

## Article

# Evolution of Fish and Shellfish Supplies Originating from Wild Fisheries in Thailand Between 1995 and 2015

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**Abstract:** Fisheries resources play a crucial role in economic development, food security, and healthy nutrition for humans. Consequently, fisheries are of paramount importance for several Sustainable Development Goals, in particular SDGs 1 and 8, which are related to poverty and economic growth, as well as SDGs 2 and 3, which are about zero hunger and good health. On the other hand, fisheries can also negatively influence the ecosystem (SDG 14, life below water). Thailand is one of the world's most significant producers and exporters of fisheries products. This present work describes the evolution of wild fisheries production in Thailand for over twenty years and discusses its impact on fish and shellfish supplies. The present overview uses mainly the official statistical catch data of Thailand. From 1995 to 2015, Thailand's marine fisheries production gradually decreased from approximately 2.8 million tonnes to 1.3 million tonnes per year. Concerning taxonomic composition of the catches, no dramatic shifts were recorded during the 20-year period. The main observation seems that for less abundant taxa, such as Chirocentridae, Sillaginidae, Ariidae, Sharks, and Psettodidae, their part in the catch was halved between 1995 and 2015. On the other hand, inland capture fisheries remained constant at 0.2 million tonnes per year. The annual value of wild fisheries production was, on average US\$1.7 billion. Notably, trawl fishing systematically reduced during these two decennia, resulting in a fishing efficiency of approximately 140 tonnes of demersal fish per trawl unit per year in 2015. During 2008–2015, the number of registered gill net fishing boats drastically increased from 2,300 to 6,600, and this has led to a dramatic decline in fishing efficiency to about 10% in 2014–2015. More in general, Thailand's continuous decline in marine capture production was linked to increased fuel prices, tightening restrictions by neighbouring countries for access into their exclusive economic zone, and the depletion of resources due to overfishing and illegal fishing. Against rising concerns about the sustainability of intensive fishing practices in recent years, Thailand is ramping up efforts to reduce the exploitation of fishery resources to levels that would achieve maximum sustainable yields. In particular, the intensity of fishing based on gill nets needs to be addressed in the future. Hence, Thailand's fisheries production faces the pressure of realising the importance of sustainable fisheries resources management and its impact on marine life and biodiversity, in addition to its role as a significant food source for a healthy population.

**Keywords:** capture fisheries; food production; biological diversity; Thailand's fisheries

## 1. Introduction

The world's population has increased from 6.5 billion in 2005 to 7.5 billion in 2017 and is expected to reach 9.0 billion by 2050 [1]. Over the next decades, the global food system will hence need to supply enough calories, proteins, and micronutrients to feed the growing population [2,3]. Recent statistics suggested that micronutrient deficiencies continue to affect hundreds of millions of people [4]. More than 250 million children worldwide are at risk of vitamin A deficiency. Nearly two billion individuals are iodine deficient, and 17% of the world's population have inadequate zinc intake [4,5]. Therefore, providing food and nutrition security to the world population is a challenge faced by humanity [1,3]. The Sustainable Development Goals (SDGs), particularly SDG 2 (*'End hunger, achieve food security and improved nutrition, and promote sustainable agriculture'*) and SDG 14 (*'Conserve and sustainably use the oceans, seas, and marine resources for sustainable development'*), of the 2030 Agenda for Sustainable Development of the UN, highlight the importance of fisheries resources in developing countries to help sustain essential food production and nutrition, hence safeguarding global food security [1]. Indirectly, fisheries are also important for economic development (related to SDGs 1 and 8) and the health of people (SDG 3), the latter in particular due to the high nutritious value of seafood.

Fisheries resources play a critical role in provisioning quality food and nutrition for human consumption [3,4,6,7]. Several studies have examined the links between fish and food security, as fish is known to be an excellent source of animal proteins, micronutrients, and vitamins [8–11]. The Food and Agriculture Organization of the United Nations (FAO) [4] recognises that the consumption of a certain amount of fish, in particular, fatty fish, is associated with a reduced risk of coronary heart disease and stroke. More importantly, there is convincing evidence that a variety of fish species provide diverse and nutritious food for humans [12,13]. As the benefits of fish to nutrition and health are well-documented, estimated global fish consumption has grown from an average of 10 kg/capita/year (kg/c/y) in the 1960s to 14 kg/c/y in the 1990s and 20 kg/c/y in 2014 [13], and it is expected to increase to 22 kg/c/y in 2024 [7].

Thailand is a global fisheries producer and exporter. According to the FAO [14], the country ranks among the top twenty-five countries in terms of marine fisheries production. The Thai fishery industry has developed rapidly over the last decades and has significantly contributed to socio-economic development [15]. According to the latest available statistics collected by the Department of Fisheries (DoF) [16], Thailand's fisheries production in 2016 exceeded more than 2 million tonnes, of which 1.5 million tonnes (63%) were from capture fisheries and 0.9 million tonnes (37%) from aquaculture. The value of the fisheries exports was estimated at US\$6.3 billion in 2016 [16]. In 2016, the fisheries sector contributed to around 0.8% of the total gross domestic product and 9.0% of the agricultural sector's gross domestic product [17]. Employment in the country's agricultural sector, including fisheries, account for 34% of the country's workforce [18].

By analysing the trends in fisheries production, one could infer the changes in the global and regional significance of fish stocks, including consumption patterns, human nutrition, and environmental concerns [19]. Hence, the primary purpose of this study is to examine the evolution of wild fisheries production in Thailand and its impact on the available supplies and biological diversity of fish and shellfish. Our analysis focuses on Thailand's status and the trend of capture fisheries production for the past 20 years. The review is based mainly on official catch statistics dating back to 1995. Furthermore, we also review literature related to Thailand's fisheries production as a reference in the data analysis.

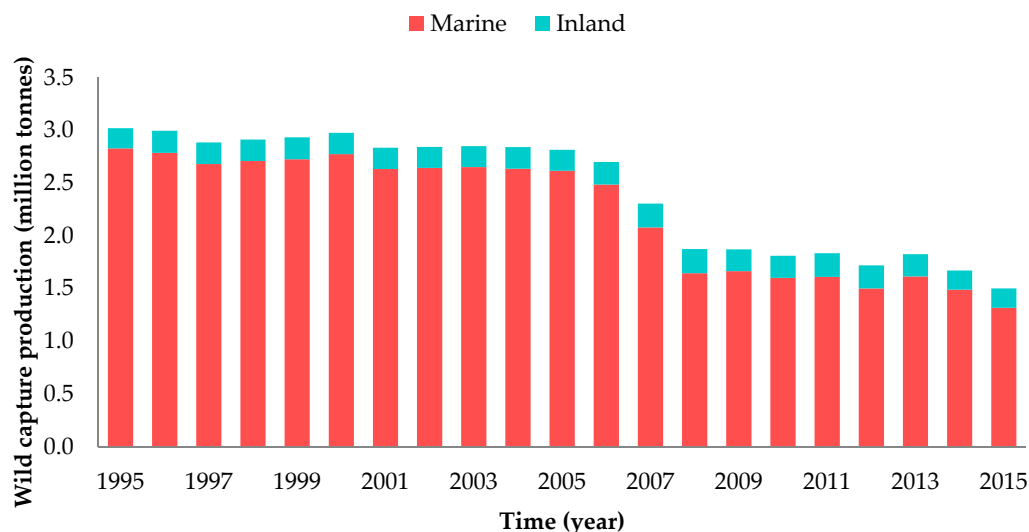
## 2. Evolution of Fisheries Production in Thailand During 1995–2015

Thailand, situated in the middle of mainland Southeast Asia, lies between 5°–20° N and 97°–106° E, with a total land area of approximately 514,000 km<sup>2</sup>, and it is divided into 77 Provinces [15]. The country has a total coastal length of more than 2600 km, comprising 1870 km on the Gulf of Thailand and 730 km on the Andaman Sea [20]. The fishing area and the exclusive economic zone of Thailand

cover a total area of 420,280 km<sup>2</sup>, divided into two distinct areas: 304,000 km<sup>2</sup> in the Gulf of Thailand, Pacific Ocean on the east, and 116,280 km<sup>2</sup> in the Andaman Sea, the Indian Ocean on the west [21].

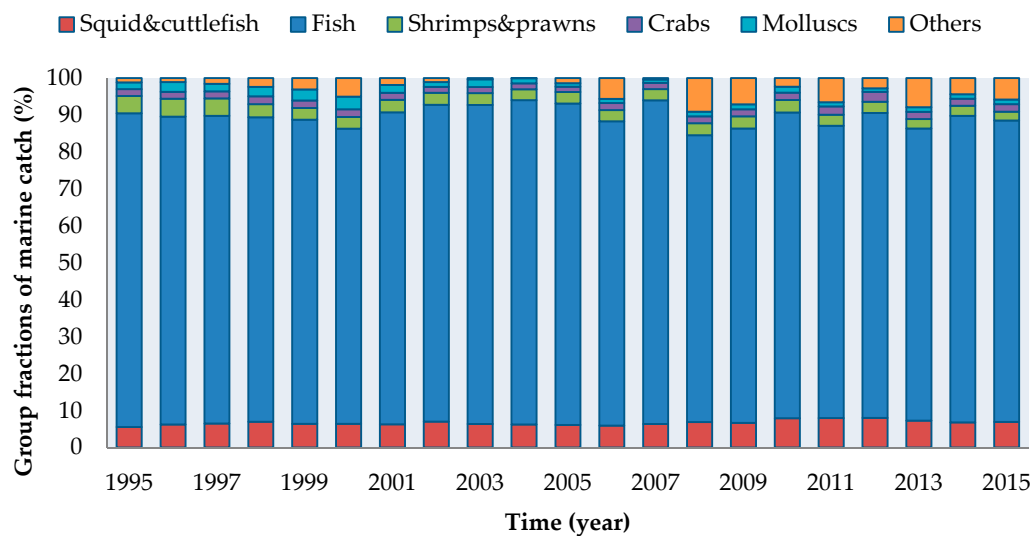
The wild capture production is broadly divided into two categories: marine production and inland production. Thailand's marine fisheries consist of two categories: commercial fisheries, and artisanal fisheries. Based on the Royal Ordinance on Fisheries B.E. 2558 (2015), there are two categories that are distinguished by gross vessel tonnage. On the one hand, commercial fishing vessels are considered powered boats of over ten gross tonnage [21]. On the other hand, artisanal fishing vessels are those smaller than ten gross tonnage, and are either non-powered or have outboard or inboard engines. In general, a wide variety of fishing gear including gill nets, falling nets, traps, and hook and line can be used for artisanal vessels, while commercial vessels mainly use bottom trawls, purse seines, and falling nets [21,22]. Artisanal vessels operate with high-efficiency fishing gear, e.g., trawls, surrounding nets, dredges, anchovy falling net, and light luring vessels, and need to have a commercial fishing license. In 2018, there were 37,698 registered fishing vessels in Thailand, about 70% of which were artisanal [23].

The total marine catch in Thailand had decreased gradually since the late 1990s. The annual estimated catch of fisheries exceeded two million tonnes between 1995 and 2007 (Figure 1). After that, marine fisheries catch gradually declined from 1.6 million tonnes in 2008 to 1.3 million tonnes in 2015 [24–44]. Meanwhile, inland capture remained constant at 0.2 million tonnes. The decline in marine capture production in Thailand resulted from the depletion of resources due to overexploitation, environmental degradation [4,21], and neighbouring countries such as Indonesia and Myanmar tightening restrictions on foreign fishing access within their exclusive economic zone [4,21,45]. The FAO [46] indicated that fuel price changes could influence whether marine capture increases or decreases. During 1995–2015, diesel prices increased from 0.3 US\$/liter to 0.7 US\$/liter (Bank of Thailand, 2015). A negative correlation between the total marine catch and diesel prices was found in Thailand ( $r = -0.901$ ,  $p < 0.01$ ).

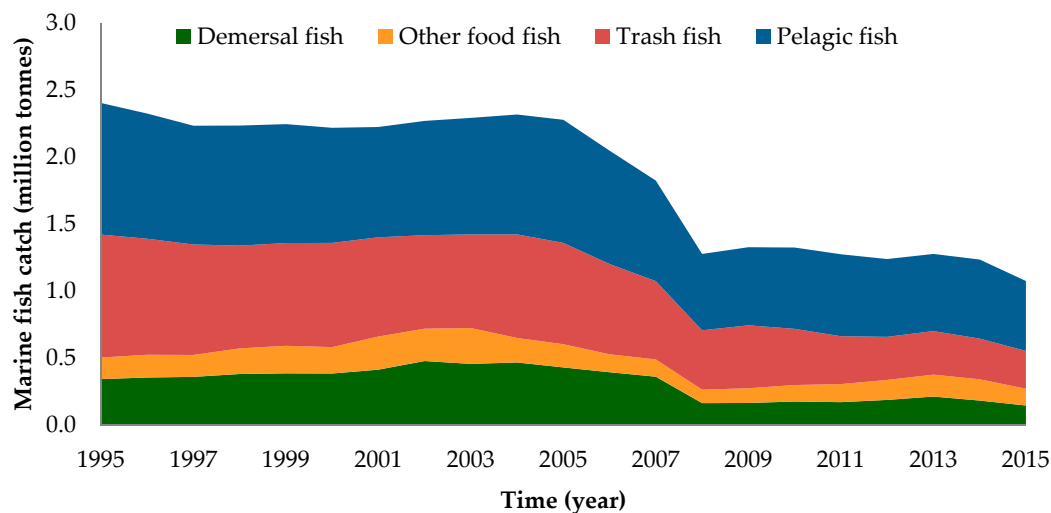


**Figure 1.** The graph demonstrates Thailand's wild capture production from 1995 to 2015. Based on the Department of Fisheries [24–44].

From 1995 to 2015, the average marine fisheries catch consisted of 83% fish, 7% squid and cuttlefish, 3% shrimp and prawn, 2% crab, 2% mollusc, and 3% others (Figure 2). The monetary value of each category accounted for 60%, 18%, 15%, 6%, 0.8%, and 0.2%, respectively [24–44]. According to the DoF statistics, marine fish catch is divided into four categories: pelagic fish, demersal fish, other food fish, and trash fish. Based on the national marine fish catches from 1995 to 2015, pelagic fish are, on average, the largest contributor (42%), followed by trash fish (32%), demersal fish (17%), and other food fish (9%) (Figure 3).



**Figure 2.** Percentage of marine catch composition in Thailand from 1995 to 2015. Based on the Department of Fisheries [24–44].

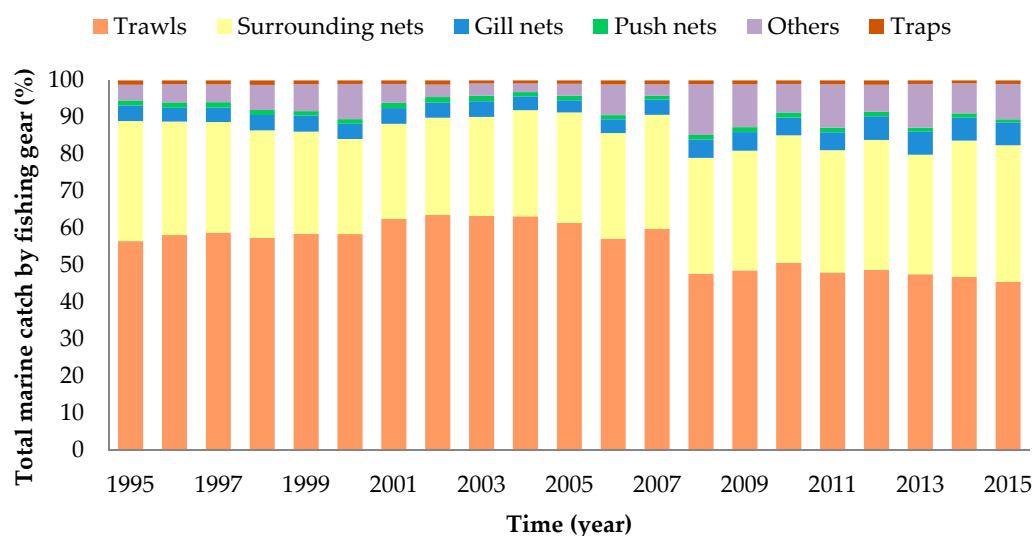


**Figure 3.** The contribution of different fish groups to Thailand's marine fish catch from 1995 to 2015. Based on the Department of Fisheries [24–44].

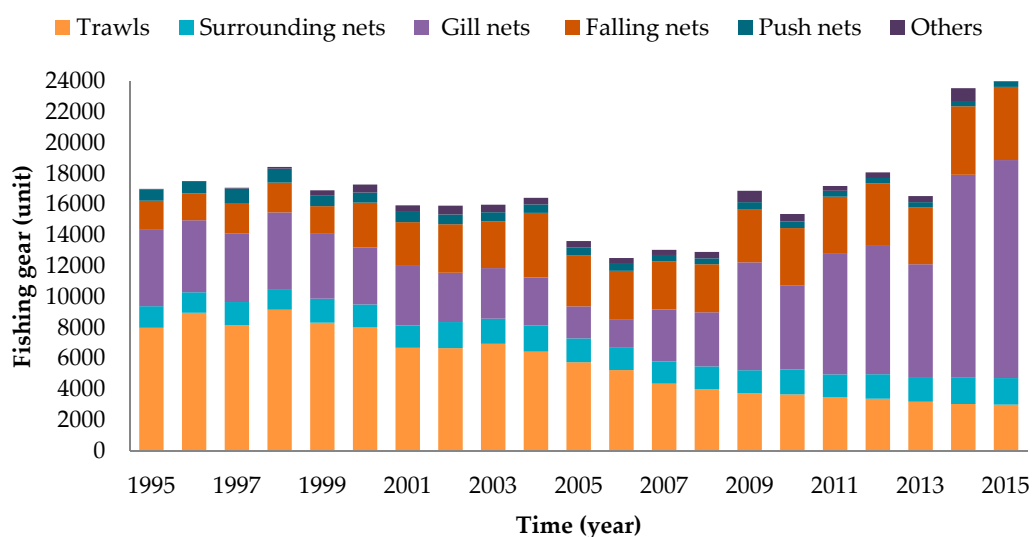
Among all fishing methods, trawling alone was responsible for 57% of the total production. The rest was from surrounding nets (30%), gill nets (4%), traps (1%), push nets (1%), and other methods (7%), e.g., shellfish collecting, hook and line, and lift nets (Figure 4). Although trawls are mainly used for fishing in Thai waters, the total number of Thai trawl fleets decreased steadily from about 8000 units in 1995 to 3000 units in 2015 (Figure 5). The Thai government implemented a stricter regulation to reduce the fishing effort and fishing capacity to mitigate the problem of overfishing [21,45]. Figure 6 shows the efficiency of trawls. Interestingly, trawl fishing systematically reduced during the study period, leading to a 66% reduction in efficiency compared to its peak value for fishing demersal and trash fish. The sudden increase in the efficiency of trawls in 2007 may be a consequence of a general drop of fishing gear during 2005–2006 (cf. Figure 5). On the other hand, the number of gill nets increased from about 5000 units to 14,000 units during the 20-year period. Between 2008 and 2015, the number of registered gill net fishing boats (e.g., Spanish mackerel gill nets, short mackerel gill nets, and short mackerel encircling gill nets) drastically increased from 2300 to 6600. While pelagic fish catches remained stable, the efficiency dramatically declined to about 10% in 2014–2015 based on comparison

with the maximum in 1996 (Figure 7). The data were calculated using the amount of fish caught and units of fishing gear (Appendix A; Tables A1 and A2).

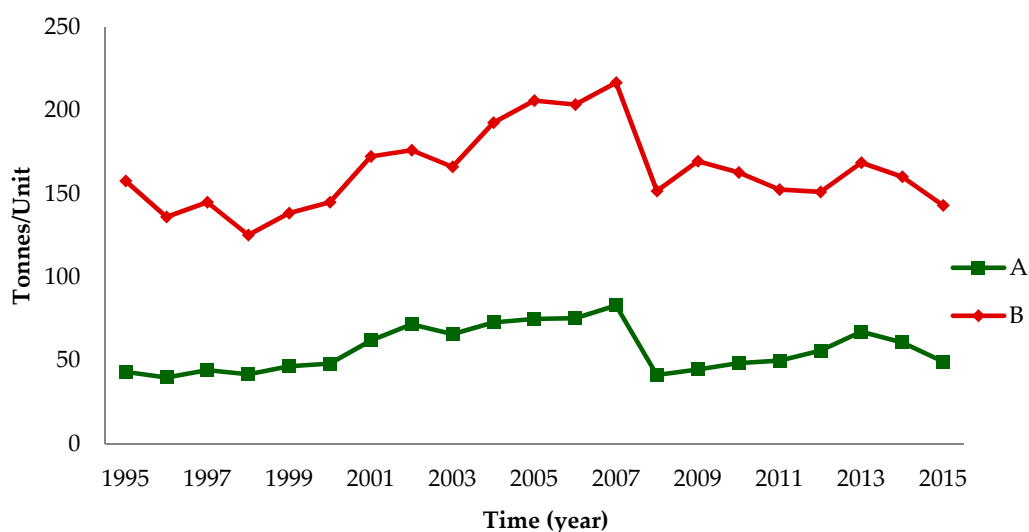
According to the DoF statistics, on average, 69% of the marine catches were from the Gulf of Thailand, whereas 31% came from the Andaman Sea. It is estimated that from 2003–2015 the catch per unit effort for fish caught in the Gulf of Thailand by trawling increased slightly from 21.4 kg/h to 22.6 kg/h, while in the Andaman sea, the increase was higher, from 39.5 kg/h to 59.6 kg/h [47]. (Appendix A; Figures A1 and A2). Recent assessments on Thailand's fish stocks estimated that the fishing effort for demersal fish in 2015 exceeded the level, which would produce a maximum sustainable yield of 32.8% in the Gulf of Thailand and 5.3% in the Andaman Sea. Meanwhile, the fishing effort of pelagic fish exceeds the optimum level by 27.0% in the Gulf of Thailand and 16.5% in the Andaman Sea [21].



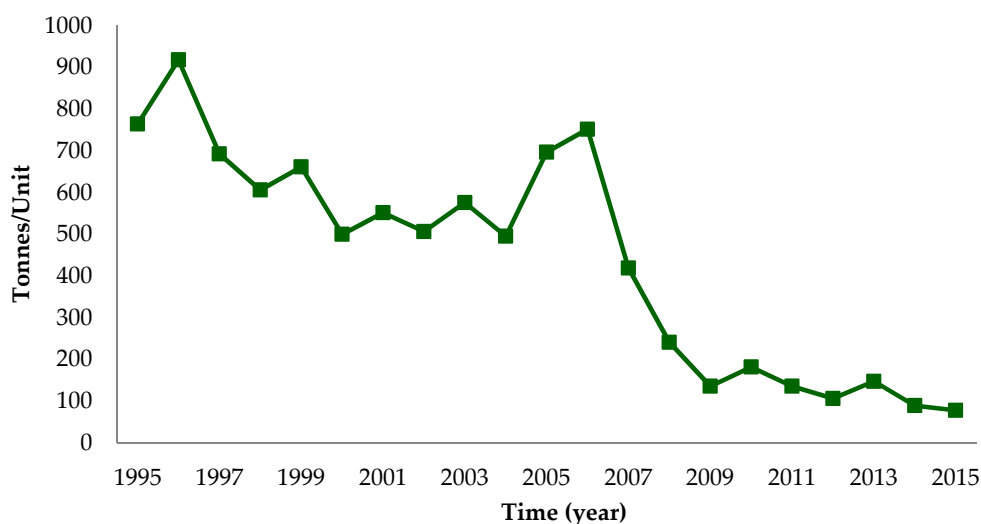
**Figure 4.** Percentage of marine catch by type of fishing gear from 1995 to 2015. Based on the Department of Fisheries [24–44].



**Figure 5.** Amount of fishing gear in Thailand from 1995 to 2015. Based on the Department of Fisheries [24–44].



**Figure 6.** The efficiency of trawls for demersal fish (tonnes/unit) is determined from the amount of demersal fish and trash fish caught (tonnes) (A), and the amount of demersal fish (B).



**Figure 7.** The efficiency of gill nets for pelagic fish (tonnes/unit) is determined from the amount of pelagic fish caught (tonnes) divided by some gill nets (e.g., Spanish mackerel gill nets, short mackerel gill nets, short mackerel encircling gill nets). Based on the Department of Fisheries [24–44].

### 3. Taxonomic Diversity in Fisheries Production

Over the 20-year assessment period (1995–2015), at least 25 families and groups of marine fish and shellfish were recorded on the list of Thailand's marine fisheries catch. Table 1 illustrates the taxonomic composition of total marine fish caught. All species mentioned on the list of landings of Thailand's marine fisheries were identified using a guide to the global fish database, Fishbase, and the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species. The major taxonomic composition of pelagic fish are Scombridae (e.g., short mackerel, Indian mackerel, king mackerel, longtail tuna, kawakawa, and frigate tuna) (38.1%), Carangidae (e.g., round scad, hardtail scad, trevally, bigeye scad, and black pomfret) (22.1%), Clupeidae (sardine) (16.6%), Engraulidae (anchovy) (19.0%), Chirocentridae (wolf herring) (1.2%), Sphyrnidae (barracuda) (2.0%), Mugilidae (mullet) (0.7%), Stromateidae (silver pomfret) (0.1%), and Polynemidae (threadfin) (0.1%). Meanwhile, the majority of demersal fish are from the Nemipteridae (26.0%), specifically threadfin bream and monocle bream, followed by Priacanthidae (bigeye) (22.8%), Synodontidae (lizardfish) (16.9%), Sciaenidae (croaker) (10.1%), and Trichiuridae (hairtail) (4.1%). Altogether, they constitute

about 81% (118,877 tonnes) of the total catches of the demersal groups in 2015 [44]. On the other hand, four families (i.e., Cyprinidae, Channidae, Clariidae, and Osphronemidae) were mentioned for freshwater fish. The Cyprinidae family, specifically common silver carp, contributed the most (11.6%) to the national freshwater capture production in 2015 [44]. Concerning taxonomic composition of the catches, no dramatic shifts were recorded during the 20-year period. The main observation seems that for less abundant taxa, such as Chirocentridae, Sillaginidae, Ariidae, Sharks, and Psettodidae, their part in the catch was halved between 1995 and 2015.

**Table 1.** Taxonomic composition of marine and inland fish groups caught by Thai fishing vessels during 1995–2015 based on the Department of Fisheries [24–44].

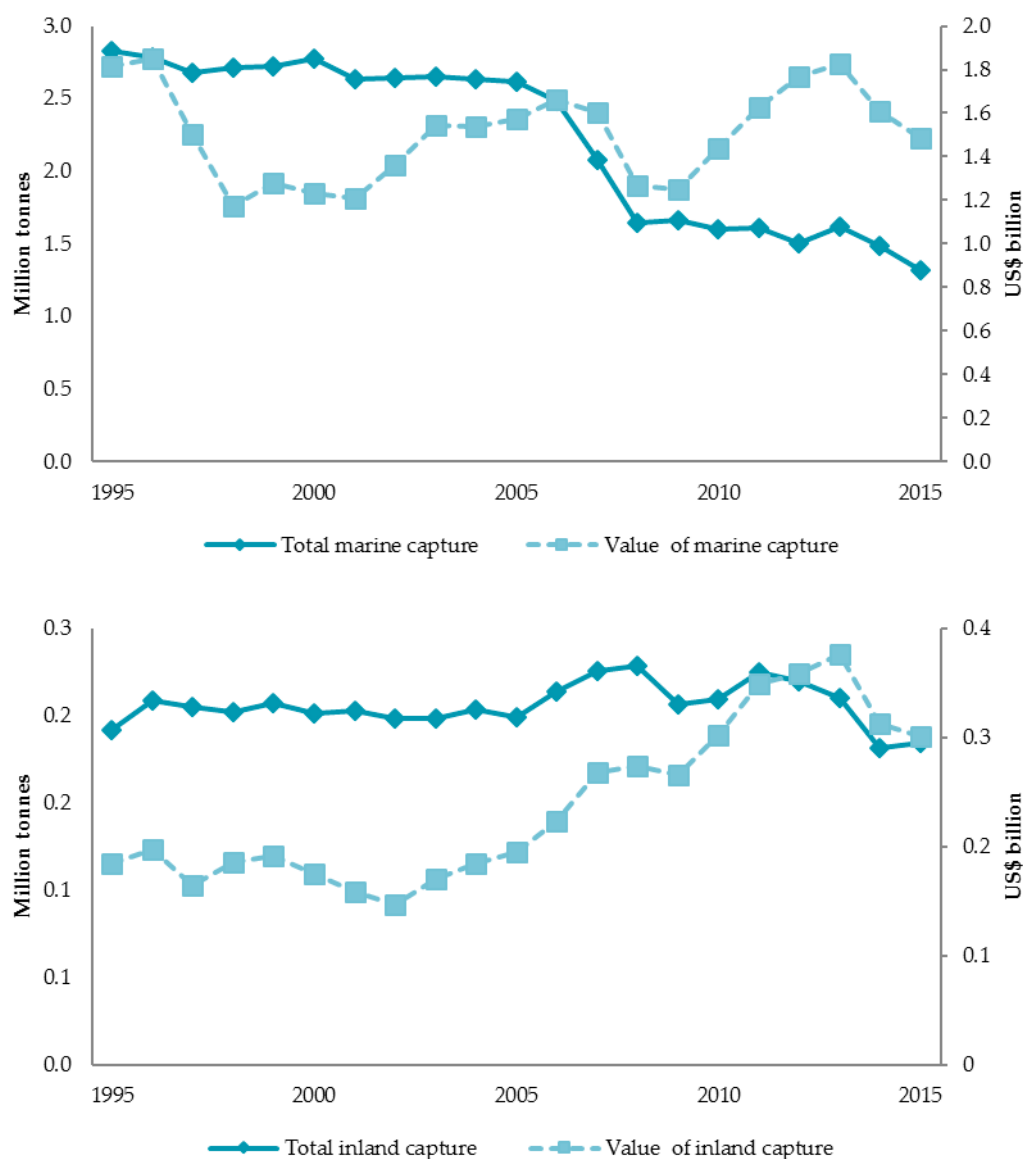
Taxon	Percentage of Total Wild Fish Catch					Average from 1995–2015
	1995	2000	2005	2010	2015	
<b>Marine fish catch</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
Pelagic fish group	41.0	39.0	40.0	46.0	48.0	42.0
Demersal fish group	14.0	17.0	19.0	13.0	14.0	17.0
Other food fish group	7.0	9.0	8.0	9.0	12.0	9.0
Trash fish group	38.0	35.0	33.0	32.0	26.0	32.0
<b>Pelagic fish group</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
Scombridae	38.4	36.4	42.7	35.6	32.3	38.1
Carangidae	20.7	23.1	22.4	21.4	27.4	22.1
Clupeidae	20.0	19.1	13.9	15.3	15.6	16.6
Engraulidae	17.1	16.7	17.4	22.9	19.6	19.0
Chirocentridae	1.6	1.7	1.1	0.9	0.6	1.2
Sphyraenidae	1.2	1.9	1.7	2.5	3.7	2.0
Mugilidae	0.5	1.0	0.5	1.2	0.6	0.7
Stromateidae	0.2	<0.1	0.2	0.1	0.2	0.1
Polynemidae	0.2	<0.1	0.1	0.2	0.1	0.1
<b>Demersal fish group</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
Nemipteridae	27.2	26.6	24.3	25.0	33.5	26.0
Synodontidae	20.4	18.1	12.3	18.1	22.4	16.9
Priacanthidae	20.1	19.6	28.1	21.4	15.7	22.8
Sciaenidae	6.9	10.4	11.5	14.2	4.9	10.1
Trichiuridae	4.2	4.2	3.6	4.1	4.0	4.1
Latjanidae	4.1	2.1	3.8	1.9	7.1	3.2
Cynoglossidae	3.7	4.2	1.7	3.3	1.6	3.1
Rays	2.9	3.5	3.0	2.7	2.2	3.0
Serranidae	2.7	2.0	1.7	2.8	3.4	2.1
Sillaginidae	1.9	2.0	3.9	1.4	0.9	2.5
Ariidae	1.6	2.9	2.4	1.0	0.9	2.3
Sharks	1.5	2.9	1.8	1.1	0.7	2.0
Psettodidae	1.3	0.6	1.1	0.8	0.4	0.9
Muraenesocidae	1.2	0.4	0.7	1.8	1.6	0.8
Plotosidae	0.2	0.3	0.1	0.2	0.6	0.2
Latidae	<0.1	0.2	<0.1	<0.1	0.1	0.1
<b>Inland fish catch</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
Cyprinidae	12.0	20.4	25.0	19.7	11.6	16.9
Channidae	11.6	10.2	6.5	10.8	8.2	9.3
Clariidae	4.3	9.7	3.5	5.3	4.6	4.7
Osphronemidae	0.1	0.3	0.6	2.3	1.6	1.1
Fish mixed group	71.9	59.3	64.4	61.9	74.0	68.0

#### 4. The Value of Thailand's Wild Capture Production

Fisheries play a significant role in sustaining the country's food security, as well as contributing to the local and national economies [6]. From 1995 to 2015, the annual value of marine fisheries catch was



about US\$1.5 billion (2.2 million tonnes) on average, whereas the value of inland capture fisheries was estimated to be around US\$0.2 billion (0.2 million tonnes) (Figure 8).



**Figure 8.** Quantity and value of wild capture production in Thailand from 1995 to 2015. Based on the Department of Fisheries [24–44].

As mentioned in the DoF database, trends in the price of all marine species slightly increased over the past decade (Appendix A; Table A3). For instance, the price of short mackerel (*Rastrelliger brachysoma*) grew from 0.8 US\$/kg in 1995 to 1.4 US\$/kg in 2015. The average price of marine fish species grew from 0.1 to 4.6 US\$/kg. The species with the highest price was the silver pomfret (*Pampus argenteus*) (4.6 US\$/kg), followed by blackbanded kingfish (*Seriolina nigrofasciata*) (3.4 US\$/kg) and groupers (3.4 US\$/kg). The average price of giant tiger prawn (*Penaeus monodon*) was the highest among all shrimp and prawns (8.2 US\$/kg).

## 5. Discussion

Fisheries resources play an essential role in supplying food and essential nutrition to feed the country's growing population as well as generating economic activities nationally [48,49]. However, based on the DoF database from 1995 to 2015, there was a downward trend in the landings of Thailand's



marine fisheries in the Indian and Western Pacific Oceans. According to past assessments, fishing efforts had exceeded the levels that produce the maximum sustainable yield in the waters of Thailand, and many marine fish stocks had dwindled. For example, commercial fish species such as Indian mackerel (*Rastrelliger kanagurta*), lizardfish (*Saurida undosquamis* and *S. elongata*), and bigeye scad (*Selar crumenophthalmus*) were estimated to be overfished in 2007 [50–53]. Many fisheries in Thai waters face substantial pressures due to increased human population, overexploitation of marine resources, and weak enforcement of existing laws or insufficiency of necessary regulations targeting stock sustainability [45].

In 2015, the EU gave a “yellow card” status to Thailand’s marine fisheries as a warning that Thailand needs to strengthen its laws against illegal, unreported, and unregulated fishing, and it needed to improve its monitoring, control, surveillance systems, and traceability of landings. Otherwise, it will face a ban on its exports to the EU [54]. As a result, Thailand has started addressing its illegal fishing and unsustainable fishing practices [45,54]. The government attempts to deter illegal fishing activities and amend fisheries laws in order to prevent marine resources from being damaged and to promote sustainable utilisation of fisheries resources [21,45]. To reform Thai marine fisheries and to address the aforementioned issues, three critical documents have been approved by the Cabinet of Thailand since 2015: the Royal Ordinance on Fisheries B.E. 2558 (2015), the Fisheries Management Plan of Thailand 2015–2019, and the National Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing 2015–2019 [45,48]. As a result of Thailand’s enormous effort fighting with illegal, unreported, and unregulated fishing, the EU has lifted its yellow card in 2019 [55].

Among all fishing methods used, trawling accounted for 57% of the total catch weight in Thai waters, with an average catch of 2.2 million tonnes from 1995–2015. However, the number of trawlers has been decreasing steadily over the last decade as a result of stricter regulations aimed to mitigate the problem of overfishing [21,45]. Consequently, the number of boats using gill nets drastically increased during the same period. Based on available data from the DoF, we estimated the efficiency of fishing gear (i.e., trawls and gill nets) from the number of registered boats (by type of fishing gear) and the total amount of catch. Our estimations can be used to monitor the management of fishery resources. We recognise several factors that can influence the amount of catch per boat, i.e., the size of the gear, the frequency of fishing activity, fish abundance in the area, and the captain’s skill have not been taken into account [56,57]. Consequently, collecting more quantitative evidence is of paramount importance in obtaining more accurate data on maximum sustainable yield. This could be obtained via better and more standardized monitoring of the fish communities, monitoring, and assessment of the fishing yields for each type of gear, particularly gill nets and obtain more quantitative and integrated insights in impacts of fishing via models.

According to the international online fish database, the Scombridae consists of about 54 species of fifteen genera that are found throughout the world in tropical and subtropical seas [58]. Most species are considered commercially important [59]. For example, short mackerel (*Rastrelliger brachysoma*) is distributed over the Pacific Ocean and in the Andaman Sea to Thailand, Indonesia, Papua New Guinea, the Philippines, Solomon Islands, and Fiji. IUCN [59] indicated that this species is highly targeted in commercial and artisanal fisheries and is caught using a variety of equipment (e.g., gill nets, purse seines, and bamboo stake trap). In Thailand, mackerels (*Rastrelliger* spp.) are the most abundant pelagic fish caught [22], accounting for about 11% (116,900 tonnes) of the total national marine fish caught in 2015 [44].

The identification of fish species diversity can show a unique regional source of species occurrences [13], and can help estimate the nutritional contribution of marine fish to human diets [60]. As different fish species can provide differing proteins, micronutrients, and vitamins, having extensive marine biological diversity is vital for a well-rounded diet [9,12,61]. Around 2500 species of fish are available for human consumption [46]. Fish in different habitats, e.g., in the pelagic zone and demersal zone, also produce different compositions of fish oils [62]. Several authors provide examples of the nutritional significance of different fish species [7,63–65]. For example, Bogard, et al. [65] analysed

the nutrient profiles of 55 local fish, shrimp, and prawn species in Bangladesh to demonstrate the variation in potential nutrient contributions of different species. They found that the contribution from a standard portion (50 g/day for pregnant and lactating women and 25 g/day for infants) of some fish species, including chapila (*Gudusia chapra*), darkina (*Esomus danricus*), mola (*Amblypharyngodon mola*), and najari icha (*Macrobrachium malcolmsonii*), would meet ~25% of the iron recommended nutrient intake for pregnant and lactating women and infants. Similarly, Thilsted [66] found that some small indigenous fish in Bangladesh, e.g., mola (*Amblypharyngodon mola*) and chanda (*Parambassis ranga*), have a high vitamin A content of >2500 and 1500 µg retinol activity equivalents (RAE)/100 g raw edible parts, respectively.

Several studies have suggested that the identification of food species can improve diets in different local contexts and ensure diet quality [67,68]. The database of Thailand's Department of Fisheries however, does not include the catches at the species level. We propose that in the future, the species of catch should be identified with its family and genus. This information could be used for a more accurate nutritional evaluation, and potentially for devising the country's policies in order to optimize nutrition and safeguard food security.

## 6. Conclusions

In this study, we examined Thailand's fishing industry, which is involved in wild captures. Although wild fisheries constitute a significant source of food and income, unsustainable practices had made negative impacts on the marine ecosystem. Recently, catches on the coastal waters of Thailand exceeded the maximum sustainable yield substantially, and many marine fish stocks are being depleted. Consequently, the landings of Thai marine fisheries had decreased gradually in the past two decades, simultaneously with an increase in fish and shellfish price. In order for future generations to coexist with the ocean and adequately consume seafood, both quantitatively and financially, the Thai fishing industry must fully recognize the importance of sustainable resource management and take immediate action.

**Author Contributions:** Main idea, T.S. and P.G.; The structure of the manuscript and analysis, T.S., P.N., C.L., and P.G.; Writing—original draft, T.S.; Writing—review and editing, T.S., P.N., C.L., and P.G.

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**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 results.

## Appendix A

**Table A1.** The amount of demersal fish and trash fish caught and the number of trawls in Thailand from 1995 to 2015. The efficiency of trawls is calculated as the number of fish caught per trawl.

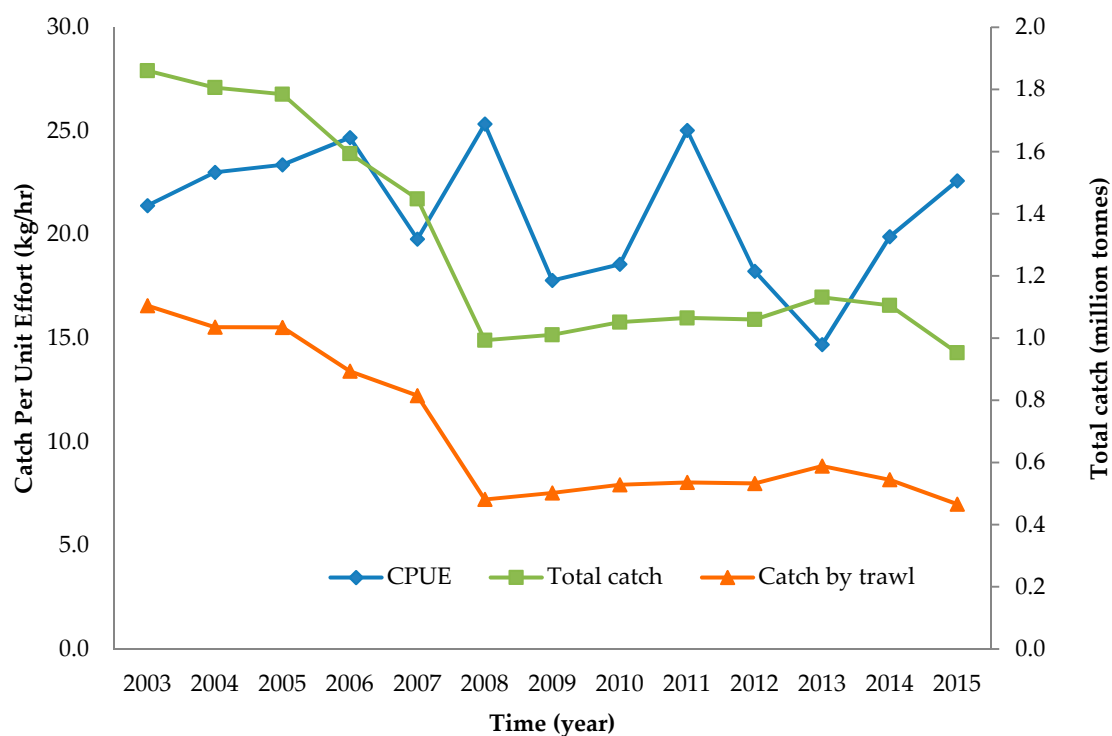
Year	Demersal Fish (tonnes) (A)	Trash Fish (tonnes) (B)	Demersal Fish and Trash Fish Caught (tonnes) C = (A) + (B)	Number of Trawls (unit)	The Efficiency of Trawls for Demersal Fish and Trash Fish Caught (tonnes/unit)
1995	344,728	915,944	1,260,672	7995	157.7
1996	356,552	864,130	1,220,682	8972	136.1
1997	360,916	822,110	1,183,026	8165	144.9
1998	382,152	764,991	1,147,143	9161	125.2
1999	386,707	765,209	1,151,916	8324	138.4
2000	385,391	775,079	1,160,470	8008	144.9
2001	414,680	738,538	1,153,218	6689	172.4

Table A1. Cont.

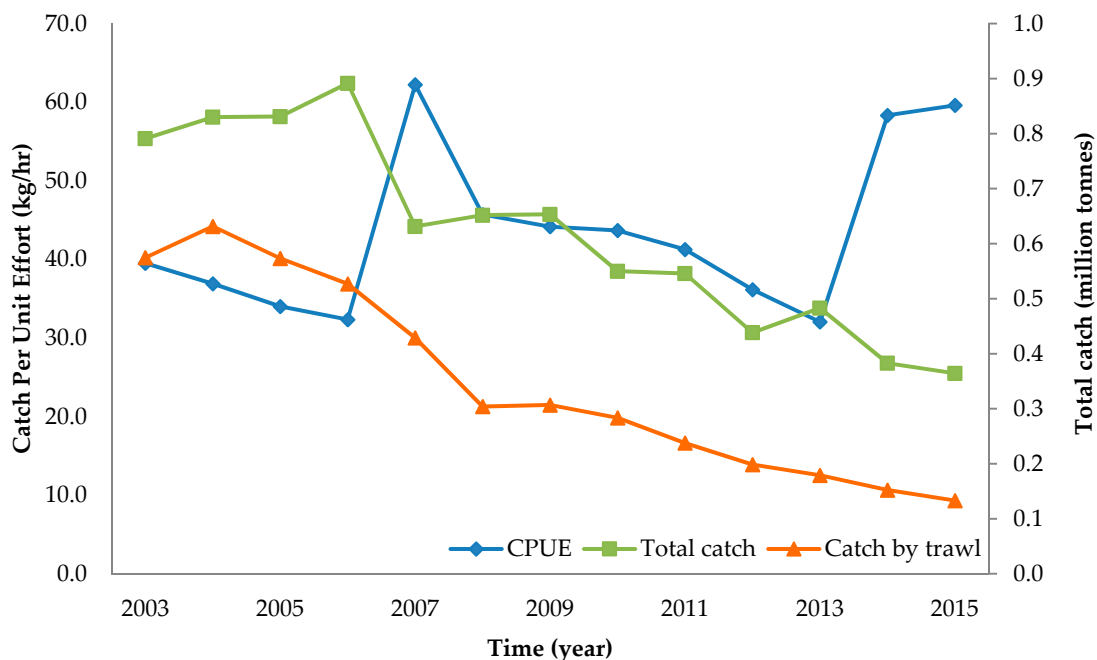
Year	Demersal Fish (tonnes) (A)	Trash Fish (tonnes) (B)	Demersal Fish and Trash Fish Caught (tonnes) C = (A) + (B)	Number of Trawls (unit)	The Efficiency of Trawls for Demersal Fish and Trash Fish Caught (tonnes/unit)
2002	478,538	696,641	1,175,179	6675	176.1
2003	457,129	697,145	1,154,274	6949	166.1
2004	468,638	771,723	1,240,361	6439	192.6
2005	431,036	754,416	1,185,452	5757	205.9
2006	394,984	672,686	1,067,670	5246	203.5
2007	361,864	583,076	944,940	4363	216.6
2008	165,856	442,648	608,504	4013	151.6
2009	167,143	468,807	635,950	3751	169.5
2010	177,185	418,990	596,175	3663	162.8
2011	172,839	355,813	528,652	3466	152.5
2012	189,100	321,732	510,832	3384	151.0
2013	214,531	323,632	538,163	3192	168.6
2014	184,700	301,942	486,642	3038	160.2
2015	147,578	281,027	428,605	2997	143.0
Mean ± SD	316,297 ± 117,494	606,489 ± 209,623	922,787 ± 315,184	5726.0 ± 2169.0	163.8 ± 24.3

**Table A2.** The amount of pelagic fish caught and number of gill nets (e.g., Spanish mackerel gill nets, short mackerel gill nets, and short mackerel encircling gill nets) in Thailand from 1995 to 2015. The efficiency of gill nets is calculated as the number of fish caught per gill net.

Year	Pelagic Fish Caught (tonnes)	Number of Gill Nets (unit)	The Efficiency of Gill Nets for Pelagic Fish (tonnes/unit)
1995	980,742	1283	764.4
1996	931,939	1015	918.2
1997	885,279	1278	692.7
1998	894,259	1475	606.3
1999	885,680	1339	661.4
2000	857,917	1716	500.0
2001	822,006	1490	551.7
2002	851,184	1680	506.7
2003	868,637	1508	576.0
2004	892,565	1802	495.3
2005	916,531	1315	697.0
2006	844,184	1123	751.7
2007	748,980	1787	419.1
2008	568,724	2358	241.2
2009	581,371	4281	135.8
2010	605,831	3330	181.9
2011	610,149	4490	135.9
2012	578,771	5437	106.5
2013	575,395	3900	147.5
2014	589,722	6594	89.4
2015	520,656	6658	78.2
Mean ± SD	762,405.81 ± 154,667.13	2660 ± 1831.7	286.6 ± 84.4



**Figure A1.** Total catch (million tonnes) in Thai water, catch per unit effort (kg/h) of capture fisheries, and catch by trawl in the Gulf of Thailand. Adapted from an official report of the Department of Fisheries in Thailand [32–44] and the Office of Natural Resources and Environmental Policy and Planning [47].



**Figure A2.** Total catch (million tonnes) in Thai water, catch per unit effort (kg/h) of capture fisheries, and catch by trawl in the Andaman sea of Thailand. Adapted from an official report of the Department of Fisheries in Thailand [32–44] and the Office of Natural Resources and Environmental Policy and Planning [47].

**Table A3.** Prices of fish and shellfish products during 1995–2015, based on the Department of Fisheries [24–44].

Marine Species	The Average Price of Marine Species (US\$/kg)	Year				
		1995	2000	2005	2010	2015
Anchovy ( <i>Stolephorus</i> spp.and <i>Encrasicholina</i> spp.)	0.3 ± 0.1	0.2	0.1	0.2	0.4	0.4
Barracuda ( <i>Sphyraena</i> spp.)	1.1 ± 0.3	1.2	0.8	0.9	1.4	1.5
Black pomfret ( <i>Parastromateus niger</i> )	2.4 ± 0.9	3.1	1.3	2.0	3.0	3.6
Blackbanded kingfish ( <i>Seriolina nigrofasciata</i> )	3.4 ± 1.0	3.9	2.6	2.5	5.1	4.7
Bigeye ( <i>Priacanthus</i> spp.)	0.5 ± 0.2	0.4	0.2	0.4	0.6	0.8
Bigeye scad ( <i>Selar crumenophthalmus</i> )	0.6 ± 0.3	0.4	0.2	0.4	0.8	1.2
Catfish eel ( <i>Plotosus</i> spp.)	2.1 ± 0.7	1.3	1.5	1.5	2.6	2.9
Croaker (Croaker groups)	0.8 ± 0.2	0.8	0.6	0.6	1.0	1.0
Conger eel ( <i>Congresox</i> spp.)	0.9 ± 0.1	0.9	0.7	0.8	0.7	1.0
Kawakawa ( <i>Euthynnus affinis</i> )	0.7 ± 0.3	0.5	0.4	0.5	0.9	1.1
Flatfish ( <i>Paraplagusia</i> spp.)	1.0 ± 0.3	1.0	0.6	0.8	1.3	1.4
Hairtail ( <i>Trichiurus</i> spp.)	0.9 ± 0.2	0.7	0.7	0.9	0.7	1.2
Indian halibut ( <i>Psettodes erumei</i> )	1.4 ± 0.4	1.5	0.9	1.1	1.4	1.7
Indian mackerel ( <i>Rastrelliger kanagurta</i> )	0.8 ± 0.3	0.6	0.5	0.6	0.9	1.3
Narrow-barred Spanish mackerel ( <i>Scomberomorus commerson</i> )	2.6 ± 0.8	1.9	1.7	2.2	3.2	3.9
Lizardfish ( <i>Saurida</i> spp.)	0.5 ± 0.2	0.4	0.2	0.5	0.6	0.7
Longtail tuna ( <i>Thunnus tonggol</i> )	0.9 ± 0.3	0.6	0.6	0.7	1.2	1.3
Monocle bream ( <i>Scolopsis</i> spp.)	0.9 ± 0.4	0.4	1.2	1.1	1.1	1.2
Mullet ( <i>Liza</i> spp.)	1.5 ± 0.5	1.4	1.2	1.2	1.8	2.0
Red snapper ( <i>Lutjanus argentimaculatus</i> )	2.6 ± 1.0	2.2	1.4	2.3	3.9	4.1
Round scad ( <i>Decapterus</i> spp.)	0.6 ± 0.2	0.4	0.3	0.7	0.8	1.0
Sand whiting ( <i>Sillago sihama</i> )	1.8 ± 0.6	2.8	1.7	1.0	1.8	2.3
Sardine ( <i>Sardinella</i> spp.)	0.3 ± 0.2	0.2	0.1	0.2	0.5	0.6
Sea bass ( <i>Lates calcarifer</i> )	3.2 ± 1.1	3.6	3.5	2.6	3.8	4.3
Sea catfish ( <i>Arius</i> spp.)	1.0 ± 0.3	0.8	0.8	0.9	1.2	1.5
Short mackerel ( <i>Rastrelliger brachysoma</i> )	0.9 ± 0.2	0.8	0.6	0.7	1.1	1.4
Silver pomfret ( <i>Pampus argenteus</i> )	4.6 ± 1.0	5.7	3.8	4.1	4.1	7.6
Trevally ( <i>Selaroides leptolepis</i> )	0.7 ± 0.3	0.6	0.4	0.6	0.9	1.1
Threadfin ( <i>Eleutheronema tetradactylum</i> )	2.5 ± 0.6	2.5	1.8	2.3	2.2	2.8
Threadfin bream ( <i>Nemipterus hexodon</i> )	0.8 ± 0.3	0.7	0.4	0.7	1.0	1.2
Wolf herring ( <i>Chirocentrus</i> spp.)	0.9 ± 0.2	1.1	0.6	0.9	1.0	1.4
Grouper ( <i>Epinephelus coioides</i> )	3.4 ± 1.2	3.4	2.3	3.2	4.9	4.8
Rays	0.7 ± 0.4	0.5	0.3	0.5	1.2	1.1
Sharks	1.0 ± 0.4	0.8	0.5	0.9	1.5	1.6
Trash fish	0.1 ± 0.1	0.1	0.1	0.1	0.2	0.2
Acetes ( <i>Acetes</i> spp.)	0.4 ± 0.1	0.7	0.3	0.4	0.5	0.6
Banana prawn ( <i>Fenneropenaeus merguensis</i> )	6.4 ± 0.8	7.7	5.6	5.5	6.9	7.9
Flathead lobster ( <i>Thenus orientalis</i> )	3.9 ± 0.9	3.8	2.9	3.4	4.4	5.1
Giant tiger prawn ( <i>Penaeus monodon</i> )	8.2 ± 1.0	9.6	8.2	7.7	7.1	8.8
King prawn ( <i>Penaeus latisulcatus</i> )	4.4 ± 1.4	6.6	2.6	5.6	6.9	4.7
School prawn ( <i>Metapenaeus</i> spp.)	3.4 ± 0.4	3.6	3.0	3.0	3.3	4.0

Table A3. Cont.

Marine Species	The Average Price of Marine Species (US\$/kg)	Year				
		1995	2000	2005	2010	2015
Swimming crab ( <i>Portunus pelagicus</i> )	2.6 ± 1.2	1.8	1.4	1.9	3.5	4.9
Mangrove crabs ( <i>Scylla serrate</i> )	3.2 ± 1.4	4.8	1.8	2.6	4.8	4.3
Squid ( <i>Loligo</i> spp.)	2.1 ± 0.7	2.3	1.4	1.6	2.3	3.1
Cuttlefish ( <i>Sepia pharaonis</i> )	2.0 ± 0.5	2.4	1.4	1.6	2.3	2.6
Octopus ( <i>Octopus</i> spp.)	1.2 ± 0.5	0.7	0.7	0.9	1.6	2.3
Short-necked clam ( <i>Paphia undulata</i> )	0.4 ± 0.3	0.3	0.3	0.2	0.6	0.9
Scallop ( <i>Amusium</i> spp.)	1.5 ± 0.5	2.2	1.0	2.2	1.2	1.9

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