Biological Trace Element Research, 196, 618–628. https://doi.org/10.1007/s12011-019-01925-x

APROMAR. (2018). La Acuicultura en España 2018. http://www.apromar.es/sites/default/files/2018/APROMAR_Informe_ACUICULTURA_2018.pdf (Accessed 5 June 2019).

Arechavala-Lopez, P., Cabrera-Álvarez, M. J., Maia, C. M., & Saraiva, J. L. (2022). Environmental enrichment in fish aquaculture: A review of fundamental and practical aspects. Reviews in Aquaculture, 14(2), 704–728.

Arias, J., Laksá, U., & Fridriksdóttir, R. (2022). Results-based management in practice: Lessons learnt and policy recommendations from the implementation of RBM in European fisheries outside Europe. Marine Policy, 139. 105038.

Asche, F., Eggert, H., Oglend, A., Roheim, C. A., & García, M. D. (2022). Aquaculture: Externalities and policy options. Review of Environmental Economics and Policy, 16, 282–305. https://doi.org/10.1086/721055

Asche, F., Hansen, H., Tveteras, R., & Tveterås, S. (2009). The salmon disease crisis in Chile. Marine Resource Economics, 24(4), 405–411.

Aslan, S.S., Guven, K.C., Gezgin, T., Alpaslan, M., & Tekinay, A. (2007). Comparison of fatty acid contents of wild and cultured rainbow trout *Onchorhynchus mykiss* in Turkey. Fisheries Science 2007, 73:1195–1198.

Atalah, J., & Sánchez-Jerez, P. (2020). Global assessment of ecological risks associated with farmed fish escapes. Global Ecology and Conservation, 21, e00842. https://doi.org/10.1016/j.gecco.2019.e00842

Attia, A. S., Abou Elez, R. M., El-Gazzar, N., Elnahriry, S. S., Alfifi, A., Al-Harthi, H. F., Alkhalifah, D.H.M., Hozzein, W.N., Diab, H.M., & Ibrahim, D. (2024). Cross-sectional analysis of risk factors associated with *Mugil cephalus* in retail fish markets concerning methicillin-resistant *Staphylococcus aureus* and *Aeromonas hydrophila*. Frontiers in Cellular and Infection Microbiology, 14, 1348973.

Aura, C. M., Nyamweya, C. S., Njagi, G., Mwarabu, R. L., Ongore, C. O., Awuor, F. J., Keyombe, J L., Musa, S., Awandu, H., Awoko, W., Macharia, S., & Abila, R. O. (2023). Restocking of small water bodies for a post Covid recovery and growth of fisheries and aquaculture production: Socioeconomic implications. Scientific African, 19, e01439.

Austin, B., Lawrence A.L., Can., E., Carboni, C., Crockett, J., Demirtaş Erol, N., Dias Schleder, D., Jatobá, A., Kayış, Ş., Karacalar, U., Kizak, V., Kop, A., Thompson, K., Mendez Ruiz, C. A., Serdar, O., Seyhaneyildiz Can, S., Watts, S., & Yücel Gier, G. (2022). Selected topics in sustainable aquaculture research: Current and future focus. Sustainable Aquatic Research, 1(2), 74-125.

Azhar, M.H., & Memis, D. (2003). Application of the IMTA (integrated multi-trophic aquaculture) system in freshwater, brackish and marine aquaculture. Aquatic Sciences and Engineering, 2, 106-121.

Baag, S., & Mandal, S. (2022). Combined effects of ocean warming and acidification on marine fish and shellfish: A molecule to ecosystem perspective. Science of the Total Environment, 802, 149807.

Bai, L., Han, Y., & Ikebe, K. (2023). The value of traditional fishing from the perspective of cultural heritage: A case study of seine fishing in Ichinomiya-cho, Kujukuri-hama. Sustainability, 15(4), 3855.

Bekhit, A. E. D. A. A. (Ed.). (2022). Fish roe: biochemistry, products, and safety. Academic Press.

Bøhn, T., Strøm, J. F., Sanchez-Jerez, P., Keeley, N. B., Johansen, T., Gjelland, K. Ø., Sandlund, N., Saether, B.-S., Saetra, I., Olsen, E.M., Skjaeraasen, J.E., Meier, S., vsn der Meeren, T., & Bjørn, P. A. (2024). Ecological interactions between farmed Atlantic salmon and wild Atlantic cod populations in Norway: A review of risk sources and knowledge gaps. Reviews in Aquaculture, 16(3): 1333-1350. https://doi.org/10.1111/raq.12899

Boissy, J., Aubin, J., Drissi, A., van der Werf, H.M..G, Bell, J.G., & Kaushik, S. (2011). Environmental impacts of plant-based salmonid diets at feed and farm scales. Aquaculture, 321, 61–70. https://doi.org/10.1016/j.aquaculture.2011.08.033

Bouwmeester, M. M., Goedknegt, M. A., & Thieltges, D. W. (2021). Collateral disease: Aquaculture impacts on wildlife infections. Journal of Applied Ecology, 58, 453–464.

Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., McNevin, A.A., Tacon, A.G.J., Teletchea, F., Tomasso, J.R., Tucker, C.S., & Valenti, W. C. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. Journal of the World Aquaculture Society, 51(3), 578–633.

Brooks, B. W., Lazorchak, J. M., Howard, M. D., Johnson, M. V. V., Morton, S. L., Perkins, D. A., Reavie, E.D., Scott, G.I., Smith, S.A., & Steevens, J. A. (2016). Are harmful algal blooms becoming the greatest inland water quality threat to public health and aquatic ecosystems? Environmental Toxicology and Chemistry, 35(1), 6–13.

Burr, M. L. (1989). Fish and cardiovascular system. Progress in Food & Nutrition Science, 13, 291–316.

Cahu, C., Selen, P., & Lorgeril, M. D. (2004). Farmed and wild fish in prevention of cardiovascular disease: Assessing possible differences in lipid nutritional values. Nutrition, Metabolism and Cardiovascular Diseases, 14, 34–41.

Can, E., Austin, B., Steinberg, C. E. W., Carboni, C., Sağlam, N., Thompson, K., Yiğit, M., Can, S.S., & Ergün, S. (2023). Best practices for fish biosecurity, well-being, and sustainable aquaculture. Sustainable Aquatic Research, 2 (3), 221–267.

Cantillo, J., Martín, J. C., & Román, C. (2023). Understanding consumers' perceptions of aquaculture and its products in Gran Canaria island: Does the influence of positive or negative wording matter? Aquaculture, 562, 738754.

Cao, L., Diana, J. S., & Keoleian, G. A. (2013). Role of life cycle assessment in sustainable aquaculture. Reviews in Aquaculture, 5(2), 61-71.

Chen, L., Zeng, W., Rong, Y., & Lou, B. (2022). Compositions, nutritional and texture quality of wild-caught and cage-cultured small yellow croaker. Journal of Food Composition and Analysis, 107, 104370.

Chu, Y., Ding, Z., Wang, J., Xie, J., & Ding, Y. (2023). Factors affecting the quality of frozen large yellow croaker (*Pseudosciaena crocea*) in cold chain logistics: Retention time and temperature fluctuation. Food Chemistry: X. 18, 100742.

Claret, A., Guerrero, L., Aguirre, E., Rincón, L., Hernández, M. D., Martínez, I., Peleteiro, J.B., Grau, A., & Rodríguez-Rodríguez, C. (2012). Consumer preferences for sea fish using conjoint analysis: Exploratory study of the importance of country of origin, obtaining method, storage conditions and purchasing price. Food Quality and Preference, 26, 259–266. https://doi.org/10.1016/j.foodqual.2012.05.006

Conte, F., Passantino, A., Longo, S., & Voslářová, E. (2014). Consumers' attitude towards fish meat. Italian Journal of Food Safety, 3, 178–181. https://doi.org/10.4081/ijfs.2014.1983

Corbau, C., Nardin, W., Vaccaro, C., Vona, I., & Simeoni, U. (2023). Experimental design and field deployment of an artificial bio-reef produced by mollusk shell recycling. Marine Environmental Research, 183, 105833.

Custodio, M., Espinoza, C., Orellana, E., Chanamé, F., Fow, A., & Peñaloza, R. (2022). Assessment of toxic metal contamination, distribution, and risk in the sediments from lagoons used for fish farming in the central region of Peru. Toxicology Reports, 9, 1603–1613.

Da Silva, D. C., Lopes, S. M., de Aquino, N. S. M., de Oliveira Elias, S., Duda, H. A., & Tondo, E. C. (2020). Mathematical modelling and validation of *Salmonella enterica* growth in sushi exposed to different time-temperature scenarios found in real sushi establishments. Food Research International, 136, 109609.

De Carvalho, D. A., Amaral, S., & Alves, L. M. (2023). Climate change adaptation frameworks in fishing communities: A systematic review. Ocean & Coastal Management, 243, 106754.

Dos Santos, C. A. M. L., & Howgate, P. (2011). Fishborne zoonotic parasites and aquaculture: A review. Aquaculture, 318, 253–261.

Du, X., Zhang, W., He, J., Zhao, M., Wang, J., Dong, X., Fu, Y., Xie, X., & Miao, S. (2022). The impact of rearing salinity on flesh texture, taste, and fatty acid composition in largemouth bass (*Micropterus salmoides*). Foods, 11(20), 3261.

Du, Y., Sun, J., & Zhang, G. (2021, October). The impact of overfishing on environmental resources and the evaluation of current policies and future guidelines. In 2021 International Conference on Public Relations and Social Sciences (ICPRSS 2021) (pp. 1120–1124). Atlantis Press.

Dunham, R. A., & Su, B. (2020). Genetically engineered fish: potential impacts on aquaculture, biodiversity, and the environment. GMOs: Implications for Biodiversity Conservation and Ecological Processes, 241-275.

Dvoretsky, A. G., & Dvoretsky, V. G. (2024). Distribution patterns and biological aspects of *Strongylocentrotus droebachiensis* (Echinoidea: Echinoida) in Russian waters of the Barents Sea: Implications for commercial exploration. Reviews in Fish Biology and Fisheries, 1-15.

Engle, C. R., Quagrainie, K. K., & Dey, M. M. (2016). Seafood and aquaculture marketing handbook. John Wiley & Sons.

Falconer, L., Middelboe, A. L., Kaas, H., Ross, L. G., & Telfer, T. C. (2020). Use of geographic information systems for aquaculture and recommendations for development of spatial tools. Reviews in Aquaculture, 12, 664–677. https://doi.org/10.1111/raq.12345

FAO (2022). The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation. Rome: FAO. https://doi.org/10.4060/cc0461en

FAO (2024). In Brief to The State of World Fisheries and Aquaculture 2024: Blue Transformation in Action. Rome: FAO. https://doi.org/10.4060/cd0690en

Ferrette, B. L. D., Dominques, R. R., & Mendonça, F. F. (2019). DNA-based species identification of shark finning seizures in Southwest Atlantic: Implications for wildlife trade surveillance and law enforcement. Biodiversity and Conservation, 28, 4007–4025.

Flores-Kossack, C., Montero, R., Kollner, B., & Maisey, K. (2020). Chilean aquaculture and the new challenges: Pathogens, immune response, vaccination, and fish diversification. Fish & Shellfish Immunology, 98, 52–67. https://doi.org/10.1016/j.fsi.2019.12.093

Freitas, J., Vaz-Pires, P., & Câmara, J. S. (2020). From aquaculture production to consumption: Freshness, safety, traceability and authentication, the four pillars of quality. Aquaculture, 518, 734857.

Fuentes, A., Fernández-Segovia, I., Serra, J. A., & Barat, J. M. (2010). Comparison of wild and cultured sea bass (*Dicentrarchus labrax*) quality. Food Chemistry, 119, 1514–1518.

Fulke, A. B., Ratanpal, S., & Sonker, S. (2024). Understanding heavy metal toxicity: Implications on human health, marine ecosystems and bioremediation strategies. Marine Pollution Bulletin, 206, 116707.

Galparsoro, I., Murillas, A., Pinarbasi, K., Sequeira, A. M. M., & Stelzenmüller, V. (2020). Global stakeholder vision for ecosystem-based marine aquaculture expansion from coastal to offshore areas. Reviews in Aquaculture, 12, 2061–2079. https://doi.org/10.1111/raq.12422

Gatlin, D. M. (2024). Aquatic animal nutrition. In E. Can & B. Austin (Eds.), Proceedings of the 1st International Symposium on Sustainable Aquatic Research (pp. 1–173). Türkiye: Sustainable Aquatic Research. https://doi.org/10.5281/zenodo.14016308

Glover, K. A., Wennevik, V., & Grefsrud, E. S. (2020). The future looks like the past: Introgression of domesticated Atlantic salmon escapees in a risk assessment framework. Fish and Fisheries, 21, 1077–1091.

Goglio, P., Van Den Burg, S., Kousoulaki, K., Skirtun, M., Espmark, Å. M., Kettunen, A. H., & Abbink, W. (2022). The environmental impact of partial substitution of fish-based feed with algae-and insect-based feed in salmon farming. Sustainability 14, 12650.

Gomez, D. K., Baeck, G. W., Kim, J. H., Choresca Jr, C. H., & Park, S. C. (2008). Molecular detection of betanodavirus in wild marine fish populations in Korea. Journal of Veterinary Diagnostic Investigation, 20(1), 38-44.

Gough, C. L., Dewar, K. M., Godley, B. J., Zafindranosy, E., & Broderick, A. C. (2020). Evidence of overfishing in small-scale fisheries in Madagascar. Frontiers in Marine Science, 7, 317.

Grigorakis, K., Alexis, M.N., Taylor, K.D.A., & Hole, M. (2002). Comparison of wild and cultured gilthead sea bream (Sparus aurata); composition, appearance and seasonal variations. International Journal of Food Science & Technology, 37, 477-484. https://doi.org/10.1046/j.1365-2621.2002.00604.x

Guillen, J., Asche, F., Carvalho, N., Polanco, J.M.F., Llorente, I., Nielsen, R., Nielsen, M., & Villasante, S. (2019). Aquaculture subsidies in the European Union: Evolution, impact and future potential for growth. Marine Policy 104, 19–28.

Habib, S. S., Naz, S., Fazio, F., Cravana, C., Ullah, M., Rind, K. H., Attaullah, F., Filiciotto, F., & Khayyam, K. (2024). Assessment and bioaccumulation of heavy metals in water, fish (wild and farmed), and associated human health risk. Biological Trace Element Research, 202(2), 725–735.

Hajipour, N., Valizadeh, H., & Ketzis, J. (2023). A review of fish-borne parasites in Iran. Veterinary Medicine and Science, 9, 748–777.

Hasan, M., Hassan, L., Abdullah Al, M., Kamal, A. H. M., Idris, M. H., Hoque, M. Z., Mahmoood, R., Alam, M.N., & Ali, A. (2024). Human intervention caused massive destruction of the second largest mangrove forest, Chakaria Sundarbans, Bangladesh. Environmental Science and Pollution Research, 31(17), 25329-25341.

Heberer, T. (2009). Organic compounds used in aquaculture. In Hormones and pharmaceuticals generated by concentrated animal feeding operations: transport in water and soil (pp. 95-114). New York, NY: Springer US.

Henard, C., Saraiva, M. R., Ściślak, M. E., Ruba, T., McLaggan, D., Noguera, P., & van West, P. (2022). Can Ulcerative Dermal Necrosis (UDN) in Atlantic salmon be attributed to ultraviolet radiation and secondary *Saprolegnia parasitica* infections? Fungal Biology Reviews, 40, 70-75.

Hernández-Cabanyero, C., & Amaro, C. (2020). Phylogeny and life cycle of the zoonotic pathogen *Vibrio vulnificus*. Environmental Microbiology, 22, 4133–4148.

Hoang, T., Nguyen, B. T., & Huynh, Q. V. (2024). Performance of domesticated tiger shrimp postlarvae (*Penaeus monodon*) and mud crab (*Scylla paramamosain*) in extensive rice-shrimp ponds. Aquaculture Research, 2024(1), 5773446.

Hossain, M. A. (2011). Fish as a source of n-3 polyunsaturated fatty acids (PUFAs), which one is better—farmed or wild? Advance Journal of Food Science and Technology, 3, 455–466.

Huang, P., Shen, G., Gong, J., Zhu, M., Wang, Y., Zhang, X., Ame, K.H., Zang, Y., & Shen, H. (2020). A novel Distro-like virus discovered in *Procambarus clarkii* with “Black May” disease. Journal of Fish Diseases, 44, 803–811.

Huang, W., Song, B., Liang, J., Niu, Q., Zeng, G., Shen, M., Deng, J., Luo, Y., Wen, X., & Zhang, Y. (2021). Microplastics and associated contaminants in the aquatic environment: A review on their ecotoxicological effects, trophic transfer, and potential impacts to human health. Journal of Hazardous Materials, 405, 124187.

Jacobs, J. M., Howard, D. W., & Harrell, R. M. (2009). Historical presence (1975–1985) of mycobacteriosis in Chesapeake Bay striped bass (*Morone saxatilis*). Diseases of Aquatic Organisms, 85, 181–186.

Jeanson, A. L., Gotzek, D., Mam, K., Hecht, L., Charvet, P., Eckerström-Liedholm, S., Cooke, S.J., Pool, T., Elliott, V., & Torres, Y. (2022). Inland fisheries management—case studies of inland fish. Contribution to the Emerging Methods and Topics section of the 2nd edition of the Encyclopedia of Inland Waters. Elsevier, UK. pp. 343-354.

Jensen, I. J., Eilertsen, K. E., Otnæs, C. H. A., Mæhre, H. K., &

Elvevoll, E. O. (2020). An update on the content of fatty acids, dioxins, PCBs, and heavy metals in farmed, escaped, and wild Atlantic salmon (*Salmo salar* L.) in Norway. Foods, 9(12), 1901.

Johansen, L. H., Jensen, I., & Bergh, O. (2011). Disease interaction and pathogen exchange between wild and farmed fish populations with special reference to Norway. Aquaculture, 315, 167–186.

Johansson, N., Svensson, K. M., & Fridberg, G. (1982). Studies on the pathology of ulcerative dermal necrosis (UDN) in Swedish salmon (*Salmo salar* L.) and sea trout (*Salmo trutta* L.) populations. Journal of Fish Diseases, 5, 293–308.

Johnston, I. A., Li, X., Vieira V.L.A., Nickell, D., Dingwall, A., Alderson, R., Campbell, P., & Bickerdike, R. (2006). Muscle and flesh quality traits in wild and farmed Atlantic salmon. Aquaculture 256, (1–4), 323–336. https://doi.org/10.1016/j.aquaculture.2006.02.048.

Khan, M., Rahman, M. M., & Lively, J. A. (2024). Detection of pathogenic bacteria in retailed shrimp from Bangladesh. Food Science & Nutrition 12, 6379-6388. https://doi.org/10.1002/fsn3.4260

Krešić, G., Dujmić, E., Lončarić, D., Zrnčić, S., Liović, N., & Pleadin, J. (2022). Fish consumption: Influence of knowledge, product information, and satisfaction with product attributes. Nutrients, 14(13), 2691.

Krkosek, M., Lewis, M. A., & Volpe, J. P. (2006). Epizootics of wild fish induced by farm fish. Proceedings of the National Academy of Sciences USA, 103, 15506–15510.

Kumar, K. S., Kumari, S., Singh, K., & Kushwaha, P. (2021). Influence of seasonal variation on chemical composition and nutritional profiles of macro- and microalgae. Recent Advances in Micro and Macroalgal Processing: Food and Health Perspectives, 14–71.

Kurath, G., & Winton, J. (2011). Complex dynamics at the interface between wild and domestic viruses of finfish. Current Opinions in Virology, 1, 73–80.

Kyule, D. N., Maingi, J. M., Njeru, E. M., & Nyamache, A. K. (2022). Molecular characterization and diversity of bacteria isolated from fish and fish products retailed in Kenyan markets. International Journal of Food Science, 2022(1), 2379323.

Lagno, A. G., Lara, M., Gaete, A., & Montecinos, K. (2019). Recovering sustainability after a health crisis in aquatic animals. Revue Scientifique et Technique-Office International des Epizooties, 38, 601–613. https://doi.org/10.20506/rst.38.2.3007

Lively, J. A., & McKenzie, J. (2023). Discards and bycatch: A review of wasted fishing. Advances in Marine Biology, 95, 1–26.

López-Mas, L., Claret, A., Reinders, M. J., Banovic, M., Krystallis, A., & Guerrero, L. (2021). Farmed or wild fish? Segmenting European consumers based on their beliefs. Aquaculture, 532, 735992.

Lu, T. H., Chen, C. Y., Wang, W. M., & Liao, C. M. (2021). A risk-based approach for managing aquaculture used oxytetracycline-induced TetR in surface water across Taiwan regions. Frontiers in Pharmacology, 12, 803499.

Ma, Y. B., Zou, W. G., Ai, C. X., Luo, X., Liu, S. T., Huang, H. Q., Chen, Y.-X., You, W.-W., & Ke, C. H. (2023). Interactive effects of diet and water temperature on the nutritional value, flavor, and sensory quality in hybrid abalone (*Haliotis discus hannai♀ × H. fulgens♂*) meat. Aquaculture, 567. https://doi.org/10.1016/j.aquaculture.2023.739241

Martínez-Gómez, C., & Vethaak, A. D. (2019). Understanding the impact of chemicals on marine fish populations: The need for an integrative approach involving population and disease ecology. Current Opinion in Environmental Science & Health, 11, 71–77.

Matsche, M. A., Overton, A., & Rosemary, K. M. (2010). Low level of splenic mycobacteriosis in migratory striped bass *(Morone saxatilis*) from North Carolina and Chesapeake Bay, USA. Diseases of Aquatic Organisms, 90, 191–189.

Maynou, F., Garcia de Vinuesa, A. G., & Demestre, M. (2021). Relative catch performance of two gear modifications used to reduce bycatch of undersized fish and shrimp in Mediterranean bottom trawl fisheries. Marine and Coastal Fisheries, 13, 518–533.

Melikh, T., Voit, D., & Archybisova, D. (2019). Agricultural integration in recreational tourism: Features of development and management of coastal territories. Baltic Journal of Economic Studies, 5, 84–89.

Meng, H., Hayashida, H., Norazmi-Lokman, N. H., & Strutton, P. G. (2022). Benefits and detrimental effects of ocean warming for Tasmanian salmon aquaculture. Continental Shelf Research, 246, 104829.

Mengual, I. L., Sanchez-Jerez, P., & Ballester-Berman, J. (2021). Offshore aquaculture as climate change adaptation in coastal areas: Sea surface temperature trends in the Western Mediterranean Sea. Aquaculture Environment Interactions, 13, 515–526.

Mihafu, F. D., Issa, J. Y., & Kamiyango, M. W. (2020). Implication of sensory evaluation and quality assessment in food product development: A review. Current Research in Nutrition and Food Science Journal, 8(3), 690–702.

Mohanty, B.P., Mahanty, A., Ganguly, S., Mitra, T., Karunakaran, D. & Anandan, R. (2019). The information about nutritional composition is useful for consumer, processor, food policy authorities. Food Chemistry, 293, 561-570. https://doi.org/10.1016/j.foodchem.2017.11.039

Monteiro, M. J. P., & Almeida Costa, A. I. (2024). In Sensory Evaluation and Consumer Acceptance of New Food ProductsPrinciples and Applications, ed. A. I. D. A. Costa, M. J. P. Monteiro, and E. Lamy, Royal Society of Chemistry, 2024, vol. 4 (3), 53-85.

Mordecai, G. J., Miller, K. M., & Joy, J. B. (2021). Aquaculture mediates global transmission of a viral pathogen to wild salmon. Science Advances, 7.

Morris, J. G. (2003). Cholera and other types of vibriosis: A story of human pandemics and oysters on the half shell. Clinical Infectious Diseases, 37, 272–280.

Mozaffarian, D., Lemaitre, R. N., Kuller, L. H., Burke, G. L., Tracy, R. P., & Siscovick, D. S. (2003). Cardiac benefits of fish consumption may depend on the type of fish meal consumed: The Cardiovascular Health Study. Circulation, 107, 1372–1377.

Mugwanya, M., Dawood, M. A., Kimera, F., & Sewilam, H. (2023). Replacement of fish meal with fermented plant proteins in the aquafeed industry: A systematic review and meta-analysis. Reviews in Aquaculture, 15(1), 62-88.

Munro, A. L. S., & Gauld, J. A. (1996). Scottish fish farms annual production survey 1995. SOAEFD Marine Laboratory, Aberdeen.

Murray, A. G., & Peeler, E. J. (2005). A framework for understanding the potential for emerging diseases in aquaculture. Preventive Veterinary Medicine, 7, 223–235.

Nash, C. E. (2011). History of Aquaculture. Blackwells, Oxford, UK. https://doi.org/10.1002/9780470958971

National Research Council (NRC). (1993). Nutrient requirements of fish. Washington, DC: National Academy Press, p. 114.

Navarro-Segura, L., Ros-Chumillas, M., Martínez-Hernández, G. B., & López-Gómez, A. (2020). A new advanced packaging system for extending the shelf life of refrigerated farmed fish fillets. Journal of the Science of Food and Agriculture, 100(12), 4601-4611.

Naylor, R., Hindar, K., Fleming, I. A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., & Mangel, M. (2005). Fugitive salmon: Assessing the risks of escaped fish from net-pen aquaculture. BioScience, 55(5), 427-437.

Nguyen, K. Q. (2024). Catches in derelict bigfin reef squid (*Sepioteuthis lessoniana*) trap fishery. Regional Studies in Marine Science, 78. 103797.

Nijman, V. (2023). Illegal trade in protected sharks: The case of artisanal whale shark meat fisheries in Java, Indonesia. Animals, 13(16), 2656.

Nishinari. (2020). Textural characteristics of world foods. K. Nishinari (Ed.). John Wiley & Sons Incorporated.

Onmaz, N. E., Yildirim, Y., Karadal, F., Hizlisoy, H., Al, S., Gungor, C., Disli, H.B., Barel, M., Dishan, A., Tegin, R.A.A., & Simsek, E. (2020). *Escherichia coli* O157 in fish: Prevalence, antimicrobial resistance, biofilm formation capacity, and molecular characterization. LWT, 133, 109940.

Oomen, C. M., Feskens, E. J., Räsänen, L., Fidanza, F., Nissinen, A. M., Menotti, A., Kok, F.J., & Kromhout, D. (2000). Fish consumption and coronary heart disease mortality in Finland, Italy, and The Netherlands. American Journal of Epidemiology, 151(10), 999-1006.

Orban, E., Nevigato, T., Lena, G.D., Casini, I., & Marzetti, A. (2003). Differentiation in the lipid quality of wild and farmed seabass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*). Journal of Food Science, 68, 128-132. https://doi.org/10.1111/j.1365-2621.2003.tb14127.x

Özçiçek, E. (2018). Keban Baraj Gölü Pertek Bölgesinde yetiştiriciliği yapılan ve doğadan avlanan gökkuşağı alabalığının (*Oncorhynchus mykiss*, Walbaum 1792) besin düzeylerinin karşılaştırılması. Doktora Tezi, Munzur Üniversitesi Fen Bilimleri Enstitüsü, Tunceli.

Özçiçek, E., Can, E., & Yılmaz, Ö. (2022). Comparison of nutrient contents of wild and farmed rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) from Keban Dam Lake in Eastern Anatolia region of Turkey. Aquaculture Research, 53, 2457–2463. https://doi.org/10.1111/are.15763

rundvåg, G. & Straume, H.-M. (2023). Is capture-based aquaculture viable? The case of Atlantic cod in Norway. Aquaculture, 572, 739520

Pham, C. V., Wang, H. C., Chen, S. H., & Lee, J. M. (2023). The threshold effect of overfishing on global fishery outputs: International evidence from a sustainable fishery perspective. Fishes, 8(2), 71.

Piggot, G. M., & Tucker, B. W. (1990). Seafood: Effects of technology on nutrition. CRC Press, Boca Raton, Florida, USA, pp. 337.

Prabhakar, P. K., Vatsa, S., Srivastav, P. P., & Pathak, S. S. (2020). A comprehensive review on freshness of fish and assessment: Analytical methods and recent innovations. Food Research International, 133, 109157.

Prasongdee, T. K., Seesui, K., & Intapan, P. M. (2022). High prevalence of intestinal capillariasis in chronic diarrhea patients in Thailand: Serological screening using a rapid lateral-flow immunochromatographic assay. American Journal of Tropical Medicine and Hygiene, 107, 370–372.

Pu, D., Shan, Y., Wang, J., Sun, B., Xu, Y., Zhang, W., & Zhang, Y. (2024). Recent trends in aroma release and perception during food oral processing: A review. Critical Reviews in Food Science and Nutrition, 64(11), 3441–3457.

Puniwai, N., Canale, L., Haws, M., Potemra, J., Lepczyk, C., & Gray, S. (2014). Development of a GIS-based tool for aquaculture siting. ISPRS International Journal of Geo-Information, 3, 800–816. https://doi.org/10.3390/ijgi3020800

Roccatello, R., Endrizzi, I., Aprea, E., & Dabbou, S. (2024). Insect-based feed in aquaculture: A consumer attitudes study. Aquaculture, 582, 740512.

Rodriguez, C., Mith, H., Taminiau, B., Bouchafa, L., Van Broeck, J., Soumillion, K., Ngyuvula, E., García-Fuentes, E., Korsak, N., Delmée, M., & Daube, G. (2021). First isolation of *Clostridioides difficile* from smoked and dried freshwater fish in Cambodia. Food Control, 124, 107895.

Saichua, P., Nithikathkul, & Kaewpitoon, N. (2008). Human capillariasis in Thailand. World Journal of Gastroenterology, 14(4), 506–510.

Sargent, J. R. (1997). Fish oils and human diet. British Journal of Nutrition, 78(1), 5–13.

Silva, P. M., Pita, C., & Teixeira, C. M. (2024). Two realities in the Portuguese tuna fishery: What happens in the largest EEZ of European Union? Regional Studies in Marine Science, 103719.

Simionov, I. A., Petrea, S. M., & Neculita, M. (2021). Assessment of global warming impact on aquatic ecosystems: A state-of-the-art perspective. Scientific Papers-Series E: Land Reclamation Earth Observation & Surveying Environmental Engineering, 10, 166–171.

Simopoulos, A. P. (2006). Evolutionary aspects of diet, the omega-6/omega-3 ratio, and genetic variation: Nutritional implications for chronic diseases. Biomedicine & Pharmacotherapy, 60(9), 502–507.

Simukoko, C. K., Mwakalapa, E. B., Bwalya, P., Muzandu, K., Berg, V., Mutoloki, S., Polder, A., & Lyche, J. L. (2022). Assessment of heavy metals in wild and farmed tilapia (*Oreochromis niloticus*) on Lake Kariba, Zambia: Implications for human and fish health. Food Additives & Contaminants: Part A, 39(1), *74*–91.

Singh, A., Mittal, A., & Benjakul, S. (2022). Undesirable discoloration in edible fish muscle: Impact of indigenous pigments, chemical reactions, processing, and its prevention. Comprehensive Reviews in Food Science and Food Safety, 21(1), 580–603.

Sripradite, J., Thaotumpitak, V., Atwill, E. R., Hinthong, W., & Jeamsripong, S. (2024). Distribution of bacteria and antimicrobial resistance in retail Nile tilapia (*Oreochromis* spp.) as potential sources of foodborne illness. Plos one, 19(4), e0299987.

Stevens, B. G. (2021). The ups and downs of traps: Environmental impacts, entanglement, mitigation, and the future of trap fishing for crustaceans and fish. Symposium on Shellfish – Resources and Invaders of the North. Journal of Marine Science, 78, 584–596.

Stormo, S. K., & Skåra, T. (2023). How to limit cook loss when preparing cod (Gadus morhua): The constraints of temperature and time. International Journal of Gastronomy and Food Science, 33, 100759.

Gastronomy and Food Science, 33, 100759.

Su, P., Chang, J., Yu, F., Wu, X., & Ji, G. (2024). Microplastics in aquaculture environments: Sources, pollution status, toxicity and potential as substrates for nitrogen-cycling microbiota. Agricultural Water Management, 304, 109090.

Tacon, A.G.J. & Metian, M. (2013). Fish matters: Importance of aquatic foods in human nutrition and global food supply. Reviews in Fisheries Science, 2, 22-38. https://doi.org/10.1080/10641262.2012.753405

Tamburini, E., Turolla, E., Fano, E. A., & Castaldelli, G. (2020). Sustainability of mussel (*Mytilus galloprovincialis*) farming in the Po river delta, northern Italy, based on a life cycle assessment approach. Sustainability, 12(9), 3814.

Tang, K. F. J., & Bondad-Reantaso, M. G. (2019). Impacts of acute hepatopancreatic necrosis disease on commercial shrimp aquaculture. Revue Scientifique et Technique-Office International des Epizooties, 38, 477–489. https://doi.org/10.20506/rst.38.2.2999

URL1.https://amosinstitute.com/blog/wild-caught-vs-sustainably-farmed-fish/ (17.11.2024).

URL2.https://www.baliksevdam.com/konu/dogadan-yakalanan-balik-mi-yoksa-kultur-ciftlik-baligi-mi.1459/ (17.11.2024).

URL3. Geneva Environment Network. (15 Jul 2021). https://www.genevaenvironmentnetwork.org/resources/updates/overfishing/

URL4.https://tarim.ibb.istanbul/tarim-ve-su-urunleri-mudurlugu/hal-fiyatlari.html, Access 10.12.2024.

URL5.https://eislem.izmir.bel.tr/tr/BalikHalFiyatlari/21, Access 10.12.2024.

Verbeke, W., Sioen, I., Brunsø, K., De Henauw, S. & Van Camp, J. (2007). Consumer perception versus scientific evidence of farmed and wild fish: exploratory insights from Belgium. Aquaculture International 15, 121-136, https://doi.org/10.1007/s10499-007-9072-7

Villasante, S., Sumaila, U. R., Da-Rocha, J. M., Carvalho, N., Skerritt, D. J., Schuhbauer, A., Cisneros-Montmayor, A.M., Bennett, N.J., Hanich, Q., & Prellezo, R. (2022). Strengthening European Union fisheries by removing harmful subsidies. Marine Policy, 136, 104884.

Vollset, K. W., Lennox, R. J., & Miller, K. M. (2021). Wild salmonids are running the gauntlet of pathogens and climate as fish farms expand northwards. ICES Journal of Marine Science, 78, 388–401.

Wang, L., Jia, S.-P., Zhang, L., Ma, F.-R., Zhang, M., Yu, M., Jiang, H.-X., Qiao, Z.-G., & Li, X. J. (2022). Comparative study on nutritional quality and volatile flavor compounds of muscle in *Cyprinus carpio haematopterus* under wild, traditional pond and in-pond raceway system culture. *Aquaculture Reports, 25,* 101194.

Wang, L., Xiong, J., Xu, C., Qin, C., Zhang, Y., Yang, L., Zhi, S., Feng, J., & Nie, G. (2024). Comparison of muscle nutritional composition, texture quality, carotenoid metabolites and transcriptome to underlying muscle quality difference between wild-caught and pond-cultured Yellow River carp (*Cyprinus carpio haematopterus*). Aquaculture, 581, 740392.

Wootton, E. C., Woolmer, A. P., Vogan, C. L., Pope, E. C., Hamilton, K. M., & Rowley, A. F. (2012). Increased disease calls for a cost-benefits review of marine reserves. PLoS One, 7(12), e51615.

Wuertz, S., Orban, A., Schaefer, F. J., Overton, J. L., & Krüger, A. (2023). Carotenoids and retinoids in the gonad of brood-stock pikeperch: accumulation during vitellogenesis and influence on egg quality in farmed pikeperch Sander lucioperca. Animal Reproduction, 20(1), e20220103.

Xiao, Y., Liu, S., Gao, Y., Zhang, Y., Zhang, Q., & Li, X. (2022). Determination of antibiotic residues in aquaculture products by liquid chromatography tandem mass spectrometry: Recent trends and developments from 2010 to 2020. Separations, 9(2), 35.

Yerlikaya, P., & Yatmaz, H.A. (2025). A comparative study of amino acids and B-group vitamins of commercial fish species. Turkish Journal of Fisheries and Aquatic Sciences, 25, TRJFAS25890. https://doi.org/10.4194/TRJFAS25890

Yu, M., Herrmann, B., Liu, C., Zhang, L., & Tang, Y. (2023). Effect of codend design and mesh size on the size selectivity and exploitation pattern of three commercial fish in stow net fishery of the Yellow Sea, China. Sustainability, 15(8), 6583.

Yuan, B., Yue, F., Wang, X., & Xu, H. (2021). The impact of pollution on China marine fishery culture: An econometric analysis of heterogeneous growth. Frontiers in Marine Science, 8, 760539.

Yüngül, M., & Özdemir, Y. (2017). Digestion in fish, digestive enzymes and secretions. International Journal of Pure and Applied Sciences, 3(2), 20–32.

Zhang, Z., Sun, Y., Sang, S., Jia, L., & Ou, C. (2022). Emerging approach for fish freshness evaluation: Principle, application and challenges. Foods, 11(13), 1897.

Zhang, Y. H., Yu, Q. Y., & Hong, H. (2023). Dual cryoprotective and antioxidant effects of young apple polyphenols on myofibrillar protein degradation and gelation properties of bighead carp mince during frozen storage. Journal of Food Science, 88, 4560–4573.

Zhuang, S., Tan, Y., Hong, H., Li, D., Zhang, L., & Luo, Y. (2022). Exploration of the roles of spoilage bacteria in degrading grass carp proteins during chilled storage: A combined metagenomic and metabolomic approach. Food Research International, 152, 110926.