




Review

Links and Trade-Offs between Fisheries and Environmental Protection in Relation to the Sustainable Development Goals in Thailand

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Received: 8 December 2019; Accepted: 27 January 2020; Published: 2 February 2020



Abstract: The fisheries sector significantly contributes to global food security, nutrition, and livelihood of people. Its importance for economic benefits, healthy diets, and nutrition, and achieving sustainable food systems is highlighted by several Sustainable Development Goals (SDGs), i.e., SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 14 (Life Below Water). However, due to unprecedented population levels, the contribution of the fisheries sector to fulfill these roles is challenging, particularly given additional concerns regarding environmental well-being and sustainability. From this perspective, this study aims to identify the links and trade-offs between the development of this sector and the environmental sustainability in Thailand via a critical analysis of their trends, current ecological impacts, and more importantly, their contributions to several individual SDGs. A time-series of Thailand's fisheries production from 1995 to 2015 indicates a recent reduction from around 3.0 million tons in 1995 to 1.5 million tons in 2015 of wild fish and shellfish from marine and freshwater habitats. The maximum sustainable yield of these species has been exceeded. Conversely, Thailand's aquaculture production has continued to grow over the last decade, resulting in a reduction of mangrove forest area, wild fish stocks, and water quality. While capture fisheries and aquaculture production significantly contribute to several SDG targets, there are potential trade-offs between their development and the achievement of SDGs within the planet dimension, i.e., SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14, and SDG 15 (Life on Land). On the one hand, the mitigation of overfishing will be beneficial for the targets of SDG 14, leading to more sustainable resource management. On the other hand, it might cause a decrease in the volume of marine catches and economic and social profits. We conclude that the SDGs can serve as a framework for both policymakers and industrial workers to monitor and compromise on regulations that will optimize productivity in the context of sustainable development.

Keywords: capture fisheries; aquaculture production; environmental management; sustainability; SDGs; Thailand

1. Introduction

Food security is of global importance due to the staggering increase in population and consumption, while land, water, and climate concurrently degrade worldwide [1–3]. The fisheries sector, an industry

that comprises wild capture fisheries and aquaculture, is vital to ensure global food security. It is an essential contributor to wholesome fish and shellfish, which are excellent dietary sources of animal proteins, micronutrients, and vitamins [4–6]. Accordingly, several Sustainable Development Goals (SDGs) from the UN's 2030 Agenda for Sustainable Development, such as SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 14 (Life Below Water), highlight the importance of fishery resources to achieve sustainable food systems, develop economic benefits and provide nutrition in order to safeguard global food security [3,6,7].

There are different types of interactions between the SDGs and the fisheries sector [8]. Unprecedented population levels and increased demands for seafood have challenged the growth of the fisheries sector, along with increased requirements related to sustainability and environmental well-being. The world's fisheries production totaled 170.9 million tons in 2016, of which 90.9 million tons (53%) were from capture fisheries and 80.0 million tons (47%) were from aquaculture [3]. Thailand was in the world's top twenty-five countries in terms of capture fisheries production in 2016 [3], with estimated yields of up to 2.4 million tons, of which 63% came from capture production and the remaining 37% came from aquaculture production [9]. In addition to providing food security, fisheries are an essential national economic activity and source of nutrients for the Thai population [10]. Unfortunately, a recent assessment by the Department of Fisheries (DoF) [11] indicated that fish catches have greatly exceeded the maximum sustainable yield (MSY) in the coastal waters of Thailand.

Catches from marine fisheries have been declining globally and regionally due to overfishing (mainly by industrial fleets) and resource depletion [12,13]. Meanwhile, aquaculture continues to increase and intensify as a means to increase seafood production in the face of the growing demand for a source of animal protein [14,15]. This has led to considerable impacts on the environment, such as decreasing the area of mangrove forests and increasing nutrient pollution near coastal ponds and cages [16,17]. Therefore, the present work aims to examine the trends of the fisheries sector in Thailand and to analyze temporal trends. We also describe the interaction between the fisheries sector and the SDGs, including the trade-offs that must be considered when steering the entire sector towards more environmentally-friendly approaches.

We present our analysis in four different parts. In the first section, we focus on the state and trends of capture and aquaculture production in Thailand from 1995 to 2015 in order to discuss how fishery products are used in trade. In the second section, we elaborate on the ecological links between capture and aquaculture production, while the third and fourth section review the interactions between the SDGs and the fisheries sector and provide an additional focus on the preservation of the planet and the biosphere, respectively.

2. Overview of Fisheries Production in Thailand

The fisheries sector in Thailand combines wild capture and aquaculture production. Figure 1 demonstrates Thailand's fisheries' production between 1995 and 2015. For wild capture production (marine and freshwater), this period consisted of three phases: stable production from 1995 to 2006, gradual reduction between 2007 and 2008, and stabilization at a lower level from 2008 onwards. During the first phase, annual catch neared 3 million tons, with 93% coming from marine capture and 7% coming from inland capture. The decrease during 2006–2008 was mainly due to neighboring countries such as Indonesia and Myanmar tightening restrictions on foreign fishing access within their exclusive economic zone [11,12,18]. Overexploitation, environmental degradation, and increased fuel prices also played a part in the reduction [10,11,19,20]. As a result, since 2009, Thailand's wild capture production has remained stable at approximately 1.7 million tons. Meanwhile, yields from aquaculture (freshwater and marine) rose from 0.6 million tons in 1995 to 0.9 million tons in 2015. An estimated 62% (617,000 tons) originated from coastal aquaculture, and the remaining 38% (384,000 tons) originated from freshwater aquaculture [21].

Estimates over the past decade have shown that the annual value of fisheries production was estimated at US\$3900 million, of which 44% (US\$1740 million) were from wild capture fisheries and

56% (US\$2220 million) were from aquaculture [21]. The composition of wild capture in Thailand is 85% fish, 6% squid and cuttlefish, 3% shrimp, and 6% others (e.g., crabs and mollusks). Meanwhile, 40% of aquaculture yields come from shrimp, closely followed by fish (38%) and mollusks (22%).

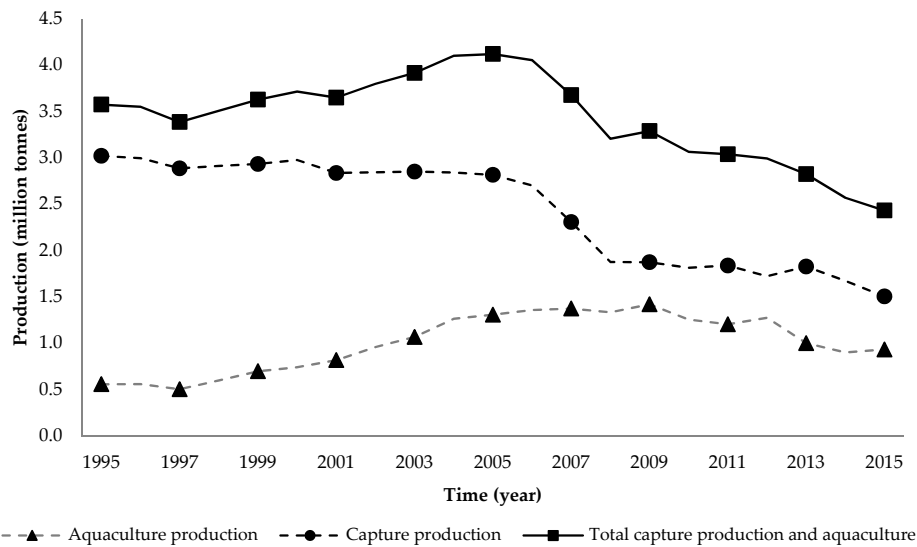


Figure 1. The yield of capture and aquaculture from 1995 to 2015. Based on data from the Department of Fisheries (DoF) [21].

Thailand is one of the world’s largest seafood producers and exporters. Fisheries play a significant role in sustaining the country’s food security, as well as contributing to the local and national economies [22]. From 1995 to 2015, the value of fisheries exports increased from US\$4680 million (1.2 million tons) to US\$6000 million (1.7 million tons) per year. Meanwhile, the value of fisheries imports rose from US\$880 million (0.9 million tons) to US\$2630 million (1.6 million tons) per year (Figure 2) [21]. In 2015, the country’s exports and imports each reached 1.6 million tons [21]. In the same period, fishery products in airtight containers (e.g., tuna, sardine, and shrimp) accounted for 36% of the total exported fishery products [21]. In 2015, half of the total fishery exports were to five destinations: Japan (14%), the United States (17%), the European Union (EU) (7%), China (7%), and Malaysia (6%). About 9% of the exported fishery products were fish meal, which mostly went to China (38%), Japan (24%), and Vietnam (20%). As for imported fishery products, 92% were fresh chilled or frozen, 3% were prepared or preserved, and 2% were fish meal [21]. By quantity, 44% of fishery imports came from China (15%), Taiwan (9%), the United States (8%), Japan (7%), and Vietnam (6%) [21].

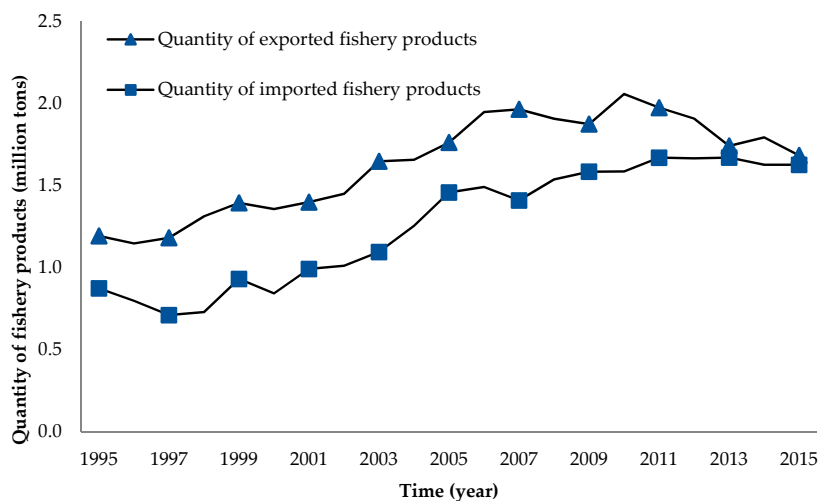


Figure 2. Cont.

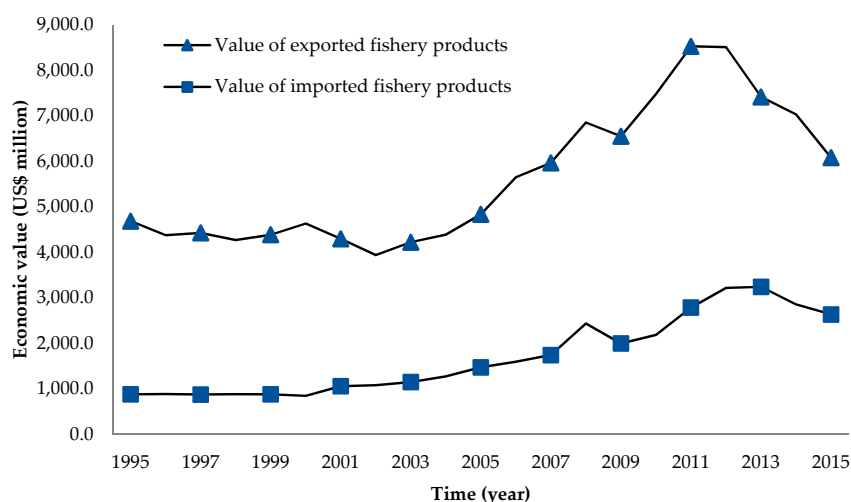


Figure 2. Quantity and value of exported and imported fishery products from 1995 to 2015. Based on data from the DoF [21].

3. Ecological Links between Wild Capture and Aquaculture Production

In Thailand, marine aquaculture production has dramatically expanded over the past few decades. From 1995 to 2015, the land area that was taken up by coastal aquaculture was on average 78,000 ha per year [21]. Out of this total area, 66,100 ha of land (84%) were used for shrimp farming, 11,200 ha (14%) were used for shellfish farming, and the remaining areas were applied for fish farming. Farmed shrimp supplies totaled at around 0.4 million tons annually between 1995 and 2015 [21]. It seems that shrimp is now primarily produced to boost and develop the national economy [23]. Nevertheless, it has been concluded that the growing production of aquaculture has been degrading the freshwater environment and threatening coastal ecosystems and ocean resources (Figure 3) [24]. The use of wild fish to feed farmed fish can have negative effects on wild fishery resources [25,26], while aquaculture tends to impact wild fisheries through habitat modification, the collection of wild seedstock, the introduction of exotic species and pathogens that harm wild fish population, and nutrient pollution [24]. Many of the initial environmental concerns with shrimp farming were regarding the conversion of coastal lands, which could lead to the degradation of mangroves and the loss of nursery habitats for marine animals [24,27–31]. This transformation can lead to a loss of essential ecosystem services that are generated by mangroves such as coastal protection, flood control, sediment trapping, and water treatment, which may result in a serious reduction of stocks of marine animals [24].

A significant environmental impact of aquaculture systems results from their effluents that pollute the water [16]. Several studies have indicated that when left untreated, wastewater that is filled with fish feces and leftover feed could lead to nutrient pollution near coastal ponds and cages [24,32]. Untreated wastewater could hence cause coastal eutrophication, which negatively affects water quality [33]. Coastal water quality has also been affected due to the use of antibiotics on shrimp culture [24,30]. Antibiotics are commonly used in shrimp farming to prevent and treat disease outbreaks, as they have become frequent enough to negatively affect shrimp yields in recent years [30,34]. Holmström et al. [35] showed that the majority of shrimp farmers along the Thai coast used antibiotics in their farms. Of the 76 farmers interviewed, 74% used antibiotics in their shrimp ponds. The use of antibiotics also causes problems for trade. The EU has implemented more stringent quality-control policies and thus imposed bans on shrimp imports from Thailand due to the detection of drug residues [30]. The Government of Thailand has invested in universities and quasi-public institutions such as the Thai National Center for Genetic Engineering and Biotechnology in order to address aquatic animal diseases in aquaculture [30].

The use of wild fish to feed aquaculture populations generates direct pressure on fishery resources [24]. Between 1995 and 2015, the annual estimates of low value/trash fish production in Thailand averaged 606,000 tons, with a value of approximately US\$74 million [21]. The proportion of trash fish to total marine

fishes caught in Thai coastal waters decreased from 38% in 1995 to 26% in 2015 (Table 1). Supongpan and Boonchuwong [36] indicated that about 42% of trawler catches in the Gulf of Thailand in 2007 comprised small trash fish, with 35% of these fish belonging to juvenile members of commercial fish species. Trash fish can be used in several ways, e.g., being processed into fish meals or fish oils, directly used as feed for aquaculture or poultry farms, and being fermented into fish sauce or Budu sauce for human consumption [26,37]. Traditionally, trash fish are referred to as “Plaped,” which means “fish for ducks” because they used to chiefly be fed to ducks, and, later, animal livestock. With the emergence of coastal cage fish farming, more trash fish are used in fish feed for aquaculture production [38].

Table 1. The proportion of trash fish to total marine fishes caught in Thai coastal waters, their value, and the number of fish meal factories from 1995 to 2015.

Year	% Trash Fish out of Total Marine Fishes Caught	Value of Trash Fish (US\$ million)	Number of Fish Meal Factories
1995	38	92	122
2000	35	58	96
2005	33	76	99
2010	32	87	87
2015	26	66	70

Source: DoF [21].

Limits to wild capture fisheries can affect aquaculture industries. A study by Boonyubol and Pramokchutima [25] pointed out that only six fish meal factories existed in Thailand as of 1967. The number of factories increased to meet increasing demands in the 1970s and 1980s, but the industry shrank again from the 1990s onwards. The number of fish meal factories steadily decreased from 122 plants in 1995 to 70 plants in 2015 [21]. A possible reason for this may be the decline of total trash fish landings in Thailand, as they are the primary source of raw materials in fishmeal manufacturing [25]. The landings of trash fish have continuously declined from over 900,000 tons in 1995 to 280,000 tons in 2015 [21]. More specifically, annual marine capture production has decreased, most likely due to the exploitation of marine fish stocks beyond the maximum sustainable yield. Therefore, Thailand is currently working to reform its fisheries and reduce its fishing efforts to levels that are estimated to achieve the maximum sustainable yield [11,12].

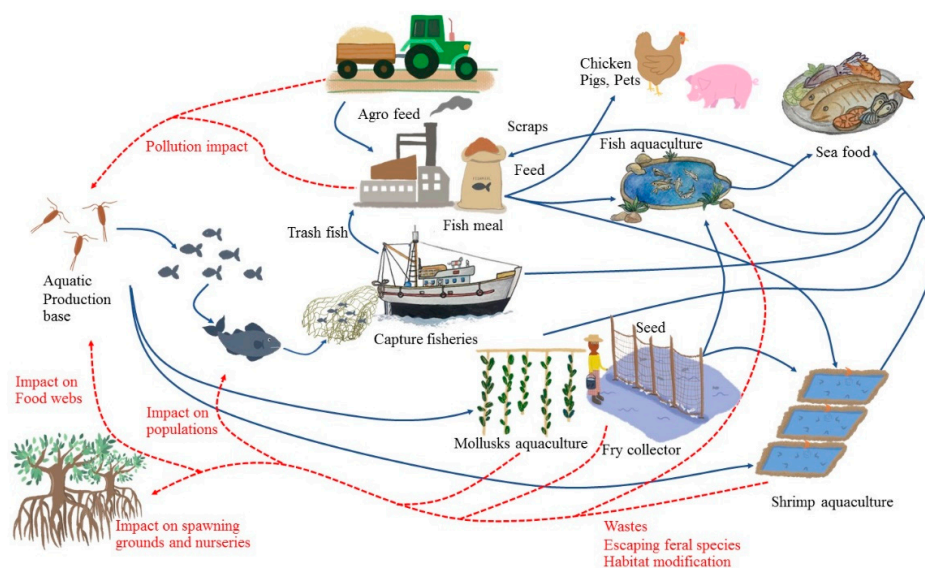


Figure 3. The ecological links between aquaculture and capture productions. The blue lines demonstrate the relationship between capture and aquaculture production to the human consumption of seafood. The hatched red lines indicate the negative impacts of the productions on mangrove and marine ecosystems. Adapted from Naylor et al. [24].

4. Interlinkages between the Fisheries Sector and the Sustainable Development Goals with Regards to Environmental Sustainability

4.1. Overview of the Contributions of Fisheries to the Achievement of the SDGs

The 2030 Agenda for Sustainable Development from the UN is a plan of action for the prosperity of people and the planet. This Agenda contains 17 SDGs, 169 targets, and 232 indicators which encompass five dimensions (5P's): (1) People (SDGs 1, 2, 3, 4, and 5); (2) Planet (SDGs 6, 12, 13, 14, and 15); (3) Prosperity (SDGs 7, 8, 9, 10 and 11); (4) Peace (SDG 16); and (5) Partnership (SDG 17) [7]. The interdependence of each target means that an integrated and coordinated implementation of the SDGs is required [7]. Since the fisheries sector is crucial to ensure sustainable development, several of the SDG targets pertain to this industry (Figure 4).

With regards to SDGs 1, 2, 3, 4, and 5, the production of both wild capture and aquaculture generates income to support local and national economies (SDG 1), improves nutrition and safeguards global food security (SDG 2), and ensures healthy lives (SDG 3). Considering quality education (SDG 4) and gender equality (SDG 5), small-scale fisheries could be a significant contributor to improve the status of women working in small-scale fisheries [39]. Moreover, fishing and related activities can directly provide food and income for households and communities, which may allow more children to have access to education [39].

In regard to the targets of SDGs 7, 8, 9, 10, and 11, fish waste holds a potential for biogas production and could be a solution for cheap fuel and sustainable waste management [40]. This contributes to SDG 7, which focuses on affordable and clean energy. As for SDG 8 (Economic Growth), capture fisheries and aquaculture employed almost 60 million people globally in 2016, with the majority from developing countries [3]. SDG 9 aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Innovative aquaculture technologies have been increasingly developed and used for sustainable aquaculture practices. For instance, several recent studies have examined alternative sources of protein (e.g., algae meal, soy meal, wheat gluten, corn gluten, and insects) to replace fishmeal and fish oil in aquafeed production [41,42]. Furthermore, fisheries are key to eliminating hunger, promoting health, and reducing poverty by providing essential nutrients, especially for the poor (SDG 10) [18]. Artisanal or small fishing villages play an active role in conserving, protecting, and safeguarding their marine resources through the use of traditional and customary practices [39,43–45]. This can lead to fishing systems that are guaranteed for future generations, preserving biological and cultural heritage (SDG 11) [39,43].

The fisheries sector contributes to peace and partnership issues. The availability of seafood as a food source can help avert food shortages, which are considered a driver for violence-related issues (SDG 16) and the basis for local and international partnerships that are related to food production and trade (SDG 17) [46].



Figure 4. The contributions of capture fisheries and aquaculture production in underpinning the achievement of the Sustainable Development Goals (SDGs). Adapted from Ho and Goethals [46].

4.2. Fisheries in Thailand and the Environment-Related SDGs: An Intricate Relationship

We only discuss the interaction between the fisheries sector and the SDGs in the context of biosphere preservation (Table 2). This consists of five SDGs in total: (i) ensuring the availability and sustainable management of water and sanitation for all (SDG 6), (ii) ensuring sustainable consumption and production patterns (SDG 12), (iii) taking urgent action to combat climate change and its impact (SDG 13), (iv) conserving and sustainably using the oceans, seas and marine resources for sustainable development (SDG 14), and (v) protecting, restoring and promoting the sustainable use of terrestrial ecosystems, sustainably managing forests, combatting desertification, halting and reversing land degradation, and halting biodiversity loss (SDG 15).

SDG 6 focuses on the sustainable management of water and sanitation for all. Water (quantity and quality) and the fisheries sector are inextricably linked. As a result, most of the targets to achieve SDG 6 are beneficial for the sustainable development of wild capture and aquaculture production. For example, healthy inland aquatic ecosystems are indicators of good water quality and are an ideal fisheries resource that requires minimal treatment (SDG target 6.1 and 6.6) [3]. SDG targets 6.4 and 6.5 pertain to the management of water resources, which can help guarantee sustainable water management for agriculture, domestic consumption, ecological balance, or hydropower [46]. The resulting water security will highly benefit fisheries and aquaculture farms.

While fisheries production requires good quality water, aquaculture farms and fishing vessels also have a direct impact on water quality. Globally, over 80% of wastewater is released to the environment without adequate treatment [47]. In aquaculture farms, the release of wastes may contaminate nearby water bodies with harmful chemicals and inflict eutrophication [24,34]. In Thailand, based on the Pollution Control Department [48], the average amount of untreated wastewater from coastal shrimp culture between 1995 and 2015 was estimated at 730,000,000 m³ per year (1943.97 m³ wastewater per ton of shrimp yield). Furthermore, antibiotics are another pressing concern. In Thailand, the majority of Thai farmers use antibiotics to prevent disease outbreaks, specifically in shrimp cultures [35]. Although antibiotics can tackle animal diseases, they can lead to water pollution. The use of chemicals and therapeutics in aquaculture is a major and complex ongoing issue with implications for SDGs related to water quality, health and safety, resource use efficiency, and biodiversity [49].

Two indicators were proposed to track the progress of target 6.3 (reducing pollution level, controlling the disposal of hazardous substances and treating the wastewater): the proportion of wastewater safely treated and proportion of bodies of water with good ambient water quality [50]. More than 50% of domestic wastewater flows was safely treated in 56 out of the 79 countries listed on the Global SDG Indicators Database [50]. The majority of 56 countries were high-income countries (e.g., Malta, Switzerland, The Netherlands, Germany, and Japan). Many countries, including Thailand, did not have sufficient data for their performance to be evaluated [51]. This is commonly observed in developing countries due to the lack of infrastructure, financing measures, and technical and institutional capacity [47].

SDG 12 promotes responsible consumption and production trends, focusing on sustainable management of natural resources, recycling, and sound management of chemicals and waste [7]. Responsible consumption and production would mean that the fisheries sector needs to use their coastal and marine resources as efficiently as possible. Possible methods of improving efficiency include closer performance monitoring of businesses, regulatory constraints, and systems such as product certification, traceability systems, and ecolabelling [52–54]. These systems have been implemented to fulfill different consumer needs; for instance, traceability systems can ensure product origin, safety, and quality. They reassure consumers and processing companies that the animal was legally caught and that the quality was adequate for sale. In addition, to prevent, deter, and eliminate illegal, unreported, and unregulated fishing, the EU established a Community system (Council Regulation No 1005/2008) in January 2010. Regional fisheries management organizations followed the EU's lead by introducing catch documentation schemes to their member countries—including Thailand—that have attempted

to implement the specified practical measures. Nevertheless, due to limited human, monetary, and technical resources, studies on the effectiveness of these systems have yet to be conducted [55].

SDG 13 pays attention to climate change and its impacts. Capture fisheries and aquaculture have a lower environmental impact than ruminant meat production [3]. Inland fisheries have a particularly low carbon footprint when compared with other food sources [3]. Climate change is becoming a threat for fisheries and aquaculture production. Several studies have indicated that climate change would globally impact the potential of fisheries through changes in species distributions and/or a shifting production as species move to new habitats [56,57]. This change in the productivity of fisheries has been observed earlier in many countries. The shift in spatial distributions and range of tuna species is expected to have knock-on effects on coral reef fisheries in the western Indian Ocean [58]. In South and Southeast Asia, for example, Barange, et al. [56] predicted that by 2050, climate change would decrease the region's total productive potential due to a temperature increase of approximately 2 °C. Climate change would impact widely-distributed, top-fished species, e.g., hilsa shad (*Tenuulosa ilisha*), Indian oil sardine (*Sardinella longiceps*), Bombay duck (*Harpadon nehereus*), Indian mackerel (*Rastrelliger kanagurta*), Indian salmon (*Eleutheronema tetradactylum*), small tunas and squids [58].

Additionally, climate change has resulted in increasing land and sea surface temperatures, widespread reduction of snow and ice, and sea-level rises. Coastal zones of Thailand, for instance, have experienced increases in sea level at the rate of 3 mm to 10.5 mm per year in the last two decades [59]. Rising sea levels can lead to coastal erosion, seawater intrusion, and floods [60]. Note that strategies to improve short-and long-term performance of fisheries industry, such as reducing feet capacity and reducing vessel speed, can offer a particular benefit in reducing fuel use and emissions [61].

SDG 14 is directly related to conserving and using the oceans and their resources for sustainable development. The targets of SDG 14 are designed to reduce pollution (SDG target 14.1 and 14.3), restore and enhance habitats of wild juveniles (SDG target 14.2 and 14.5), and regulate fish harvesting (SDG target 14.4 and 14.6). These targets would require some trade-offs to be made by capture fisheries and aquaculture farms, even though they would provide benefits on the long run. An example of such a trade-off is with SDG target 14.1 (reduction of marine pollution from land-based activities) since fishery production processes constitute a significant source of marine pollution. Oil spills are a recurring issue that is considered to be one of the most damaging to marine environments and sustainable water management. According to the Marine Department [62], there were around 230 oil spill incidents recorded in Thai waters over 40 years, from 1973–2015. Causes of these spills are usually marine transportation, installation, and vessel navigation, but they could also be due to the smuggling and dumping of oil waste from ships [63,64]. The most recent oil spill occurred in 2013, in which a pipeline operated by PTT Global Chemical leaked, spilling approximately 50,000 liters of oil [63]. This incident affected the coastal ecosystem, coastal resources, aquaculture production, and tourism of Thailand [65]. Marine debris and marine litter resulting from capture and aquaculture production can also disrupt ocean ecosystems [66].

The main aim of SDG targets 14.4 and 14.6 is to mitigate overfishing and restore fish stocks, which can lead to sustainable resource management in the future. The ocean has always been the most significant contributor to fisheries production worldwide [26]. In 2016, it was responsible for 87% (79.3 million tons) of global capture production (90.9 million tons), with inland production making up the other 13% (11.6 million tons) [3]. Nonetheless, the performance of fisheries management is mainly assessed by the state of targeted fish stocks [8,26]. Globally, 59.9% of fish stocks assessed are classified as maximally sustainably fished stocks, while 33.1% and 7.0% were estimated to be overfished and underfished stocks, respectively [3]. In the waters of Thailand, total marine catch has decreased in recent years [11]. This is most likely due to the maximum sustainable yields of several species being exceeded, e.g., Indian mackerel (*Rastrelliger kanagurta*), lizardfish (*Saurida undosquamis* and *S. elongata*) and bigeye scad (*Selar crumenophthalmus*) [67–70]. To prevent marine resources from being depleted and to promote sustainable fishing, a reformation of Thai marine fisheries was ordered, e.g., the Royal Ordinance on Fisheries B.E. 2558 (2015), Fisheries Management Plan of Thailand 2015–2019, and

National Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing 2015–2019 [12,55]. Further improvement to fisheries management is needed to reduce overfishing and biodiversity loss [8]. Strategies to eliminate illegal fishing, reduce fishing effort, and decrease harvest will benefit the development of fisheries in a long term. In the short term, however, aggressive fishery reforms will reduce the amount of marine catch as well as have economic and social repercussions on profits, especially in Asia [71].

Finally, SDG 15 aims to protect and restore terrestrial and inland freshwater ecosystems, sustainably manage forests, and halt biodiversity loss [7]. Most of the targets to achieve this SDG are beneficial toward the sustainable development of inland and marine fisheries production [3]. An important indicator for measuring biodiversity loss is the Red List Index, which is based on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species. In 2019, the database lists around 27,000 species as being threatened from a total of 1.7 million species in four categories (vertebrates, invertebrates, plants, and fungi & protists), with around 2,300 species of these being fishes (6.8% of total fish species). According to the United Nations List of Protected Areas by the United Nations Environment World Conservation Monitoring Center (UNEP-WCMC) [72], from 1962 to 2014, the world's protected area has increased in size from 24.0 to 32.8 million km². Thailand's protected area exceeds more than 103,000 km², of which about 97,390 (19% of the total land area) km² were terrestrial protected areas and approximately 5,770 km² (2% of the total marine area) were marine areas [73]. Although the potential benefits of protected areas are a mainstay of biodiversity conservation [74], it might cause short-term reduction of fisher's profits because of a limitation of fishing area.

Invasive alien species and ecological damage are a threat to global biodiversity [75]. SDG target 15.8 is designed to prevent and reduce the impact of invasive alien species on land and water ecosystems. Introduction of invasive alien species for production purposes can cause detrimental damage to the composition of an ecosystem [76]. For example, the introduction of Nile tilapia (*Oreochromis niloticus*), a highly invasive fish that plagues a variety of ecosystems, particularly those located in tropical regions [77], can reduce or even eliminate some aquatic species [78]. According to the Global Invasive Species Database by the ISSG [79], several invasive species of plants (e.g., *Eichhornia crassipes*, *Alternanthera philoxeroides*, and *Limnocharis Flava*) and animals (e.g., *Achatina fulica*, *Carassius auratus*, and *Pomacea canaliculata*) have been reported in Thailand. They have a potential to pose ecological, economic, and social problems. For example, water hyacinth (*Eichhornia crassipes*) is originally native to South America [77]. It is particularly prevalent in estuarine habitats, lakes, urban areas, watercourses, and wetlands. Infestations of this weed block the waterways, limiting boat traffic, swimming, and fishing, and its expansion prevents sunlight and oxygen from reaching the water column and submerged plants. The shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems [77]. In order to combat the threats from alien species on biodiversity (and by extension, on the economy and well-being of the people), Thai government agencies have drafted several relevant documents, e.g., Convention on Biological Diversity (CBO), and the Master Plan for Integrated Biodiversity Management B.E. 2558-2564 (2015–2021).

Table 2. An overview of the interactions between planet-based SDGs and the fisheries sector.

SDG	Issue	Purpose of SDGs	Type of Interaction	Impact of the Implementation to Achieve SDGs on the Development of Fisheries Sector	Impact of the Development of Fisheries Sector on the Achievement of SDGs
6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all	Positive	<ul style="list-style-type: none"> - Good water quality supports fisheries production and aquaculture. - Sustainable management of water resources is essential in maintaining capture fisheries and aquaculture farms. 	<ul style="list-style-type: none"> - Practical as well as conceptual low and high-tech solutions have been designed for environmentally-friendly aquaculture farming.
			Negative	<ul style="list-style-type: none"> - Regulations on the usage of water and chemicals (e.g., antibiotics) related to emerging pollutants may impede aquaculture production. 	<ul style="list-style-type: none"> - Fisheries can be a major source of water pollution. - The release of untreated wastewater and sewage sludge from fish farms has been contaminating receiving water bodies with harmful chemicals, inflicting eutrophication in many lakes and rivers worldwide [24,34].
12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns	Positive	<ul style="list-style-type: none"> - Implementation of a compliance system decreases the options of selling illegally obtained products and creates a fairer market. 	<ul style="list-style-type: none"> - Traceability and eco-labeling systems can guarantee product origin, safety, and quality [52–54].
			Negative	<ul style="list-style-type: none"> - Implementation of a compliance system can decrease overall income within fisheries sector. - The discovery of drug residues in exports from Thailand led to shrimp import bans in Europe and elsewhere [30]. 	<ul style="list-style-type: none"> - About 20% (11–26 million metric tons) of global fish catch are caught illegally [71]. - The drugs being used in fisheries, such as antibiotic, are detrimental to achieving the targets.
13	Climate Action	Take urgent action to combat climate change and its impacts	Positive	<ul style="list-style-type: none"> - Reduction of frequency and/or intensity of storms, floods, and droughts to reduce the effect of climate change on capture and aquaculture production [56,57,60]. 	<ul style="list-style-type: none"> - Inland fisheries have a particularly low carbon footprint when compared to other food sources [3]. - Use of more environmentally-friendly fuels can decrease the exhaust of greenhouse gases.
			Negative	<ul style="list-style-type: none"> - Fisheries management efforts aimed at reducing overcapacity and rebuilding stocks may require significant reforms. The costs of required actions for these reforms may be unaffordable in many countries [61]. 	<ul style="list-style-type: none"> - Parker et al. [61] revealed that marine fisheries consumed 40 billion liters of fuel in 2011 and generated a total of 179 million tons of CO₂-equivalent GHGs (4% of global food production)
14	Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development	Positive	<ul style="list-style-type: none"> - Strategies to eliminate illegal fishing, reduce fishing effort, and decrease harvest will benefit the development of fisheries in the long term. 	<ul style="list-style-type: none"> - Use coastal areas for aquaculture more efficiently and limit the conversion of mangrove forests.
			Negative	<ul style="list-style-type: none"> - Several regulations and measures can reduce economic and social profit [71]. - The reduction of marine catches can affect aquaculture production, as capture fisheries are a major source of fishmeal and fish oil, which are still essential raw materials for the aquaculture feed industry [24,38]. 	<ul style="list-style-type: none"> - Marine debris and marine litter resulting from capture production and aquaculture can disrupt ocean ecosystems [66]. - Overfishing and illegal fishing can disrupt the natural ecosystem [71].

Table 2. Cont.

SDG	Issue	Purpose of SDGs	Type of Interaction	Impact of the Implementation to Achieve SDGs on the Development of Fisheries Sector	Impact of the Development of Fisheries Sector on the Achievement of SDGs
15	Life on Land	Promote, protect, and restore the terrestrial ecosystem, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss	Positive	- Protected areas are a mainstay of biodiversity conservation and a habitat of wild juveniles [74].	- Healthy inland aquatic ecosystems are indicators of good water quality [3].
			Negative	- Marine protected areas for conservation may be a limitation of fishing.	- The ongoing growth of aquaculture requires more land area and often results in the transformation of multifunctional habitats into areas optimized for a single function, e.g., the conversion of mangrove forests into shrimp farms. - Introduction of invasive alien species for production purposes can cause detrimental damage to the composition of an ecosystem [76].

5. Conclusions

In this paper, we consider the intricacies of the fisheries sector in light of SDGs, and we describe the contribution of fisheries towards SDGs and vice versa. We draw several important conclusions. First, wild capture plays a crucial role in supplying nutritious food and generating economic growth. However, annual capture production has been diminishing due to stock exploitation, in which the maximum sustainable yields of fish stocks are exceeded. As a result, we have seen an improvement of the national legislations of responsible fisheries management in Thailand. Second, the intensification of aquaculture production has dramatically increased in recent decades and has been responsible for most of the yield increases in seafood supply. Nevertheless, this rapid growth has also led to tremendous damage to habitats, water quality, and the structure and functioning of marine ecosystems. Moving forward, good farming practices and state-of-the-art innovations, e.g., improved feed technology, the development of alternative sources of protein to replace and reduce the use of fishmeal, and water treatment, must be carefully managed by the government in order for Thailand to fully achieve the balance between ample production and environmental sustainability.

To that end, the Sustainable Development Goals guide future policies on fishing and aquafarming. The production of both fishing, farming, and aquaculture are of paramount importance for SDGs—SDGs 1, 5, 8 and 10 in particular, as they are related to poverty alleviation and economic growth, as well as SDGs 2 and 3, which are related to zero hunger and good health. We note a strong interaction between environment-related SDGs (6, 12, 13, 14, and 15) and the fisheries sector. Findings here will help to illuminate the potential role of wild capture and aquaculture in achieving the SDGs. Nonetheless, several trade-offs need to be considered for this purpose. Consequently, both policies and research must focus more on effective management strategies of fisheries to reduce the environmental impacts and biodiversity loss in the future, while safeguarding food supply and individual incomes.

Author Contributions: Conceptualization, T.S., L.H. and P.G.; The structure of the manuscript and analysis, T.S., L.H., W.V.E., C.L., and P.G.; Writing-original draft, T.S.; Writing-review and editing T.S., L.H., W.V.E., C.L., and P.G. All authors have read and agreed to the published version of the manuscript.

Funding: Thaksin University supported this work through a Ph.D. scholarship (64.01/20196).

Acknowledgments: Special thanks are extended to Parichate Tangkanchanapas, Adhinand Indrapim, Saowalak Roongtawanreongsri, Atiruj Theppawong, Chananchida Sang-aram, and Stijn Bruneel for their helpful comments.

We thank Palarat Dechakijpaisan and Chalitta Prasertwong for drawing of pictures. We are also grateful for the input of the anonymous reviewers, which improved both the content and structure of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest. The sponsor had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the result.

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