Review of past stock assessments relevant to the Vung Tau Fisheries Improvement Project (FIP)

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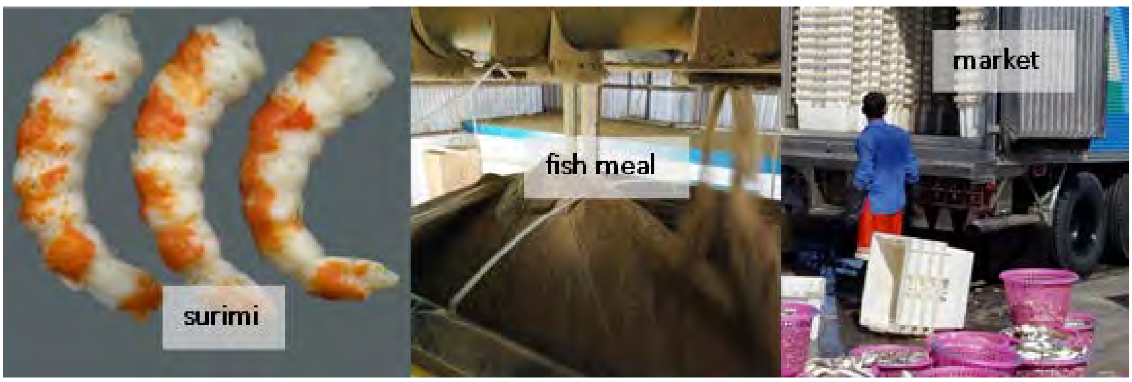


A guidance document for the Vung Tau FIP

Contents

1. INTRODUCTION

As part of the Fisheries Action Plan (FAP) that was developed to address the gaps identified in the MarinTrust fishery assessment carried out in July 2021, action 2.2.1.1 is to provide guidance on "Review of past stock assessment results related to the Ba Ria-Vung Tau trawl fishery". The aim of the review was to set the background for (i) a workshop to identify gaps in the past assessments and plan future assessments, (ii) conduct stock assessments based on existing and new data and input into the development of a trawl fishery management plan (FMP).

The report considers:

1. Past assessments and potential catch estimates;
2. Fishery independent research vessel surveys;
3. Gaps in the past assessments; and
4. Overall conclusions

The annexes give examples of more modern multi-species and single- species stock assessments that could be used in future FIP assessments.

Quote from a Vietnamese fisher -The Mekong Eye 25 April 2022

"Because the nets near the Vietnamese shore were empty, I had to look for vessels that went further. Sometimes they go into the waters of Malaysia and Indonesia," Tu said.

"Fish in the waters of Indonesia and Malaysia are more numerous and larger. Fish in the sea of Vietnam only weigh 1-3kg, while there, the fish are 6-7kg or more," he said.

"Two ships operated in parallel with each other, pulling the net, several kilometres long, behind them. The meshes were very tiny, so it captured all creatures: squid, lobster, tortoise, turtle, big fish, baby fish, even coral," said Tu.

2. FISHING AREAS AND ZONES

This report refers to the "Fishing areas" and "Fishing zones" of Vietnam. The following maps identify these areas and zones to help put the stock assessment results in context. The four fishing areas are (i) Gulf of Tonkin, (ii) Central, (iii) Southeast and (iv) Southwest (Figure 1 left-hand side) and three fishing zones are (i) coastal area (11.12 km from the beach to the coastal line for vessels with engine under 20 HP), (ii) inshore area (43.8 km from coastline to the offshore line for vessels with engine from 20-90 HP) and (iii) and offshore area (between the inshore line and the outer boundary of the exclusive economic zone of Vietnam's Sea area and fishing zone) for vessels with engine over 90 HP) (Figure 1 right-hand side).

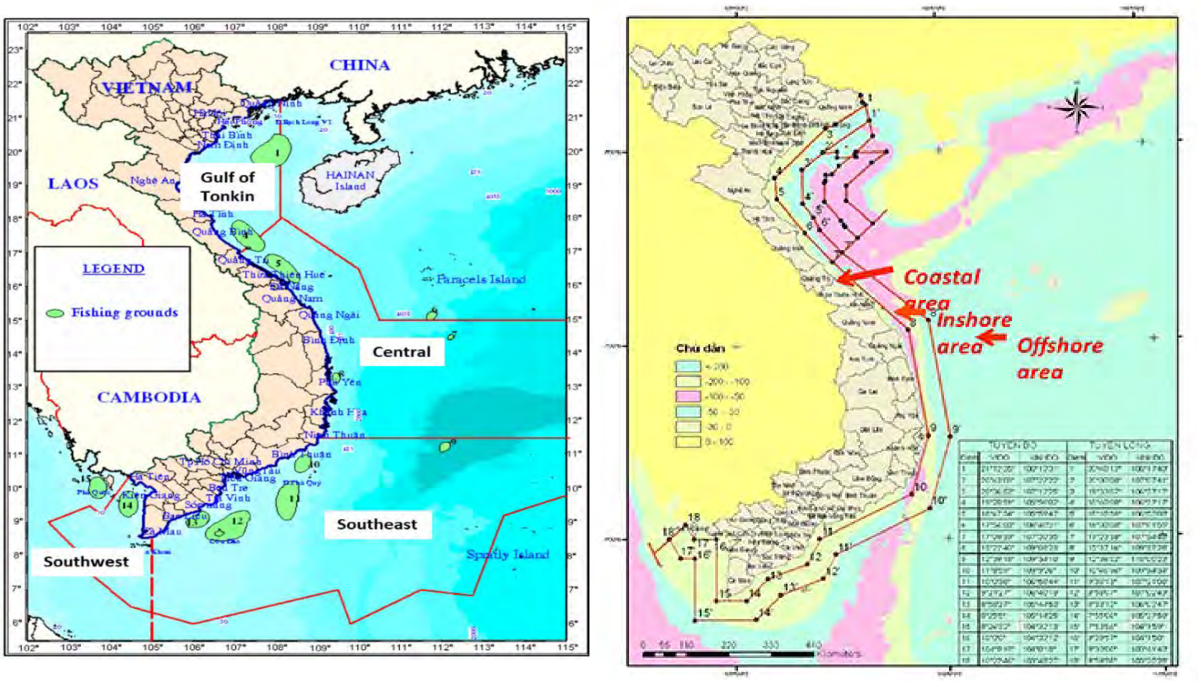


Figure 1: The four fishing areas and three fishing zones of Vietnam. ***Source: Son (2003)*** **and** ***SEAFDEC (2017), respectively***

3. CATCH HISTORY

Section 4 presents data on the biomass (abundance of fish) and the potential yield (estimated as the maximum sustainable yield (MSY)). To understand the relevance of these estimates, we need to be able to compare them with the actual catch taken from the fishery.

The main data sets used to describe the catch are:

a. Catch estimates as reported by the Food and Agriculture Organization of the United Nations (FAO), which is based on the data reported from the Vietnam Government Statistics Office (GSO), available at https://www.fao.org/fishery/en/statistics/software/fishstatj

b. Recent data available on the GSO website https://www.gso.gov.vn/en/agriculture-forestry-and-fishery/

c. Catch data for 2000-2005 and 2015-2020 estimated during the Assessment of Living marine Resources in Vietnam project (ALMRV) and the Comprehensive Survey for Marine Fisheries Resources in Vietnam Project_DA47-I.9. Hai (2018) and Vu et al. (2021)

d. Reconstructed catch data available on the Sea Around Us (SAUP) website https://www.seaaroundus.org/

3.1 All Vietnamese marine waters

According to the FAO and GSO reports, the total catch for all waters of Vietnam increased from 529,440 tonnes in 1971 to 3,553,735 in 2020 (shown as a black line Figure 2). However, there is considerable uncertainty in these figures, as shown by the more comprehensive data collection for 2000 -2005 during the ALMRV project and for 2015-2020 during Project_DA47-I.9 2015-2020 (orange and green histograms in Figure 2). This showed that the catch was under-reported by about 40% in the period 2000-2005 and, although it had similar levels of catch in 2015-2020, the trend suggested that the catch had in fact plateaued around 3.4 million tonnes during this period.

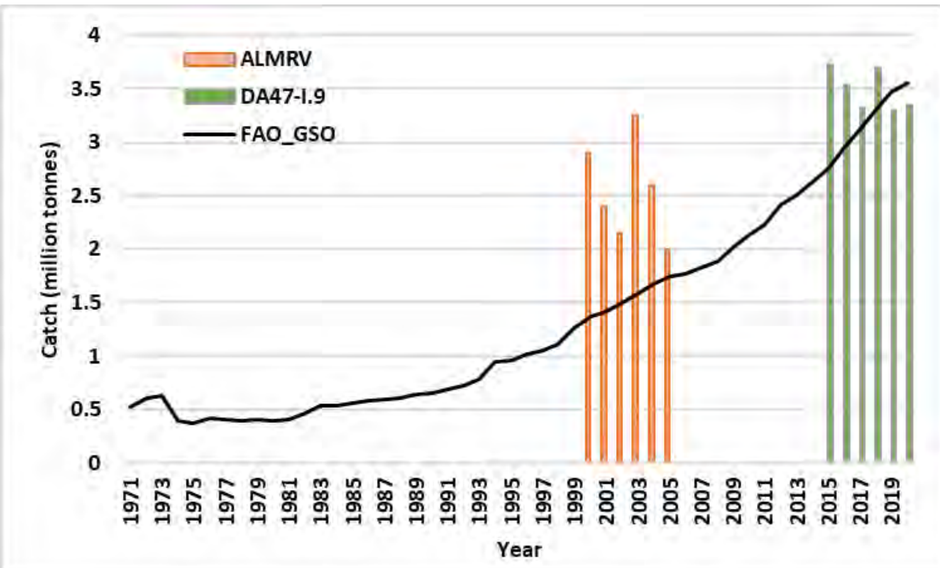


Figure 2: Total marine catch for all Vietnam waters 1971-2020 reported by the FAO/GSO (black line) and estimated during the ALMRV and DA47-I.9 projects (orange and green histograms). ***ALMRV = and DA47-I.9 = Comprehensive Survey for Marine Fisheries Resources in Vietnam Project. Source: FAO/GSO, ALMRV II, DA47-I.9.***

The SAUP reconstructed the FAO catch data and adjusted it for under-reporting and also included catches from foreign fleets in Vietnamese waters. Details of the reconstruction can be found in Teh et al. (2014). In the SAUP data set, the catch increased from 865,600 tonnes in 1971 to 3,715,000 tonnes in 2018 (Figure 3).

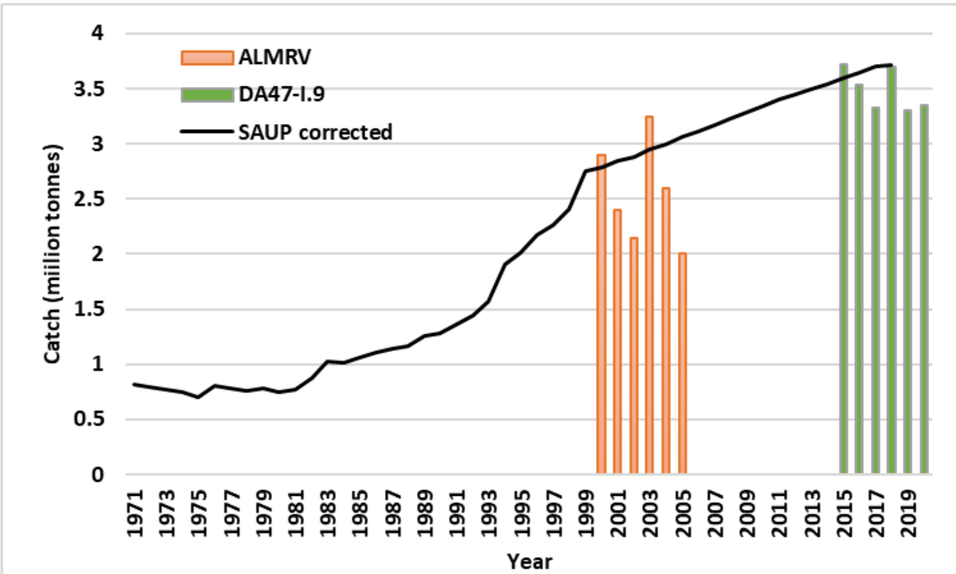


Figure 3. Total catch in Vietnamese marine waters 1971 – 2018 reported by the Sea Around US Project (SAUP) and estimated during the ALMRV and DA47-I.9 projects (orange and

green histograms). ***ALMRV = Assessment of Living marine Resources in Vietnam Project and DA47-I.9 = Comprehensive Survey for Marine Fisheries Resources in Vietnam Project.***

As can be seen in Figure 3, the SAUP data set is a better fit to the RIMF estimates. Note that the graph does not include catches by foreign vessels. When these are included, the catch in 2018 increased to 4,351,685 (a catch 0f 592,000 tonnes allocated to China).

According to the estimates made by the ALMRV and DA47-I.9 projects, the catch from trawls increased significantly in the decade from 2000-2005 to 2015-2020 (around 0.5 million to 1.8 million tonnes). Gill net and line catches declined while purse seine and other gears remained relatively stable (Figure 4).

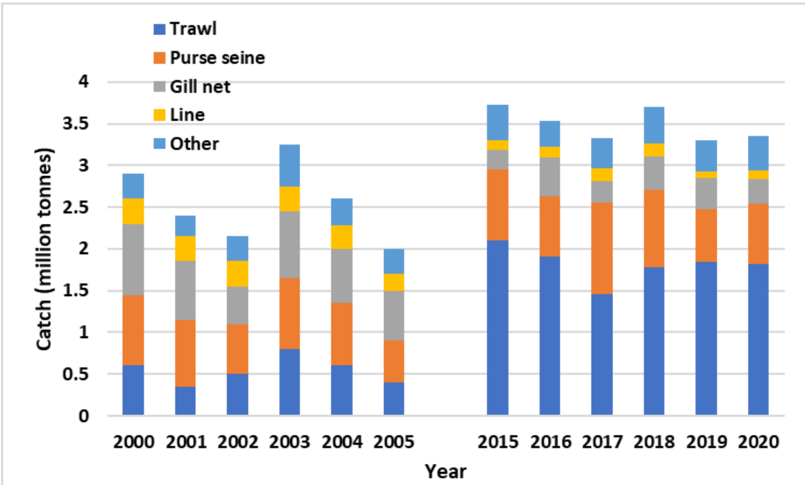


Figure 4. Catch by major fishing gears in Vietnamese marine waters 2000 – 2020 estimated during the ALMRV and DA47-I.9 projects. ***ALMRV = Assessment of Living Marine Resources in Vietnam Project and DA47-I.9 = Comprehensive Survey for Marine Fisheries Resources in Vietnam Project.***

3.2 Catch by fishing areas and provinces

The only publicly available catch data disaggregated to provinces is the GSO data set from 1995 – 2020. During this period, catches in the Southeast fishery were consistently 25% of the country total (Figure 5).

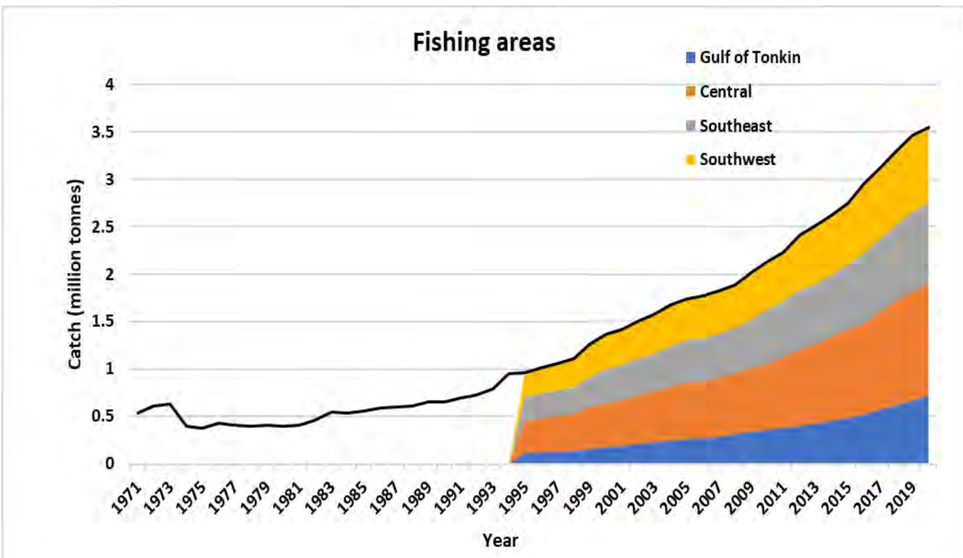


Figure 5. Catches in the four main fishing areas of Vietnam 1995-2020. ***Source GSO***

In the Southeast fishery area, catches from the Ba Ria – Vung Tau province were about 40% of the Southeast fishery area (about 10% of the Vietnam total) and ranged from 96,200 tonnes in 1995 to 350,000 tonnes in 2020 (Figure 6).

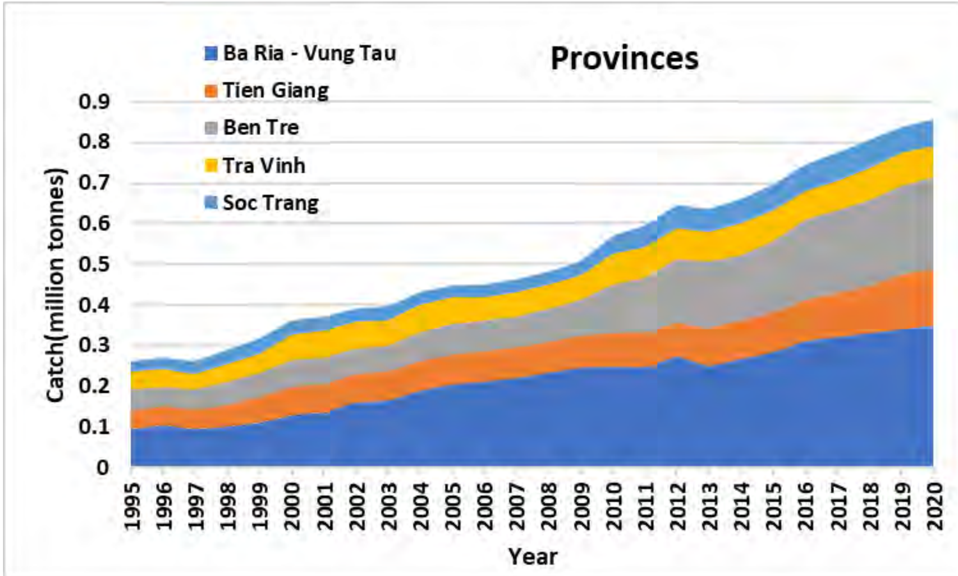


Figure 6. Catches in the five marine provinces of the Southeast fishery 1995-2020. ***Source GSO***

For later reference, Table 1 shows the average catches by decades for (i) total Vietnam, (ii) Southeast fishery and (iii) Ba Ria – Vung Tau province (possible ranges shown by the FAO/GSO, ALMRV/DA47-I.9 projects and SAUP estimations).

Table 1: Average catches by decade for (i) total Vietnam, (ii) Southeast fishery and (iii) Ba Ria – Vung Tau province (BRVT)

		1950s	1960s	1970s	1980s	1990s	2000s	2010s
Total	FAO/GSO	132,600	493,464	464,620	533,394	920,529	1,679,080	2,750,703
	SAUP	252,169	854,535	780,108	1,019,234	1,915,562	3,030,827	3,542,775
	ALMRV/ DA47-I.9						2,628,889	3,488,500
Southeast	Southeast GSO*	36,437	135,600	127,674	146,572	244,957	430,717	697,005
	Southeast SAUP**	69,347	234,997	214,530	280,289	526,779	833,477	974,263
BRVT	BRVT GSO*	15,912	59,216	55,754	64,007	106,518	234,828	323,992
	BRVT SAUP**	30,260	102,544	93,613	122,308	229,867	363,699	425,133

* Estimated by percentage 1950s- 1980s. ** Estimated by percentage 1950 - 2020

4. PAST ASSESSMENTS AND PREDICTIONS OF POTENTIAL CATCH

4.1 Fishery-dependent data

4.1.1 Early assessments – 1970s and 1980s

Fishery-dependent data

A number of early exploratory fishing ventures were carried out in Vietnamese waters in the 1970s and 1980s at the time industrial fishing was expanding rapidly across Southeast Asia. These include:

1. Indo-Pacific Fisheries Commission South Sea Fisheries Development and Coordinating Program (Aoyama 1973 and SCS 1978a)
2. Indonesian-German groundfish fisheries surveys (SCS 1978b)
3. Taiwan assessment on groundfish resources in the Sunda Shelf area of the South China Sea (Yeh et al. 1981)

Case 1: Table 2 presents a summary of some of the stock assessments on groundfish.

Table 2: Results of early stock assessments carried out in the 1970s. *Source: Yeh et al. 1981*

	Trawlable area	**Virgin biomass**	**MSY**		
Depth zone	Yeh et al. 1981	Yeh et al. 1981	Yeh et al. 1981	Aoyama 1973	SCS 1978
<50m	135,800	551,000	250,000	212,000	451,000
>50m	82,700	325,000	150,000		
Total	218,500	876,000	400,000		

MSY = Maximum sustainable yield

Yeh et al. 1981 estimates were based on surplus production modelling using the decline in catch per unit effort (CPUE) of Taiwanese pair trawlers from 1970 to 1977 for depths <50m and Gulland's formula (MSY = x M virgin biomass) for depths >50m where x is a proportionality constant and M is the instantaneous rate of mortality. The virgin biomass (abundance of fish before fishing began) summed over both depth zones was 876,000 tonnes and the potential maximum sustainable yield (MSY) was estimated as 400,000 tonnes. The MSY for waters less than 50m was 250,000 tonnes (Figure 7). Based on the maximum catch up until that time, Yeh et al. 1981 predicted that there was considerable room for further expansion, especially in the deeper water zones. Note: that the catch figures used by Yeh et al. were only about 50% of the total catch at that time and probably only referred to groundfish resources.

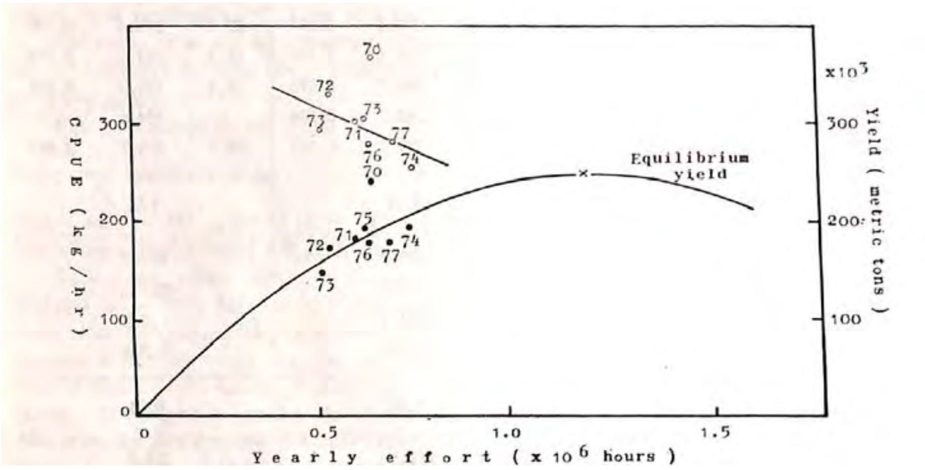


Figure 7: Plot of the mean annual CPUE and annual catch versus fishing effort and the estimated equilibrium yield curve for Vietnamese waters <50m. *Source Yeh et al. 1981.*

Comparable results were obtained by Aoyama (1973). SCS (1978 a and b) estimated a higher MSY based on more coastal resource surveys.

Case 2: Thuoc (1985) (cited in Thuoc and Son (1997)) provided estimates of the standing stock (current biomass) and potential yields for the four fishing areas in Vietnam that included pelagic fish (Table 3). The estimate of the standing stock and MSY for Southeast Vietnam at that time was 1,200,230 tonnes and 433, 156, respectively, which was 33% of all Vietnam waters. They concluded that the inshore and nearshore fish stocks are exploited at, or most likely well above, their potential sustainable yields. There is thus little or no scope for further expanding coastal fisheries.

Table 3: Current biomass (standing stock) and potential yield estimates in the 1980s.
Source: Thuoc (1985), cited by Thouc and Son (1997))

Fishing area	Fishery Group	Standing stock (tonnes)	Potential yield (tonnes)
Tonkin Gulf	Pelagic fish	390,000	156,000
	Demersal fish	504,839	166,596
Central	Pelagic fish	500,000	200,000
	Demersal fish	118,125	389,810
Southeast	Pelagic fish	524,000	210,000
	Demersal fish	676,230	223,156
Southwest	Pelagic fish	316,000	126,000
	Demersal fish	541,425	178,670
Total	Pelagic fish	1,730,000	692,000

	Demersal fish	1,840,619	607,404
Total	All fish	3,570,619	1,299,404

Uncertainty and assumptions in the early estimates

It is now well established that early estimates of the MSY underestimate the true MSY of a given fishery (e.g. Fulton et al. (2022). This is because (i) the estimate is an extrapolation of the early catch data and CPUE data– the MSY is usually not known until it is reached and the fishery has become overfished and (ii) the resources become much more productive as the slower growing/longer-lived predators (e.g. rays, sharks, snappers) are fished out resulting in increases in more productive species such as cuttlefish, squid and crabs (known as prey releases) (see Fulton et al. (2022) for an example in Thai waters of the Gulf of Thailand.)

It is also difficult to determine the area and resource types that are covered in these assessments. For example, Yeh et al. 1981 uses "Total yearly demersal catch data for 1970-1977" for the inshore area (<50m) and the actual trawl density for the offshore area (>50m). Thus, the biomass estimate and MSY refer only to demersal fish resources, whereas Thuoc (1985) includes pelagic resources, but it is not clear whether this includes shrimps and crabs.

4.1.2 Assessments during the 1990s

Case 1: Son and Thuoc (2003) summarized the results of stock assessments carried out in the 1990s. They concluded that the standing stock (biomass) was 3.4 – 3.5 million tonnes with a potential yield of 1.4 – 1.5 million tonnes (Table 4). This was similar to the earlier estimates of Thouc (1985), with an increase in the potential yield of 12%.

The total catch at this time was 1.7 – 3.0 million tonnes (extracted from Table 1), indicating that the catch was greater than the MSY at this time. However, the report focuses on the coastal area where it was concluded that coastal demersal resources in almost all areas are exploited at or above their sustainable levels. They recommended that the government therefore emphasizes that any further expansion of the marine capture fishery should be targeted at under-exploited resources and that the fishing pressure on coastal stocks should be reduced (e.g. by establishing alternative employment opportunities for fishers).

Table 4: Standing stock (current biomass) and potential yields in the 1990s. Source: *Son and Thuoc (2003)*

Fishing area	Area (km^2)	Fishery group	Standing stock (tonnes)	Potential yield (tonnes)
Tonkin Gulf	77,173	Small pelagics	390,000	156,000
		Demersal	115,972	61,465
		Shrimps and lobsters	1,390	696
Central	78,974	Small pelagics	500,000	200,000
		Demersal	112,070	59,397
		Shrimps and lobsters	22533.5	15,387

Southeast	222,258	Small pelagics	524,000	209,600
		Demersal	1,051,117	557,092
		Shrimps and lobsters	22,534	461,268
Southwest	49,048	Small pelagics	316,000	126,000
		Demersal	92,721	49,142
		Shrimps and lobsters	3249	1,614
Total		Small pelagics	2,040,000	814,100
		Demersal	1,371,881	727,097
		Shrimps and lobsters	49,706.00	478,964
Total	427,453	All fish	3,461,587	1,454,193

Uncertainty and assumptions in the 1990s estimates

The same issue in the estimation of the MSY detailed above also refers to these estimates – the estimates only refer to the ecosystem and species composition of the resources as they were at that time. The 1990s was a period of rapid growth in catch and fishing effort (see Figures 1 and 2 for catch trends), and changes in the composition of the resources, with more productive species becoming more abundant over time.

4.1.3 More recent assessments

All areas

Case 1: Nguyen et al. (2018) used catch and effort (total HP) data from 1976 to 2016 (sourced from MARD) to estimate the MSY, maximum economic yield (MEY) and the fishing effort at the MSY and MEY (FMSY and FMEY) using bio-economic modelling - an extension of the Schaefer surplus production model incorporating additional terms to account for the bycatch *(trash fish)* and habitat damage associated with fishing activities. The MSY for the whole of Vietnam marine waters using the standard model was 3.63 million tonnes and the MEY was 3.62 million tonnes (Table 5). This is considerably higher than the estimates in the 1970s and 1980s.

Table 5: Maximum sustainable yield (MSY), maximum economic yield (MEY) and fishing effort at MSY and MEY in 2016 *Source: Nguyen et al. (2018)*

	MSY (million tonnes)	Effort at MSY (million HP)	MEY (million tonnes)	Effort at MEY (million HP)
Standard	3.63	7.82	3.62	7.36
Ecosystem externalities	2.44	6.41	2.44	6.41

According to the reported effort data, the fishing effort needed to produce the MSY (7.82 million HP) was reached in 2012, and exceeded since that date (Figure 8). In 2016, the fishing effort was 1.5 times the effort needed to produce the MSY.

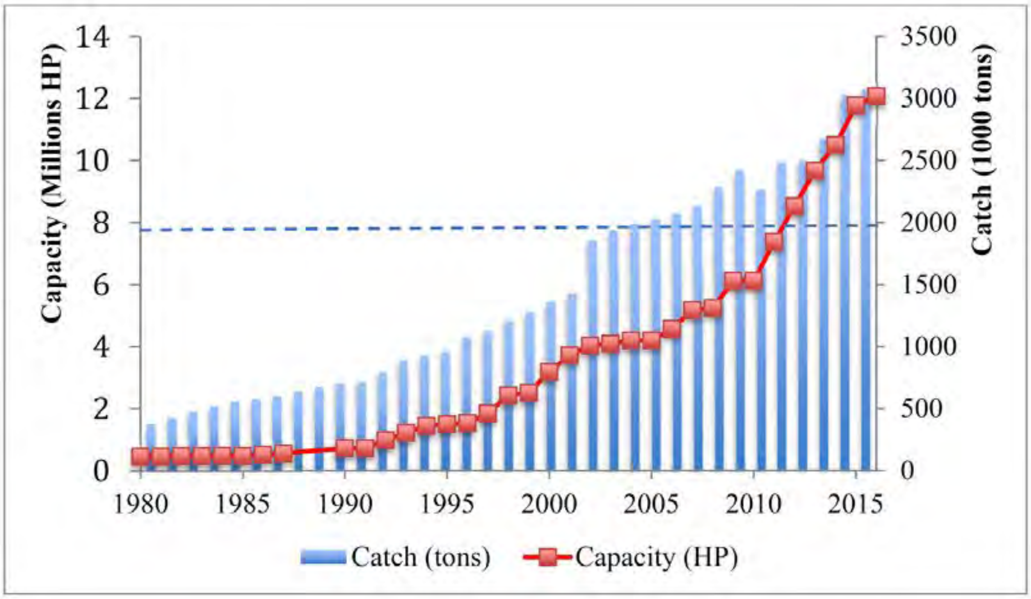


Figure 8: Trend in total catch and fishing effort (horse power (HP)) 1980-2016. The dotted line is the fishing effort at the maximum sustainable yield (FMSY) that was exceeded in 2012. ***Source: Nguyen et al. (2018)***

The fishing effort was also 1.6 times the effort needed to achieve the MEY and the current revenue is well below that at the MEY. The fishery is operating close to the open access point where the total costs equal the total revenue and there is no rent/profit (Figure 9).

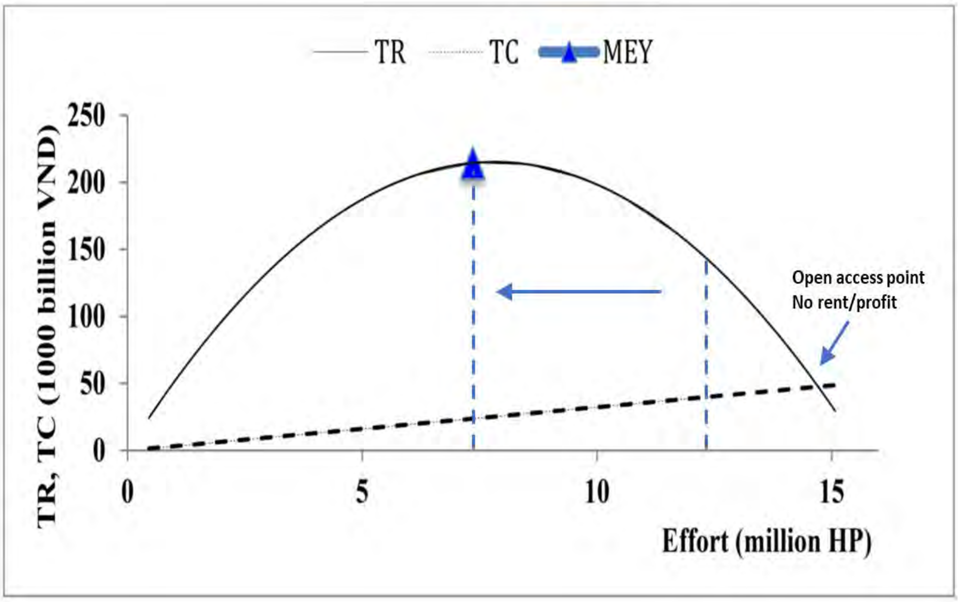


Figure 9: Total costs (TC) and total revenue (TR) in relation to fishing effort. ***Source: Nguyen et al. (2018)***

Nguyen et al. (2018) recommended that the effort needs to be reduced by about 35% and 39% to achieve the MSY and MEY, respectively. If externalities are considered, the situation is even worse.

Case 2: Vu et al. (2021) estimated MSY estimates for trawling in all four fishing areas in Vietnam based Fox surplus production models using data from 2014-2020 sourced from the DA47-I.9 project (Table 6). For trawling, Vu et al. (2021) provided the following results (Table 6)

Table 6: Potential yield (MSY) for trawling and fishing effort at the MSY (FMSY) for the four Vietnam fishing areas. ***Source: Vu et al. (2021)***

	Tonkin Gulf	**Central**	**Southeast**	**Southwest**	**Total**
MSY (thousand tonnes)	218	393	732	667	1,876
FMSY (thousand vessel days)	470	959	1,295	504	2,600
2019-2020 catch (thousand tonnes)	208	245	729	639	1,822
2019-2020 fishing effort (thousand vessel days)	489	599	1,335	875	3,299

The MSY for trawling across all fishing areas was estimated as 1.876 million tonnes at a fishing effort at MSY (FMSY) of 2.6 million vessel days. In the year 2019-2020 the fishing effort was estimated as 3,299 million vessel days, exceeding the FMSY by 26.9% (699 thousand vessel days). The total trawl catch in 2019-2020 was only 1,822 million tonnes, 54,000 tonnes lower than MSY. Thus, fishing effort has exceeded the FMSY and catches have been reduced to below the MSY because they have been overexploited.

In the Southeast area during the year 2019-2020, the fishing effort has surpassed the FMSY of 1.295 million vessel days and the catch is lower than MSY of 732 thousand tonnes, indicating that the fishing effort has exceeded the allowable threshold and catch cannot increase without a decrease in fishing effort.

Nguyen and Vu (2021) also estimated that the total biomass of the different fisheries resources form the ALMRV and DA47-I.9 projects (see Section 4.2.1 below).

Uncertainty and assumptions in the recent estimates

These more recent estimates are more appropriate for the current fishery that has been undergoing large changes in species composition as a result of heavy fishing over the past four decades. However, it still suffers from only having a small number of data points and the correct MSY is difficult to pinpoint. Figure 10 shows an example for the Southeast fishing area that shows how uncertain the model is based on limited data with little contrast.

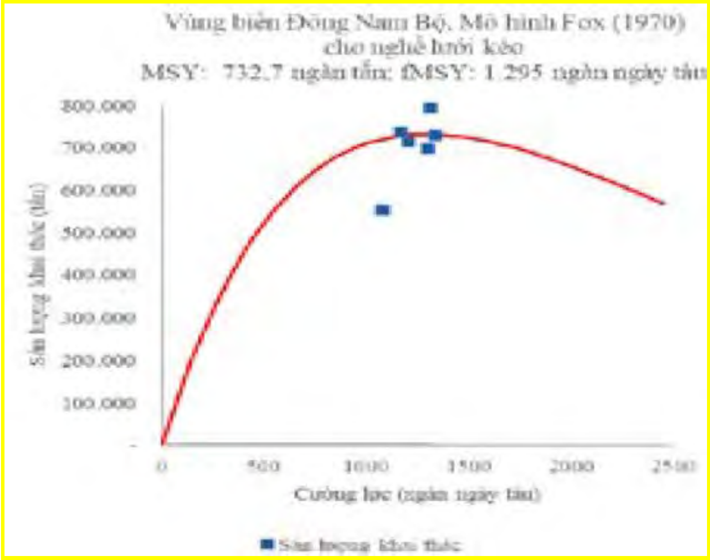


Figure 10: Fox surplus production model fit for the Southeast fishing area based on 2014-2020 data. ***Source: Vu et al. (2021)***

Southeast fishing area

Case 1: Bui (2014) assessed the status of the offshore fishery in an area an extended area of the Southeast and Southwest waters of Vietnam (offshore waters of provinces Quang Ngai to Kien Giang using a Schaefer surplus production model, based on GSO data from 2008 – 2012 (Table 7). The assessment was confined to vessels <50HP and covered five fishing gear types – trawl (single otter trawl, pair trawl, midwater otter trawl, pelagic pair trawl and otter twin trawl, (ii) gillnets (set gillnets, encircling gill nets, trammel nets and combine gillnets), (iii) Seines (surrounding nets, including purse seines), (iv) hook and line (hand lines, pole and lines, trolling lines, set longlines and longlines), (v) other. For all fishing gears, the MSY estimate was 1,146 tonnes. The sustainable number of fishing vessels in this offshore area was 14,915 vessels (5,010 trawlers). He concluded that the fishing intensity of trawlers had surpassed the FMSY by 56.3% (2,823 vessels) and recommended a reduction in the fishing intensity of trawlers in offshore waters. He suggested policies to support conversion of trawlers to other forms of fishing and/or support to transfer to other jobs.

Table 7: Potential yield (MSY) for trawling and fishing effort at the MSY (FMSY) for five fishing gears in offshore waters of the extended Southeast fishing area. ***Source: Bui (2014)***

	FMSY (vessels)	Number of vessels 2012	MSY (thousand tonnes)	Catch 2012 (thousand tonnes)
Trawl	5,010	7,833	762	549
Gillnet	2,469	2,053	129	76
Seine	2,998	1,505	137	165
Hook and line	1,934	1,284	26	25
Other	2,501	703	92	93
TOTAL	14,912	15,111	1,146	811

Case 2: Hung (2018) also carried assessments of the fishing effort and biomass of the trawl fishery in Southeast offshore waters, again using GSO data from 2008 - 2012. The provinces included Binh Thuan, Ba Ria-Vung Tau, Can Gio, Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau. This assessment used Kobe plots to examine changes in the biomass relative to the biomass at MSY (B/BMSY) and the fishing effort relative to the fishing effort at MSY (FMSY is plotted against the F/FMSY for the years 2008 – 2012). Hung (2018) concluded that for trawlers over 250 HP the fishery resources were both overfished (B/BMSY <1) and subject to overfishing (F/FMSY > 1) in all years of assessment. The trawlers in the 90 to 249 HP showed that before 2010, the stock biomass was overfished but not subject to overfishing, but after 2010, the stock was subjected to overfishing. For trawlers < 90 HP, fishing effort was still under the overfishing threshold, but the biomass was overfished.

Uncertainty and assumptions in the recent Southeast fishery assessments

As with other assessments based on the surplus production model, there is only a small number of data points (years) and little contrast among these (Figure 11). For example, in estimating the MSY for trawling (Bui, 2014), the fit to the data shows that the MSY had already been reached, but other interpretations are possible. The MSY for all fishing gears in this offshore area was double that estimated by Vu et al. (2021) for the combined inshore and offshore Southeast fishing area. However, because they both included different areas and size of vessels, comparisons are difficult.

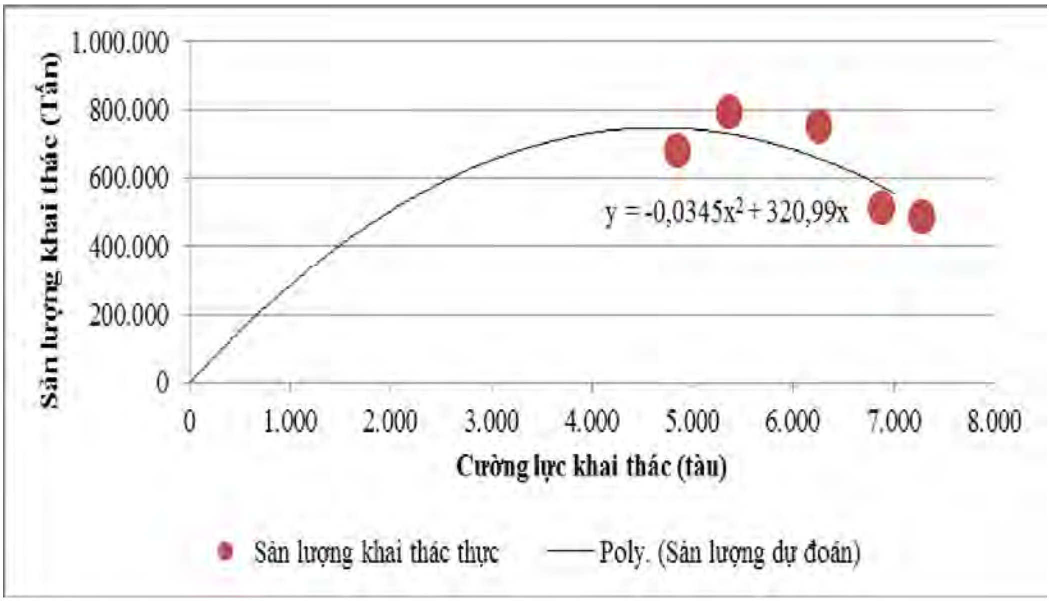


Figure 11: Schaefer surplus production model fitted to the trawl data 2008 – 2012 in offshore waters off the provinces of Quang Ngai to Kien Giang. ***Source Bui (2014)***

Similarly, the Kobe plots of Hung (2018) are based on only a small number of data points (Figure 12).

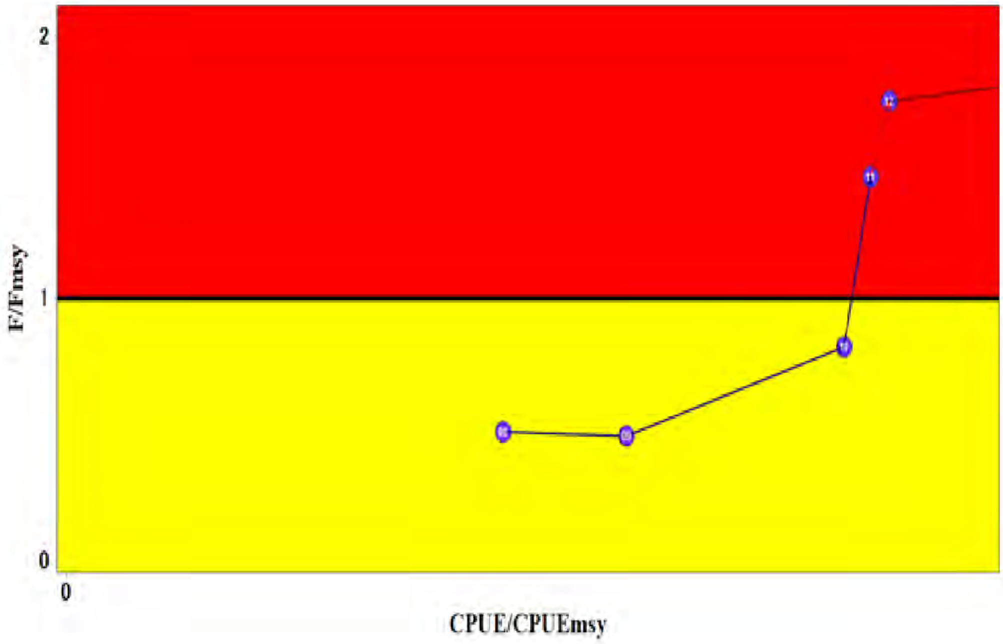


Figure 12: Kobe plot showing the fishing effort relative to the sustainable fishing effort (F/FMSY) against the biomass relative to the biomass at MSY (B/BMSY) for trawlers 250-249 HP, 2008 – 2012. Source: ***Hung (2018)***

The analysis of Bui (2014) also depended on standardizing the relative fishing effort of five very different fishing gear types, which requires data on relative fishing power of the gear type (formula of Robson (1966), presented in Sparre and Venema (1997)). This can introduce considerable uncertainty into the total MSY and FMSY estimates.

Ba Ria – Vung Tau province

Case 1: Nguyen et al. (2022) presented results for the MSY and the corresponding level of fishing effort (FMSY) in the coastal and inshore areas of Ba Ria _Vung Tau province, using a Schaefer surplus production model based on DA47-I9 project data from 2016 – 2019, the "Investigation and assessment of aquatic resources in coastal and inshore waters of BR - VT province" project data from 2020 to 2021 and the GSO statistical data on the number of vessels and annual catches (in the period 2016 - 2020) (Fisheries Sub-Department of BR-VT).

The sustainable number of total vessels was estimated as 2,765 vessels, which is close to the current number (Table 8). However, the number of trawlers and purse seiners far exceeded the sustainable numbers. As a result, the current catch of the trawlers and purse seiners is well below the potential yield that could be achieved if the fishing effort was reduced.

Table 8: Potential yield (MSY) for trawling and fishing effort at the MSY (FMSY) for four fishing gears in coastal and shore waters of the Southeast fishing area. ***Source: Nguyen et al. 2022***

	FMSY	Current vessel number (2020)	MSY (tonnes)	Current catch (2020) (tonnes)
Trawl	48	83	2,485	1,325
Gillnet	2,459	2,296	10,881	15,570

Traps and pots	249	243	531	747
Purse seines	9	17	7,934	6,207
Total	**2,765**	**2,639**	**21,831**	**23,849**
Total adjusted*		**2,902**		**37,513**

**Total adjusted to include vessels and catch not included in the analysis*

Uncertainty and assumptions in the recent Ba Ria – Vung Tau assessments

As with all other studies, the analysis of Nguyen et al. (2022) is only based on a small number of years, with little contrast (Figure 13). Also, standardization of these different fishing gear types using the formula of Robson (1966) as described by Sparre and Venena (1997) is a challenge.

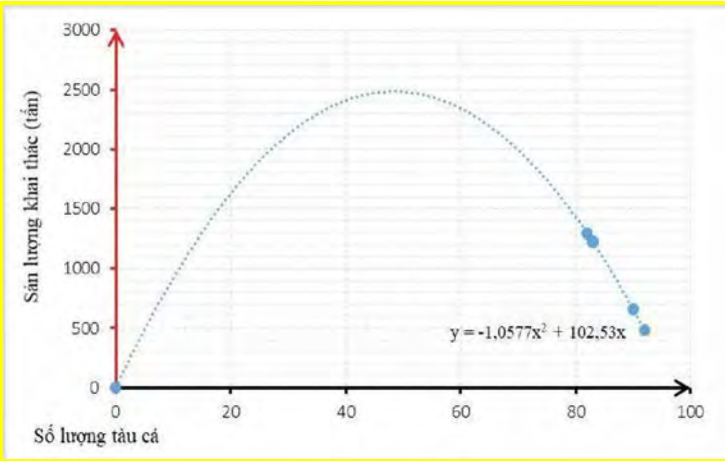


Figure 13: Schaefer surplus production model fitted to the trawl data 2016 - 2020 in coastal inshore waters off the Southeast fishing area. ***Source Nguyen et al. 2022***

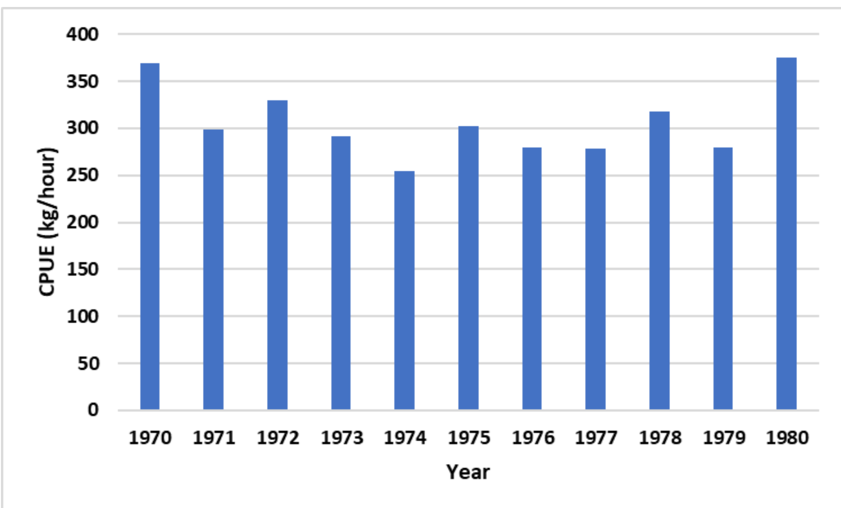
4.2 Fishery-independent data

4.2.1 Relative biomass estimates

There have been a number of fisheries research surveys carried out in Vietnam that provide valuable information on the status of fish stocks over time. These include:

Early fisheries resource surveys

Case 1: Taiwanese pair trawl. Yeh et al. (1981) analysed the trend in the CPUE of pair trawlers



(headrope of 100m and trawl speed of 3 knots) in Vietnam waters from 1970 -1980 (Figure 14). These CPUEs reflect the relative abundance fairly early in the development of the fishery and in the case of the offshore area, probably the virgin biomass.

Figure 14: Catch per unit effort of Taiwanese pair trawlers operating in Vietnamese waters 1970 – 1980. Source: Yeh et al. (1981)

Case 2: Trawl survey undertaken by the SEAFDEC vessel RV Changi using a trawl net with head rope length of 36 m. and cod-end mesh size of 56 mm towed at a speed of 2.5 to 4.5 knots (Senta et al. 1977). The vessel carried out 39 hauls in the southern part of Vietnam and recorded a CPUE of 74.2 kg/hour.

Case 3: Joint Viet Xo fishing surveys 1978-1988. The survey included 22 different vessels covering 31 trips and 4,412 stations (1,312 deepwater) in the waters of Vietnam. No details are available about the vessels. The survey results ranged from 90 – 490 kg/hour across the years 1978 to 1988 (Nguyen 2009) (Figure 15).

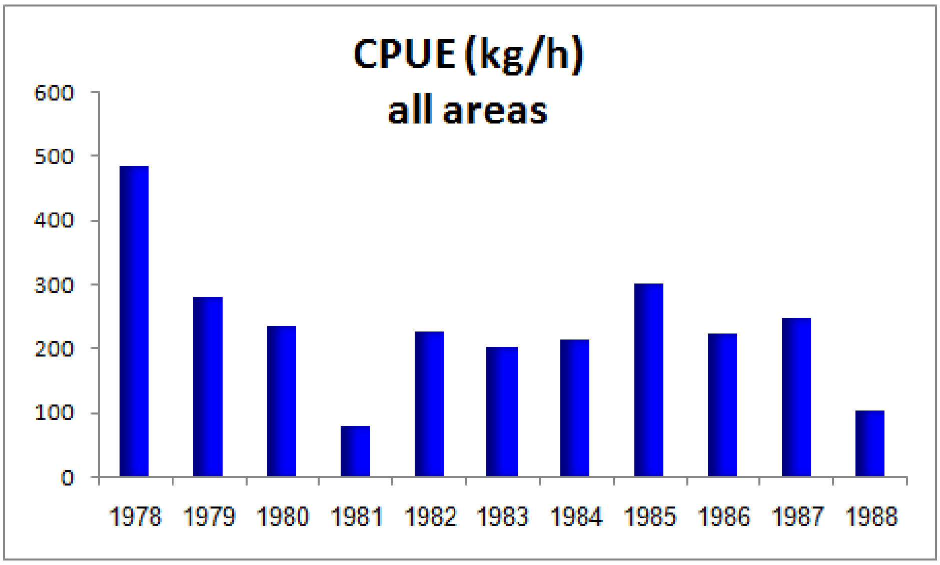


Figure 15: Catch per unit effort of the joint Viet-Xo surveys operating in Vietnamese waters 1978 – 1988. ***Source: Nguyen (2009)***

More recent resource surveys

Case 1: Assessment of Living Marine Resources in Vietnam project (ALMRV) Phase 1 1996-1997. Two surveys were conducted in the Southeast area during phase 1, covering 292 stations (63 in the deep-sea area).

The results of these surveys were included in the coalition by Nguyen and Vu (2021) and are included in Table 9 below.

Case 2**:** Assessment of Living Marine Resources in Vietnam project (ALMRV) Phase 2 2000-2005: The survey programme was initiated in 2000 and was composed of a bottom trawl survey and a gill-net survey. Two areas were covered by the surveys: (1) the Gulf of Tonkin and (2) the southern waters of the Southeast fishery (including fishing grounds of BRVT) and Southwest fishery areas.

Data for 2000 – 2003 were reported by Son and Thuoc (2003) for the Gulf of Tonkin, Southeast and Southwest fishing areas. The time series is too short for an analysis of trends over time, but it does give some information on depth distribution of fish in the surveys (e.g.

for the Southeast area (Figure 16) that demonstrated the depleted nature of the coastal and inshore regions.

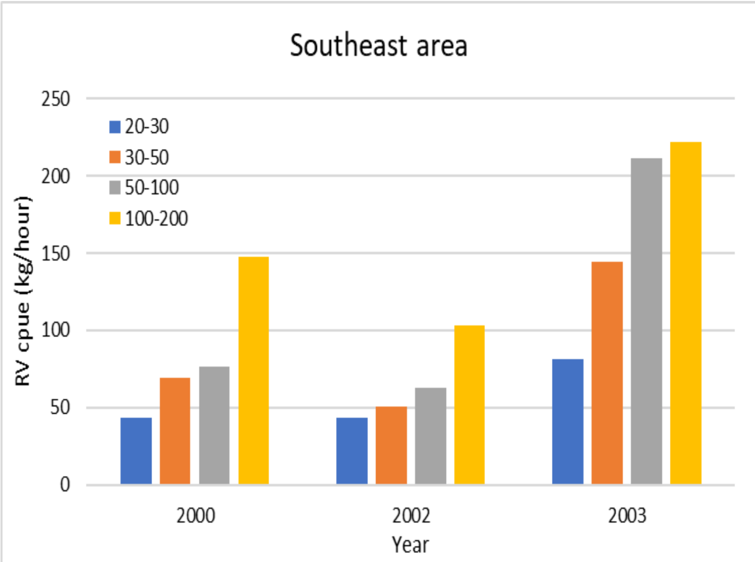


Figure 16: Catch per unit effort by depth of surveys conducted 2000-2003. ***Source :Son et al. (2013)***

The results of all surveys were collated by Nguyen and Vu (2021) and are included in Table 9 below.

Case 3: The Comprehensive Survey for Marine Fisheries Resources in Vietnam – DA47-I.9 project 2012-2020: During the period 2012-2020, the fisheries resources surveys were continued following the design of the ALMRV-phase 2 project. Bottom trawl survey targets demersal fish and shellfish communities; pelagic gillnet survey targets tunas and other large pelagic species and acoustic survey has been used to investigate small pelagic fish resources.

Snap shots of these surveys were used in various reports. For example, Nguyen (2013) used the results of the surveys in 2012-2013 to demonstrate the relative abundances of different ecological groups, different monsoon seasons and water depth as a basis for developing marine protected areas in Vietnam. The effect of seasonal monsoons in the four fishing areas are shown in Figure 17.

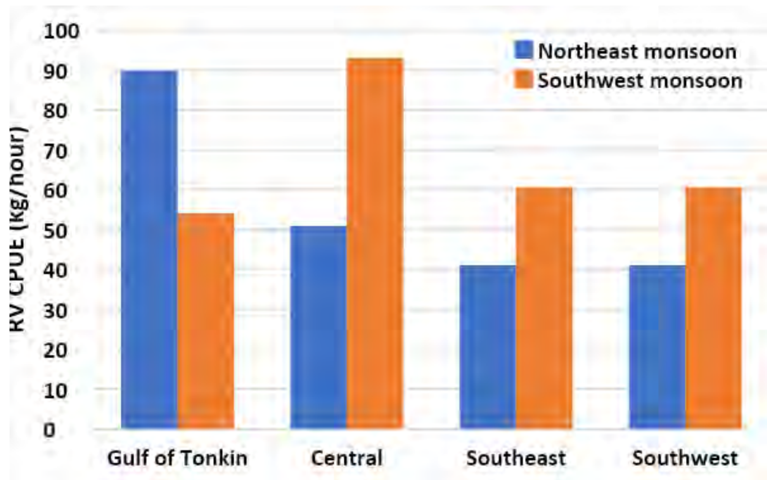


Figure 17: Relative abundance (kg/hour) during the two seasonal monsoons in 2012-2013. ***Source Nguyen (2013)***

Nguyen and Vu (2021) provided a comprehensive summary of all surveys from 1996 – 2018. They concluded that the trawl and drift gillnet surveys showed a depletion in both the demersal and large pelagic resources. The latest trawl CPUE values in the Gulf of Tonkin, Southeast and Southwest fishing areas was relatively low in comparison with the 1996-2000 surveys (Table 9).

They also concluded that the quality of the resources was also declining with economically important species being replaced by low-value species. They noted that some of the high trophic level species were heavily exploited and that the proportion of trash fish was increasing in trawl catches. There was also an increase in the ratio of pelagic fish to demersal fish in the trawl survey data.

Table 9: Overall results of the trawl surveys carried out under the Assessment of Living Marine Resources in Vietnam project (ALMRV) Phase 1 and 2 and the Comprehensive Survey for Marine Fisheries Resources in Vietnam DA47-I.9 ***Source: Nguyen and Vu (2021)***)

		Jun-96	**Dec-96**	**Dec-97**							
AMLRV Phase 1	**Gulf of Tonkin**	150.2	141.1								
	Central	90.0	59.3								
	South-east	202.1	192.0	193.4							
	South-west										
	Average	**147.4**	**130.8**	**193.4**							
		Jun-00	**Nov-00**	**May-01**	**Nov-01**	**May-02**	**Nov-02**	**Jun-03**	**Nov-03**	**Jun-04**	**Jun-05**
AMLRV Phase 2	**Gulf of Tonkin**			93.8	89.7			78.4		167.2	69.7
	Central									82.6	123.3
	South-east	81.9	97.4			81.1	55.0		90.5	71.8	57.0
	South-west	78.6	63.2			83.4	60.0		63.8	58.2	36.9
	Average	**80.3**	**80.3**	**93.8**	**89.7**	**82.3**	**57.5**	**78.4**	**77.2**	**95.0**	**71.7**
DA47-I.9	**Gulf of Tonkin**	**Dec-12**	**Jun-13**	**Sep-16**	**Aug-18**						
	Central	100.5	61.5	49.9	52.0						
	South-east	64.6	80.1	46.2	52.7						

South-west	37.2	47.8	39.1	35.6
Average	50.1	42.9	59.4	35.0
	63.1	**58.1**	**48.7**	**43.8**

Based on (i) trawl surveys, (ii) acoustic surveys and (iii) biomass estimates of skipjack and yellowfin tuna, Nguyen and Vu (2021) estimated that the total biomass of Vietnam's fisheries resources in 2016-2020 as 3.95 million tonnes, comprising of 62.1% small pelagic fishes (2,45 million tons), 23.8% large pelagic fishes (940 thousand tons), 10.3% demersal fishes (408 thousand tons), 2.2% cephalopods (88 thousand tons), 1.5% crustacean (58 thousand tons) and 0.1% of other species (about 2.7 thousand tons). In comparison to the previous biomass estimate in 2011-2015 using the same methods and surveyed area, total biomass had declined about 9.4%, of which the demersal resources decreased 18.4%, small and large pelagic resources were reduced by about 7.3% and 8.8%, respectively.

These relative biomass estimates are analysed further in Annex 1, which compares these with neighbouring country's survey results.

4.2.2 Length-based stock assessments

Case 1: According to Nguyen (2016), out of 29 species (39 analyses) analysed from their length frequency distributions in 2014-2015 using the ELEFAN package of FISAT II, 63% of the of the species were subject to overfishing ($E = F/Z > 0.55$) (Table 10). In the Southeast fishing area, 5 out of the eight species analysed were subjected to overfishing. In all areas, there were very few species still subjected to low fishing intensity.

Table 10: Estimates of the exploitation rate of 29 species of economically important fish taken from the four main fishing areas. Note that an exploitation rate >0.55 is categorized as being unsustainably high. *Source: Nguyen (2016)*

Group	Common name	Scientific name	Gulf of Tonkin	Central	South east	South west	Offshore
Pelagic	Japanese scad	*Decapturus maruadsi*	0.55	0.56	0.57		
	Shorthead anchovy	*Encrassicholina heteroloba*	0.51			0.46	
	Buccaneer anchovy	*Encrassicholina punctifer*		0.56			
	Indian mackerel	*Rastrelliger kanagurta*	0.67	0.55	0.67	0.51	
	Short mackerel	*Rastrelliger brachystoma*				0.63	
	Bullet tuna	*Auxis rochei*		0.57	0.78		
	Frigate tuna	*Auxis thazard*		0.45	0.50		
	Yellowtail scad	*Atule mate*				0.50	
	Yellowstripe scad	*Selaroides leptolepis*				0.44	
	Threadfin porgy	*Evynnis cardinalis*	0.64				
Demersal	Japanese threadfin bream	*Nemipterus japonicus*					
	Threadfin bream	*Nemipterus mesoprion*	0.50				
	Forktail threadin bream	*Nemipterus fucosus*			0.50		
	Red bigeye	*Priacanthus macracanthus*		0.62	0.56		
	Greater lizardfish	*Saurida tumbil*	0.57	0.41	0.66		
	Brushtooth lizardfish	*Saurida undosqamis*	0.60				
	Slender lizardfish	*Saurida elongata*				0.60	
	Snakefish	*Trachinocephalus myops*		0.55			
	Japanese goatfish	*Upeneus japonicus*		0.59	0.38		
	Yellowfin goatfish	*Mulloidicthys vanicolensis*				0.48	
	Lattice monocle bream	*Solopsis taeniopterus*				0.40	
Crustacea	Whiskered velvet shrimp	*Metapenaeopsis barbata*	0.46				
	Junga shrimp	*Metpenaeus affinis*	0.45				
	Green tiger shrimp	*Penaeus semisulcatus*				0.57	
Cephalopod	Mitre squid	*Loligo chinensis*		0.71			
	Indian squid	*Loligo dauvacelli*		0.65		0.56	
Large pelagic	Yellowfin tuna	*Thunnus albacores*					0.73
	Bigeye tuna	*Thunnus obesus*					0.68
		Percent overfishing	**44%**	**82%**	**63%**	**44%**	**100%**

High > 0.55
Moderate 0.45-0.55
Low < 0.45

Ba Ria – Vung Tau province

Case 1: Huy (2022) analysed the length-frequency data collected for 13 economically important species from the coastal and inshore areas of Ba Ria - Vung Tau province in 2019 – 2021 using the ELEFAN package of FISAT II. The analysis showed that Indian mackerel and Japanese goatfish were subjected to severe overfishing and Japanese scad, threadfin bream, red bigeye and Indian squid were subjected to overfishing (exploitation rate < 0.6) (Table 11). The remainder had sustainable fishing pressure.

Table 11: Estimates of the exploitation rate and fishing pressure for 13 economically important species in Ba Ria – Vung tau province. Note that an exploitation rate >0.6 is categorized as being unsustainably high. ***Source: Huy (2022)***

Group	Common name	Scientific name	Total mortality (Z)	Natural mortlity (M)	Fishing mortality (F)	Explotation rate (E = F/Z)	Fishing pressure
Pelagic fish	Japanese scad	*Decapturus maruadsi*	1.38	0.53	0.85	0.62	High
	Indian mackerel	*Rastrelliger kanagurta*	4.26	0.95	3.31	0.78	Very high
	Thai anchovy	*Stolephorus dubiosus*	1.86	1.03	0.83	0.45	Moderate
Demersal fish	Greater lizardfish	*Saurida tumbil*	2.83	0.7	2.13	0.75	Very high
	Threadfin bream	*Nemipterus furcosus*	1.84	0.63	1.21	0.66	High
	Japanese goatfish	*Upeneus japanicus*	3.40	0.84	2.56	0.75	Very high
	Silver whiting	*Sillago shihama*	1.92	1.21	0.71	0.37	Low
	Red bigeye	*Priacanthus macracanthus*	1.10	0.4	0.7	0.64	High
	Razorfish	*Xyrichtis triviatus*	2.90	1.84	1.06	0.37	Low
Squid	Snakefish	*Trachinocephalus myops*	1.08	0.77	0.31	0.29	Low
Shrimp	Indian squid	*Loligo duvauceli*	1.33	0.53	0.8	0.60	High
Crab	Rainbow shrimp	*Parapenaeopsis sculptilis*	1.70	0.77	0.93	0.55	Moderate
	Red swimming crab	*Portunus hannii*	5.29	3.24	2.05	0.39	Low

Huy (2022) also estimated the size at maturity (Lm50) for the following species (Table 11).

Table 12: Species used to estimate the proportion of juvenile fish in different fishing gear (see Table 13) in Ba Ria – Vung Tau province. ***Source: Huy (2022)***

Rastrelliger brachysoma	Short mackerel	*Decapterus maruadsi*	Japanese scad
Terapon theraps	Largescaled terapon	*Megalaspis cordyla*	Torpedo scad
Selaroides leptolepis	Yellowstripe scad	*Atule mate*	Yellowtail scad
Stolephorus indicus	Indian anchovy	*Sardinella aurita*	Round sardinella
Stolephorus dubiosus	Thai anchovy	*Sardinella gibbosa*	Goldstrip sardinella
Moolgarda perusii	Longfinned mullet	*Portunus sanguinolentus*	Threespot swimming crab
Pennahia anea	Donkey croaker	*Portunus pelagicus*	Blue swimming crab
Dendrophysa russelii	Goatee croaker	*Sepiella inermis*	Spineless cuttlefish
Johnius belangerii	Belanger's croaker	*Loligo duvauceli*	Indian squid
Sillago shihama	Silver sillago	*Metapenaeus affinis*	Jinga shrimp
Harpadon nehereus	Bombay duck	*Metapenaeopsis barbata*	Whiskered velvet shrimp
Alepes kleinii	Razorbelly scad	*Penaeus merguiensis*	Banana prawn
Anodontostoma	Chacunda gizzard shad	*Parapenaeopsis hardwicki*	Spear shrimp
Saurida tumbil	Greater lizardfish	*Squilla nepa*	Smalleye mantis shrimp

Huy (2022) then used these data to estimate the proportion of juvenile fish in different fishing gears (Table 13) based on the species composition in each gear. The highest proportion of juveniles was in powered push nets (100%), followed by stick held dip nets (74%). Bottom trawl, surface gill net, pair trawls, folding traps, anchovy purse seines, single trawl and falling nets all had high percent juveniles (49% - 67%). The lowest was hook and line with 27%.

Table 13: Percentage juveniles taken in fishing gears in Ba ria – Vung Tau coastal and inshore waters. ***Source Huy (2022)***

Fishing gear	% juveniles
Powered push net	100%
Stick held dip net	74%
Folding crab trap??	67%
Stick falling net	63%
Stake set net/stow net	62%
Single trawl	61%

Anchovy purse seine	60%
Folding net	59%
Pair trawls	54%
Surface gill net	53%
Bottom trawl	49%
Hook and lines	27%

Uncertainty and assumptions of length-based estimates

The length-based analyses of Nguyen (2016) and Huy (2022) used older equilibrium models that may be erroneous. These types of models were originally developed to estimate growth and often do not give a very accurate estimation of fishing morality (F) or natural mortality (*M)* (e.g. M estimated by Pauly's temperature equation). Another important assumption is that the length frequency data is representative of the total population. Samples taken from commercial gear are often biased because of selectivity of the gear, a problem more acute in pelagic fish where the sample is taken from surrounding gear that targets a particular size range of fish.

5. CONCLUSIONS AND DISCUSSION

5.1 Gaps in past assessments

<u>Multi-species assessment models</u>

Production models are based on outdated equilibrium models*:* All of the production models available for this review used such equilibrium-based surplus production models. Many texts and reports have warned against using equilibrium models (e.g. Hilborn and Walters, 1992) as the data do not meet the equilibrium assumption of the model i.e. it assumes that each year's catch and effort data represent an equilibrium situation (i.e. the catch was the surplus production for that level of effort). However, this assumption means that if the effort level changes then biomass instantaneously jumps to its new stable equilibrium point with a new associated surplus production (catch). This is impossible and this fundamental weakness destroys the validity of the model.

The other concern is that equilibrium models provide only a single point estimate of parameters such as the MSY, which ignores the uncertainty in the estimation resulting from uncertainty in the catch data and estimates of CPUE. More recently, biomass dynamic/model are being used (e.g. JABBA (Winker et al. 2018) and SRAPLUS (Ovando et. al. 2021)). These packages use time series fitting, which is now considered the best available method for fitting a production model. This approach allows for estimation of the parameter values that provide the best fit to the model given the time series of data available; it provides estimated values for the model parameters, associated error and the level of correlation between the different parameters.

An example using JABBA for Southeast Vietnam is at Annex 2.

Estimates based on only a small number of years*:* All the stock assessments in this review tend to be based on the results of short projects (e.g. ALMRV and DA47-I.9) or short time series of commercial data (e.g. Figures 7 and 10). This results in a lack of contrast between the different data points, making estimates MSY, BMSY and FMSY unreliable. Ideally, a surplus production model requires both increases and decreases in the abundance of fish (e.g. CPUE). With just a decrease in CPUE over a few years, the analysis is what is known as a "one-way-street". As Hilborn and Walters noted in their classic text book - you don't know if you have reached the MSY until after you have passed it.

Separate estimates for different groups/gears, areas/zones*:* Each author(s) tended to provide assessments for only a selected fishing group (e.g. groundfish), fishing gear (e.g. trawl), and selected fishing area and/or zone (e.g. coastal and inshore zone of Ba Ria – Vung Tau province). These separate models tend to ignore any technical interaction between the fleets and the areas and multiple parameter estimates are developed for the same species/species groups. For example, different MSY values are generated for the same fish groups. It is difficult to determine how these different estimates should be handled. Should they be dealt with independently or combined?

Disaggregating the assessments can also mean that one of the basic assumptions of these types of models – viz: the fish stock is a unit stock with no net immigration or emigration. For example, if fish migrate out of the coastal area as they grow, then the catch does not reflect the total loss to the fishery and the catch per unit area will not reflect the relative abundance of fish over time. Care is needed to define practical metiers that do not break the assumptions of the model.

Very few overall summaries of all the different smaller assessments exist. The more comprehensive summaries are from donor-supported projects (e.g. Proceeding of the Technical Seminar on South China Sea Fisheries Resources, funded by the Japan International Cooperation Agency, "Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand" funded by the Global Environment Facility (GEF) and the "Sustainable Management of Coastal Fish Stocks in Asia" funded by the Asian Development Bank proved to be the most informative for this review. However, the most recent review paper was published in 2003, now 20 years ago.

Research vessel results not fully analysed to provide assessments on the status of stocks: Despite the fact that there has been a fairly comprehensive coverage of fishery surveys, including early surveys and then more standardized surveys from 1996 to 2018 have not been used systematically for stock assessments. Some results of current biomass have been published, but again, no comprehensive summary of trends has been conducted.

An example based on research survey data from 1996-2018 using JABBA for Southeast Vietnam is at Annex 2.

<u>Single-species length-based assessments</u>

Production models used are outdated equilibrium models: As pointed out in the sections on uncertainties and assumptions, length-based analyses carried out in Vietnam used older equilibrium models, which may be erroneous. FISAT II, for example, was developed to produce estimates of fish growth in the absence of age data and these types of models often do not give a very accurate at estimating fishing morality (F), or natural mortality (*M)* (e.g. M estimated by Pauly's temperature equation). Samples taken from commercial gear are often biased because of selectivity of the gear, a problem more acute in pelagic fish where the sample is taken from surrounding gear that targets a particular size range of fish.

The other concern is that the model provides a single point estimate of parameters such as the E = F/Z, which ignores the uncertainty in the estimation resulting from uncertainty in the length data and input parameters, such as M. More recently, the length-based spawning potential ratio (LBSPR) (Hordyk et al., 2015) is being used. This also allows the stochastic SPR estimation using the bootstrap method.

An example using LBSPR for Sri Lanka and Indonesia is at Annex 2.

Single-species length-based modelling is restricted to common economic species: Staples et al. (in press) have recently summarized why restricting the analyses to common economic species can give very misleading and erroneous conclusions on the status of the overall fishery. These include:

1. The sum of the individual stocks maximum sustainable yield (MSYs) is greater than the aggregate multi-species MSY (MMSY) (see Fulton, this report).
2. In a multi-species fishery fished at MMSY, some stocks will be below their MSY, some at or around MSY and some above MSY.
3. Just considering the status of a small number of common species results in a biased view of the status of a multi-species fishery.

Staples et al. (in press) and others (e.g. Leadbitter et al. 2023) advocate the selection of a set of indicator species, which is a way to choose what is monitored and analysed to help focus on the linkage between fishery status and management response. The first step is to select indicator species based on PSA/vulnerability scores and importance for management (management determining species). It is important that the selected indicator species have ongoing assessments and there is a need to identify the ongoing assessment methods and ensure adequate monitoring. It is useful to select three groups of species based their single-species MSY (Newman *et al.* 2018):

- Likely 'overfished' high-risk/vulnerability species
- Likely 'sustainably fished' medium-risk/vulnerability species
- Likely 'underfished' low-risk/vulnerability species (high resilience)

Table 14 shows an example of selecting indicator species based on the criteria of (i) inherent vulnerability, (ii) current risk, (iii) management importance.

Table 14: An example of selecting indicator species based on the criteria of (i) Inherent vulnerability, (ii) current risk, and (iii) management importance.

Species chosen for assessment by population model	Species	Inherent vulnerability	Current risk	Management importance	Combined
***	Species 1	4	4	**5**	**80**
***	Species 2	4	3	**5**	**60**
***	Species 3	3	2	**3**	**18**
***	Species 4	3	2	2	12
***	Species 5	3	3	**4**	**36**
	Species 6	2	2	2	8

Source: Modified from Newman et al. (2018)

5.2 Overall conclusions based on the assessments

Surplus production models

Even with the gaps and uncertainties identified in the section above, the overwhelming evidence is that the fishery resources in waters of Vietnam are both overfished and still subjected to overfishing (Table 15). Warnings of overfishing in the coastal waters started in the 1980s. By the 200s, it appears that all stocks assessed were overfished.

Table 15: Summary of past surplus production modelling.

Period	Area	Zone	Fishery group/gear	Biomass status	Fishing effort status	Reference
1970s	All Vietnam	Offshore	Groundfish	Underfished	Underfished	Yeh et al. (1981)
1980s	All Vietnam	Coastal and inshore	Demersal and pelagic	Overfished		Thuoc and Son (1997)
1990s	All Vietnam	Coastal and inshore	All fish	Overfished		Son and Thuoc (2003)
2000s	All Vietnam	All waters	All fish	Overfished	Overfishing	Ngyuyen et al. (2018)
2000s	Southeast	Offshore	Trawl	Overfished	Overfishing	Bui (2014)
2010s	All Vietnam	All waters	Trawl	Overfished	Overfishing	Vu et al. (2021)
2010s	Southeast	Offshore	Trawl>90Hp	Overfished	Overfishing	Hung (2018)
2010s	Southeast	Offshore	Trawl<90HP	Overfished	Underfishing	Hung (2018)
2010s	BR - VT	Coastal and inshore	Trawl	Overfished	Overfishing	Nguyen et al. (2022)
2010s	BR - VT	Coastal and inshore	Purse seine	Overfished	Overfishing	Nguyen et al. (2022)

A summary of the biomass and MSY estimates from surplus production models is at Appendix 1. This shows:

a. For both all Vietnam waters and for the Southeast fishery, the catch exceeded the MSY in the 1980 - 1990s and was then consistently lower in the subsequent decades. This indicates that the fisheries reached their MSYs in the 1980 – 1990s and have been overfished ever since.

b. The biomass has been reduced to a level below the MSY for many species groups/gears and areas. Either the catch or the fishing effort needs to be controlled to bring the fisheries back to a sustainable level.

c. In the one example where the current biomass was compared directly with the biomass at the MSY (BMSY), it was shown that for trawlers of all sizes, the biomass had been reduced below the BMSY (Bui, 2018). On average, the biomass was approximately 30% - 70% too low to be able to produce the MSY.

d. Because the MSY was estimated for different groups of fish (e.g. demersal/pelagic), different gears (e.g. trawls/gillnets) and different time periods, it is difficult to provide a reliable estimate of the MSY for either all waters of Vietnam or the Southeast fishery (a rough estimate of the MSY for Vietnam wasters is ~ 2.5 – 3.5 million tonnes). For trawl fisheries in the Southeast area, the MSY is around 750,000 tonnes.

However, management should be based on the estimates of biomass in relation to the biomass at MSY (BMSY) and the fishing effort relative to MSY (FMSY), not the actual MSY that is dome-shaped curve relative to fishing effort and changes as the species composition of the fishery changes over time.

It also appears that the estimates of biomass based on survey data tended to underestimate the actual biomass. For example, the biomass for the Southeast fishing area was estimated as 1.6 million tonnes, which is only about 3x the current catch. For all of Vietnamese waters the biomass was estimated to be 3-4 million tonnes, which is approximately equal to the current catch (it's very unlikely that the catch = the biomass). The JABBA assessment presented in Annex 2 indicated that the current biomass was closer to 2.2 million tonnes in the Southeast and 9 million tonnes in all waters.

In terms of the fishing effort, only a small proportion of the stock assessments provided information on the sustainable fishing effort (e.g. the sustainable number of fishing vessels or HP). Results are mainly for more recent assessments (2010s), as summarized in Appendix 2.

The following conclusions can be made:

1. In nearly all examples, the fishing effort is greater than the fishing effort at the MSY (FMSY).
2. One estimate made in 2018, recommended that the fishing effort needed to be reduced by 35% - 39% of the level in 2016.
3. In most examples, it was the trawlers that were in excess of their FMSY.
4. There are insufficient assessments carried out to provide a reliable estimate of the optimum vessel number for any fishery, but trawler numbers were about 50%-70% too high.
5. The main conclusion is that fishing effort needs to be reduced to a sustainable level.

<u>Length-based models</u>

The results of length-based models based on selected species is consistent with a fishery resource that is being subjected to overfishing (Table 16).

1. In both the offshore assessment and the coastal and inshore assessment, a high percentage of the selected species (62.5% and 53.9%, respectively) were subjected to overfishing.
2. Only a small number of stocks were being subjected to underfishing.
3. The selected species were all relatively resilient species and there is no data on the status of more vulnerable species such as rays and sharks.

Table 16: Status of selected species in (i) offshore area and (ii) coastal and inshore area of Ba Ria – Vung tau. ***Source: Nguyen (2016) and Huy (2022).***

Offshore							
	Gulf of Tonkin	Central	South east	South west	Offshore	Total	
Overfishing	5	9	5	4	2	25	**62.5%**
Moderate fishing	4	1	2	3	0	10	**25.0%**
Underfishing	0	1	1	3	0	5	**12.5%**
Coastal Ba Ria - Vung tau							
Overfishing			7				**53.9%**
Moderate fishing			2				**15.4%**
Underfishing			4				**30.8%**

Appendix 1: Summary of the estimates of biomass and MSY

Demersal/trawl group = light red; all marine fish = light blue

<u>All Vietnam</u>

Year	Zone	Group/gear	Biomass	B/BMSY	MSY	Source
1970s		Demersal	876,000		400,000	Yeh et al. (1981)
1980s	Inshore and offshore	Demersal	1,840,619		607,404	Thuoc (1985) cited by Thuoc and Son (1997)
		Pelagic	1,730,000		692,000	
		All marine fish	1,840,619		607,404	
1990s	Inshore and offshore	Demersal	1,371,881		727,097	Son and Thuoc (2003)
		Small pelagics	2,040,000		814,100	
		Shrimps and lobsters	49,706		478,964	
		All marine fish	3,461,587		2,020,161	
2010s	Inshore and offshore	All marine fish			3,630,000	Nguyen et al. (2018)
	Inshore and offshore	Trawl			1,876,000	Vu et al. (2021)
	All zones	All marine fish	3,950,000			Nguyen and Vu (2021)

Southeast Fishery

Year	Zone	Group/gear	Biomass		MSY	Source
1980s	Inshore and offshore	Demersal	676,230		223,156	Thuoc (1985) cited by Thuoc and Son (1997)
		Pelagic	524,000		210,000	
		All marine fish	676,230		223,156	
1990s	Inshore and offshore	Demersal	1,051,117		557,092	Son and Thuoc (2003)
		Small pelagics	524,000		209,600	
		Shrimps and lobsters	22,534		461,268	
	Inshore and offshore	Trawl			732,000	Vu et al. (2021)
2010s	Offshore	Trawl			762,000	Bui (2014)
		All marine fish			1,146,000	
	Offshore	Trawl < 90HP		<1		Hung (2018)
		Trawl 90-249HP		<1		
		Trawl >250HP		<1		

Ba Ria - Vung Tau

Year	Zone	Group/gear	Biomass		MSY	Source
2010s	Coastal and inshore	Trawl			2,485	Nguyen et al. 2022
		All marine fish			21,831	

MSY = maximum sustainable yield, B/BMSY = current biomass/biomass at MSY.

Appendix 2: Summary of the estimates of fishing effort

Demersal/trawl group = light red; all marine fish = light blue

All Vietnam

Year	Zone	Fishery	FMSY	F/FMSY	Source
2010s	Inshore and offshore	Trawl	3,277,300*		
		All marine fish	1,295,000*		Vu et al. (2021)

Southeast

Year	Zone	Fishery	FMSY	F/FMSY	Source
2010s	Offshore	Trawl	5010		Bui (2014)
		All marine fish	14,912		
2010s	Inshore and offshore	All marine fish	7,820,000*		Nguyen et al. (2018)
2010	Inshore and offshore	Trawl	1,295,000*		Vu et al. (2021)
2010s	Offshore	Trawl < 90HP		<1	
		Trawl 90-249HP		>1	Hung (2018)
		Trawl >250HP		>1	

Ba Ria - Vung Tau

Year	Zone	Fishery	FMSY	F/FMSY	Source
2010s	Coastal and inshore	Trawl	48		Nguyen et al. (2022)
		All marine fish	2765		

MSY = maximum sustainable yield, B/BMSY = current biomass/biomass at MSY.

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Annex 1: Fishery-independent research vessel surveys in Vietnam and adjacent countries

A1.1 Introduction

Fisheries independent trawl surveys, especially those carried out during the early phases of the development of a fishery are important for providing estimates of:

1. Stock biomass at different points in time (based on swept area);
2. Relative abundance indices as input into stock assessments; and
3. Information for setting priors for Bayesian stock assessment modelling.

In this review, the trawl survey results for Southeast and Southwest Vietnam are analyzed and compared with similar surveys conducted in waters of other countries in the Gulf of Thailand and adjacent waters based on a report by Staples et al. (2023). Relative biomass (kg/hour) of the total catch (all species combined) of trawl surveys were collated from published reports, scientific papers and data provided to the FAO in Malaysia and Thailand – a total of 190 surveys.

A1.2 Data

For Vietnam, the survey data included:

- Joint Viet Xo fishing surveys 1978-1988.
    - 22 vessels covering 31 trips and 4,412 stations (1,312 deepwater)
- Assessment of Living Marine Resources in Vietnam project (ALMRV) Phase 1 1996-1997
- Assessment of Living Marine Resources in Vietnam project (ALMRV) Phase 2 2000-2005
- The Comprehensive Survey for Marine Fisheries Resources in Vietnam – DA47-I.9 project 2012-2020

A1.3 Standardized CPUE results

The data were standardized as much as possible using generalized linear modelling (GLM) for:

- Gear (mesh size, head rope length)
- Depth and season
- Vessel length overall (loa) and horsepower (HP)

However, due to a large amount of missing data, the results are based on taking only year and area into account (Figure A1.1). This showed that:

- All areas, including Southeast and Southwest Vietnam, showed similar patterns of depletion
- The median virgin biomass was around 300 kg/hour across all areas
- The relative biomass is now around 10% of virgin in all areas i.e. 30 kg/hour

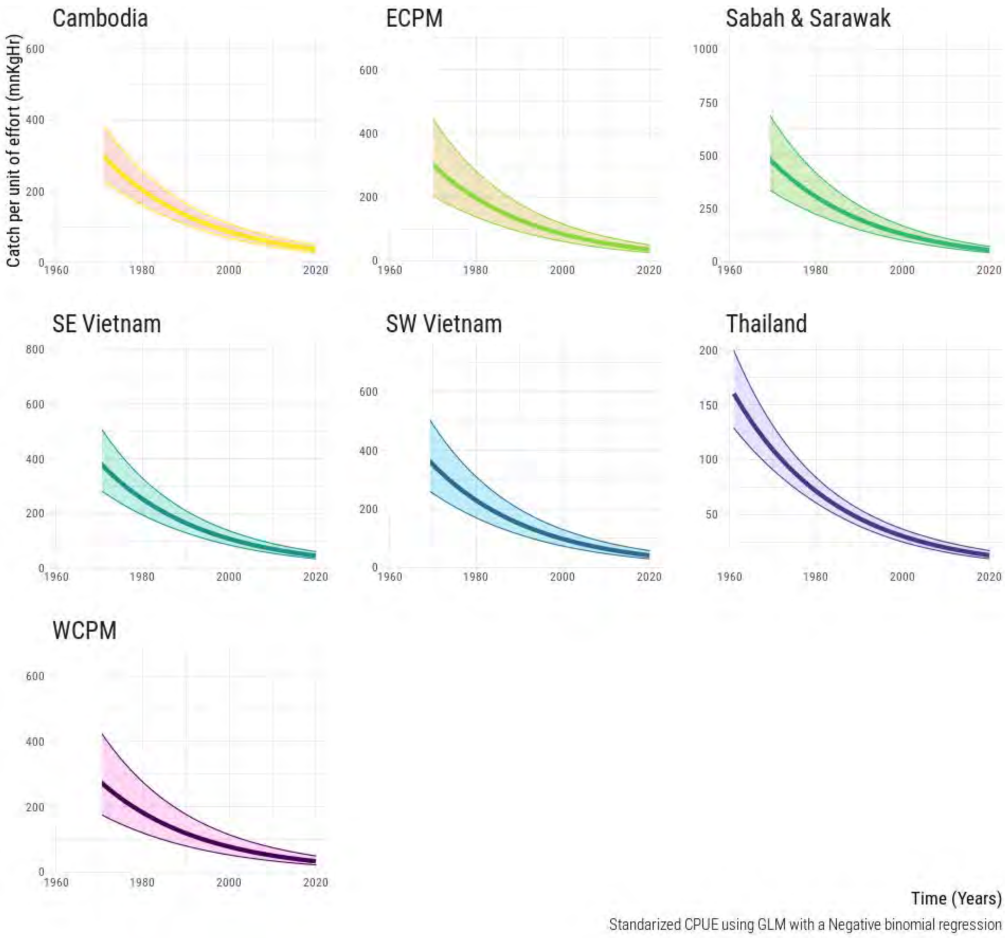


Figure A1.1: Standardized catch per unit effort for seven areas in Southeast Asia based on research surveys conducted from 1960 to 2020. ***ECPM = East coast peninsular Malaysia WCPM = West coast peninsular Malaysia***

An attempt was also made to carry out a manual standardization. This involved:

1. (To the extent possible) Selecting trawl surveys conducted in waters <50 m;
2. (To the extent possible) Correcting the cod-end mesh size to a standard 40 mm, using surveys where both 25 mm and 40 mm codends were used simultaneously as a correction factor: and
3. Correcting for vessel loa and HP by reducing the CPUE in proportion to the median size of vessels.
4. Examining the possibility of correcting for season (there were not enough comparisons to assess the effect of season and this was not included in this analysis).

When the research survey CPUEs are plotted with the total catch of each area (Figure A1.2) this shows that:

- Relative biomass (kg/hour) declined in all areas with the onset of industrial fishing (increased catches);
- The timing of this decline differed among areas reflecting the different development histories of the fisheries. For example, the CPUE declined rapidly in the 1960s in Thailand, the 1970s in Cambodia and not until the 1980s in Vietnam; and

- There are some signs of recovery, or at least stability, in Thailand and Cambodia.

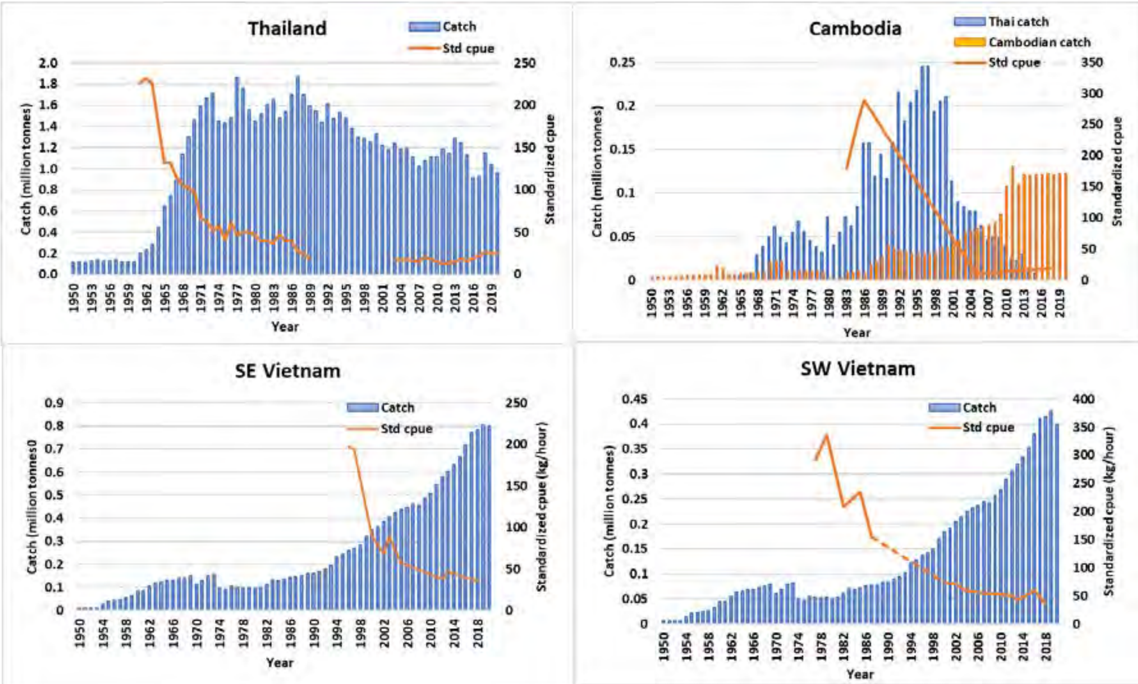


Figure A1.2: Catch (million tonnes) and (manual) standardized CPUE for Thailand, Cambodia, Southeast Vietnam and Southwest Vietnam. ***Source: Catch data modified from FAO FishStatJ 2022, to correct for catches taken outside of the respective EEZs and disaggregated to differing areas based on national catch data. Research vessel survey data as described in the text.***

The ratio of the latest CPUE and the earliest CPUE results were 11.2%, 7.7%, 10.7% and 10.5% for Thailand, Cambodia, Southeast Vietnam and Southwest Vietnam, respectively. The accepted limit where recruitment impairment occurs is 20%, indicating that overall, the fisheries resources in the Vietnam Southeast and Southwest areas, as is the case in other countries, are in a bad shape and risk collapse unless better fisheries management is introduced.

Annex 2: Example dynamic biomass/production model for the Vietnamese Southeast fishery and length-based spawning potential ratio model for Sri Lanka and Indonesia

Example 1: Multi-species dynamic biomass/production model

> **Disclaimer:** The example stock assessment results used in this paper are for demonstration purposes only and should not be interpreted as statements of the status of the actual fisheries or stocks shown, without further diagnostic analyses

Catch and indices of abundance data were fitted to a Pella-Thompson surplus production model (SPM) using JABBA (Winker et al. 2018), available at https://github.com/jabbamodel/JABBA..

Data used in the assessment included:

1. Historical catch data extracted from the Food and Agriculture Organization of the United Nations (FAO) FishStatJ database that is based on the data reported to it from the Vietnam Government Statistics Office (GSO), available at https://www.fao.org/fishery/en/statistics/software/fishstatj
2. Recent catch data available on the GSO website https://www.gso.gov.vn/en/agriculture-forestry-and-fishery/
3. Reconstructed catch data available on the Sea Around Us (SAUP) website https://www.seaaroundus.org/
4. Research vessel CPUE survey data: 1996-2018: Nguyen and Vu (2021) (surveys carried out by the same vessel and fishing gear based on a systematic survey pattern)
5. Reconstructed fishing vessel and horse power data Rousseau et al. (2019) (data provided by Fulton pers comm).

Model fitting

SPMs estimate changes in biomass as a function of the biomass of the preceding year, the surplus production of biomass in a given year, and the removal by the fishery in the form of catch. In SPMs, somatic growth, reproduction, natural mortality, and associated density-dependent processes are captured in the interplay of two major parameters - the intrinsic rate of population increase (r) and the carrying capacity (K).

The model fits the data using a Bayesian mode where the probability to represent all uncertainty within the model are used. This includes both the uncertainty in both the input and output. The model fit starts with informed values (called priors) and fits the data to the model to provide estimates of the parameters (called posteriors).

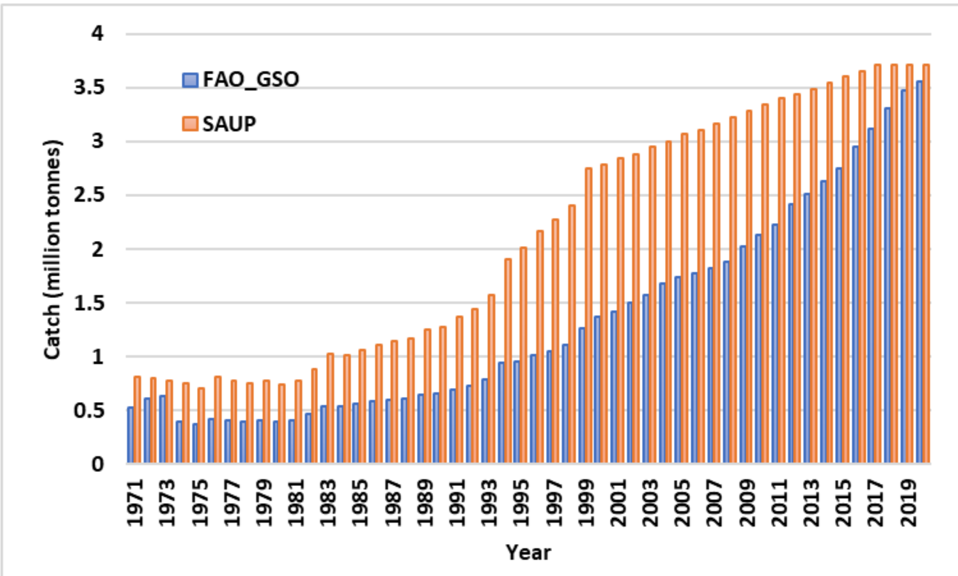
The SPM model requires a time-series of catches, a time-series of abundance indices, and an estimate of initial biomass, and a prior for r. Two types of abundance indices were used to fit the model. The first was the research vessel survey CPUE results (kg/hour) and the second was the commercial CPUE results (Tonnes/HP). For both analyses, a base case value of prior r = 0.3 was used (based on values extracted from FishBase (Froese and Pauly, 2022)) For the commercial CPUE, an initial biomass of 90% of the virgin biomass was used (heavy industrial fishing in Vietnam did not really expand until the 1980s) and for the research vessel CPUE, a value of 0.5 was used.

	r value	r_cv	Initial biomass	Initial biomass _cv
Commercial CPUE	0.3	0.25	0.9	0.1
Research vessel CPUE	0.3	0.25	0.5	0.1

The JABBA default package sets the K prior to 8 times the maximum catch with a cv of 1.0.

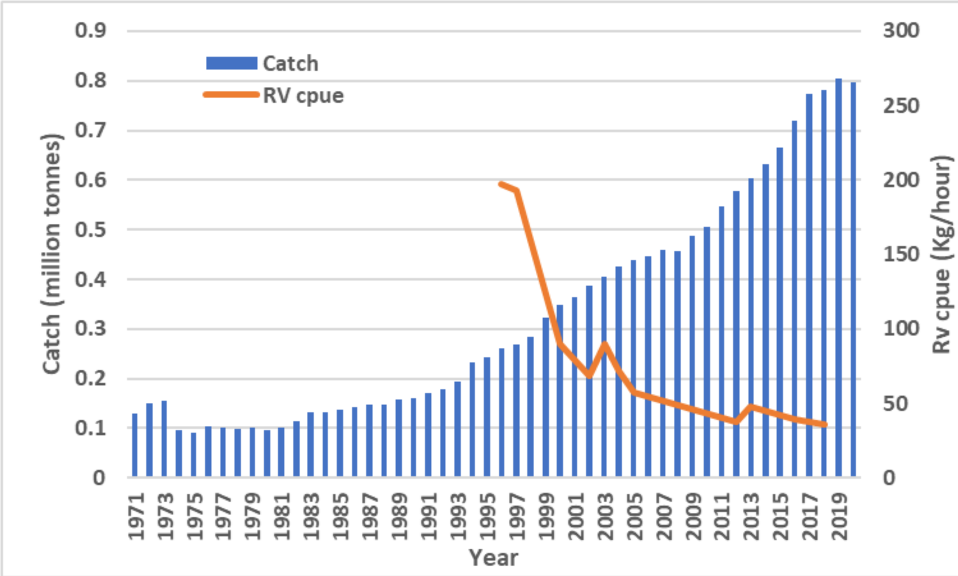
Catch data

The base case used the data reported by the FAO/GSO. For comparisons, the reconstructed data of SAUP was used.



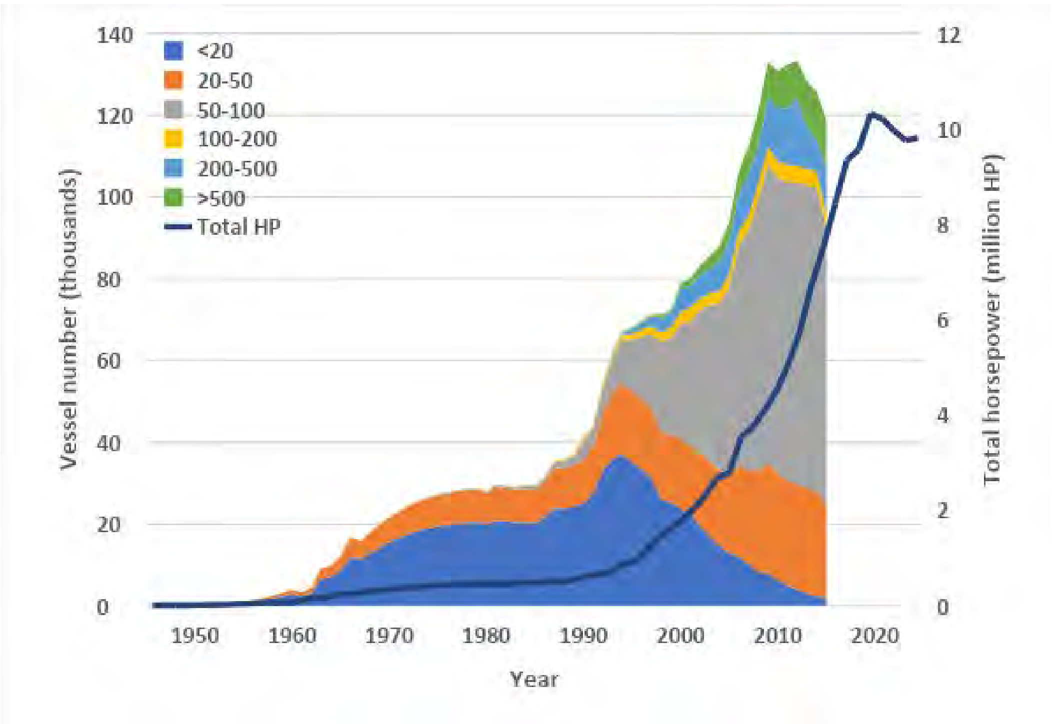
Research vessel data

The research data CPUE was an interpolated time series based on the observed research vessel results from 1996 – 2018, as described in Annex 1.



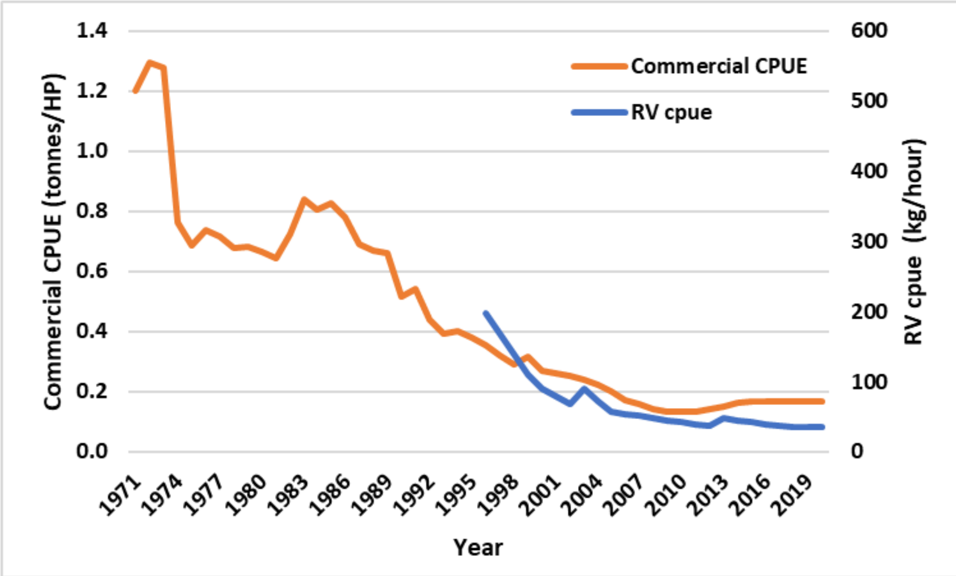
Commercial effort data and CPUE

The analysis used the reconstructed vessel data of Rousseau et al. (2019).



The commercial CPUE was calculated as the FAO/GSO catch for each year divided by the total HP. To adjust for technological "effort creep" the effort was increased by 1% per year.

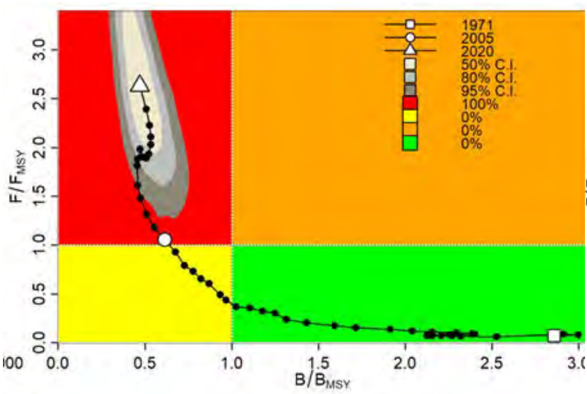
The change in relative abundance, as indicated by both the research vessel CPUE and the commercial CPUE showed similar overall trends for the period when both data sets are available.



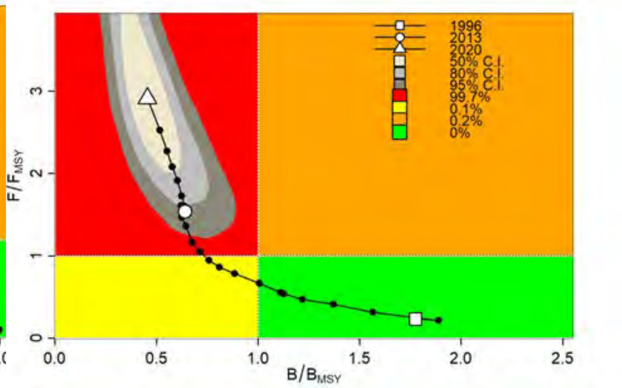
Model results

FAO/GSO catch data

The JAABA analyses using the FAO/GSO catch and (i) the commercial CPUE and (ii) the research vessel CPUE as the index of abundance, showed that the fishery resource is both overfished and still subjected to overfishing. In both cases, the current B/BMSY and F/FMY are in the red quadrant of the Kobe plot. For sustainability, the B/MSY and F/FMY need to be in the green quadrant.



Commercial CPUE



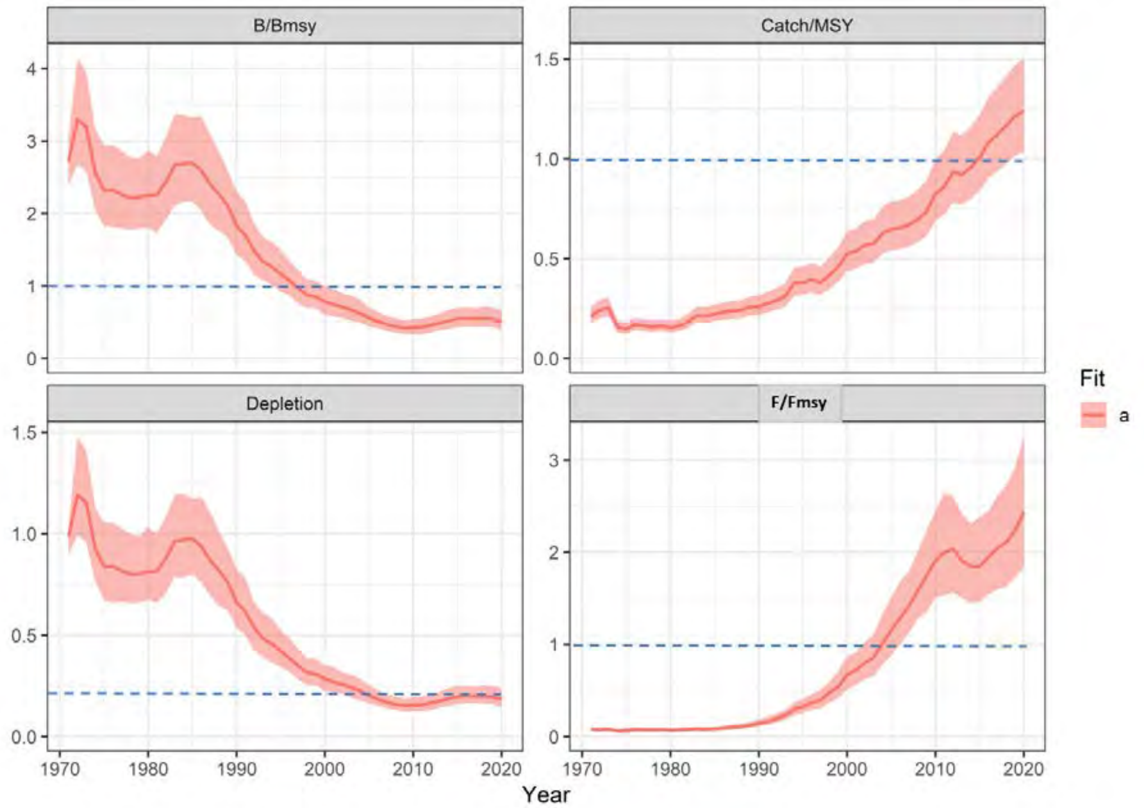
Research vessel CPUE

The pattern and parameter estimates were similar, regardless of which index of abundance was used. In both cases, the MSY estimate was about 650,000 tonnes. The current biomass was only 0.5 of the biomass at MSY (Target B/BMSY = 1)) and the fishing mortality was 2.5 – 2.9 higher than the fishing mortality at the MSY (Target F/FMSY = 1). The current biomass is around 2.276 million tonnes – about ~18-19% of the virgin biomass. A commonly accepted limit for the point of recruitment impairment (PRI) is 20%.

	Commercial CPUE			**Research vessel CPUE**			**Status**
MSY	522,113	**687,676**	992,085	477,495	**647,676**	952060	

B/BMY	0.316	**0.471**	0.686	0.257	**0.454**	0.781	**Overfished**
F/FMSY	1.561	**2.631**	4.217	1.548	**2.913**	5.068	**Overfishing**
B/Bo	0.126	**0.188**	0.274	0.102	**0.181**	0.313	**Under BLIM**

In terms of the past history, overfishing started to occur in the early 2000s, at which time the biomass became overfished, and never recovered. The graph below shows the historical trends for the commercial CPUE fit.

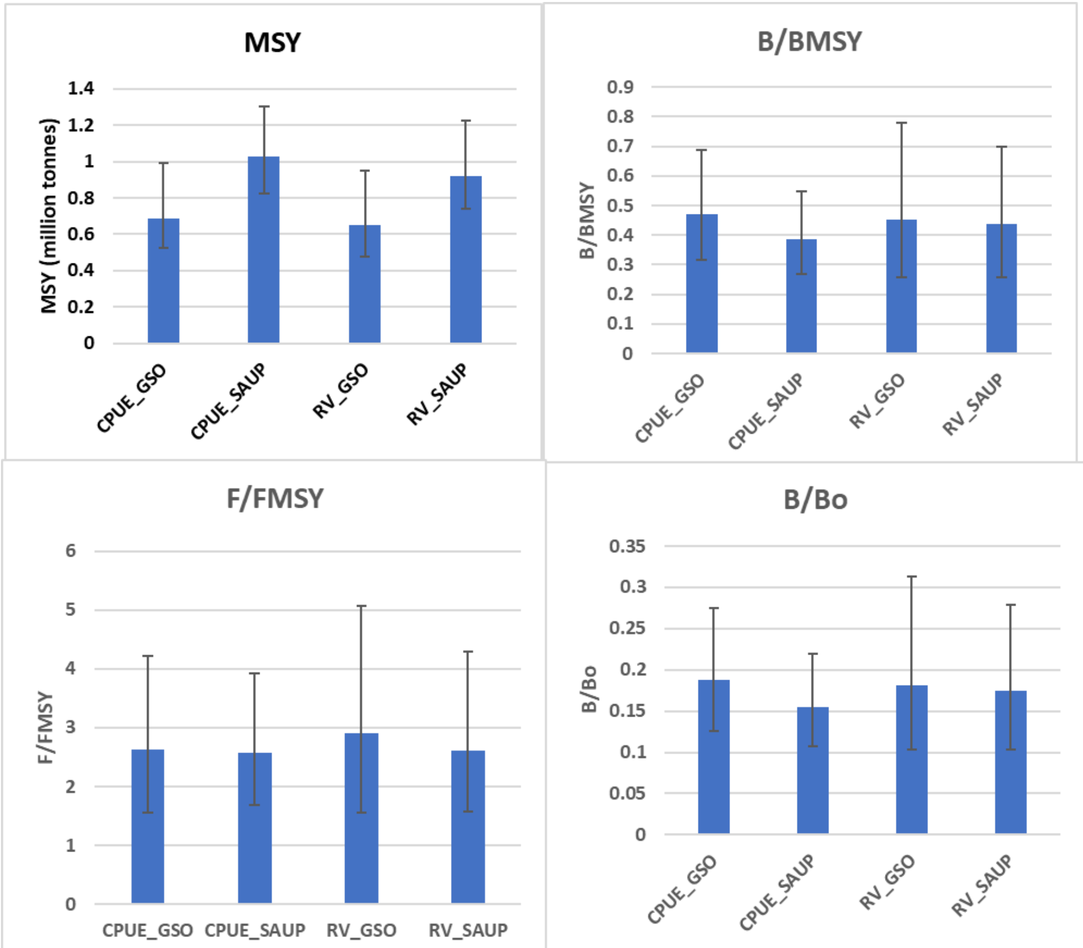


One unusual result is that the catch has continued to increase. Classical fisheries science predicts that the catch will decline once the stock has become overfished (i.e. the biomass drops below the biomass needed to produce the MSY). There are several possible explanations for this:

1. The reported catch does not reflect the actual catch. The fact that there is little variation in the reported catch each year and that increased almost every year is highly unusual. In comparison, during the ALMRV project and the DA47-I.9 project, the catch estimate varied considerably from year to year and did not increase at a steady rate (see Figure 1 and 2 in the main text). Several reports have previously stated that the catch is in fact set by the government to reflect annual production targets.
2. Fishing has continued to “fish down the food chain” with increasing amounts of smaller more productive fish (e.g. shrimp, crabs, squid and small/low value trash) being caught as the fishing pressure increased.

3. A significant part of the catch in more recent years has come from outside of the Vietnam EEZ.

There is evidence that options 1 and 2 are probable, but little information is available to test for options 3. As a trial, the stock assessment was carried out using the SAUP catch data. Because the catch estimates were larger, the estimates of the MSY were larger, but the other parameter ration was not that different. Note that because the basis of the SAUP reconstruction was the catch reported by the GSO, the catch also kept on increasing.



Example 2: Length-based spawning potential ratio (LBSPR)

The following is a summary of a study using the LBSPR method for the blue swimming crab in Sri Lanka and Indonesia (Prince et al. 2020). The purpose of the study was to document the application of the LBSPR methodology to the Sri Lankan and Indonesian blue swimming crab fisheries and to initiate some discussion of the management issues raised by the techniques' application, and how it might be used within harvest strategies.

The LBSPR (Hordyk et al., 2015) model was used for both species using the r package available at [https://cran.r-project.org/web/packages/LBSPR/vignettes/LBSPR.html.](https://cran.r-project.org/web/packages/LBSPR/vignettes/LBSPR.html) The methodology estimates the spawning potential ratio (SPR) of a population, which is a metric emphasizing the risk of recruitment declining in the future. When left unfished, fish can complete their full lifespan and achieve 100% of their natural reproductive (spawning) potential. By reducing the average lifespan of fish in a population, fishing can cause a decline in the reproductive or spawning potential of stocks below the natural unfished levels (<100%). Thus, SPR represents the proportion of the natural unfished spawning potential of populations that remains in fished populations.

To determine the optimal levels of fishing for these two species, standard international measures were applied. Specifically, 20% SPR is used as a limit reference point (LRP), which stocks should be prevented from falling below. An SPR at the range of 30-40% is considered a target range that would optimize long-term yields. An SPR of approximately 50% indicates a level that will likely optimize the economic returns from a fishery (Mace, 1994).

Length data

In both Sri Lanka and Indonesia initial sampling trials were conducted to understand temporal and geographic variability of size compositions, and on this basis locally appropriate sampling protocols were developed and implemented.

In Sri Lanka blue swimming crab sampling was focused in January to February of each year during which multiple landing and collection sites from two fisheries were sampled each for a few days. In the Palk Bay fishery data were collected and pooled from several landing sites and collection centres, in each of the three districts (Jaffna, Kilinochchi and Mannar) along the northern, western and southern shorelines of Palk Bay. In the Gulf of Mannar fishery, sampling was focused on five collection centres that received blue swimming crab from about eleven landing sites along the shoreline of the Puttalam Estuary, and three sea fishing grounds along the coast of the Gulf of Mannar. Teams of local youth and women from the surrounding fishing communities were trained and employed to collect the data. At each sampling site all the blue swimming crabs landed each day of sampling were measured; male and female crabs were measured to the nearest 1.0 mm and the reproductive status of female crabs was recorded. The data reported here were collected during the 2014–2018 fishing seasons.

In Indonesia representative landing sites in each of the 7 main fishing grounds, representing fisheries management area (FMA) of 712 in the Java Sea (Gresik, Pemalang, Pameskasan, Pati) and FMA 714 in Tiworo Strait of Southeast Sulawesi (Kasiputeh, Kendari, Pamandati) were selected for monitoring, and trained data collectors were stationed at each to collect data for several days each month of the year. In addition to recording the daily catch and effort of individual fishers, the data collectors sub-sampled ~20 kg of the landed blue swimming crab, recording gender, maturity, carapace width to the nearest 1.0 mm, and weight to the nearest gram. The data reported here were collected during the period November 2017 to October 2018.

Model fitting

Input parameters

Life history parameters (Linf, k and M)

The inputs to the LBSPR model are:

(i) the ratio of natural mortality/the von Bertalanffy growth parameter (k/M),

(ii) the mean asymptotic length (Linf);

(iii) the variability of length-at-age (CVLinf), normally assumed to be around 10%; and

(iv) an estimated size of maturity (Lm) specified in terms of the length at which 50% (L50%) and 95% (L95%) of a population is mature.

For this study, twenty publications were collected for three *Portunus* species, *P. sanguinolentus*, *P. segnis* and *P. pelagicus* from which estimates of M/k and Lm/L∞ could be derived (see Table below). The estimated mean Lm/L∞ = 0.52 (n = 13, S.D. = 0.09) and mean M/k = 1.26 (n = 34, S.D. = 0.31).

Published name	Sex	L∞	k	L50	M	L50/L∞	M/k	Max age	Reference
P. pelagicus	M	175	1.6	90	2	0.51	1		Sumpton et al. (1994)
P. pelagicus	F	170	1.6	90	2	0.53	1		Sumpton et al. (1994)
P. pelagicus	F	167	1.1	106	2	0.63	1.5		Kunsook et al. (2014)
P. pelagicus	F	173	0.7		1		1.3		Hamid and Wardiatno (2015)
P. pelagicus	M	152	0.9		1		1.2		Hamid and Wardiatno (2015)
P. pelagicus	F	187	1.1		1		1		Ernawati (2013)
P. pelagicus	M	185	1.3		1		1		Ernawati (2013)
P. pelagicus	M	CL81	1.2		2		1.3		Sunarto (2012)
P. pelagicus	F	154	1.1		1		1.1		Kembaren et al. (2012)
P. pelagicus	M	159	1.3		1		1.1		Kembaren et al. (2012)
P. pelagicus	F	186	1.5		1		0.9		Ihsan Wiyono et al. (2014)
P. pelagicus	M	174	1.2		1		1.2		Ihsan Wiyono et al. (2014)
P. pelagicus	All	179	1.5		2		1.1		Sawusdee and Songrak (2009)
P. pelagicus	F	211	1.1	80	2	0.38	1.7	2.5	Sukumaran and Neelakantan (1997)
P. pelagicus	M	204	1	87	2	0.43	2	2.5	Sukumaran and Neelakantan (1997)
P. pelagicus	F	170	1.4	96	2	0.56	1.1	3	Dineshbabu et al. (2008)
P. pelagicus	M	169	1.3		2		1.2	3	Dineshbabu et al. (2008)
P. pelagicus	M	168	1.2		1		1.1	3	Kamrani et al. (2010)
P. pelagicus	F	178	1.1		1		1.2	3	Kamrani et al. (2010)
P. pelagicus	M	CL103	1.9		3		1.7		Mehanna et al. (2013)
P. pelagicus	M	100	1.6		2		1	3	Josileen and Menon (2007)
P. pelagicus	F	197	1.1		2		1.5	3	Josileen and Menon (2007)
P. sanguinolentus	F	162	1.6	83	2	0.51	1.2		Sarada (1998)
P. sanguinolentus	M	172	1.5		2		1.3		Sarada (1998)
P. sanguinolentus	M	162	1.1		1		1		Pillai & Thirumilu 2012 In Dash et al
P. sanguinolentus	F	169	1.3		1		0.9		Pillai & Thirumilu 2012 In Dash et al
P. sanguinolentus	All	179	1.2	97	2	0.54	1.5		Dash et al. (2013)
P. sanguinolentus	F	188	0.8	80	1	0.43	1.7	3	Sukumaran and Neelakantan (1997)
P. sanguinolentus	M	195	1	87	1	0.45	1.4	3	Sukumaran and Neelakantan (1997)
P. sanguinolentus	F	170	1.6	90	2	0.53	1.2	2.5	Dineshbabu et al. (2007)
P. sanguinolentus	M	205	0.9		2		1.9		Lee and Hsu (2003)
P. sanguinolentus	F	194	1	135	2	0.7	1.9		Lee and Hsu (2003)
P. segnis	F	185	1.6	113	1	0.61	0.9		Safaie et al. (2013a,b)
P. segnis	M	191	1.7		2		0.9		Safaie et al. (2013a,b)

Note: References in the table can be found in Prince et al. (2020)

Model results

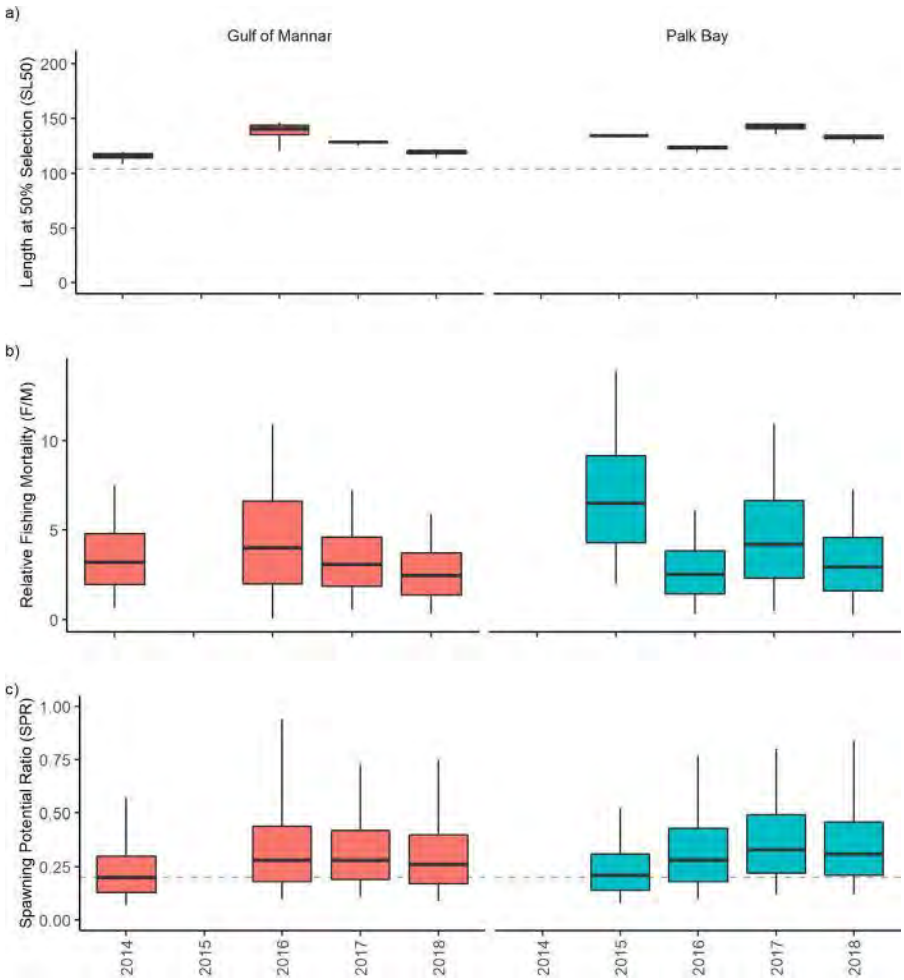
Estimates of L50 and L95

From the Indonesian size of maturity data (n=55,179) we estimated L50 = 101 mm and L95 = 103 mm and from the Sri Lankan size of maturity data (n = 15,012) we estimated L50 = 104 mm and L95 = 124 mm.

Results of length-based spawning potential ratio analysis

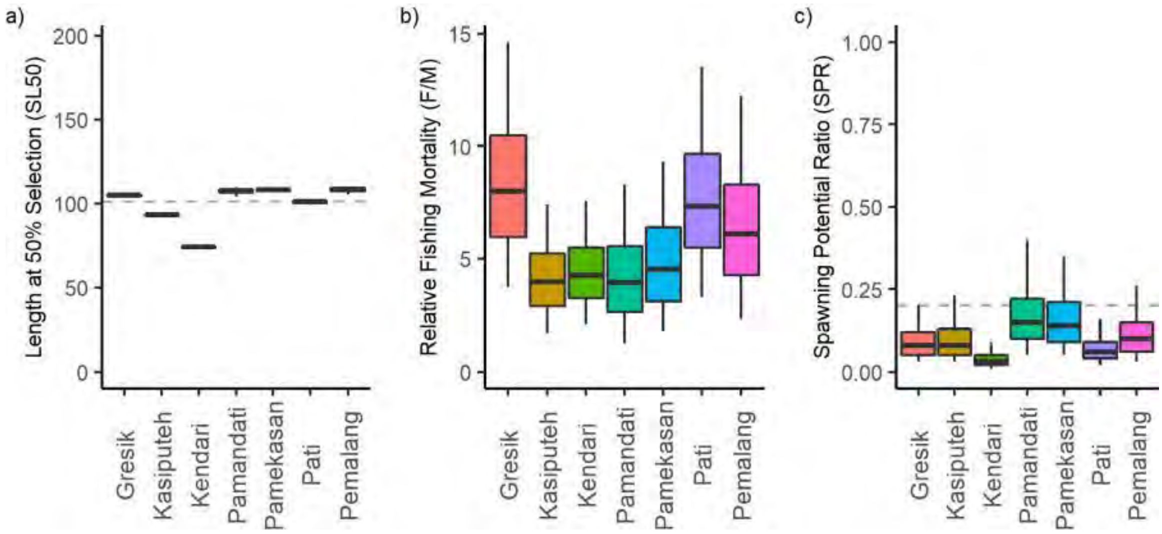
Sri Lanka

The mean estimates of SL50% from the two Sri Lankan fisheries ranged from 116–142 mm (fishing with relatively large mesh nets). The mean estimates of F/M on the Sri Lankan fishing grounds were all relatively high, ranging from 2.7 to >4. The mean estimates of SPR ranged from 0.24–0.35 in the Gulf of Mannar, and similarly ranging from 0.24–0.37 in Palk Bay.



Indonesia

From the Indonesian sites most of the mean estimates of SL50% were around 100 mm (range 93–108 mm), considerably lower than estimated for Sri Lanka (116–142 mm) (fishing being mainly with traps). The outlier was Kendari with the smallest mean estimate of SL50% = 74 mm (fishing with mini-trawl in that area). The mean estimates of F/M from the Indonesian sites are all very high >4, but overlap with the Sri Lankan estimates. The mean estimates of SPR in Indonesia are all very low, ranging from 0.04 in Kendari to 0.17 in Pamandati.



Conclusions

This study demonstrates the technical feasibility of applying the LBSPR methodology to small-scale, data-poor blue swimming crab fisheries in Southeast Asia. Requiring only the simplest of data (i.e., size composition and size of maturity data) assessments can be completed with basically trained field staff, as demonstrated by the employment of community members in Sri Lanka.

In both countries the LBSPR assessments are successfully informing and supporting discussions about sustainability, focusing them on the issue of managing size selectivity, one of the few management controls available to fisheries managers in many small-scale fisheries. In Sri Lanka the methodology is demonstrating that the larger size selectivity using crab nets with 114 mm mesh size can preserve a conservatively high level of SPR despite relatively high fishing pressure.

In Indonesia application of the technique has increased focus on the need to fully implement previously promulgated regulations banning trawling and establishing an initial minimum size limit. Escape gaps in traps, with dimensions of 115 mm x 35 mm were also suggested. We have suggested how the system of ongoing LBSPR assessment being implemented in Indonesia could be successfully used within the harvest control rule of the harvest strategy being developed for the fishery.

References

Prince, J., Steven Creech, S., Madduppa, H. and Hordyk, A (2020) Length based assessment of spawning potential ratio in data-poor fisheries for blue swimming crab (*Portunus spp.*) in Sri Lanka and Indonesia: Implications for sustainable management. *Regional Studies in Marine Science 36 (2020) 101309*