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Review

Status of Southeast Asian fisheries: distinctive characteristics and pathways to sustainable fisheries

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Abstract

Southeast Asia is a vast tropical region comprised of 11 countries and has experienced uniquely prominent development, particularly in capture fisheries. The large exclusive economic zones and continental shelf areas heavily support the region's fisheries, with capture fisheries production having steadily increased over the past 30 years, outperforming other regions. The percentage of fishers as a share of the total population in this region is 3.4 times that of the world average. The region's per capita supply of aquatic foods is 1.9 times higher than the world average. Despite warnings of overfishing for decades, the region has a 3.6 times higher ratio of underfished marine stocks as compared with the global estimate, primarily owing to the prevalence of artisanal or small-scale fisheries and non-selective fisheries, which are supported by high biodiversity. However, the growth of the per capita supply of aquatic foods has plateaued in recent years. As Southeast Asia's population is expected to stabilize in about the year 2055 at 113% of its current size, the demand for aquatic food products will likely level off, enabling a transition toward sustainable fisheries.

Keywords: capture fishery; Southeast Asia; sustainable fisheries; overfishing

Introduction

The global fraction of overfished stocks is increasing and reached 37.7% in 2019 (FAO 2024c). Adding to this, the world population and the per capita consumption of aquatic foods have both increased, amounting to a rapid increase in the consumption of aquatic products globally. World capture fisheries have essentially plateaued since the 1990s, although rapidly increasing aquaculture production has helped to meet the increased demand for aquatic products (FAO 2024c). Even so, aquaculture production must contend with various environmental risks and conflicts with society (Subasinghe et al. 2009).

Capture fisheries in Southeast Asia (SEA) are unique. The region's capture fisheries production increased steadily between 1950 and 2017 (Fig. 1) (FAO 2024b). The FAO (2024c) categorized temporal patterns in fisheries landings for the period 1950–2021 by FAO fishing area, with a given area showing either a continuously increasing trend, oscillation after reaching a plateau, or a decreasing trend following a peak. Of 15 FAO major marine fishing areas, four have been categorized as showing a continuously increasing trend; of those, two fishing areas surround SEA countries, namely Eastern Indian Ocean Fishing Area 57 and Western Central Pacific Fishing Area 71 (FAO 2024c).

However, overfishing and important fish stock depletions in marine waters of SEA have been reported since the 1970s (Pauly 1979, 1987; Pauly and Thia-Eng 1988; Silvestre et al. 2003; Stobutzki et al. 2006). According to some papers, overfishing of most of the near-shore fisheries in the region is almost universally accepted (Pomeroy 2012; Pomeroy et al. 2016). Major reasons pointed out for fish stock depletion are overcapacity (Sugiyama et al. 2004), high demand, and human population increases (Pomeroy 2012).

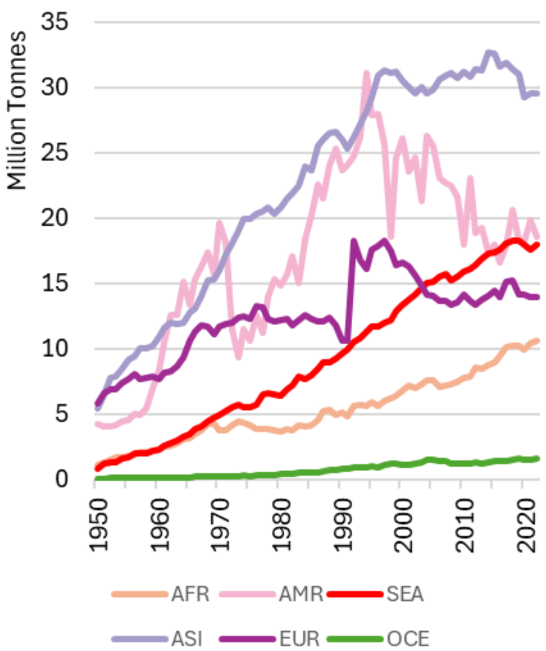

Fig. 1 Capture fisheries production by region (see Table 1 for abbreviations)

Table 1 Abbreviation and hex code colour for the names of regions

Regions	**Abbrev.**	**Colour**
Africa	AFR	#F5B090
Americas	AMR	#F4B4D0
Southeast Asia	SEA	#FF0000
Asia except SEA	ASI	#A59ACA
Europe	EUR	#A5D4AD
Oceania	OCE	#9FD9F6
Other	OTR	#F5B2B2
World	WOR	#003300

Table 2 Abbreviation and hex code colour for the names of Southeast Asian countries

Country	**Abbrev.**	**Colour**
Brunei Darussalam	BN	#f39800
Cambodia	KH	#1d2088
Indonesia	ID	#e60012
Lao PDR	LA	#00a0e9
Malaysia	MY	#0068b7
Myanmar	MM	#009944
Philippines	PH	#009e96
Singapore	SG	#920783
Thailand	TH	#fff100
Timor-Leste	TL	#8fc31f
Viet Nam	VN	#e4007f

PDR: People's Democratic Republic

This contradiction leads to several questions. How do SEA fishery resources differ from those in the rest of the world? What factors contribute to their uniqueness? Despite claims of overfishing in the region decades ago, why have fish catches continued to increase steadily? Is SEA still experiencing overfishing today? Given the region's growing population and rising demand for aquatic foods, to what extent do SEA fisheries need to increase their catches further? Finally, can sustainable fisheries be realistically achieved in SEA?

Surprisingly, little information has been available to answer these questions. Although FAO statistics describe fisheries trends in Asia as a whole, the calculations are strongly influenced by the data from large countries, such as China and India, and therefore, the trends do not necessarily represent the situation in SEA in particular (FAO 2024c). The Southeast Asian Fisheries Development Center (SEAFDEC) is an inter-governmental body that publishes valuable online data on fisheries and, once every five years, produces a report titled ‘Southeast Asian State of Fisheries and Aquaculture’ (SEAFDEC 2022). However, no comparisons with other regions are provided in the report, and the position of SEA fisheries in the world is not sufficiently described. Some fisheries authorities in SEA countries have published catch statistics online, but these can be challenging to access partly because of some limits to domestic access and writing in different languages. As such, only scattered evidence or references are available. To gain an overview of the future of sustainable fisheries in SEA based on evidence, it is essential to review the statistics of SEA fisheries as a whole.

This review examines the current state of capture fisheries in SEA based on published information, focusing on trends in production, the numbers of fishers, productivity, consumption, and the status of stocks in comparison with other regions to outline a vision for achieving sustainable fisheries in the region.

Delineation of SEA

SEA is a southeastern subregion of Asia, located south of China, east of the Indian subcontinent, and northwest of mainland Australia (Fig. 2). It includes 11 countries (Table 2), all of which are members of the Association of Southeast Asian Nations (ASEAN), except for Timor-Leste. However, the International Organization for Standardization (ISO 3166-2) does include Timor-Leste as a SEA country, and even though Timor-Leste is not yet an official ASEAN member state, its admission was approved in principle in November 2022.

Table 3 lists selected statistics of SEA countries. The land area of SEA is only 3.5% of the world, but the exclusive economic zones (EEZs) and continental shelf areas of the countries account for 6.8% and 13.8%, respectively. The length of the SEA coastline is 29.7% that of the world, largely owing to the contribution of two archipelagic countries, Indonesia and the Philippines (Pauly et al. 2020; CIA 2021). The population of SEA in 2022 was 681 million and 8.5% of the world’s total. Indonesia is the fourth-most populous country in the world and comprises 40% of the total population in SEA; the populations of the Philippines, Vietnam, and Thailand each contribute 10% to the total population in SEA (UN 2023a). The gross domestic product (GDP) per capita, an indicator of a country’s standard of living, widely varies from USD 1,200 in Myanmar to USD

7,800 in Singapore; the average per capita GDP in SEA is USD 5,300, which is far lower than the world average of USD 12,600 (UN 2023b).

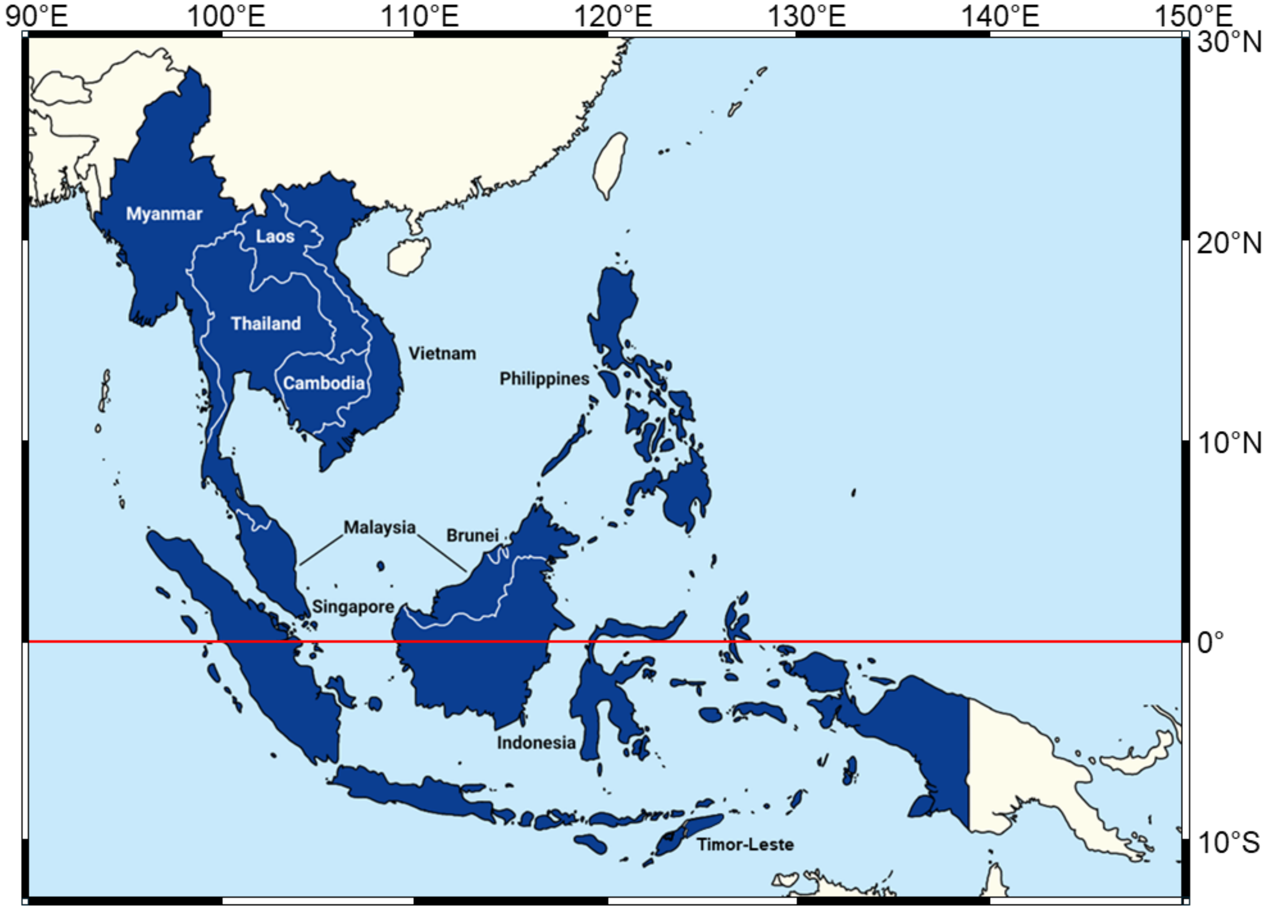

Fig. 2 Map of Southeast Asia, modified from Wikimedia (https://commons.wikimedia.org/wiki/File:Map_and_flag_of_ASEAN_countries.png)

Table 3 Selected statistics of Southeast Asian countries (see Tables 1 and 2 for abbreviations)

Country	Area (km^2)	Coastline (km)	EEZ (km^2)	Continental shelf (km^2)	Population in 2022	Per capita GDP (USD in 2022)
BN	5,765	161	10,090	8,509	449	37,152
KH	181,035	443	62,515	62,515	16,768	1,760
ID	1,910,931	54,716	6,159,032	2,039,381	275,501	4,788
LA	236,800	—	—	—	7,529	2,040
MY	330,621	4,675	334,671	323,412	33,938	11,972
MM	676,577	1,930	532,775	220,332	54,179	1,204
PH	300,000	36,289	1,590,780	272,921	115,559	3,499
SG	733	193	1,067	1,067	5,976	78,115
TH	513,140	3,219	299,397	230,063	71,697	6,909
TL	14,954	706	70,326	25,648	1,341	2,389
VN	331,345	3,444	417,663	365,198	98,187	4,164
SEA	4,501,901	105,776	9,478,316	3,549,046	681,124	5,330
WOR	130,094,010	356,000	140,107,868	25,668,891	7,975,105	12,647
Source	(UN 2023a)	(CIA 2021)	(Pauly et al. 2020)	(Pauly et al. 2020)	(UN 2023a)	(UN 2023b)

The population of SEA has been increasing rapidly (UN 2022): from 162 million in 1950 to 300 million in 1973, over 600 million in 2010, and 681 million in 2022. However, the population growth rate is estimated to decrease and reach a peak in 2055 at 776 million or 113% of the current population. By country (Table 4), Thailand's population is estimated to have peaked in 2022, Singapore and Myanmar are predicted to reach population peaks in the 2040s, and Vietnam, Brunei Darussalam, the Philippines, and Indonesia in the 2050s.

Table 4 Population projections for SEA countries and the world (see Tables 1 and 2 for abbreviations)

Country	Current population (millions)	Peak population (millions)	Year at peak	Percentage at the peak
BN	0.46	0.52	2055	114%
KH	17.31	23.39	2078	135%
ID	280.0	322.6	2059	115%
LA	7.61	10.17	2068	134%
MY	34.91	46.39	2073	133%
MM	53.95	58.64	2049	109%
PH	114.4	135.2	2057	118%
SG	5.77	6.20	2040	107%
TH	71.72	71.75	2022	100%
TL	1.38	2.09	2077	152%
VN	100.0	110.0	2050	110%
SEA	688	776	2055	113%
WOR	8,057	10,290	2084	128%

The biodiversity of SEA's marine waters is recognized as among the most extraordinary in the world. The high species richness is driven by a variety of marine ecosystems in the region, such as coral reefs, mangroves, seagrass beds, and river deltas (Tittensor et al. 2010; Kimura et al. 2014; Ming Chou 2014). Based on the vast aquatic resources in SEA, multispecies fisheries without species selectivity are widely practiced in the region (Harlyan et al. 2021).

Capture fisheries production

Trends in capture fisheries are informative because fishery productivity is a direct result of fishery activity, such as the magnitude of fishing and the local abundance of aquatic resources. Capture fishery production is also dependent on the status of stocks (Solarin et al. 2024).

Fig. 1 shows capture fishery production by region from 1950 to 2022, compiled from FAO statistics. The statistics include production from overseas fisheries, but it is less than 0.2% and negligible. By 2022, capture fisheries production in SEA had reached 18 million t, representing 19% of world capture fisheries production (FAO 2024b).

World capture fisheries production plateaued at 90 million t in the early 1990s and has remained at this level to the present. In contrast, production in SEA steadily increased between 1950 and the late 2010s, reaching 5 million in 1971, doubling by 1992, and tripling by 2004. Production in the region over 30 years (1993–2022) increased by 7.1 million t, amounting to the greatest increase among all world regions, exceeding that of the second-largest subregion, South Asia, with an increase of 4.2 million t, and that of the second-largest region, Africa with an increase of 5 million t.

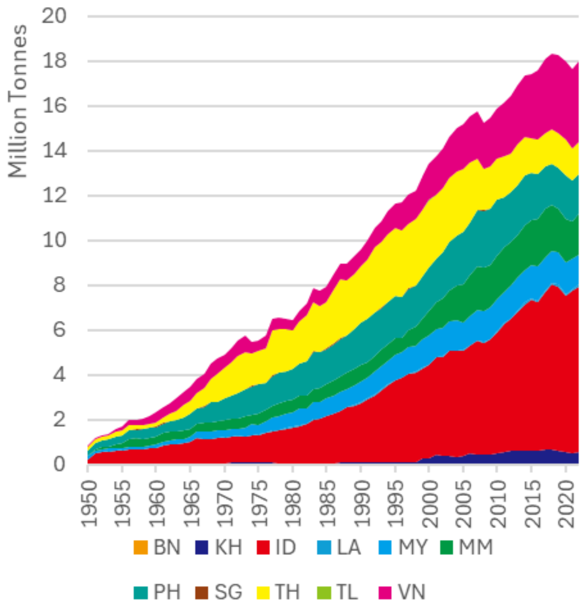

Fig. 3 Capture fisheries production in SEA among member countries (see Table 2 for abbreviations)

Fig. 3 illustrates capture fisheries production in SEA by country from 1950 to 2022. In 2022, production from Indonesia occupied 41% of the SEA production, followed by Vietnam (20%). The total increase in production mainly stems from increased contributions by Indonesia (4.2 million t), Vietnam (2.7 million t), and Myanmar (1.1 million t) over the 30 years (1993–2022). However, production by Thailand declined by 1.5 million t in these 30 years mainly because of a rollback from marine fisheries catches outside its EEZ (Department of Fisheries Thailand 2020).

SEA production peaked at 18.2 million t in 2018. The increase in production during 5 years (2017–2022) decreased by 0.13 million t from the world's first increase. During the same 5 years, Indonesia and Vietnam continued to increase their production by 0.36 and 0.28 million t, respectively, whereas production by Myanmar decreased by 0.29 million t, and that of Malaysia, Philippines, Cambodia, and Thailand each decreased by more than 0.1 million t.

Number of fishers

The number of fishers is an essential indicator of the scale of fishing activity. Even if the number of fishers remains constant, the fishing capacity is an outcome of several factors. Specifically, the scale of the fishery (i.e., large-scale fisheries, small-scale fisheries, or artisanal fisheries), the frequency of fishing engagement (i.e., full-time fisher, part-time fisher, or occasional fisher), and the efficiency of the fishing gear used will all influence the fishing capacity of a country's fishing sector. Supposing that the composition of these factors is constant, the overall fishing effort may be proportional to the number of fishers (Sparre and Venema 1998; Matsuishi 2022).

The ratio of fishers to the total population is also an indicator of the rank of the fishing industry in a given region or country in terms of the employment it creates. Although sufficient statistics on the composition of fishers are not available for some countries, productivity, estimated from the production and number of fishers, can also be used to estimate the characteristics of the average fisher (Pascoe and Gréboval 2003).

The data cited here are taken from published FAO reports. *The State of World Fisheries and Aquaculture 2024* (FAO 2024c) reports the number of fishers by region in 1995, 2000s, 2010s, 2020 and 2022. The *Fishery and Aquaculture Statistics – Yearbook 2021* (FAO 2024a) compiles information on the number of fishers in 1995, 2000, 2005, 2010, 2015, and 2017–2021 in the top-producing capture fisheries countries.

Among the top-producing capture fisheries countries, data on fishers are not available for four of the 11 countries comprising SEA: Brunei Darussalam (BN), LA (Lao PDR), Singapore (SG), and Timor-Leste (TL). Instead, the percentage of fishers in those countries was assumed to be the percentage of fishers in the world population (0.43%), and therefore, the number of fishers was estimated from each country's population and the percentage. Since the total population of the four countries represents 2.2% of the population of SEA, the error in this estimation is considered negligible in the estimation of the total number of fishers in SEA.

To compare to the latest data on capture fisheries production (i.e., for 2022), the number of fishers in SEA in 2022 was estimated, assuming that the rate of change in 2021–2022 was the same as in 2020–2021. Since the rate of change in the reported number of SEA fishers was small (−1.3%), the error from this estimation is considered negligible. Therefore, the number of fishers in SEA countries in the 2000s and 2010s was assumed to be the number of fishers in 2005 and 2015, respectively.

The number of fishers worldwide was reported as 33.6 million in 2022, representing 0.42% of the world's population. In SEA, the number of fishers was estimated at 9.58 million, equating to 29% of the world's fishers (FAO 2024a, 2024c) (Fig. 4). The estimated fraction of fishers in the total population of SEA is 1.41%, which is more than triple that of the world average.

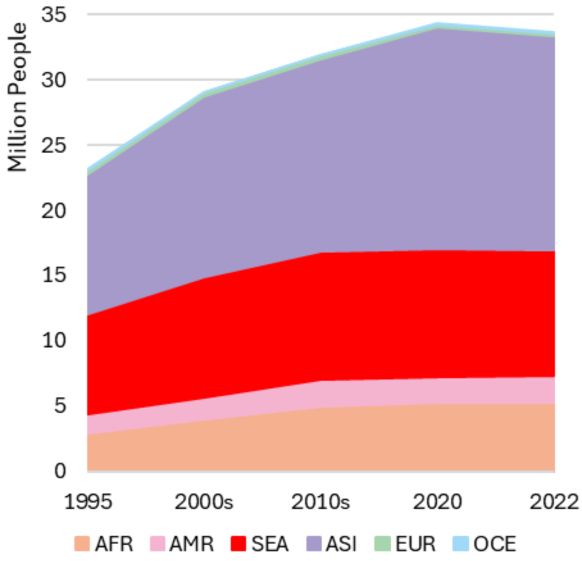

Fig. 4 Numbers of fishers by region, estimated from FAO statistics (FAO 2024a, 2024c) (see Table 1 for abbreviations)

The number of fishers in seven SEA countries that provide that data is depicted in Fig. 5. Cambodia has the highest percentage of fishers at 6.7% of the total population, followed by Myanmar at 4.6%. These countries heavily depend on fish as a source of animal protein (as described further below). Notably, Cambodia has a large lake, Tonlé Sap, and seasonally flooded swamp forests, which allow for many occasional fishers (Bann and Sopha 2020). The number of fishers in Thailand may be under-reported for small-scale fisheries.

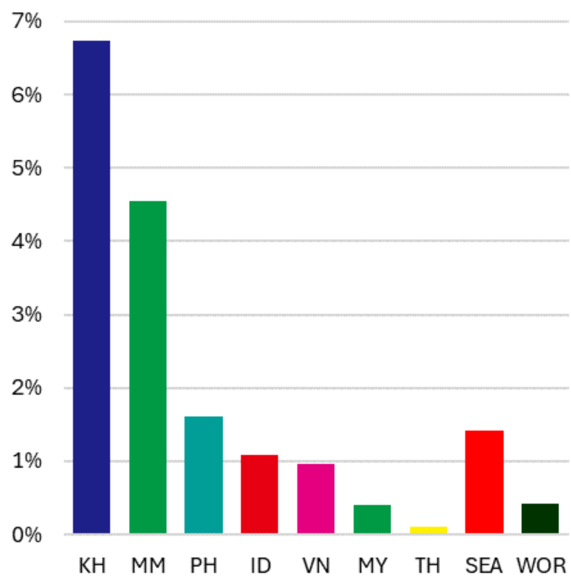

Fig. 5 Percentage of fishers in the total population in selected countries of SEA (see Tables 1 and 2 for abbreviations)

Productivity of the fisheries

Fishery productivity varies by region. As mentioned above, fishers in SEA in 2022 accounted for 29% of the total globally yet contributed only 19% to the global capture fisheries production. Capture fishery production divided by the number of fishers engaged is defined here as fisheries productivity. Comparisons of the fisheries productivity with other countries and regions will highlight fisheries sectors in that country, such as small-scale and artisanal fisheries (Pascoe et al. 2010, 2022; Matsuishi 2022).

The estimated productivity of capture fisheries in SEA is 1.9 t per fisherman per year, roughly 2/3rds the world average of 2.7 t, and 1/36th that of Europe (Fig. 6).

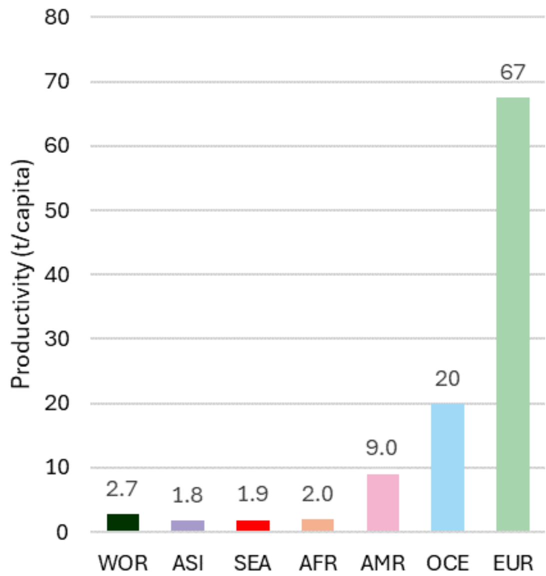

Fig. 6 Productivity of fishers in capture fisheries per year by region (see Table 1 for abbreviations)

Per capita food consumption of aquatic foods

The mass consumption of aquatic foods has been considered a reason for overfishing in SEA. Aquatic foods, also known as blue foods, is a general term that covers fish, invertebrates, algae and aquatic plants, either wild-captured or cultured, across freshwater and marine ecosystems (Pomeroy 2012; Pomeroy et al. 2016). The per capita apparent consumption of aquatic foods (kg/capita/yr) is widely used to indicate the average amount of aquatic foods people consume, calculated from the total food supply divided by the total population (Gibson 2005).

Estimates of per capita apparent consumption of aquatic foods were compiled from FAO food balance sheets, available online (FAO 2020, 2023). The target item was "fish, seafood," which covers freshwater fishes, demersal fishes, pelagic fishes, marine fishes, crustaceans, cephalopods, mollusks, and miscellaneous other aquatic animals. Although aquatic plant production is significant in SEA, it was excluded from the analysis because most aquatic plants harvested are not consumed as food.

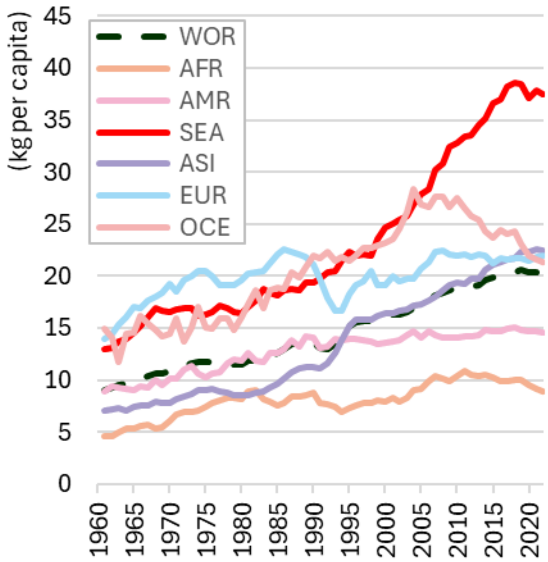

Fig. 7 Per capita aquatic food supply by world region, from 1961 to 2022, excluding aquatic plants (see Table 1 for abbreviations)

Fig. 7 illustrates the trend in per capita aquatic food supply from 1961 to 2022 by world regions. In 2022, the estimate for SEA was 37.5 kg/capita/yr, which far exceeded that of all other Regions and was 1.85 times greater than the world average.

The world per capita supply started at 9 kg/capita/yr in 1961, and by 2022, was more than double at 20 kg/capita/yr. The estimates for Europe, Africa and the Americas increased during the 20th century, but the increases have slowed in the new millennium. The estimate for Oceania peaked at 28.4 kg/capita/yr in 2004 and declined to 21 kg in 2022. However, the estimate for Asia, including SEA, has steadily increased. In 2022, the per capita aquatic food supply had tripled when compared with 1961 in both SEA and Asia except SEA. The general increase in these estimates over 30 years for the region has been significant, with SEA ranking top-most among regions (17 kg/capita/yr), followed by Asia except SEA (10 kg/capita/yr).

However, the increase in the aquatic food supply in SEA appears to have peaked in 2018, as the change over 5 years (2017–2022) has been negative (−0.74 kg per capita). Some researchers have suggested the change in food consumption behaviours due to the COVID-19 pandemic. Some research has reported that consumers intend to increase their consumption of fish out of health considerations, whereas other research has reported a slight decrease in fish supply, although the results in either case were not statistically significant (Yang et al. 2022; Hajipoor et al. 2023; Htar et al. 2023).

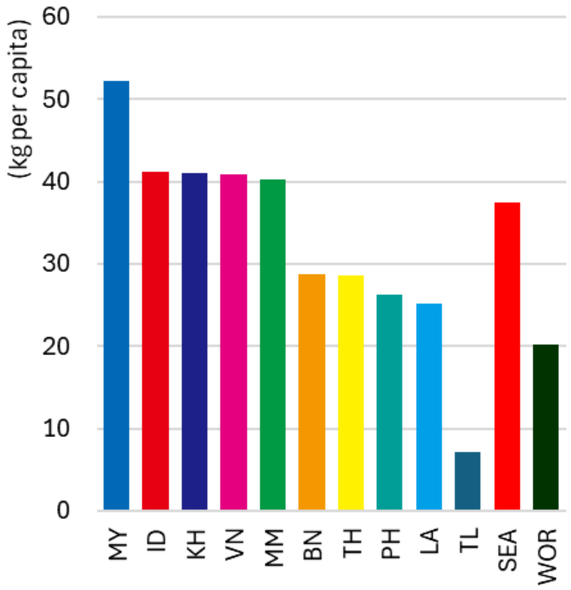

Fig. 8 Per capita supply of aquatic foods in SEA in 2022 by country, excluding aquatic plants (see Tables 1 and 2 for abbreviations)

Fig. 8 shows the per capita supply of aquatic foods in SEA in 2022, revealing values higher than the world average for all countries except Timor-Leste. That for Malaysia is 2.6 times greater than the world average, and those for Indonesia, Cambodia, Viet Nam and Myanmar are each approximately double the world average.

Dependence on fish for protein

To investigate the degree of people's dependence on aquatic foods in SEA, dependence on aquatic food for animal protein (DoF) was calculated by country using the FAO food balance sheet (FAO 2023). DoF is a widely used measure of the amount of protein (kcal) obtained from aquatic foods as a percentage of the amount of protein obtained from all animal products (Gibson 2005; Taylor et al. 2019; Boyd et al. 2022).

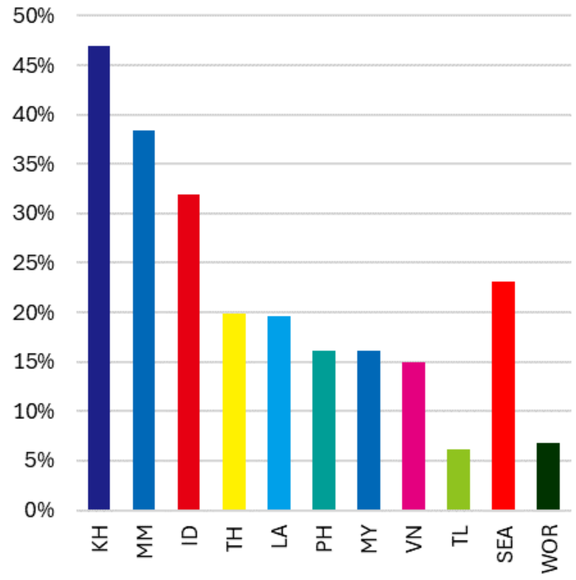

Fig. 9 Dependence on aquatic foods for protein (as a percentage of all animal products consumed) in SEA countries in 2022 (see Tables 1 and 2 for abbreviations)

Fig. 9 depicts DoF in 2022 by country. The average value of DoF across SEA countries was 23.2%, which was 3.4 times the world average and far greater than that of other regions (data not illustrated), with Africa having the next-highest value at 8.9%. In SEA, the DoF was greatest for Cambodia at 47%, followed by Myanmar and Indonesia at >30%, and for all other SEA countries except Timor-Lest, the DoF was more than double the world average.

Food security in terms of aquatic foods

Food self-sufficiency is increasingly recognized as crucial in ensuring food security and resilience against global crises. This metric refers to the capacity of a region or country to produce enough food to meet the needs of its own population without relying heavily on imports. It helps to ensure stability in the face of global crises, reduced risk of food insecurity, economic independence, environmental sustainability, coping with climate change, and support for local farmers (Clapp 2017; Baer-Nawrocka and Sadowski 2019; Enriquez 2020). In contrast, low food security in terms of aquatic foods can lead to pressure to increase production and to overfishing.

Aquatic food self-sufficiency in SEA was investigated using information from the FAO food balance sheet (FAO 2023). Here, the self-sufficiency ratio (SSR) is the percentage of aquatic foods consumed that are produced domestically, with higher values indicating greater self-sufficiency. The SSR is calculated as: production / (production + imports – exports).

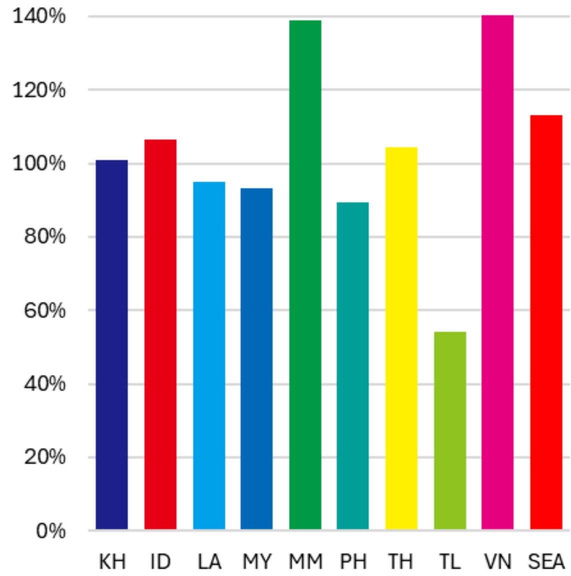

Fig. 10 Aquatic foods self-sufficiency ratio for SEA countries in 2022 (see Tables 1 and 2 for abbreviations)

Fig. 10 shows the SSR of SEA countries in 2022. The SSR of SEA was 113%, which means that aquatic food production in the region was sufficient for the demand. Viet Nam had the highest SSR at 141%, followed by Myanmar at 139%. Timor-Lest had an exceptionally low SSR, at 54%; since the total supply from the country represented 0.02% of the total in SEA, the impact of the country's low SSR was negligible. The SSR values for the other countries ranged from 89% to 107%. Some countries have high import and export volumes, but consumption was within the range of 52% (Indonesia) to 95% (Malaysia) of production, and no country exceeded 100%.

Capture fisheries by SEA are able to supply sufficient aquatic foods to the member countries, although an SSR below 100% for Timor-Leste, the Philippines, Myanmar, and Laos PDR denotes the need to import aquatic foods to satisfy domestic demands.

Stock status

Current stock levels in SEA marine waters were considered quantitatively. As mentioned, over the past several decades, the demand for aquatic foods in SEA has increased owing to population growth and rapid increases in per capita aquatic food supply, with SEA being the highest among all regions. Thus, capture fisheries have aimed to meet this demand. Considering the growth in capture fisheries despite warnings of overfishing, an overview of the current stock status is essential.

A wide range of published quantitative stock assessment results in 2018 and 2022 were collected (see Online Resource, Table S1). The resource assessment methods used were mainly surplus production models (e.g., Fox model in ASPIC [A Stock Production Model Incorporating Covariates]) and per-recruit analyses (e.g., yield per recruit [YPR] and spawning stock biomass per recruit [SPR]). The data sources included reports on resource assessments carried out by each country's government, the regional stock assessment results of SEAFDEC, and academic papers.

The results of 105 resource assessments were obtained, of which 58 were conducted in the Pacific Ocean and 47 in the Indian Ocean. Of those, 12 assessments were for neritic tuna species, 38 for pelagic species, and 55 for demersal species. The grouping of the species was based on the descriptions in FishBase (https://fishbase.se). Neritic tuna tends to have independent fishing grounds and are also highly-priced, so independent and sophisticated stock assessments of these species are being carried out worldwide (Harlyan et al. 2021; Konoyima et al. 2024).

As a biological reference point (BRP), the biomass B that achieves the maximum sustainable yield (B_{msy}), the fishing mortality F that achieves this (F_{msy}), and a proxy for these BRPs was used. The stock assessment results were categorized according to FAO definitions as overfished, maximally sustainably fished, or underfished (FAO 2024c). For the purpose of categorization, the minimum and maximum thresholds are 0.8 and 1.2, following the FAO. Hence, a fishery is classified as overfished if $B/B_{\mathrm{msy}} < 0.8$; as maximally sustainably fished if $0.8 \leqq B/B_{\mathrm{msy}} \leqq 1.2$; and underexploited if $B/B_{\mathrm{msy}} > 1.2$. A fishery is classified as underexploited if $F/F_{\mathrm{msy}} < 0.8$; as maximally sustainably fished if $0.8 \leq F/F_{\mathrm{msy}} \leq 1.2$; and as overfished if $F/F_{\mathrm{msy}} > 1.2$. If F and B are estimated but the categories differ, the result for B was prioritized.

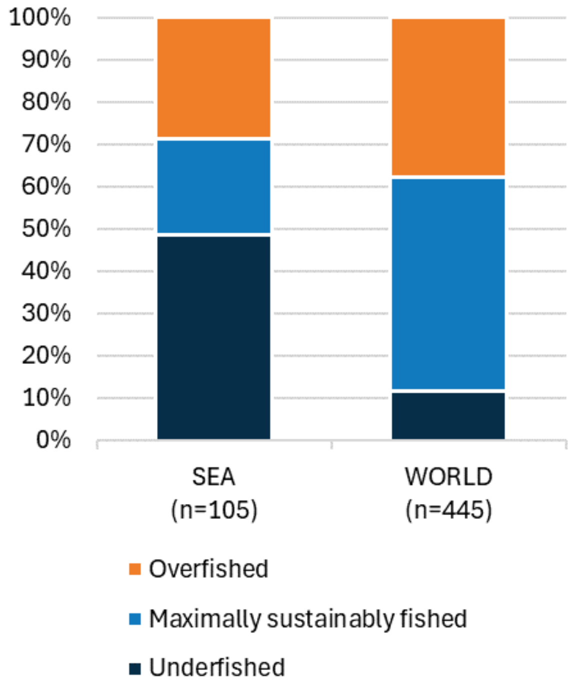

Fig. 11 Quantitative stock assessment results of randomly selected fish stocks in SEA as compared with the global stock status (FAO 2024c)

The results of all the quantitative stock assessments are listed in ESM Table S1. Fig. 11 shows the results for SEA compared with the world: 33%, 24% and 43% of the stocks in SEA waters were evaluated as overfished, maximally sustainably fished, and underfished, respectively. The difference with estimates for the world was significant ($p < 0.001$, χ^2 test). The percentage of overfished stocks in SEA waters was similar to the global percentage, but the percentage of underfished stocks was fourfold greater than in the world.

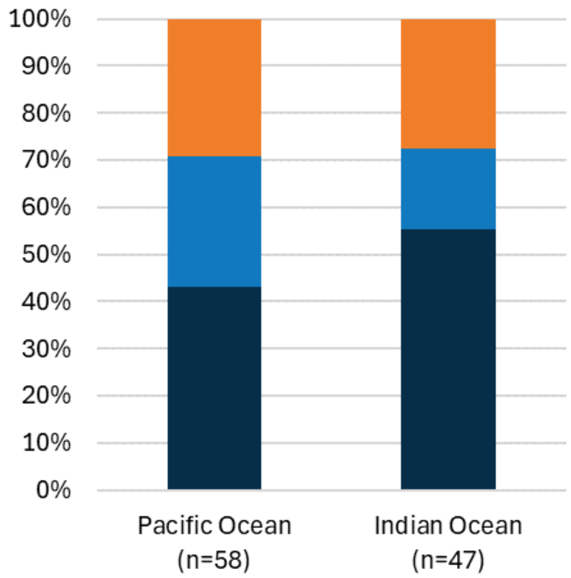

Fig. 12 Quantitative stock assessment results of randomly selected marine stocks in SEA waters by the ocean (colour legends are the same as in Fig. 11)

Fig. 12 shows the quantitative stock assessment results of randomly selected stocks in SEA by ocean. A larger percentage of underfished fisheries stocks remain in the Indian Ocean (55%) than in the Pacific Ocean (43%), but the difference was not significant.

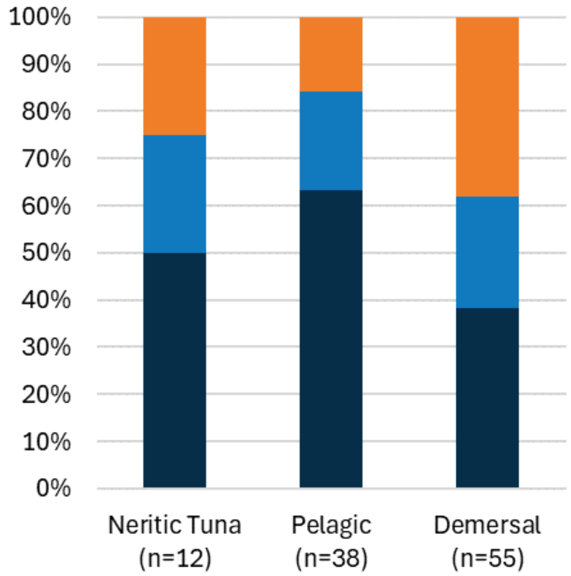

Fig. 13 Quantitative stock assessment results of randomly selected fish stocks in SEA by species groups (colour legends are the same as in Fig. 11)

Fig. 13 shows the quantitative stock assessment results of randomly selected stocks in SEA by species group. A high proportion of overfished stocks (38%) were demersal species, and the overall stock status of the demersal group is relatively poor when compared with the other two groups. However, the proportion of underfished stocks (38%) in the demersal group was more than threefold that of the global average (12%). The proportion of underfished stocks in the pelagic group was 63%, and the proportion of overfished stocks was 16%, indicating a better status when compared with the demersal group. The proportions of the different stock status categories between the pelagic and demersal groups differed significantly ($p < 0.05$, χ^2 test). Large-scale fishers mainly use trawl nets, while small-scale fishers use gill nets and longlines to catch demersal fish. However, no clear relationship was found between overfished stocks and the main fishing methods or scale of fishing.

Prospects for attaining sustainable capture fisheries in SEA

SEA has increased its capture fisheries production the most among the world's regions over the past 30 years. Whereas the capture fisheries production of other regions either plateaued or decreased, there was a steady increase in SEA. However, after peaking in 2018, the capture fisheries production in SEA has decreased and is now at a plateau.

In SEA, many people are engaged in fishing, and the proportion of fishers in the population was 3.4 times higher than the global average. Productivity is the second lowest in the world after Asia except SEA and only 68% of the world average. The per capita supply of aquatic foods in SEA is the highest among all regions, 1.9 times the world average, and the increase over the last 30 years was also the highest when compared with all other regions. However, it appears to be declining since 2018. The DoF in SEA is also the highest among the regions and 3.4 times the world average. In this way, SEA relies uniquely on capture fisheries for aquatic foods.

Overfishing of the fishery resources in SEA has been noted for decades. However, the current ratio of overfished resources was still almost the same as the global average. Moreover, the ratio of underfished stocks was 3.6 times higher than the global average.

Several factors may explain the robustness of the region's fisheries. One is the dominance of small-scale and artisanal fisheries (SSF), though they generally have low productivity. Worldwide, it is estimated that 90% of fishers are engaged in SSFs, and that SSFs produce 40% of the total fisheries output (Teh and Sumaila 2013; Ayilu et al. 2022). Defining small-scale fisheries is complex, and direct counts of small-scale fishers are challenging to obtain (Smith and Basurto 2019). However, the proportion of small-scale fishers in SEA is estimated to exceed the global average, as productivity is only 68% of the global average.

Small-scale fishing has various advantages: as its productivity is low, it is possible to provide many jobs without overfishing; the small scale of fishing gear has a low impact on the ecosystem; and the small amount of fish caught at one time ensures that the quality and freshness of the catch is high, and it is sold at a relatively high unit price. As a result, the well-being of small-scale fishers can be high, making them optimistic about fishing and helping to achieve sustainable fishing (Teh and Sumaila 2013; Teh and Pauly 2018; Anna et al. 2019; Phelan et al. 2023). Note that it is difficult for small-scale fishermen to control and monitor their activities. It is necessary to develop a fishery management framework for small-scale fishermen, such as co-management (Smith and Basurto 2019).

In addition, the high biodiversity of marine waters in SEA results in multispecies fisheries and fishing gears without species selectivity. Conventional resource assessment models typically assume single-species fisheries in temperate and subarctic regions. A general view is that catches of non-target species harm ecosystems because of accidental bycatch. Still, in recent years, it has been shown that multispecies fisheries with no species selectivity are more robust against overfishing (Garcia et al. 2012; Harlyan et al. 2019, 2021). Multispecies fisheries also have the advantage of stabilizing fishers' catches and incomes (Nakamura et al. 2023).

Various measures have been introduced to manage fishing in SEA countries. Licensing schemes, zonation, gear regulations, marine protected areas, and closed areas have begun to be implemented in many countries. In particular, much effort is being made to eradicate illegal, unreported, and unregulated (IUU) fishing. In Indonesia and Thailand, monitoring of domestic vessels is being carried out using a vessel monitoring system, and stricter controls are being implemented on foreign-registered vessels (Saleh et al. 2020). The constant efforts of fisheries management should be sustained along with innovations to improve its effectiveness.

Future production and supply of aquatic foods may be subject to fluctuations as an outcome of climate change and regime shifts (Anderson et al. 2017; Inoue et al. 2023), water pollution, dam operations (Keithmaleesatti et al. 2022; Lourenço et al. 2024), economic conditions, and the availability of other foods (Marques et al. 2018). Adding several factors whose effects are unknown may hide simple results under a cloud of complexity. Moreover, it should be considered that the projections in this review have fairly wide confidence limits in terms of single possibilities.

This study has provided insight into the goal of sustainable capture fisheries in SEA. Importantly, sustainable capture fisheries will be dependent on the region's biodiversity and self-management of its resources.

To maintain biodiversity, it is essential to encourage the practice of non-species-selective multispecies fisheries and management. Protecting, promoting, and controlling small-scale artisanal fisheries that do not destroy habitats is also essential.

It is vital to maintain fisheries under regional control. This study has shown the likelihood of a large proportion of unexploited stocks in SEA waters. Countries outside the region should not target this stock through intensified fishing in the region; in some marine waters of SEA, major powers with the intention of gaining hegemony over maritime interests are attempting to change the status quo by force.

The world population growth rate may begin to decrease in the near future, as some countries have already started to experience population declines. While it is observed that the global increase in per capita supply of seafood has ceased, domestic demands for aquatic foods are expected to decline in line with population declines. Overseas moves to secure fish catches from SEA fishing grounds should be discouraged. The philosophy of the sufficiency economy (Kansuntisukmongkol 2017), 'Knowing what is enough' is crucial for the realization of sustainable fisheries in the world.

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Figure Captions

Fig. 1 Capture fisheries production by region (see Table 1 for abbreviations)

Fig. 2 Map of Southeast Asia, modified from Wikimedia (https://commons.wikimedia.org/wiki/File:Map_and_flag_of_ASEAN_countries.png)

Fig. 3 Capture fisheries production in SEA among member countries (see Table 2 for abbreviations)

Fig. 4 Numbers of fishers by region, estimated from FAO statistics (FAO 2024a, 2024c) (see Table 1 for abbreviations)

Fig. 5 Percentage of fishers in the total population in selected countries of SEA (see Tables 1 and 2 for abbreviations)

Fig. 6 Productivity of fishers in capture fisheries per year by region (see Table 1 for abbreviations)

Fig. 7 Per capita aquatic food supply by world region, from 1961 to 2022, excluding aquatic plants (see Table 1 for abbreviations)

Fig. 8 Per capita supply of aquatic foods in SEA in 2022 by country, excluding aquatic plants (see Tables 1 and 2 for abbreviations)

Fig. 9 Dependence on aquatic foods for protein (as a percentage of all animal products consumed) in SEA countries in 2022 (see Tables 1 and 2 for abbreviations)

Fig. 10 Aquatic foods self-sufficiency ratio for SEA countries in 2022 (see Tables 1 and 2 for abbreviations)

Fig. 11 Quantitative stock assessment results of randomly selected fish stocks in SEA as compared with the global stock status (FAO 2024c)

Fig. 12 Quantitative stock assessment results of randomly selected marine stocks in SEA waters by the ocean (colour legends are the same as in Fig. 11)

Fig. 13 Quantitative stock assessment results of randomly selected fish stocks in SEA by species groups (colour legends are the same as in Fig. 11)

Electronic Supplementary Material

Fisheries Science

Status of Southeast Asian fisheries uniqueness and pathway to sustainable fisheries.

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Table S1 Selected quantitative stock assessment results in Southeast Asia. The abbreviation appears below the table.

Label	Scientific name	Group	Country/ Institute	Ocean	Method	Year	Result	Biomass Index	BRP	Effort Index	BRP	Reference
R001	*Acetes spp.*	D	MY	Pacific	ASPIC	2021	M	1.0	TBMSY	1.0	Fmsy	(Jamon et al., 2022)
R002	*Anchovy*	P	TH	Pacific	Fox	2017	U			0.3	Fmsy	(Department of Fisheries Thailand, 2020)
R003	*Anchovy*	P	TH	Indian	Fox	2017	U			0.7	Fmsy	(Department of Fisheries Thailand, 2020)
R004	*Anguilla spp.*	D	ID	Indian	Empirical	2024	U			0.5	Emsy	(Wahju et al., 2024)
R005	*Ariidae spp.*	D	MY	Pacific	ASPIC	2021	O	0.4	TBMSY	2.3	Fmsy	(Jamon et al., 2022)
R006	*Ariidae spp.*	D	MY	Indian	ASPIC	2021	U	1.7	TBMSY	0.3	Fmsy	(Jamon et al., 2022)
R007	*Atrobucca brevis*	D	ID	Indian	SPR	2021	O	0.1	BMSY			(Dimarchopoulou et al., 2021)
R008	*Atule mate*	P	MY	Indian	ASPIC	2021	U	1.6	TBMSY	0.3	Fmsy	(Jamon et al., 2022)
R009	*Chiloscyllium plagiosum*	D	MY	Pacific	YPR	2016	U			0.1	Fmax	(Pattarapongpan et al., 2022)
R010	*Chiloscyllium plagiosum*	D	MY	Pacific	YPR	2016	U			0.3	Fmax	(Pattarapongpan et al., 2022)
R011	*Chiloscyllium punctatum*	D	MY	Pacific	YPR	2016	U			0.7	Fmax	(Pattarapongpan et al., 2022)
R012	*Chiloscyllium punctatum*	D	TH	Pacific	YPR	2016	M			1.2	Fmax	(Pattarapongpan et al., 2022)
R013	*Chiloscyllium punctatum*	D	KH	Pacific	YPR	2016	U			0.2	Fmax	(Pattarapongpan et al., 2022)
R014	*Decapterus macarellus*	P	MY	Indian	ASPIC	2021	U	1.6	TBMSY	0.3	Fmsy	(Jamon et al., 2022)
R015	*Decapterus macarellus*	P	ID	Pacific	ASPIC	2022	O	0.8	Bmsy	1.4	Fmsy	(Purwanto et al., 2022)
R016	*Demersal fish Group*	D	TH	Pacific	Fox	2019	U			0.8	Fmsy	(Department of Fisheries Thailand, 2020)
R017	*Demersal fish Group*	D	TH	Indian	Fox	2017	U			0.6	Fmsy	(Department of Fisheries Thailand, 2020)
R018	*Eleutheronema tetradactylum*	D	MY	Pacific	ASPIC	2020	M	1.5	TBMSY	0.9	Fmsy	(Jamon et al., 2022)
R019	*Encrasicholina spp.*	P	TH	Pacific	T-B	2017	M			1.0	Emsy	(Department of Fisheries Thailand, 2015)
R020	*Encrasicholina spp.*	P	TH	Indian	T-B	2017	U			0.8	Emsy	(Department of Fisheries Thailand, 2015)

R021	*Engraulidae spp.*	P	MY	Pacific	ASPIC	2020	U	1.8	TBMSY	0.2	Fmsy	(Jamon et al., 2022)
R022	*Engraulidae spp.*	P	MY	Indian	ASPIC	2021	U	1.3	TBMSY	0.5	Fmsy	(Jamon et al., 2022)
R023	*Epinephelinae spp.*	D	MY	Pacific	ASPIC	2020	O	0.3	TBMSY	3.1	Fmsy	(Jamon et al., 2022)
R024	*Epinephelinae spp.*	D	MY	Indian	ASPIC	2021	M	1.1	TBMSY	0.5	Fmsy	(Jamon et al., 2022)
R025	*Epinephelus aerolatus*	D	ID	Indian	SPR	2021	O	0.2	SPR			(Dimarchopoulou et al., 2021)
R026	*Epinephelus aerolatus*	D	ID	Pacific	SPR	2021	O	0.1	SPR			(Dimarchopoulou et al., 2021)
R027	*Epinephelus amblycephalus*	D	ID	Indian	SPR	2021	O	0.2	SPR			(Dimarchopoulou et al., 2021)
R028	*Euthynnus affinis*	N	TH	Pacific	ASPIC	2018	M	1.1	Bmsy	0.9	Fmsy	(SEAFDEC/MFRDMD, 2022)
R029	*Euthynnus affinis*	N	TH	Indian	ASPIC	2018	O	0.8	Bmsy	1.4	Fmsy	(SEAFDEC/MFRDMD, 2022)
R030	*Euthynnus affinis*	N	MY	Pacific	ASPIC	2021	M	1.0	TBMSY	0.8	Fmsy	(Jamon et al., 2022)
R031	*Euthynnus affinis*	N	SEAFDEC	Indian	ASPIC	2017	U	1.3	Bmsy	0.8	Fmsy	(Nishida et al., 2017)
R032	*Euthynnus affinis*	N	SEAFDEC	Pacific	ASPIC	2017	U	1.3	Bmsy	0.7	Fmsy	(Nishida et al., 2017)
R033	*Katsuwonus pelamis*	N	IOTC	Indian	SS	2021	U	2.0	SSBmsy	0.5	Emsy	(IOTC-WPTT24 2022, 2022)
R034	*Lutjanidae spp.*	P	MY	Indian	ASPIC	2021	M	1.2	TBMSY	1.0	Fmsy	(Jamon et al., 2022)
R035	*Lutjanus campechanus*	D	MY	Pacific	ASPIC	2021	M	1.3	TBMSY	1.0	Fmsy	(Jamon et al., 2022)
R036	*Lutjanus erythropterus*	D	ID	Indian	SPR	2021	O	0.5	SPR			(Dimarchopoulou et al., 2021)
R037	*Lutjanus malabaricus*	D	ID	Pacific	SPR	2021	O	0.1	SPR			(Dimarchopoulou et al., 2021)
R038	*Lutjanus malabaricus*	D	ID	Pacific	SPR	2021	O	0.1	SPR			(Dimarchopoulou et al., 2021)
R039	*Lutjanus malabaricus*	D	ID	Indian	SPR	2021	O	0.1	SPR			(Dimarchopoulou et al., 2021)
R040	*Lutjanus russelli*	D	ID	Indian	SPR	2021	O	0.3	SPR			(Dimarchopoulou et al., 2021)
R041	*Lutjanus sebae*	D	ID	Indian	SPR	2021	O	0.0	SPR			(Dimarchopoulou et al., 2021)
R042	*Lutjanus vitta*	D	ID	Pacific	SPR	2021	O	0.3	SPR			(Dimarchopoulou et al., 2021)
R043	*Lutjanus vitta*	D	ID	Pacific	SPR	2021	O	0.1	SPR			(Dimarchopoulou et al., 2021)
R044	*Lutjanus vitta*	D	ID	Pacific	SPR	2021	O	0.4	SPR			(Dimarchopoulou et al., 2021)
R045	*Megalaspis cordyla*	P	MY	Pacific	ASPIC	2020	O	0.8	TBMSY	1.4	Fmsy	(Jamon et al., 2022)
R046	*Megalaspis cordyla*	P	MY	Indian	ASPIC	2021	U	1.5	TBMSY	0.4	Fmsy	(Jamon et al., 2022)
R047	*Metapenaeus affinis*	D	TH	Pacific	T-B	2017	M			0.9	Emsy	(Department of Fisheries Thailand, 2015)
R048	*Metapenaeus affinis*	D	TH	Indian	T-B	2017	U			0.4	Emsy	(Department of Fisheries Thailand, 2015)
R049	*Mulloidichthys martinicus*	P	MY	Pacific	ASPIC	2021	U	1.7	TBMSY	0.3	Fmsy	(Jamon et al., 2022)
R050	*Nemipterus hexodon*	D	TH	Pacific	T-B	2017	M			1.0	Emsy	(Department of Fisheries Thailand, 2015)
R051	*Nemipterus hexodon*	D	TH	Indian	T-B	2017	M			1.1	Emsy	(Department of Fisheries Thailand, 2015)
R052	*Nemipterus japonicus*	D	MY	Pacific	ASPIC	2020	M	0.9	TBMSY	1.1	Fmsy	(Jamon et al., 2022)
R053	*Nemipterus japonicus*	D	MY	Indian	ASPIC	2021	O	0.7	TBMSY	1.6	Fmsy	(Jamon et al., 2022)

R054	*Paracaesio gonzalesi*	D	ID	Indian	SPR	2021	M	1.0	SPR			(Dimarchopoulou et al., 2021)
R055	*Pelagic fish group*	P	TH	Pacific	Fox	2017	U			0.8	Fmsy	(Department of Fisheries Thailand, 2020)
R056	*Pelagic fish group*	P	TH	Indian	Fox	2017	M			0.9	Fmsy	(Department of Fisheries Thailand, 2020)
R057	*Penaeus merguiensis*	D	TH	Pacific	T-B	2017	U			0.7	Emsy	(Department of Fisheries Thailand, 2015)
R058	*Penaeus merguiensis*	D	TH	Indian	T-B	2017	M			0.8	Emsy	(Department of Fisheries Thailand, 2015)
R059	*Pennahia argentata*	D	MY	Pacific	ASPIC	2020	O	0.7	TBMSY	1.5	Fmsy	(Jamon et al., 2022)
R060	*Photololigo duvaucelii*	D	TH	Pacific	T-B	2017	M			0.9	Emsy	(Department of Fisheries Thailand, 2015)
R061	*Photololigo duvaucelii*	D	TH	Indian	T-B	2017	O			1.3	Emsy	(Department of Fisheries Thailand, 2015)
R062	*Pinjalo lewisi*	D	ID	Indian	SPR	2021	O	0.6	SPR			(Dimarchopoulou et al., 2021)
R063	*Pinjalo pinjalo*	D	ID	Pacific	SPR	2021	O	0.0	SPR			(Dimarchopoulou et al., 2021)
R064	*Plotosus lineatus*	D	MY	Pacific	ASPIC	2020	U	1.5	TBMSY	0.5	Fmsy	(Jamon et al., 2022)
R065	*Priacanthus spp.*	D	MY	Pacific	ASPIC	2020	O	0.6	TBMSY	2.2	Fmsy	(Jamon et al., 2022)
R066	*Priacanthus spp.*	D	MY	Indian	ASPIC	2021	U	1.6	TBMSY	0.2	Fmsy	(Jamon et al., 2022)
R067	*Priacanthus tayenus*	D	TH	Pacific	T-B	2017	O			2.0	Emsy	(Department of Fisheries Thailand, 2015)
R068	*Priacanthus tayenus*	D	TH	Indian	T-B	2017	U			0.7	Emsy	(Department of Fisheries Thailand, 2015)
R069	*Rastrelliger kanagurta*	P	TH	Pacific	T-B	2017	M			0.9	Emsy	(Department of Fisheries Thailand, 2015)
R070	*Rastrelliger brachysoma*	P	TH	Pacific	T-B	2017	U			0.3	Emsy	(Department of Fisheries Thailand, 2015)
R071	*Rastrelliger brachysoma*	P	TH	Indian	T-B	2017	U			0.5	Emsy	(Department of Fisheries Thailand, 2015)
R072	*Rastrelliger kanagurta*	P	TH	Indian	T-B	2017	O			1.7	Emsy	(Department of Fisheries Thailand, 2015)
R073	*Rastrelliger kanagurta*	P	MY	Pacific	ASPIC	2020	U	1.6	TBMSY	0.4	Fmsy	(Jamon et al., 2022)
R074	*Rastrelliger spp.*	P	MY	Pacific	ASPIC	2020	U	1.7	TBMSY	0.3	Fmsy	(Jamon et al., 2022)
R075	*Rastrelliger spp.*	P	MY	Indian	ASPIC	2021	U	1.5	TBMSY	0.4	Fmsy	(Jamon et al., 2022)
R076	*Sardinella gibbosa*	P	TH	Pacific	T-B	2017	M			1.1	Emsy	(Department of Fisheries Thailand, 2015)
R077	*Sardinella gibbosa*	P	TH	Indian	T-B	2017	U			0.6	Emsy	(Department of Fisheries Thailand, 2015)
R078	*Sardinella jussieu*	P	MY	Indian	ASPIC	2021	U	1.5	TBMSY	0.5	Fmsy	(Jamon et al., 2022)
R079	*Saurida elongata*	D	TH	Pacific	T-B	2017	O			1.7	Emsy	(Department of Fisheries Thailand, 2015)
R080	*Saurida elongata*	D	TH	Indian	T-B	2017	U			0.7	Emsy	(Department of Fisheries Thailand, 2015)
R081	*Saurida undosquamis*	D	TH	Pacific	T-B	2017	O			2.5	Emsy	(Department of Fisheries Thailand, 2015)
R082	*Saurida undosquamis*	D	TH	Indian	T-B	2017	M			1.1	Emsy	(Department of Fisheries Thailand, 2015)
R083	*Saurida undosquamis*	D	MY	Pacific	ASPIC	2020	O	0.3	TBMSY	3.9	Fmsy	(Jamon et al., 2022)
R084	*Scatophagus argus*	P	ID	Pacific	Empirical	2022	U			0.6	Emsy	(Manangkalangi et al., 2022)
R085	*Scomberomorus commerson*	P	SEAFDEC	Indian	ASPIC	2019	O	0.6	Bmsy	1.4	Fmsy	(Abdullah et al., 2022)
R086	*Scomberomorus commerson*	P	SEAFDEC	Pacific	ASPIC	2019	U	1.5	Bmsy	0.6	Fmsy	(Abdullah et al., 2022)

R087	*Scomberomorus commerson*	P	MY	Pacific	ASPIC	2020	O	0.8	TBMSY	1.2	Fmsy	(Jamon et al., 2022)
R088	*Scomberomorus commerson*	P	MY	Pacific	ASPIC	2020	U	1.9	TBMSY	0.1	Fmsy	(Jamon et al., 2022)
R089	*Scomberomorus guttatus*	P	SEAFDEC	Indian	ASPIC	2019	U	1.6	Bmsy	0.6	Fmsy	(Abdullah et al., 2022)
R090	*Scomberomorus guttatus*	P	SEAFDEC	Pacific	ASPIC	2019	U	1.5	Bmsy	0.5	Fmsy	(Abdullah et al., 2022)
R091	*Scomberomorus lineolatus*	P	MY	Pacific	ASPIC	2020	O	0.3	TBMSY	3.0	Fmsy	(Jamon et al., 2022)
R092	*Scomberomorus lineolatus*	P	MY	Pacific	ASPIC	2020	U	1.4	TBMSY	0.6	Fmsy	(Jamon et al., 2022)
R093	*Scylla serrata*	D	TH	Pacific	Empirical	2020	U			0.7	Emsy	(Khowhit, 2020)
R094	*Selaroides leptolepis*	P	MY	Indian	ASPIC	2021	U	1.5	TBMSY	0.4	Fmsy	(Jamon et al., 2022)
R095	*Sepiida spp.*	D	MY	Pacific	ASPIC	2021	U	1.6	TBMSY	0.4	Fmsy	(Jamon et al., 2022)
R096	*Sepiida spp.*	D	MY	Indian	ASPIC	2021	U	1.7	TBMSY	0.2	Fmsy	(Jamon et al., 2022)
R097	*Sharks group species*	P	TH	Pacific	Fox	2021	M			1.2	Emsy	(Department of Fisheries Thailand, 2021)
R098	*Sharks group species*	P	TH	Indian	Fox	2021	M			1.0	Emsy	(Department of Fisheries Thailand, 2021)
R099	*Spratelloides gracilis*	P	MY	Pacific	ASPIC	2020	M	1.0	TBMSY	1.0	Fmsy	(Jamon et al., 2022)
R100	*Thunnus albacares*	N	IOTC	Indian	SS	2021	O	0.8	SSBmsy	1.3	Fmsy	(IOTC-WPTT24 2022, 2022)
R101	*Thunnus obesus*	N	IOTC	Indian	SS	2021	O	0.9	SSBmsy	1.4	Fmsy	(IOTC-WPTT24 2022, 2022)
R102	*Thunnus tonggol*	N	SEAFDEC	Pacific	ASPIC	2018	U	1.5	Bmsy	0.5	Fmsy	(SEAFDEC/MFRDMD, 2022)
R103	*Thunnus tonggol*	N	TH	Indian	ASPIC	2018	U	1.2	Bmsy	0.7	Fmsy	(SEAFDEC/MFRDMD, 2022)
R104	*Thunnus tonggol*	N	SEAFDEC	Indian	ASPIC	2017	M	0.9	Bmsy	1.1	Fmsy	(Nishida et al., 2017)
R105	*Thunnus tonggol*	N	SEAFDEC	Pacific	ASPIC	2017	U	2.2	Bmsy	0.2	Fmsy	(Nishida et al., 2017)

Abbreviations:

D: Demersal species, N: Neritic tunas, P: Pelagic species

ID: Indonesia, KH: Cambodia, MY: Malaysia, TH: Thailand

M: Maximally sustainably fished, O: Overfished, U: Underfished

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