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Stock and risk assessments of Narrow-barred Spanish mackerel (*Scomberomorus commerson*) and Indo-Pacific king mackerel (*Scomberomorus guttatus*) resources in the Eastern Indian Ocean (1950-2020) and Western Pacific Ocean (1970-2019) based on ASPIC (*A Stock-Production Model Incorporating Covariates*)

Southeast Asian Fisheries Development Center (SEAFDEC)
Marine Fishery Resources Development
and Management Department (MFRDMD)
2022

Stock and risk assessments of Narrow-barred Spanish mackerel (*Scomberomorus commerson*) and Indo-Pacific king mackerel (*Scomberomorus guttatus*) resources in the Eastern Indian Ocean (1950-2020) and Western Pacific Ocean (1970-2019) based on ASPIC (A Stock-Production Model Incorporating Covariates)

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Coverpage image photographed by: Mohamad Syahidan Azmi and *Osman Muda*
Workshop image photographed by: Abdul Aziz Yusof

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ACRONYMS

AMSs	ASEAN Member States
ANOVA	Analysis of variance
ASEAN	Association of Southeast Asian Nations
ASPIC	A Stock-Production Model Incorporating Covariates
B1	Total biomass in the first year of stock assessment
CI	Confidential Interval
CPUE	Catch Per Unit of Effort
F	Fishing mortality
FAO	Food and Agriculture Organization
FCG/ASSP	Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic
Fmsy	Fishing mortality at MSY
GLM	Generalized Linear Model
IOTC	Indian Ocean Tuna Commission
K	Carrying capacity
MFRDMD	Marine Fishery Resources Development & Management Department
MSY	Maximum sustainable yield
q	Catchability coefficient
Q-Q Plot	Quantile-Quantile Plot
r	Intrinsic growth rate of population
r^2	Correlation coefficient
RFMO	Regional Fisheries Management Organization
RMSE	Root Mean Square Error
RPOA	Regional Plan of Action
SEAFDEC	Southeast Asian Fisheries Development Center
STD CPUE	Standardized CPUE
TAC	Total Allowable Catch
TB	Total Biomass
TBmsy	Total Biomass at MSY
TD	Training Department (SEAFDEC/MFRDMD)
ToR	Term of Reference
WS	Workshop

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Facilitators

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Nor Bariah Omaruddin	(FRIKA, DOF)
Nabilah Mustafha	(FRIKA, DOF)

PREFACE

The main objective of this work is to assess the current stock status and risk assessment of seer fish, Narrow-barred Spanish mackerel and Indo-Pacific King mackerel in Malaysian waters and the ASEAN region.

Nominal catch data were extracted from the IOTC Secretariat database from 1950–2020, and the FAO database from 1970-2019 for analysis purposes whereas the fisheries database from 2008-2020 provided by the Department of Fisheries Malaysia was used as the main data to obtain nominal CPUE.

In ASPIC analysis, four software were used during the workshop: i) CPUE Standardization, ii) Batch Job, iii) Kobe Plot, and iv) Risk Assessment.

BACKGROUND

Neritic tuna fisheries are economically important in the Southeast Asian region. Hence, the cooperation between regional or sub-regional is crucial in developing sustainable utilization of neritic tuna in this region. As a result, The Regional Plan of Action on Sustainable Utilization of Neritic Tunas in the ASEAN (RPOA-Neritic Tunas) was agreed upon by all ASEAN Member States (AMSs), which was endorsed by the 47th Meeting of SEAFDEC Council on April 2015 and the 23rd Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi).

One of the key actions in implementing the RPOA-Neritic Tunas is to enhance regional cooperation that aims to develop/improve Sub-regional Action Plans for neritic tuna fisheries. The Sub-regional Action Plan for neritic tuna fisheries supports the assessment of the stock status and trends of neritic tuna at the regional level. Consequently, the Scientific Working Group for Stock Assessment on Neritic Tunas in the Southeast Asian Region was therefore established by SEAFDEC Council directors.

Since then, several meetings of SWG-Neritic Tunas have been held, including The 1st Meeting of SWG-Neritic Tunas that agreed to include seven (7) species to be studied in the region. They are longtail tuna (*Thunnus tonggol*), eastern little tuna/kawakawa (*Euthynnus affinis*), frigate tuna (*Auxis thazard*), bullet tuna (*Auxis rochei*), bonito (*Sarda orientalis*), Indo-Pacific king mackerel (*Scomberomorus guttatus*), and Narrow-barred Spanish mackerel (*Scomberomorus commerson*). Next, the 2nd Meeting of SWG-Neritic Tunas concluded that A Stock-Production Model Incorporating Covariates (ASPIC) would be used per the first phase of the two (2) neritic tuna stock assessment. Furthermore, one of the main discussions during the 5th SWG-Neritic Tunas was the final draft of Indo-Pacific king mackerel and Narrow-barred Spanish mackerel stock and risk assessment; and the work plan for stock assessment of seer fish.

Four (4) species of tunas and tuna-like species were accessed, namely *T.tonggol*, *E.affinis*, *S.guttatus* and *S.commerson*. Four (4) regional workshops on stock and risk assessment for neritic tunas were organized from 2016 to 2020. In 2021, the fifth regional workshop was planned but due to inter-country restriction caused by COVID-19 pandemic, SEAFDEC/MFRDMD had to organize the practical workshop internally on 19-23 December 2021 at Kuala Terengganu, Malaysia. This internal workshop entitled "Workshop on Seer Fish in Malaysian Waters using ASPIC in Collaboration with DOF Malaysia." This collaboration involved using Malaysia's catch per unit effort (CPUE) data while for the catch data were obtained from IOTC and FAO website. Other collaboration was involving teaching staff (resource person) from DOF Malaysia.

SUMMARY OF STOCK STATUS

In 2021, the SWG on Neritic Tuna Stock Assessment organized a practical workshop on tuna-like species stock and risk assessment. The Workshop on Seer Fish in Malaysian Waters using ASPIC in Collaboration with DOF Malaysia was held from 19 - 23 December 2021 in Kuala Terengganu, Terengganu, Malaysia. The main objective of this work is to assess the current stock status and risk assessment of seer fish Narrow-barred Spanish mackerel and Indo-Pacific king mackerel in Malaysia waters and the ASEAN region. Nominal catch data were extracted from the IOTC Secretariat database from 1950–2019, and the FAO database from 1970-2019 for analysis purposes whereas the fisheries database from 2008-2020 provided by the Department of Fisheries Malaysia was used as the main data to obtain nominal CPUE.

There are four (4) software used in the practical workshop: i) CPUE Standardization, ii) ASPIC original application and the batch job, iii) Kobe plot, and iv) Risk Assessments. Microsoft Excel was used in data sorting and compiling.

As a result, the stock assessments for Narrow-barred Spanish mackerel stock status in the Western Pacific Ocean are in a safe situation in 2019. Based on the risk assessment results, the current catch (146,932 tons) needs to be reduced by 10% (15,000 tons) in three (3) years on average to avoid a 50% risk of total biomass (TB) and fishing mortality (F) violating their MSY levels.

However, Narrow-barred Spanish mackerel stock status in the Eastern Indian Ocean shows an overfished situation in 2020. Based on the Risk Assessment result, the current catch (41,310 tons) needs to be reduced by 20% (8,500 tons) in three (3) years to avoid a 50% risk of TB and F violating their MSY levels.

As for King Mackerel in the Western Pacific Ocean, the stock status is in the green zone (safe situation) in 2019. It is suggested that the current catch (12,962 tons) can be increased by 30% (4,000 tons) to the MSY level (17,060 tons), in which case the probability of TB and F violating their MSY levels is less than 50%.

Last but not least, the current stock status of King Mackerel in the Eastern Indian Ocean is in the red zone (overfished situation) in 2020. Based on the risk assessment results, it is suggested the current catch (13,784 tons) needs to be reduced by 40% (5,000 tons) in three (3) years to avoid a 50% risk of TB and F violating their MSY levels.

The results from the stock and risk assessments show the current level of Narrow-barred Spanish mackerel should be reduced in Eastern Indian Ocean and Western Pacific Ocean. Whereas, only Indo-Pacific king mackerel in the Eastern Indian Ocean should be reduced. *S.commerson* and *S.guttatus* are among the most commercially important fisheries resources in the SEA region, so the stock and risk assessments need to be updated at least once every three years for healthy stocks and once in two years for the unhealthy stock status.

<table>
<tr>
<td>Narrow-barred Spanish mackerel (Eastern Indian Ocean stock)
Red zone (98%) and Yellow zone (2%)
TB/TBmsy=0.647 and F/Fmsy=1.387
MSY= 45,310 tons
Current catch level: 41,539 tons</td>
<td>Narrow-barred Spanish mackerel (Western Pacific Ocean stock)
Red zone (50%), Green zone (45%) and Orange zone (5%)
TB/TBmsy=1.455 and F/Fmsy=0.555
MSY = 179,600 tons
Current catch level: 146,932 tons</td>
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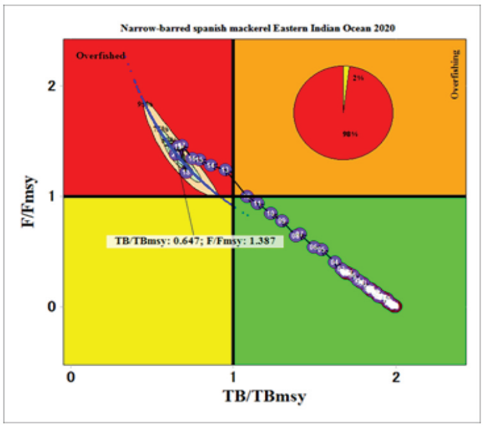
<td>
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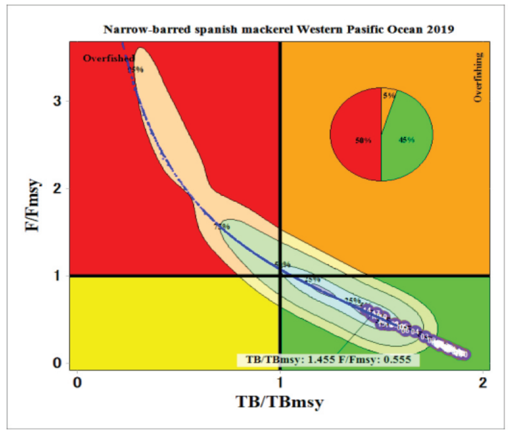
<td>
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</tr>
<tr>
<td>Indo-Pacific king mackerel (Eastern Indian Ocean stock)
Red zone (100%)
(TB/TBmsy=1.554 and F/Fmsy=0.561)
MSY= 15,070 tons
Current catch level: 13,784 tons</td>
<td>Indo-Pacific king mackerel (Western Pacific Ocean stock)
Green zone (100%)
TB/TBmsy=1.482 and F/Fmsy=0.534
MSY= 17,060 tons
Current catch level: 12,962 tons</td>
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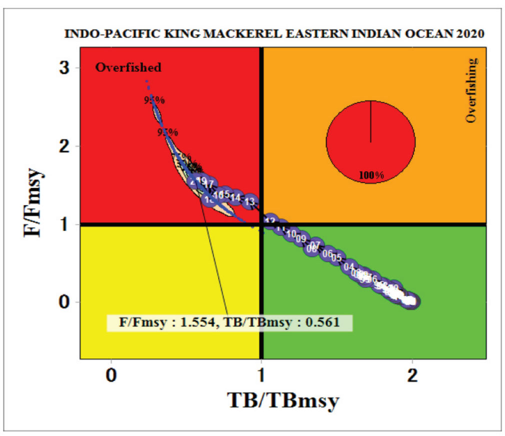
<td>
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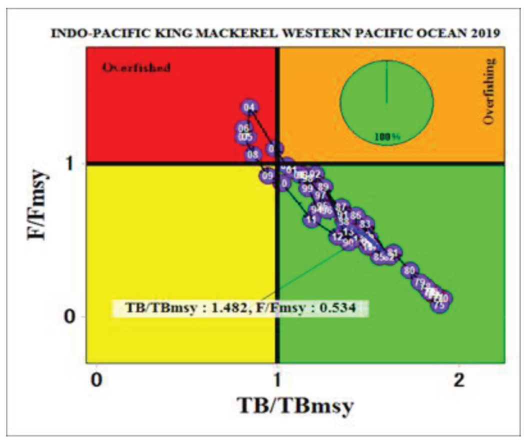
<td>
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Figure 1: Stock status based on stock and risk assessments by ASPIC.

1.0 INTRODUCTION

1.1. Data

In ASPIC, two (2) types of data are used, i.e., (a) annual total nominal catch by stock and (b) CPUE (Catch and Effort) by stock, country, gear, and area. The practical workshop constructed the most plausible catch data sets using these data. Figure 2 and Figure 3 show the specification of catch data for *S. commerson* and *S. guttatus,* respectively, in the Western Pacific Ocean and Eastern Indian Ocean.

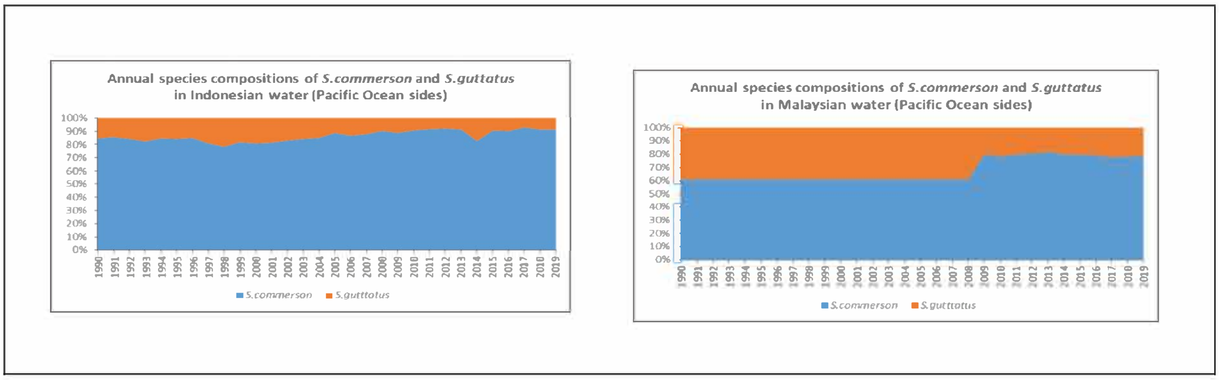


Figure 2: Annual species compositions of *S.commerson* and *S.guttatus* in the Western Pacific Ocean (Indonesian and Malaysian water).

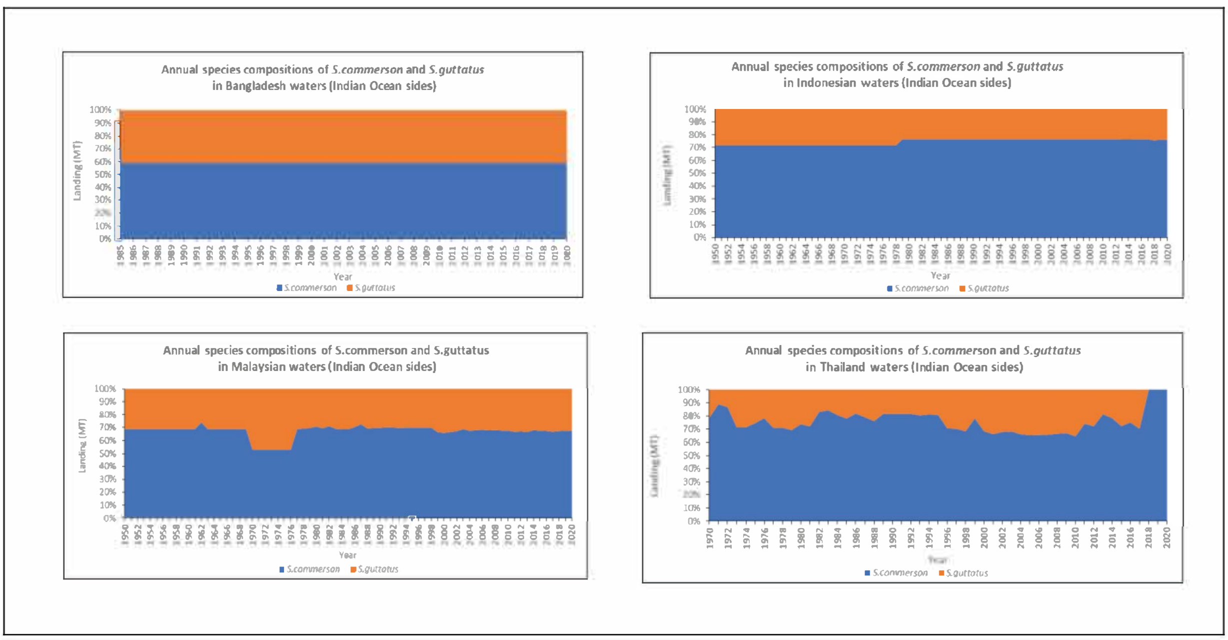


Figure 3: Annual species compositions of *S.commerson and S.guttatus* in Eastern Indian Ocean (Bangladesh, Indonesian, Malaysian, and Thailand waters).

1.2. Nominal catch

i) Catch construction

Compilation of historical nominal catches obtained from published catch data from the IOTC website (IOTC 2021), Food and Agriculture Organization (FAO-FishtatJ) (FAO 2021), and a series of Malaysian annual fisheries statistic books. Data were collected from 1950 on the IOTC website for the Eastern Indian Ocean, and data catch from FAO (Fishstat J) for the West Pacific Ocean. Using these data, catch by species in areas (Western Pacific Ocean) and Eastern Indian Ocean) were formed and used as a series of 'Global Catches' in specific areas above.

Table 1 shows results that catch trends for *S. commerson* and *S. guttatus* from the Western Pacific Ocean and Eastern Indian Ocean areas, respectively.

Table 1: Catch data of Indo-Pacific king mackerel and Narrow-barred Spanish mackerel from respective countries by species and areas.

S. commerson		***S. guttatus***	
WPO	**EIO**	**WPO**	**EIO (IOTC**
Indonesia (FAO)	Indonesia (IOTC)	Indonesia (FAO)	Philippines (FAO)
Philippines (FAO)	Bangladesh (IOTC)	Malaysia (FAO+DoFM)	Bangladesh (IOTC)
Malaysia (FAO + DoFM)	Malaysia (IOTC)		Malaysia (IOTC)
	Thailand (IOTC)		Thailand (IOTC)

Note:
FAO: Food Agriculture Organization
IOTC: Indian Ocean Tuna Commission
DoFM: Department of Fisheries Malaysia

ii) Uncertainties in the catch and effort data

Catch data from IOTC (EIO) (Figure 5 and Figure 7) has a long times series data compared to the FAO (WPO) (Figure 4 and 6), which are 71 and 51 years, respectively. These data are officially provided by each country to the organizations. However, not every Asian country provided the data to the organization. For example, only Malaysia, the Philippines, and Indonesia provide seer fish catch in the Western Pacific Ocean to FAO. While, data from IOTC and FAO do not include efforts data. In this case, nominal CPUE can only be generated from the database of Department of Fisheries Malaysia. Thus, it should be noted that such uncertainties affect the results of stock and risk assessment.

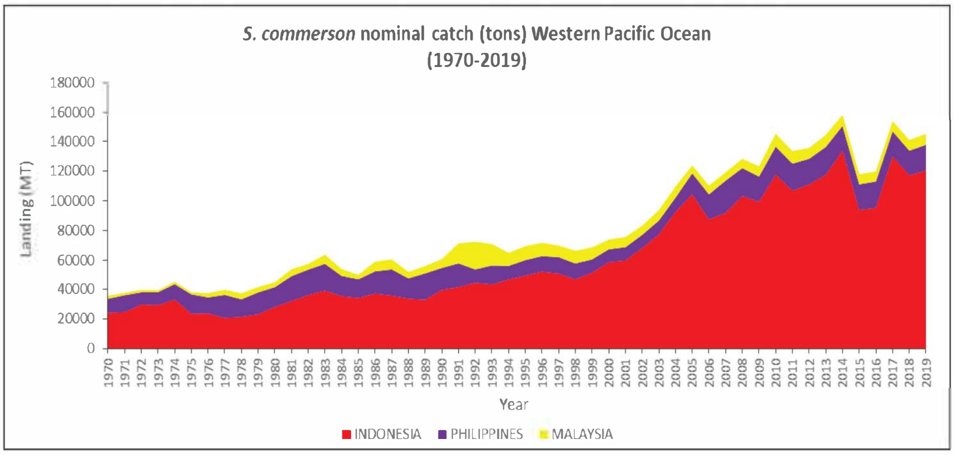


Figure 4: Nominal catch of *S. commerson* in the Western Pacific Ocean side by Indonesia, Philippines, and Malaysia (1970-2019).

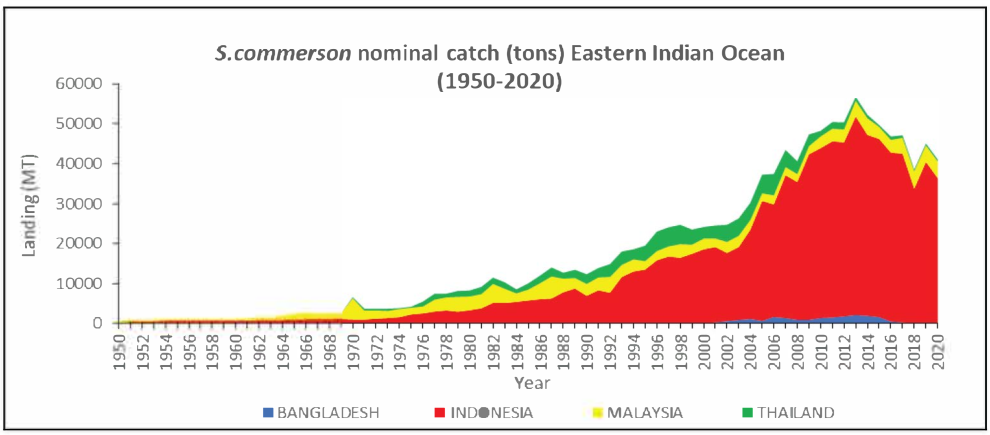


Figure 5: Nominal catch of *S. commerson* in Eastern Indian Ocean side by Bangladesh, Indonesia, Malaysia, and Thailand (1950-2020).

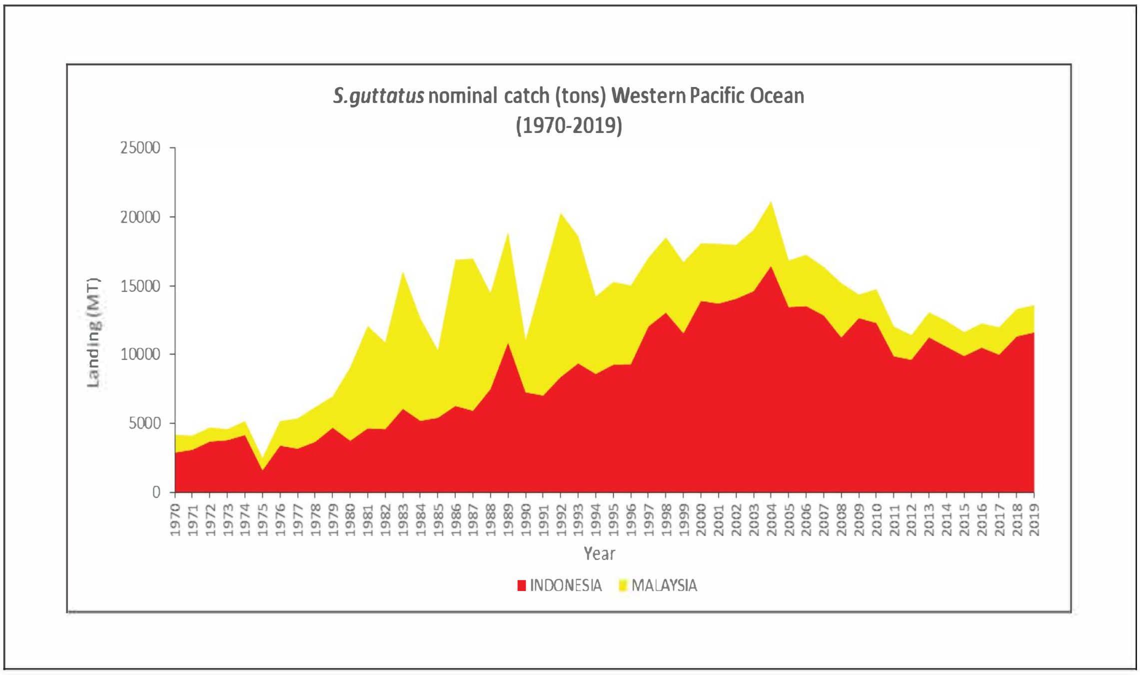


Figure 6: Nominal catch of *S. guttatus* in Western Pacific Ocean side by Indonesia and Malaysia (1970-2019).

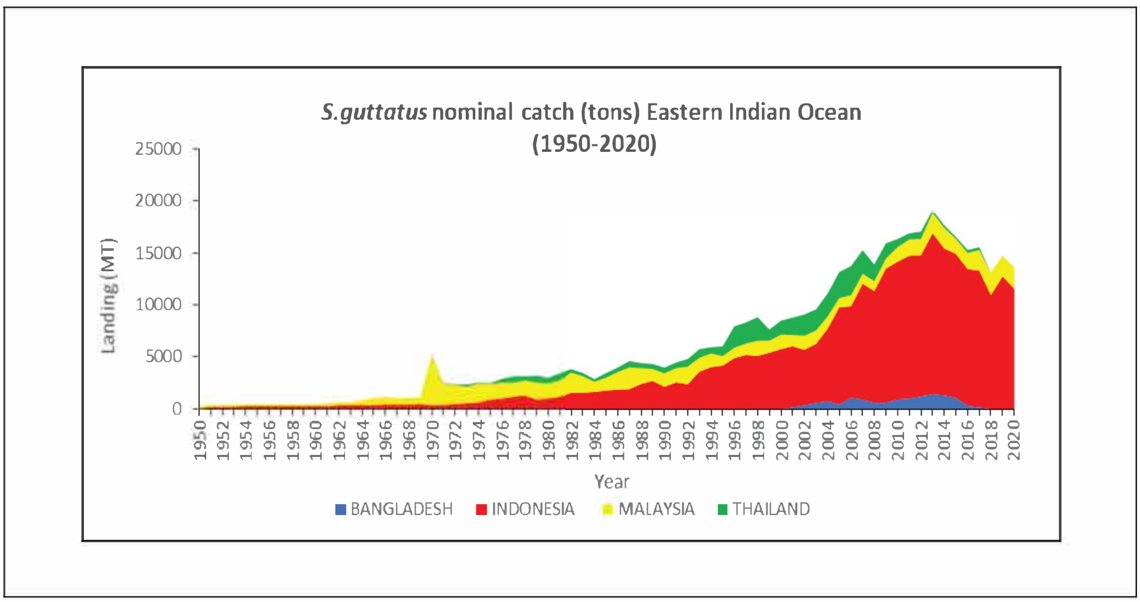


Figure 7: Nominal catch of *S. guttatus* in Eastern Indian Oceanside by Bangladesh, Indonesia, Malaysia, and Thailand (1950-2020).

1.3. Nominal CPUE

i) Collection of CPUE

Nominal CPUE is essential for ASPIC. In this analysis, nominal CPUE is generated from catch in tons and the number of vessels from several fishing gears in Malaysia (Anon 2008-2020). Selected plausible nominal CPUE of Narrow-barred Spanish and Indo-Pacific king mackerel for stock assessments as shown in Figures 8-11, which includes (a) available annual nominal CPUE (with the unit) by gear and year, (b) Catch trends, and (c) correlation between catch and selected nominal CPUE.

Nominal CPUE were selected based on the four criteria below:

a) Exclude nominal CPUE for less than ten years
b) Exclude nominal CPUE with abnormal trends
c) Exclude outliers, sudden jumps /drops, and zig-zag trend with a high magnitude
d) Select nominal CPUE with relatively high negative correlations between nominal CPUE

Country	Gear	Area	Correlation	Nominal CPUE	20xx											to be used in SA?	Reason
				Unit	9	10	11	12	13	14	15	16	17	18	19		
Malaysia	Hook & Line	Kota Belud	7.50%	tons/number of vessel												Yes	High correlation using join (12.50%)
Malaysia	Trawl	Kota Kinabalu	1.90%	tons/number of vessel												Yes	
Malaysia	Drift Net	Kunak	6.82%	tons/number of vessel												Yes	

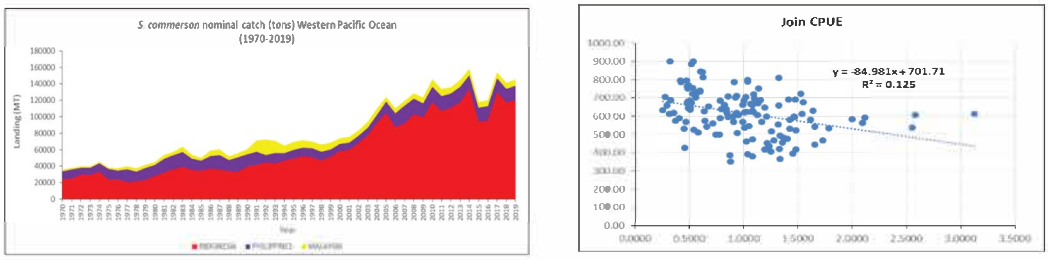


Figure 8: Catch trend and selected nominal CPUE and their correlations of *S.commerson* in the Western Pacific Ocean.

Country	Gear	Area	Correlation	Nominal CPUE	20xx												to be used in SA?	Reason
				Unit	9	10	11	12	13	14	15	16	17	18	19	20		
Malaysia	Drift Net	Melaka	1.25%	tons/number of vessel													Yes	High correlation using join (14.26%)
Malaysia	Trawl	Perak	0.38%	tons/number of vessel													Yes	
Malaysia	Drift Net	Perak	16.05%	tons/number of vessel													Yes	
Malaysia	Drift Net	Pulau Pinang	4.38%	tons/number of vessel													Yes	

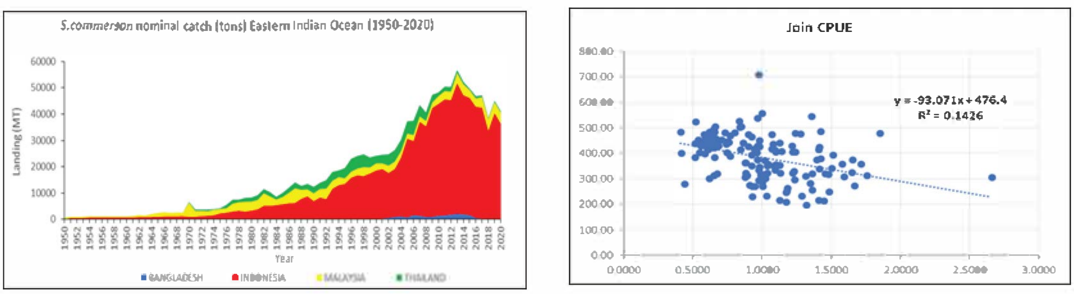


Figure 9: Catch trend and selected nominal CPUE and their correlations of *S.commerson* in the Eastern Indian Ocean.

Country	Gear	Area	Correlation	Nominal CPUE Unit	11xx 9	10	11	12	13	14	15	16	17	18	19	to be used in SA?	Reason
Malaysia	Hook & Line	Kota Belud	9.57%	tons/number of vessel												Yes	High correlation (9.57%)
Malaysia	Hook & Line	Pantai Timur	0.57%	tons/number of vessel												No	
Malaysia	Hook & Line	Sipitang	0.01%	tons/number of vessel												No	

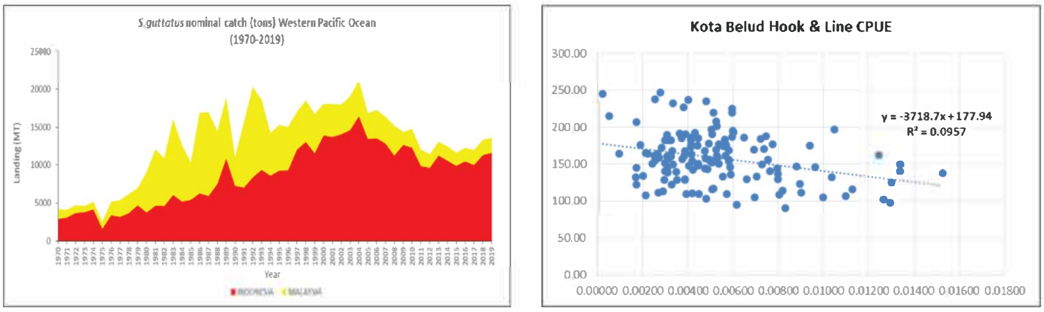


Figure 10: Catch trend and selected nominal CPUE and their correlations of *S.guttatus* in the Western Pacific Ocean.

Country	Gear	Area	Correlation	Nominal CPUE Unit	20xx 9	10	11	12	13	14	15	16	17	18	19	20	to be used in SA?	Reason
Malaysia	Drift Net	Melaka	1.62%	tons/number of vessel													Yes	High correlation using join (15.94%)
Malaysia	Drift Net	Perak	16.50%	tons/number of vessel													Yes	
Malaysia	Drift Net	Pulau Pinang	4.34%	tons/number of vessel													Yes	

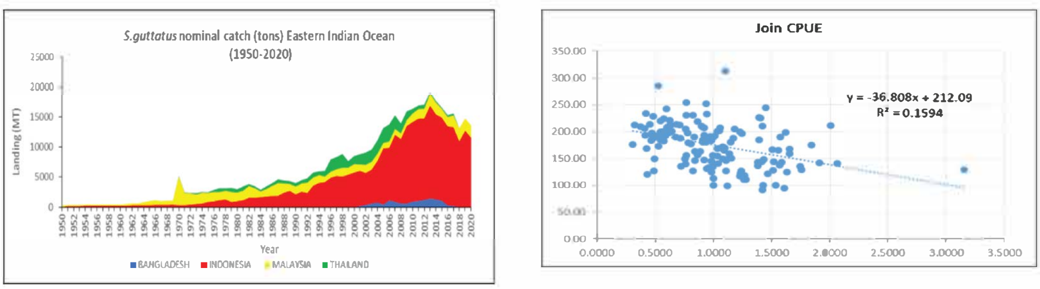


Figure 11: Catch trend and selected nominal CPUE and their correlations of *S.guttatus* in the Eastern Indian Ocean.

2.0 METHODS

Figures 12 and 13 show the methods used in the practical workshop on stock and risk assessments based on A Stock-Production Model Incorporating Covariates (ASPIC) (ver. 5) (Prager, 2004). Stock assessments are conducted by "ASPIC grid search" software developed by Nishida *et al.* (2018) and the original ASPIC program. Risk assessments were conducted using Kobe plot and risk assessment software developed by Nishida *et al.* (2018).

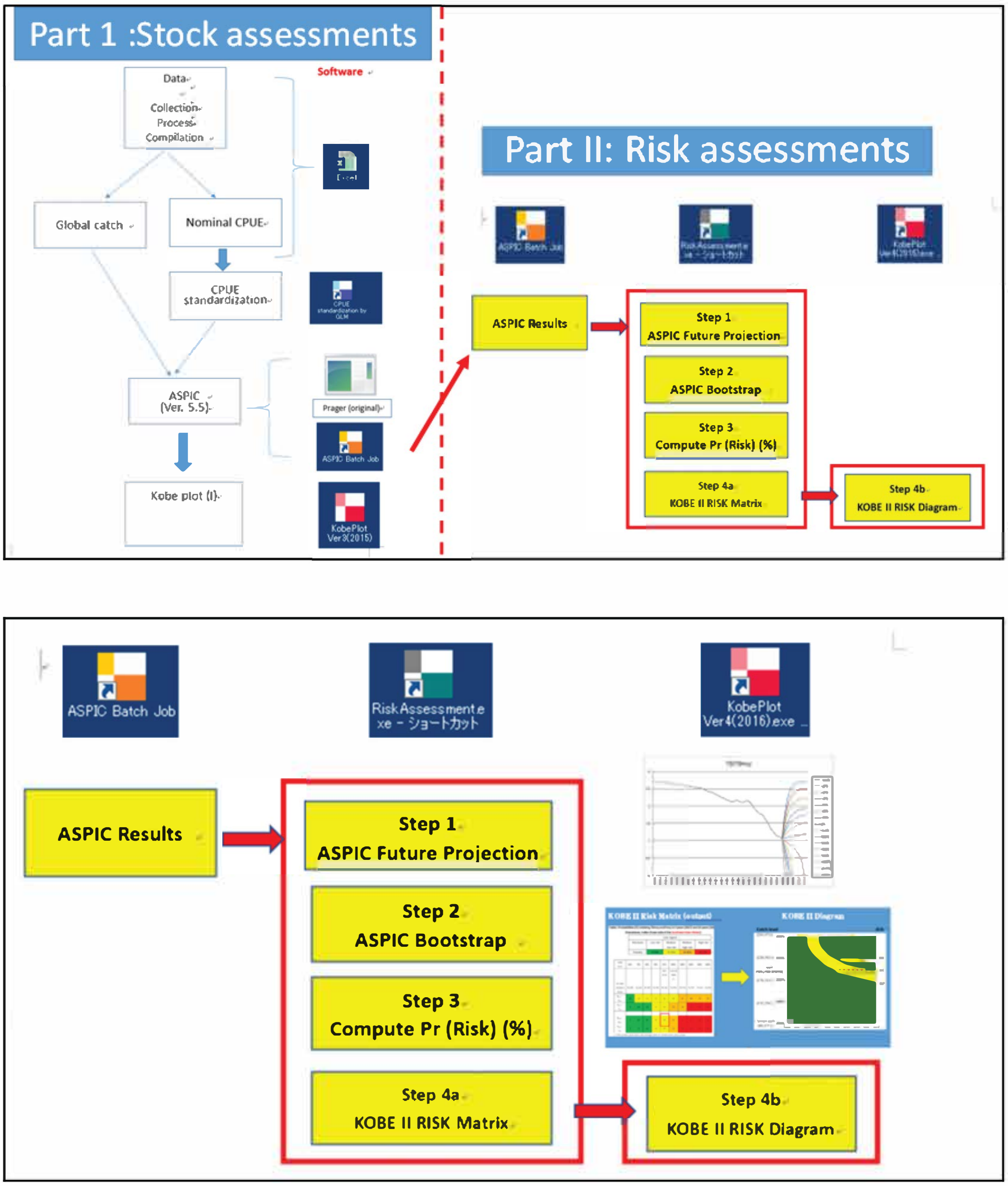
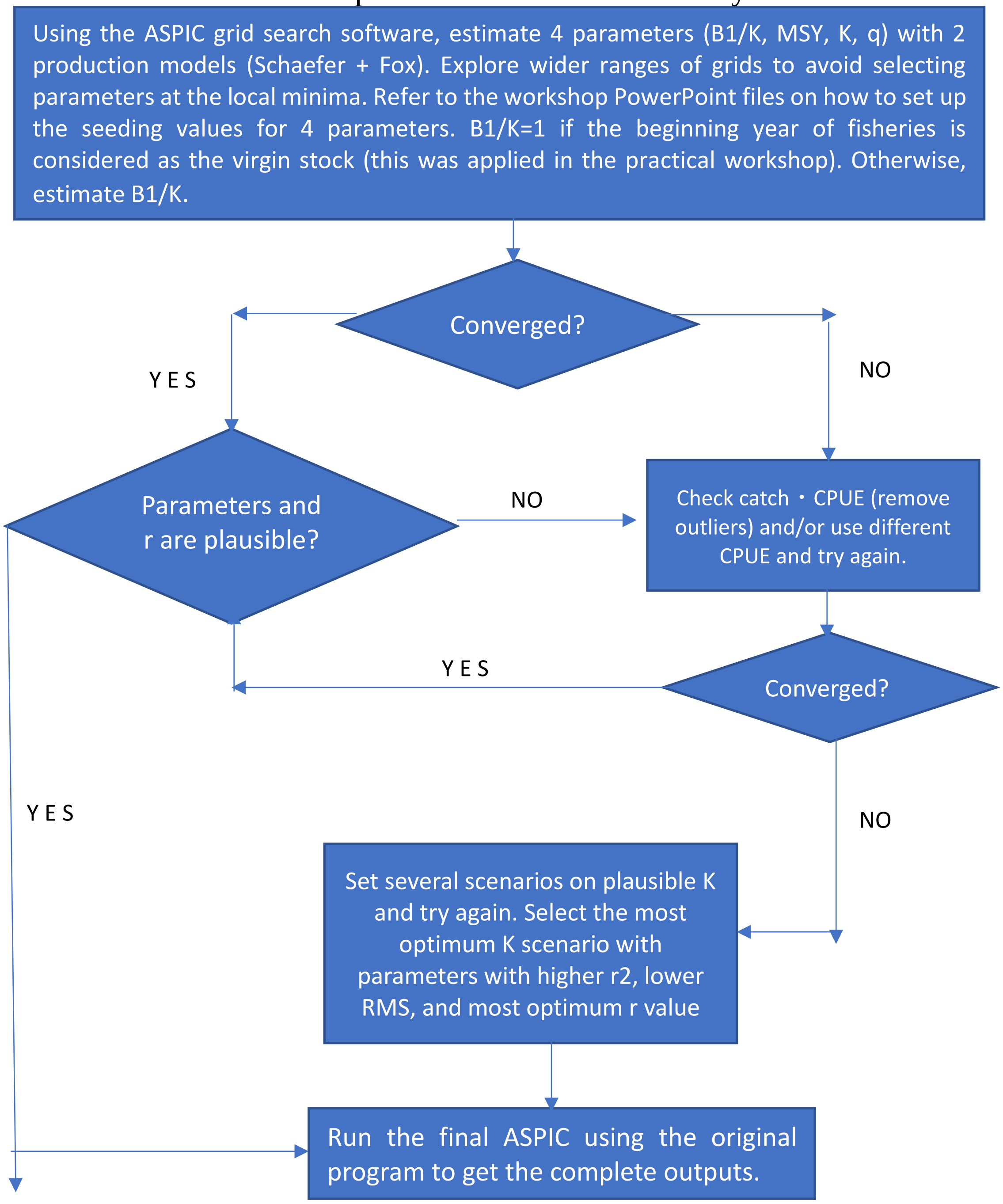


Figure 12: Flowchart of methods on stock and risk assessments based on A Stock-Production Model Incorporating Covariates (ASPIC).

Various steps and criteria were applied in running ASPIC as shown in the flowchart below.

Flowchart to implement stock assessments by ASPIC



Note
MS: Root Mean Square
r: Intrinsic population growth rate (see next page for details)

Figure 13: Flowchart to implement stock assessments by ASPIC

2.1. CPUE Standardization

Output from CPUE standardization software will produce an ANOVA table, time-series graphs of CPUE standardization with 95% confidential intervals and residual analyses (frequency distribution and QQ plots) in word file format and data(OBS+EST CPUE+CI) Nominal CPUE General Linear Model in excel file format.

r: Intrinsic population growth rate

Table 2 shows ranges of "r" (Pattarapongpan and Nishida, 2018). For these analyses, the optimum value is that the abound r=1 Narrow-barred Spanish mackerel and Indo-Pacific King mackerel.

Table 2: The ranges of "r" on *S. commerson* and *S. guttatus* from various references.

Spanish mackerel

r	Area	References
0.54 (0.27 – 1.09)	Worldwide	Fishbase
0.31	Western Australia	Mackie (2013)
0.6 – 1.5	Indian Ocean	IOTC (2015)
1.0 – 1.5	Indian Ocean	IOTC (2016)

King mackerel

r	Area	References
1.0 – 1.5	Indian Ocean	IOTC (2016)

2.2. A Stock Production Model Incorporating Covariates (ASPIC)

i) Batch Job

ASPIC Batch Job software will generate the optimum MSY, Total Biomass (TB), Fishing Mortality (F), estimate B1/K, K, and q. In batch jobs, the model surplus production model Fox and Schaefer models will be applied together with four parameters (B1/K, MSY, K, and q). The number of executed batch job depend on the setting of parameters.

ii) Parameters search

The output from the batch jobs analysis of estimate parameters is stored in Excel file format. The best combination of estimate parameters, including MSY, Total Biomass, F, TB/TBMSY, F/FMSY, and r, was selected based on the higher r^2 and lowest Root Mean Square (RMS) and also r value (closer to the optimum r).

Trials four (4) Flag code combination used to get the best estimation parameters output in ASPIC batch Jobs. Flag code (1= to estimate parameters and 0= not to estimate parameters but to provide value. The first trial is to set flag code in 1111 (B1/K, MSY, K, and q) respectively to estimate all four parameters. If there are no convergence in 1111, fixed one parameter of B1/K or K (set flag code as 0111 or 1101) and last trial if three (3) trails above fail to get convergence, fixed B1/K and K together (set flag code as 0101). It is reminded that MSY and q cannot be fixed during this analysis.

Choose a new seedling of MSY if four trials of flag code (1111, 0111, 1101, and 0101) do not have any plausible results and lastly, if there are still no plausible results, the raw data of catch and effort are not fit to ASPIC at all.

iii) Analysis ASPIC

Run ASPIC by scenario using Command Prompt, which is the best result from Batch Jobs. The ASPIC has two (2) modes of operation or program modes:

a. ASPIC fits the model in FIT mode and computes estimates of parameters and other quantities of management interest, including time trajectories of fishing intensity and stock biomass. Execution time is relatively short. File extension .FIT is the main output file from the FIT program mode to make the trajectories status stock (Kobe plots).

   Four types of times series graphs are Catch vs MSY, F vs FMSY, TB vs TBMSY, and observed vs predicted CPUE.

b. In BOT mode, ASPIC fits the model and computes bootstrapped confidence intervals on estimated quantities. Because computations are extensive, execution time in BOT mode is considerably longer than in FIT mode. File extension .BOT, .BIO (Estimated *B* and *F* trajectory for each bootstrap trial and .DET (Estimates from each bootstrap trial) are the main output files from BOT program mode,

iv) Kobe Plot

The first diagram of the results from the ASPIC analysis is the Kobe plot. The Kobe plot is used to illustrate the present status of a stock based on the fishing mortality (F) and Total biomass (TB) associated with maximum sustainable yield (MSY; i.e. F_{MSY} and TB_{MSY}). If the current fishing mortality (F) is above F_{MSY}, overfishing will occur; if the current biomass (TB; or some measure of spawning output) is below TB_{MSY}, the stock is judged as overfished. In the Kobe plot diagram, TB/TB_{MSY} is on the x-axis and F/F_{MSY} on the y-axis. The vertical and horizontal lines at 1.0 split the plot into four sections. The upper left represents undesirable catch: overfishing occurs, and an overfished stock; and the lower right represents a healthy stock: overfishing not occurs, and an underfished stock. The stock's trajectory over time is plotted so that the historical status of the stock can be seen.

2.3. Kobe matrix and risk assessment

The Kobe Strategy Matrix presents the specific management measures that would achieve the intended management target with a certain probability by a certain time. In the case of fisheries managed through effort, the outputs would be expressed as fishing effort levels or time/area closures. It would also indicate the additional levels of uncertainty associated with data gaps. Managers would be able to plan the best appropriate management methods based on the level of risk and timeframe determined according to the suitability of the fishery.

Please note that the current catch is not the actual catch of the present year but defined as the average for the last three years (2017-2019 or 2018-2020).This is because if only using the catch in the present year (2019 or 2020 for our situation) it is likely to be unusable or biased if the catch value is too low or too high which causes a sharp decrease or increase trend compared to the catch value from previous years. Threfore, the average catch for the last three years is used to produce accurate risk assessment results.

3.0 RESULTS

3.1. Narrow-barred Spanish Mackerel *S.commerson* (Western Pacific Ocean)

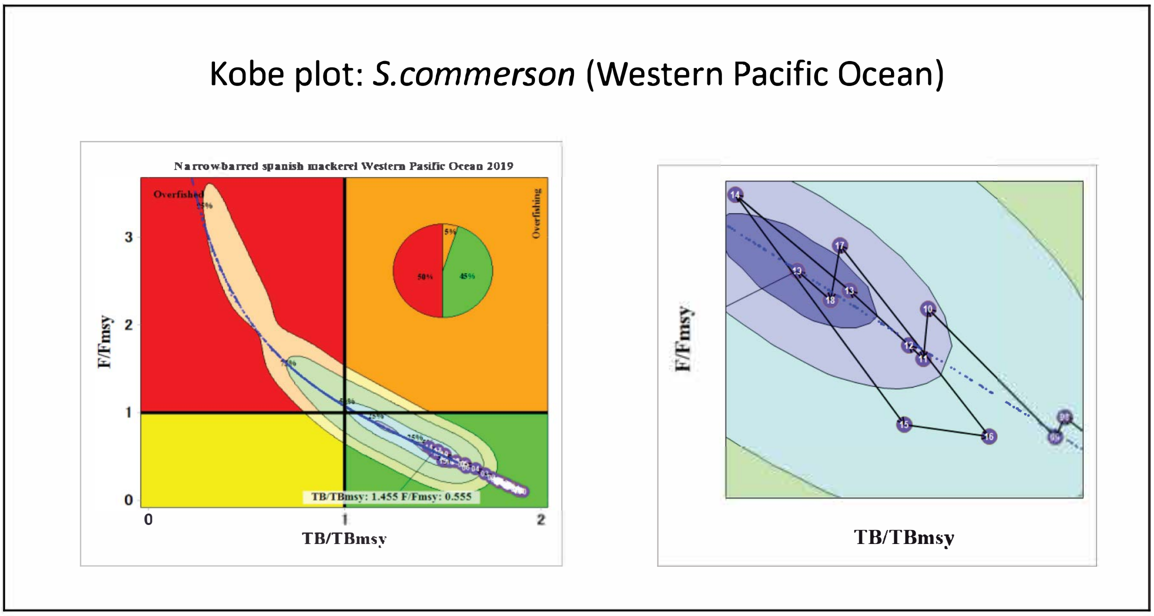


Figure 14: Kobe plot: Status stock (2019) of *S.commerson* (Western Pacific Ocean)

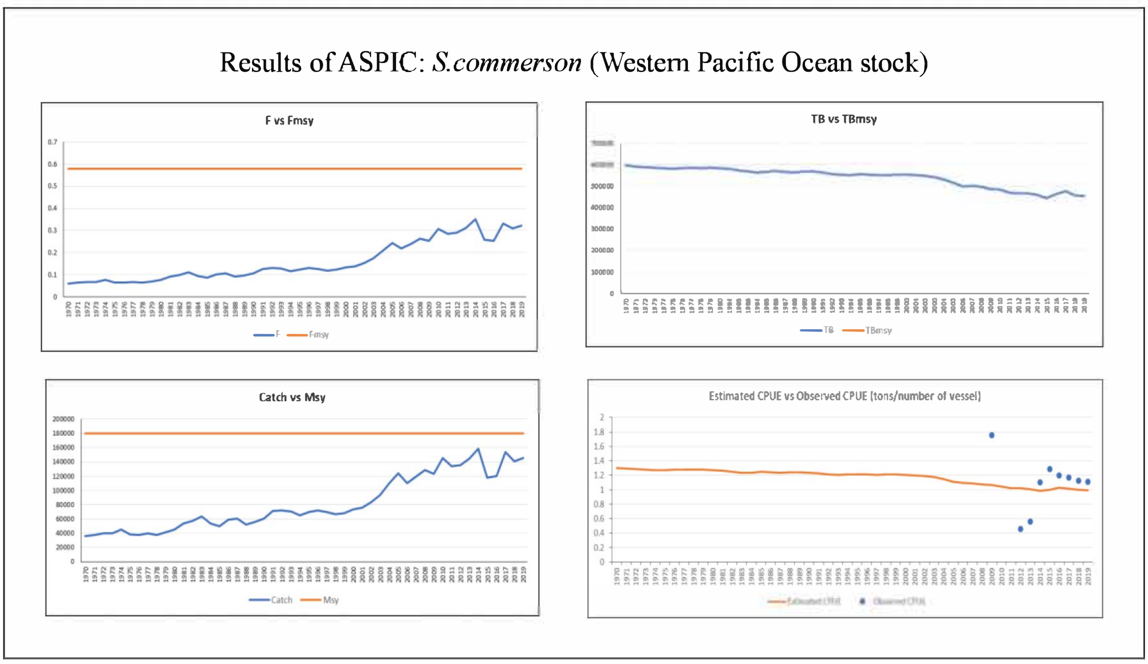


Figure 15: Results of ASPIC: *S.commerson* (Western Pacific Ocean stock)

Setting the starting guesses in the input file with data (File extension .inp), by B1/K=1.0, MSY= 111,300 (Range MSY= 93,000-217,000), K=452,000 (Range K=225,000-868,000) and q=0.0000026. There were no conversions when four parameters were estimated as a first attempt (1111). Then the workshop explored optimum parameters by setting flag code 1101. As a result, estimate TB=455,400 tons, MSY =179,600 tons, K=620,000, and q=0.00000219 were selected as the most plausible scenario in terms of r^2, RMS, and r value. Figure 14 shows the result of the Kobe plot indicating the stock status in 2019 is in the green zone (TB/TBmsy=1.455 and F/Fmsy=0.555). Figure 15 shows relevant graphs on results.

Observed CPUE were not well fit estimated CPUE as the patterns of observed CPUE are not evenly distributed around estimated CPUE. Figure 16 shows the results of risk assessments for TB and F. The stock status is in the safe zone or green zone situation with a probability of 45%. The workshop was highly concerned about this situation.

3.1.1. Risk Assessment of *S.commerson* (Western Pacific Ocean)

Based on the risk assessment, the current catch is below 22% of the MSY level, which is 146,932 tons (three years averaged in 2017-2019) and MSY (179,600), respectively (Figure 16). Potential fishing mortality at fishing mortality MSY (F/Fmsy) moving to safe or green zone areas for a period of three years and ten years requires a catch reduction of up to 60%. However, a decrease of 30% of catches is sufficient to avoid a 50% violation of MSY for both periods.

Kobe II

Risk matrix (2022+2029) (TB&F)

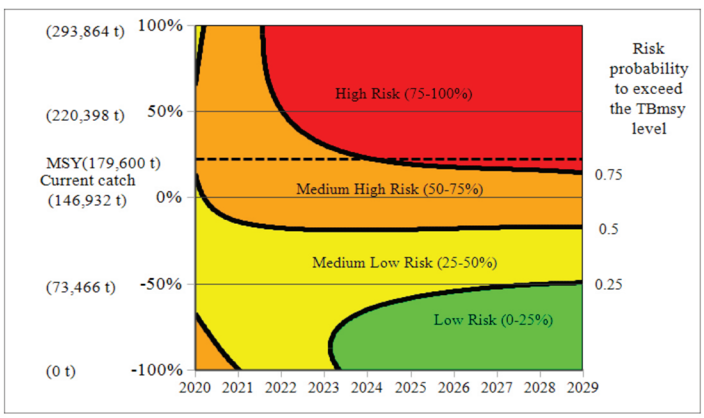
Probabilities(%) violating TBmsy and Fmsy in 3 and 10 years.

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0 - 25%	25 - 50%	50 - 75%	75 - 100

	0% (-100%)	20% (-80%)	40% (-60%)	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	100% Current catch (*)	110%	120%	122% MSY level	130%	140%	150%	200%	250%	300%
17 catch scenarios (tons)	0	29,386	58,773	88,159	102,852	117,546	132,239	146,932	161,625	176,318	179,600	191,012	205,705	220,398	293,864	367,330	440,796
TB2022 < TBmsy	31	34	39	44	47	50	54	56	60	63	64	67	70	72	87	99	100
F2022 > Fmsy	0	19	22	25	30	34	40	47	56	66	68	75	85	94	100	100	100
TB2029 < TBmsy	0	19	22	26	31	39	51	66	75	84	85	90	95	99	100	100	100
F2029 > Fmsy	0	19	22	25	30	36	46	60	73	84	85	92	98	100	100	100	100

(*)The current catch levelis the average catch in 3 recent years(2017-2019).

Risk Diagram (TB) (2020-2029)



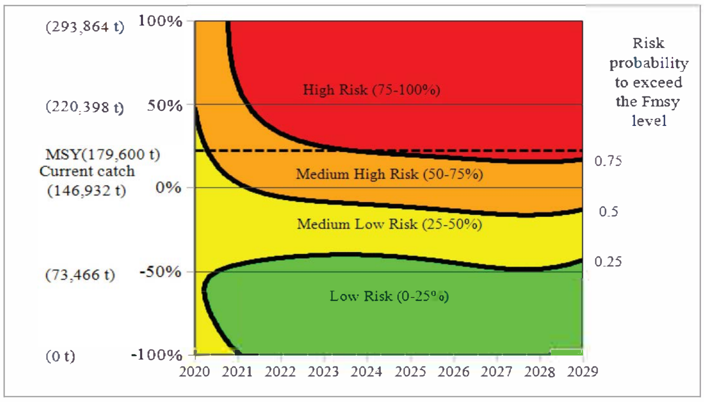
Risk Diagram (F) (2020-2029)	

Figure 16: Risk assessment of *S.commerson* in the Western Pacific Ocean.

3.2. Narrow-barred Spanish Mackerel *S.commerson* (Eastern Indian Ocean)

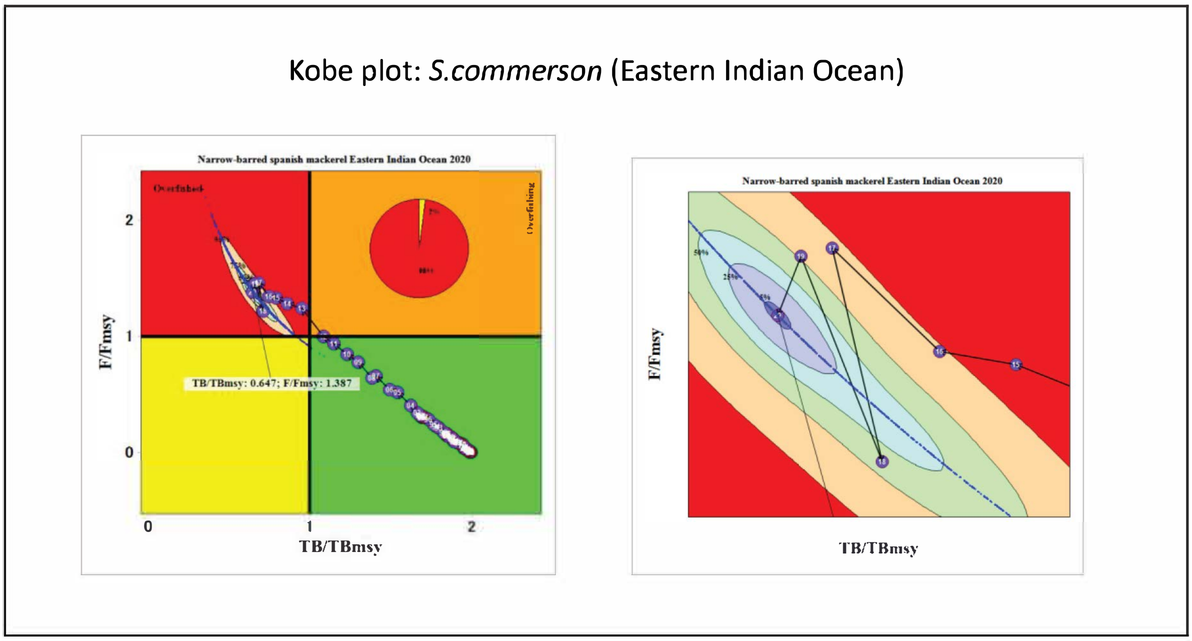


Figure 17: Kobe plot: Status stock (2020) of *S.commerson* (Eastern Indian Ocean).

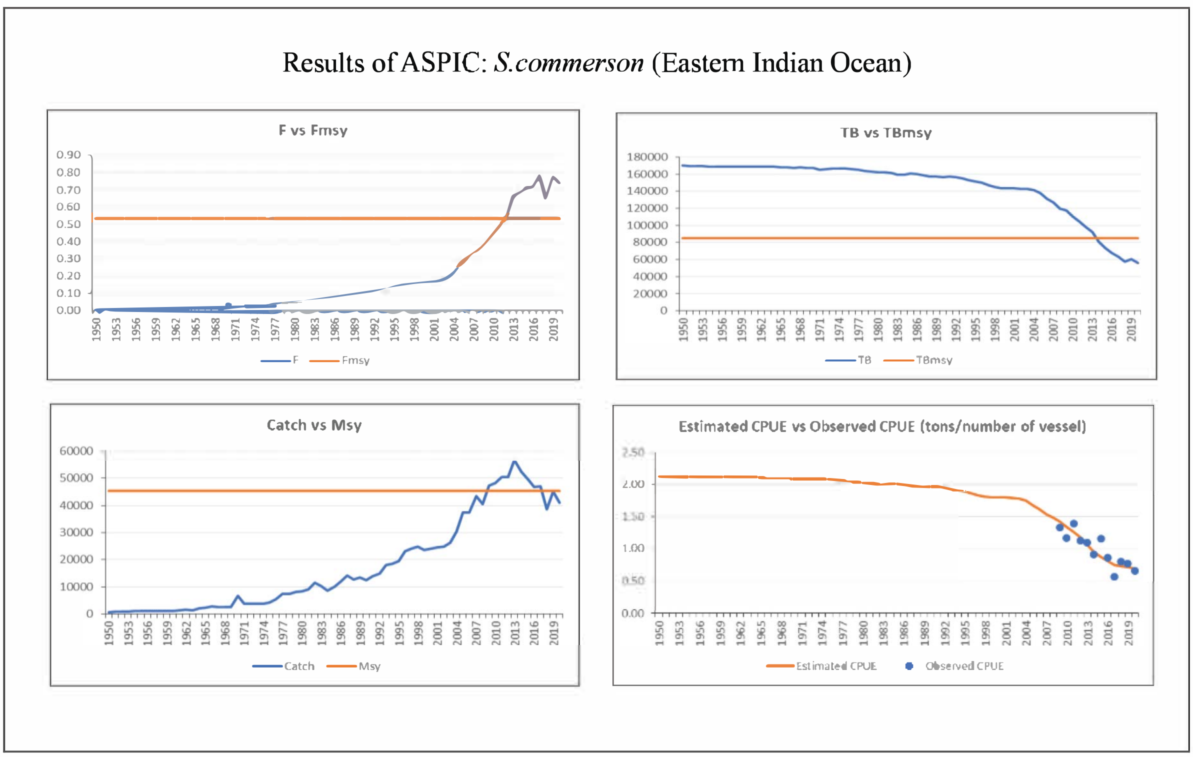


Figure 18: Results of ASPIC: *S.commerson* in the Eastern Indian Ocean

Setting the starting guesses in the input file with data (File extension.inp), by B1/K=1.0, MSY= 42,000 (Range MSY= 25,200-58,800), K=168,000 (Range K=60,000-235,000) and q=0.0.0000051. There were no conversions when four parameters were estimated as a first attempt (1111), second attempt (1101), and third attempt (0111). Then the workshop explored optimum parameters by setting flag code 0101. As a result, estimate TB=56,160 tons, MSY =45,310 tons, K=170,000 and q=0.0000125 were selected as the most plausible scenario in terms of r2, RMS, and r value. Figure 17 shows the result Kobe plot indicating the stock status in 2020 is in the red zone (TB/TBmsy=0.647 and F/Fmsy=1.387). Figure 18 shows relevant graphs on results. Observed CPUE were not well fit estimated CPUE as the patterns of observed CPUE are not evenly distributed around estimated CPUE. Figure 19 shows the results of risk assessments for TB and F.

The stock status is in the overfished zone or red zone with a probability of 98%. The workshop was highly concerned about this situation.

3.2.1. Risk Assessment of *S.commerson* (Eastern Indian Ocean)

Based on the risk assessment, the current catch is below 9% of the MSY level, which is 41,539 tons (three years averaged in 2017-2019) and MSY (45,310), respectively (Figure 19). Potential fishing mortality at fishing mortality MSY (F/Fmsy) moving to safe or green zone areas for a period of 3 years and ten years requires a catch reduction of up to 60% and 20%, respectively. However, a reduction of 20% and 10% of catches in three and ten years is sufficient to avoid 50% violation the MSY level.

Kobe II

Risk matrix (2023&2030) (T&BF)

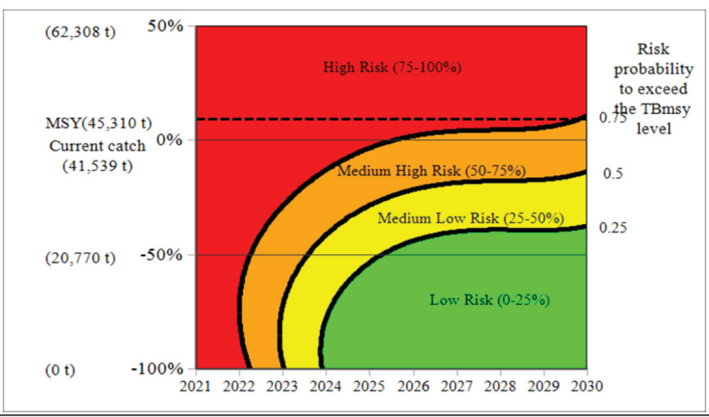
Probabilities(%) violating TBmsy and Fmsy in 3 and 10 years.

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0 - 25%	25 - 50%	50 - 75%	75 - 100

	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	100%	109%	110%	120%	130%	140%
					Current catch (*)	MSY level				
10 catch scenarios (tons)	24,923	29,077	33,231	37,385	41,539	45,310	45,693	49,847	54,001	58,155
TB2023 < TBmsy	83	90	93	96	98	99	99	100	100	100
F2023 > Fmsy	12	25	48	74	93	98	99	100	100	100
TB2030 < TBmsy	6	12	24	48	79	96	98	100	100	100
F2030 > Fmsy	6	11	23	44	76	96	98	100	100	100

(*)The current catch levelis the average catch in 3 recent years(2018-2020).

Risk Diagram (TB) (2021-2030)



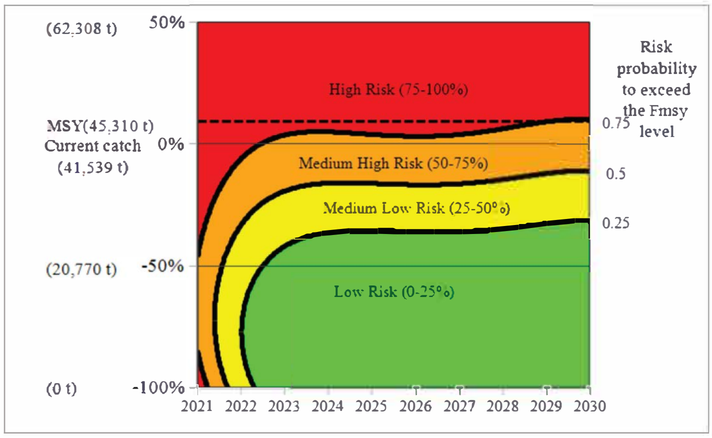
Risk Diagram (F) (2021-2030)	

Figure 19: Risk assessment of *S.commerson* (Eastern Indian Ocean).

3.3. Indo-Pacific King Mackerel *S. guttatus* (Western Pacific Ocean)

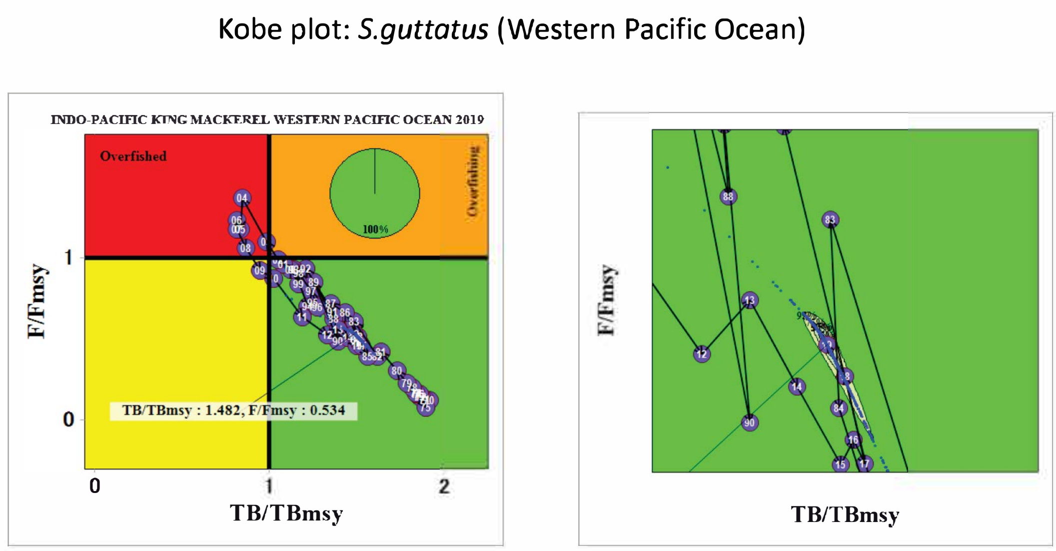


Figure 20: Kobe plot: Status stock (2019) of *S.guttatus* in the Western Pacific Ocean.

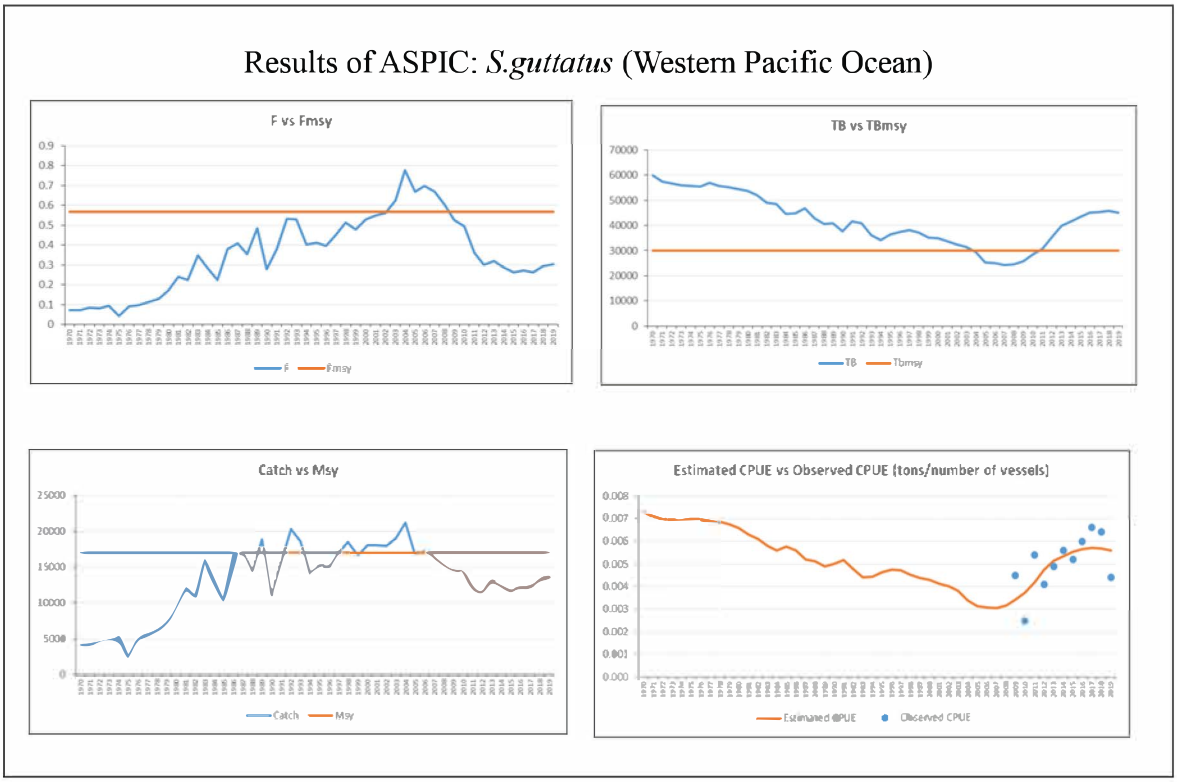


Figure 21: Results of ASPIC: *S.guttatus* in the Western Pacific Ocean.

Setting the starting guesses in the input file with data (File extension.inp), by B1/K=1.0, MSY= 15,100 (Range MSY= 9,060-21,100), K=60,400 (Range K=36,200-84,600) and q=0.00000014. There were no conversions when four parameters were estimated as a first attempt (1111), second attempt (1101), and third attempt (0111). Then the workshop explored optimum parameters by setting flag code 0101. As a result, estimate TB=45,080 tons, MSY =17,060 tons, K=60,400 and q=0.000000125 were selected as the most plausible scenario in terms of r2, RMS, and r value. Figure 20 shows the result of the Kobe plot indicating the stock status in 2019 is in the green zone (TB/TBmsy=1.482 and F/Fmsy=0.534). Figure 21 shows relevant graphs on results. Observed CPUE were not well fit estimated CPUE as the patterns of observed CPUE are not evenly distributed around estimated CPUE. Figure 22 shows the results of risk assessments for TB and F.

3.3.1. Risk Assessment of *S.guttatus* (Western Pacific Ocean side)

Based on the risk assessment, the current catch level of 12,962 tons (three years averaged in 2017-2019) is below 32% of the MSY level (17,060) (Figure 22). The catch can be increased up to 32% (4,148 tons) to the MSY level with caution.

Kobe II

Risk matrix (2022&2029) (TB&F)

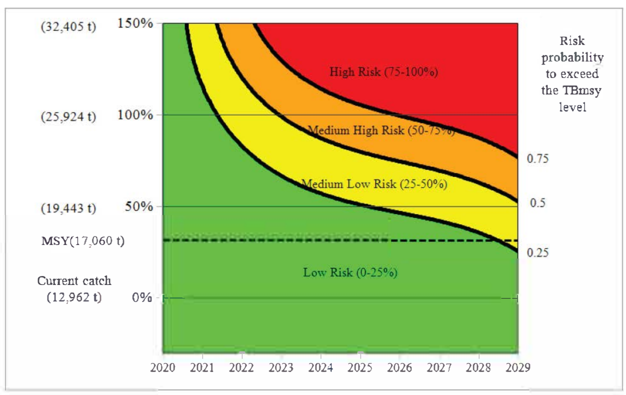
Probabilities(%) violating TBmsy and Fmsy in 3 and 10 years.

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0 - 25%	25 - 50%	50 - 75%	75 - 100

	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	100% Current catch (*)	110%	120%	130%	132% MSY level	140%
10 catch scenarios (tons)	7,777	9,073	10,370	11,666	12,962	14,258	15,554	16,851	17,060	18,147
TB2022 < TBmsy	0	0	0	0	0	0	0	0	0	0
F2022 > Fmsy	0	0	0	0	0	0	0	0	0	0
TB2029 < TBmsy	0	0	0	0	0	0	0	0	12	61
F2029 > Fmsy	0	0	0	0	0	0	0	0	18	88

(*)The current catch levelis the average catch in 3 recent years(2017-2019).

Risk Diagram (TB) (2020-2029)



Risk Diagram (F) (2010-2029)

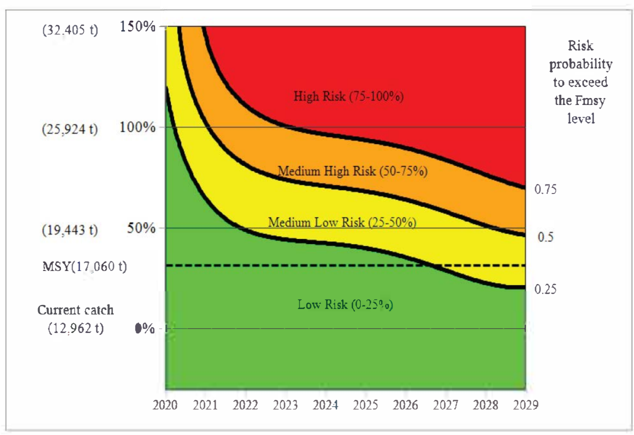


Figure 22: Risk assessments of *S.guttatus* in the Western Pacific Ocean.

3.4. Indo-Pacific King Mackerel *S. guttatus* (Eastern Indian Ocean)

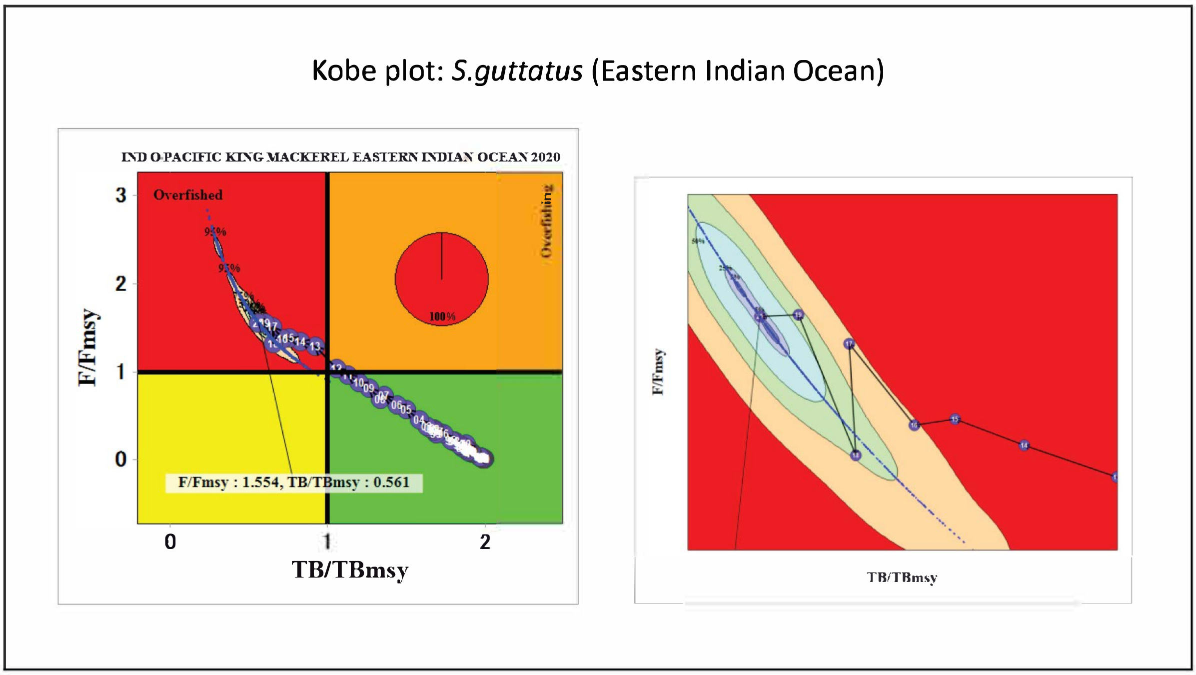


Figure 23: Kobe plot: Status stock (2020) of *S.guttatus* (Eastern Indian Ocean).

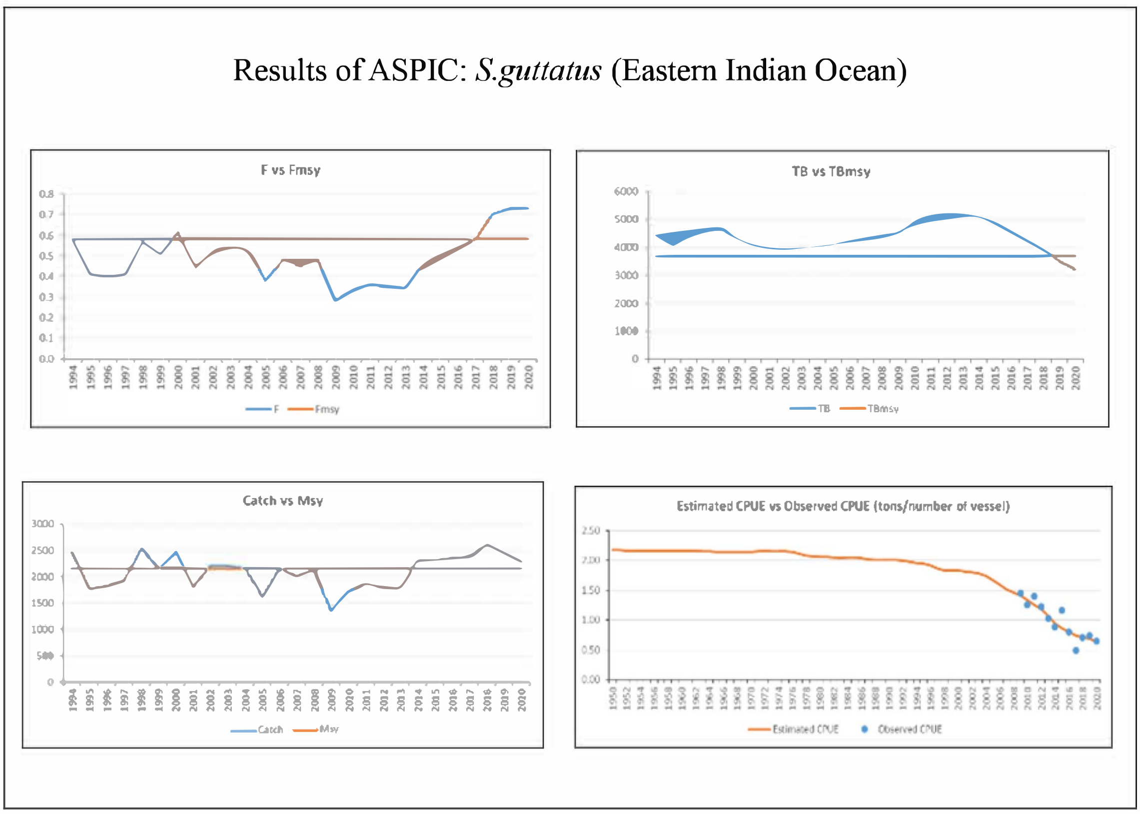


Figure 24: Results of ASPIC: *S.guttatus* in the Eastern Indian Ocean.

Setting the starting guesses in the input file with data (File extension.inp), by B1/K=1.0, MSY= 15,000 (Range MSY= 9,000-21,000), K=60,000 (Range K=23,000-84,000) and q=0.0000141. There were no conversions when four parameters were estimated as a first attempt (1111), second attempt (1101), and third attempt (0111). Then the workshop explored optimum parameters by setting flag code 0101. As a result, estimate TB=18,000 tons, MSY =15,070 tons, K=60,000 and q=0.0000363 were selected as the most plausible scenario in terms of r2, RMS, and r value. Figure 23 shows the result Kobe plot indicating the stock status in 2020 is in the red zone (TB/TBmsy=0.561 and F/Fmsy=1.554). Figure 24 shows relevant graphs on results. Observed CPUE were not well fit estimated CPUE as the patterns of observed CPUE are not evenly distributed around estimated CPUE. Figure 25 shows the results of risk assessments for TB and F.

The stock status is in the serious overfished zone or red zone with a probability of 100%. The workshop was highly concerned about this situation.

3.4.1. Risk Assessment of *S.guttatus* (Eastern Indian Ocean)

Based on the risk assessment, the current catch is below 9% of the MSY level, which is 13,784 tons (three years averaged in 2017-2020) and MSY (15,070), respectively (Figure 25). Potential fishing mortality at fishing mortality MSY (F/Fmsy) moving to safe or green zone areas for a period of 3 and ten years requires a catch reduction of up more than 40%. However, a reduction of 40% and 20% of catches in three and ten years is sufficient to avoid 50% violation of MSY level.

Kobe II

Risk matrix (2023&2030) (TB&F)

Probabilities(%) violating TBmsy and Fmsy in 3 and 10 years.

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0 - 25%	25 - 50%	50 - 75%	75 - 100

	60% (-40%)	70% (-30%)	80% (-20%)	90% (-10%)	100%	109%	110%	120%	130%	140%
					Current catch (*)	MSY level				
10 catch scenarios (tons)	8,270	9,649	11,027	12,406	13,784	15,070	15,162	16,541	17,919	19,298
TB2023 < TBmsy	95	97	98	99	99	100	100	100	100	100
F2023 > Fmsy	29	52	77	91	98	100	100	100	100	100
TB2030 < TBmsy	17	29	50	76	93	99	100	100	100	100
F2030 > Fmsy	16	27	48	73	91	99	100	100	100	100

(*)The current catch levelis the average catch in 3 recent years(2018-2020).

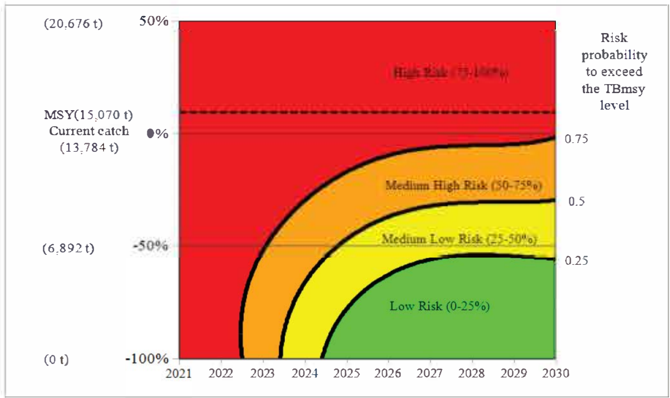
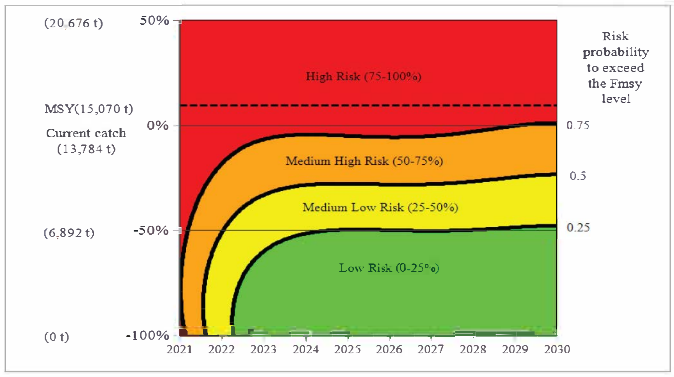
Risk Diagram (TB) (2021-2030)	
Risk Diagram (F) (2021-2030)	

Figure 25: Risk assessments of *S.guttatus* in the Eastern Indian Ocean.

4.0 DISCUSSION

Indo-Pacific king mackerel, *Scomberomorus guttatus* (locally known as Tenggiri papan), and Narrow-barred Spanish mackerel, *Scomberomorus commerson* (Locally known as Tenggiri Batang) belong to the family Scombridae and seer fish group, are pelagic species. *S. guttatus* is believed to be less migratory compared to *S. commerson* (Fishbase, 1995). The catch of *S. commerson* is consistently higher than *S. guttatus* since these fisheries were introduced five (5) to seven (7) decades ago in the Western Pacific Ocean and Eastern Indian Ocean, respectively. This seer fish is a pelagic widely distributed in coastal water, including in Malaysian waters.

During the workshop, the republished catch from Indian Ocean Tuna Commission (IOTC) Secretariat database for the period 1950-2020 and the FAO database for the period 1970- 2019 were used as a global catch in the Eastern Indian Ocean and Western Pacific Ocean area respectively.

Gentle reminded that previous analysis conducted by SEAFDEC/SEC utilized CPUE data from several member countries whereas recent discussion utilize only CPUE data from DOF Malaysia. Hence, any comparison between those two results would be incomparable. The comparison of previous (2016) and current (2020) seer fish status stocks in both regions (Western Pacific Ocean and Eastern Indian Ocean) can be discussed if both use nominal CPUE from Malaysia in ASPIC analysis.

Drift net and hook & line are the potential fishing efforts for best nominal CPUE in all areas except at Western Pacific Ocean which only hand & line can produce the best nominal CPUE. The nominal CPUE join process is carried out when more than one nominal CPUE generated in a single area (Figures 8 until 11.). Through this analysis, *S guttatus* of the Western Pacific Ocean did not go through the join process of nominal CPUE. This is because only one fishing gear is the best to get the nominal CPUE, which is hand-line.

4.1. Stock Status

Narrow-barred Spanish Mackerel *S. commerson* (Western Pacific Ocean)

The stock status of Narrow-barred Spanish mackerel for 2016 and 2019 is available based on ASPIC conducted by SEAFDEC/TD and SEAFDEC/MFRDMD respectively (Figure 26). ASPIC 2016 was conducted using nominal CPUE from the Philippine for 15 years with a high correlation (52%), while for status stock 2019, the nominal CPUE was using nominal CPUE from Malaysian for 11 years with a 12.5% correlation. The difference and uncertainty of nominal CPUE and the degree of correlation will affect the results of stock and risk assessment.

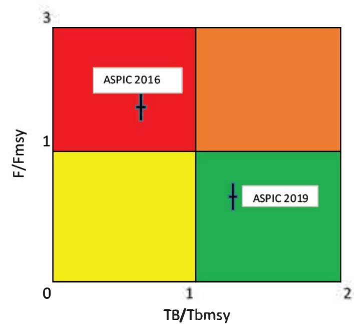


Figure 26: Comparison of stock status of Spanish mackerel (Western Pacific Ocean) between 2016 and 2019 using different (the Philippines and Malaysia) nominal CPUE and degree of correlation.

Narrow-barred Spanish Mackerel *S. commerson* (Eastern Indian Ocean)

The status of Spanish mackerel in the Eastern Indian Ocean is available for 2016 (SEAFDEC/TD), and status 2020 (from SEAFDEC/MFRDMD) showed a marked in stock changes. In 2016, the stock was on the edge of green zone, but the uncertainty of overfished was 71% compared to only 25% in the safe zone. While stocks in 2020 have been in the overfished zone with uncertainty in the red zone being higher at 99%. (Figure 27)

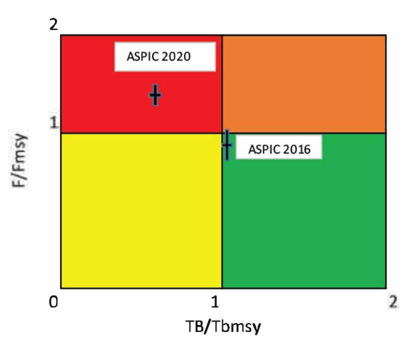


Figure 27: Comparison of stock status of Narrow-barred Spanish Mackerel (Eastern Indian Ocean) between 2016 and 2020 using Malaysian nominal CPUE.

The nominal catches of Spanish mackerel are above MSY levels (45,310 tonnes) from 2013 and prolonged to 2017, and status stocks were in the red zone. Yet, from 2018 until now, the landing was below the MSY level, but its status was still in the red zone. This is because fishing mortality (F) has remained above the Fmsy level since 2013 and has not decreased even with declining catches (Figure 18). Spanish mackerel landings declined after 2015 until the present year, but it was not enough to restore the status stock to better conditions. As proposed in management advice, a 10% reduction in catches for the next ten years is expected to restore status stock in a better zone.

Indo-Pacific King Mackerel *S. guttatus* (Western Pacific Ocean)

The status of Indo-Pacific King mackerel in the Western Pacific Ocean is available for 2016 (SEAFDEC/TD), and the status in 2019 (from SEAFDEC/MFRDMD) shows not much change in the status of stock (Figure 28). Based on the current catch in 2017-2019 is 12,962 tons and this average catch increased approximately only 10 % from the current catch in 2016, 11,592 tons (Figure 29). In this situation, the current catch of Indo-Pacific King mackerel is still below the MSY level, and the status will not much change from the previous status stock (2016). The status stock can be maintained in the safe zone if the catches can be maintained as in previous years.

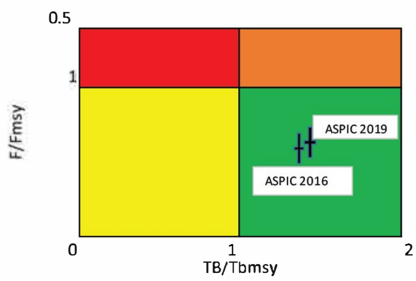


Figure 28: Comparison of stock status of Indo-Pacific King Mackerel (Western Pacific Ocean) between 2016 and 2019 using Malaysian nominal CPUE.

Probabilities(%) violating TBmsy and Fmsy in 3 and 10 years.

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0 - 25%	25 - 50%	50 - 75%	75 - 100

	60%	70%	80%	90%	100%	110%	120%	130%	131%	140%
					Current catch (*)				MSY level	
10 catch scenarios (tons)	6,955	8,114	9,274	10,433	11,592	12,751	13,910	15,070	15,130	16,229
TB2019 < TBmsy	5	5	6	6	6	7	8	8	8	9
F2019 > FMSY	2	2	2	3	4	5	6	8	9	16
TB2026 < TBmsy	2	2	2	2	3	5	7	33	38	87
F2026 > FMSY	2	2	2	2	3	4	6	36	42	97

(*)The current catch levelis the average catch in 3 recent years(2014-2016).

Figure 29: Results of risk assessment on table Kobe matrix of Indo-Pacific King Mackerel in Western Pacific Ocean 2016. (SEAFDEC/TD).

Indo-Pacific King Mackerel *S. guttatus* (Eastern Indian Ocean)

The status of Indo-Pacific King mackerel in the Eastern Indian Ocean is available for 2016 (SEAFDEC/TD), and status 2020 (from SEAFDEC/MFRDMD) showed a change in status stock from safe zone to red zone (Figure 30). ASPIC result shows the fishing mortality F exceeded the FMSY level since 2017, while the nominal catch exceeded the MSY level since 2014 (Figure 24). The continuous increase in landings since 2014 has had a high impact on the status stock of King Mackerel on the West coast of Peninsular Malaysia.

The analysis conducted for the IOTC waters using the Catch-MSY limited data showed that the status stock 2020 was still in the safe zone; however, it was approaching the overfishing and overfished areas (F/FMSY 0.98: B/BMSY 1.13) (IOTC, 2020). The status comparison between IOTC and SEAFDEC/MFRDMD is not appropriate because the present analysis conducted by SEAFDEC/MFRDMD uses data only in the Eastern Indian Ocean (Bangladesh, Indonesia, Thailand, and Malaysia) and uses relatively limited nominal CPUE data from Malaysia (Figure 31).

Clearly stated by SEAFDEC/MFRDMD, the stock status of King Mackerel in the Eastern Indian Ocean or the West Coast waters of Peninsular Malaysia has been overfished.

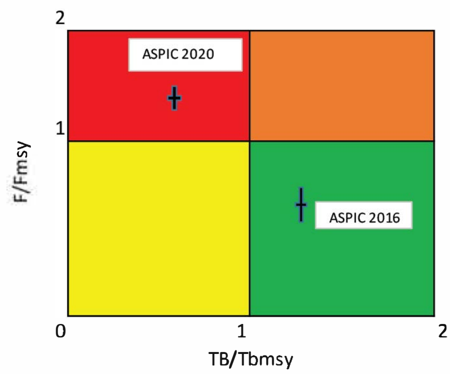


Figure 30: Comparison of stock status of Indo-Pacific King Mackerel (Eastern Indian Ocean) between 2016 and 2020 using Malaysian nominal CPUE

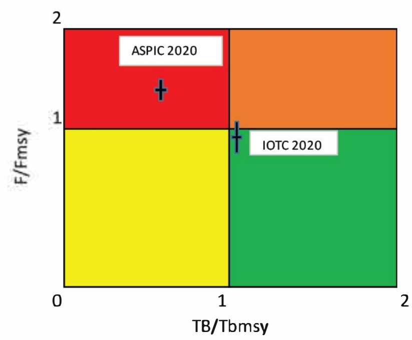


Figure 31: Comparison of stock status of Indo-Pacific King Mackerel (SEAFDEC/MFRDMD) and IOTC (using data limited Catch-MSY Method)

4.2. Optimum catch levels

The optimum catch level is based on the risk assessment results shown in the table risk matrix. Table 3 shows the summary results of stock, risk assessment and suggestion of the optimum catch level within 3 or 10 years of each species by area to management. A simple action to reduce or increase can be difficult because different fishing gears are used in Malaysia to catch *S. commerson* and *S. guttatus*.

It will get complicated when both species being caught in the same fishing gear but in different percentages. Hand & line, drift net, and trawl nets are the dominant fishing gear to caught seer fish. These three fishing gears have a high probability or potential to catch *S. commerson* compared to *S. guttatus* in Malaysian waters.

Table 3: Summary of results stock and risk assessments and the suggested optimum catch levels (TACs)

	Western Pacific Ocean		**Eastern Indian Ocean**	
	S.commerson	*S.guttatus*	*S.commerson*	*S.guttatus*
Stock status (Color in the KOBE plot)	TB/TBmsy = 1.455 F/Fmsy = 0.555 **45%**	TB/TBmsy = 1.482 F/Fmsy = 0.534 **100%**	TB/TBmsy = 0.647 F/Fmsy = 1.387 **98%**	TB/TBmsy = 1.554 F/Fmsy = 0.561 **100%**
MSY (tons)	179,600	17,060	45,310	15,070
Current catch level (tons) Average 3 years	146,932 (ave= 2017-2019)	12,962 (ave= 2017-2019)	41,539 (ave= 2018-2020)	13,784 (ave= 2018-2020)
Optimum catch level (need to update every years	102,852 (3 & 10 yr)	17,060 (3 & 10 yr)	37,385 (10yr)	9,649 (10 yr)
Reduction (-) or increase (+). From the current to optimum catch level	-30%	+32%	-10% (10yr)	-30% (10yr)

4.3. Management Advices

Narrow-barred Spanish Mackerel *S. commerson* (Western Pacific Ocean)

Based on the risk assessment, the current catch of level 146,932 tons, (three years averaged in 2017-2019) is below the MSY (179,600). Even if the current catch is below the MSY level, the catch can be maintained in the catch or should be reduced to at least 30% from the current catch to secure MSY levels for both TB and F in 50% probability of violating MSY level in three to ten years respectively.

Narrow-barred Spanish Mackerel *S. commerson* (Eastern Indian Ocean)

Based on the risk assessment, the current catch level of 41,539 tons (three years averaged in 2018-2020) is below the MSY level (45,310). Even if the current catch is below the MSY level, the catch should be reduced to at least 10% from the current catch to secure MSY levels for both TB and F with a 50% probability of violating the MSY level in 10 years. The manager can choose the best action period for ten years for fisheries managing planning of *S. commerson* in the Eastern Indian Ocean area.

Indo-Pacific King Mackerel *S. guttatus* (Western Pacific Ocean)

Based on the risk assessment, the current catch level of 12,962 tons, (3 years averaged in 2017-2019) is below the MSY level (17,060). The catch can be increased by 32% (4,148 tons) to the MSY level. Even increase to MSY level, the probabilites of violating MSY (TB and F) is less than 18% in three and ten years (2022 and 2029), respectively. The manager can choose the best action period for 3 or 10 years for fisheries managing planning of *S. guttatus* in the Western Pacific Ocean area.

Indo-Pacific King Mackerel *S. guttatus* (Eastern Indian Ocean)

Based on the risk assessment, the current catch level of 13,784 tons, (three years averaged in 2018-2020) is below the MSY level (15,070). Even if the current catch level is below MSY level, the catch should be reduced to at least 30% from the current catch to secure MSY levels for both TB and F at a 50% probability of violating MSY level in ten years. The manager can choose the best action period for ten years for fisheries managing planning of *S. guttatus* in the Eastern Indian Ocean.

5.0 FINAL REMARK

The results of the ASPIC analysis from the workshops conducted should be viewed carefully due to limited data, nominal CPUE, and the results of CPUE Standardization. This is because the data used to obtain the nominal CPUE is only from Malaysia. The overall landing data or Global Catch is not obtained comprehensively from countries in the Eastern Indian Ocean region or the Western Pacific Ocean. Of course, the results of this analysis do not show the complete accuracy of the stock status. Still, it can be used as a guide, especially for the Department of Fisheries Malaysia in managing mackerel fisheries as proposed in the management advice.

It is advisable to analyze the status stock every two years of seer fish. Also, it can review the effectiveness of control and management of seer fish fisheries as proposed in management advice. Countries' involvement in both regions should be conducted in the SEAFDEC/TD 2018 mackerel workshop to obtain more accuracy in the ASPIC analysis.

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7.0 APPENDICES

7.1. Group presentation

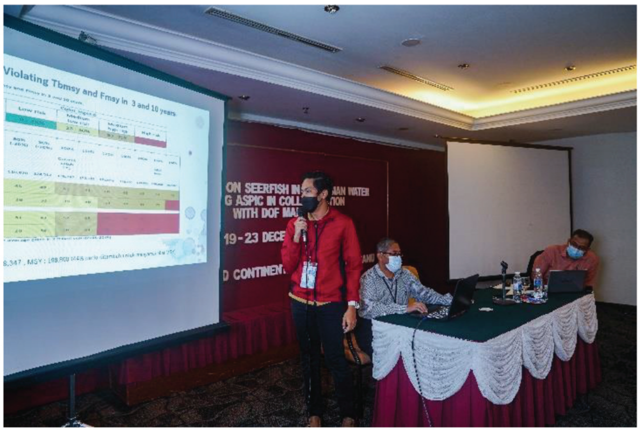

Figure 32: Presentation stock and risk assessments for *S.commerson* in WPO and EIO.

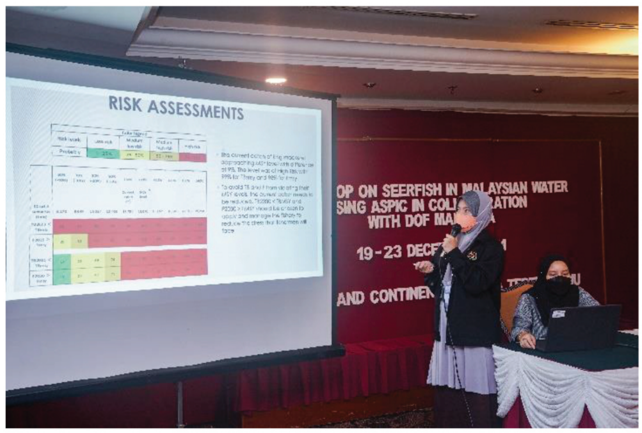

Figure 33: Presentation stock and risk assessments for *S.guttatus* in WPO and EIO.

7.2. List of Participants (Alphabatical order)

Effarina Mohd Faizal Abdullah

Hamizah Nadia Alias @ Yusof

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Mohammad Faisal Md. Saleh

Mohd Sukri Muda

Norazua Anishah Mohamad Noor

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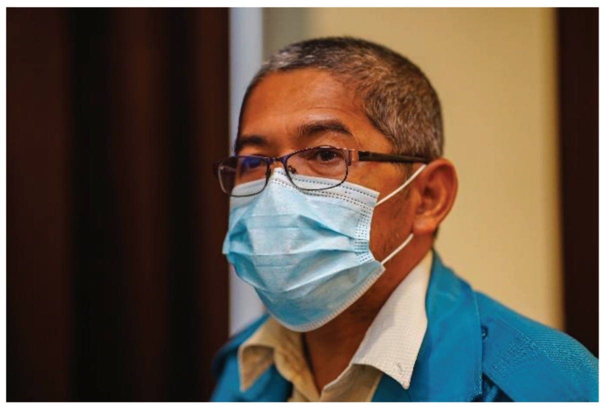

Osman Muda

Raihana Abdul Rahman

Sallehudin Jamon

7.3. Honorable Mention

Abd Haris Hilmi Ahmad Arshad
(Current Chief)

Masaya Katoh
(Former Deputy Chief)

7.4. Workshop Acticitives

Southeast Asian Fisheries Development Center (SEAFDEC)

What is SEAFDEC?

SEAFDEC is an autonomous intergovernmental body established as a regional treaty organization in 1967 to promote sustainable fisheries development in Southeast Asia. SEAFDEC currently comprises 11 Member Countries: Brunei Darussalam, Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Vision

Sustainable management and development of fisheries and aquaculture to contribute to food security, poverty alleviation and livelihood of people in the Southeast Asian region

Mission

To promote and facilitate concerted actions among the Member Countries to ensure the sustainability of fisheries and aquaculture in Southeast Asia through:

i. Research and development in fisheries, aquaculture, post-harvest, processing, and marketing of fish and fisheries products, socio-economy and ecosystem to provide reliable scientific data and information.

ii. Formulation and provision of policy guidelines based on the available scientific data and information, local knowledge, regional consultations and prevailing international measures.

iii. Technology transfer and capacity building to enhance the capacity of Member Countries in the application of technologies, and implementation of fisheries policies and management tools for the sustainable utilization of fishery resources and aquaculture.

iv. Monitoring and evaluation of the implementation of the regional fisheries policies and management frameworks adopted under the ASEAN-SEAFDEC collaborative mechanism, and the emerging international fisheries-related issues including their impacts on fisheries, food security and socio-economics of the region.

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