THE SECOND STOCK AND RISK ASSESSMENTS OF KAWAKAWA (*EUTHYNNUS AFFINIS*) AND LONGTAIL TUNA (*THUNNUS TONGGOL*) RESOURCES IN THE SOUTHEAST ASIAN WATERS USING ASPIC

Marine Fishery Resources Development and Management Department (MFRDMD)

Executive Summary

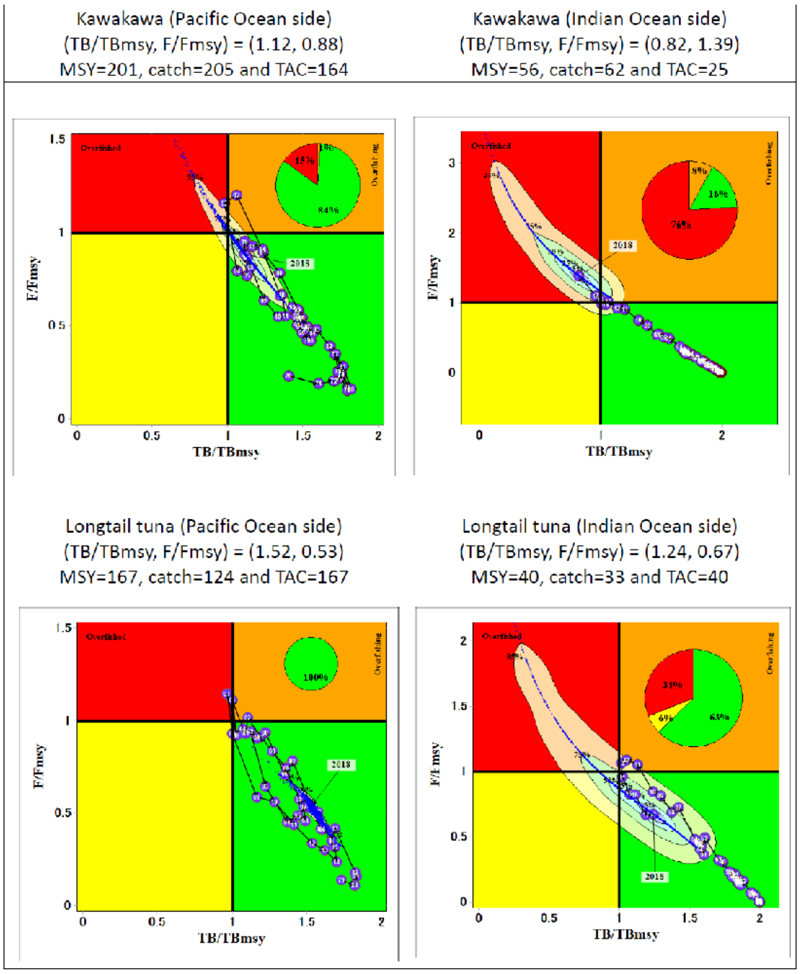
Since the establishment of the Scientific Working Group on Stock Assessment on Neritic Tunas in the Southeast Asian Region (SWG-Neritic tunas) in 2014, one of the tasks of the SWG-Neritic Tunas is to conduct the stock and risk assessments on neritic tunas in Southeast Asia waters namely: longtail tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*), narrow-barred spanish mackerel (*Scomeromorus commerson*) and Indo-Pacific king mackerel (*S. guttatus*) during 2014-2019. The results of the study were reported through the SEAFDEC Council and ASEAN mechanism.

In 2020, SEAFDEC organized the Practical Workshop on Stock Assessment of Longtail Tuna (LOT) and Kawakawa (KAW) in the Southeast Asian Waters in February 2020, at SEAFDEC/TD in Samut Prakarn, Thailand, the final report was finalized at the 6th Meeting of the SWG-Neritic Tunas on 2 December 2020 (**Annex 1**).

This study was conducted to assess the stock status and risk assessments of longtail tuna (LOT: *Thunnus tonggol*) and kawakawa (KAW: *Euthynnus affinis*) resources in the Southeast Asian region. During the SEAFDEC practical workshop in February 2020 in TD, LOT and KAW data from the Pacific Ocean and the Indian Ocean were utilized and compared to the past practical workshop in 2016. The published catch data till 2018 was mainly obtained from the IOTC (Indian Ocean Tuna Commission) and FAO. There are four 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 is also used in data sorting and compiling. As a result, the stock assessments for LOT in the Indian Ocean was in a safe situation (green zone) compared to previous assessments in 2016, which was in an overfished severe situation (red zone). Based on the risk assessment results, it is suggested that the current catch (33,000 tons) can be increased by 20% (40,000 tons), in which case the risk probability of Total Biomass (TB) and Fishing Mortality (F) violating their MSY levels are less than 50%. However, KAW stock status in the Indian Ocean shows an overfished situation compared to assessment in 2016, which is still in a safe situation. Based on the Intrinsic growth rate of population (r) the current catch (62,000 tons) needs to be reduced by 60% (25,000 tons) to avoid 50% risks of TB and F violating their MSY levels. Next, for LOT in the Pacific Ocean, is also in a safe situation like a previous assessment in 2016. It is also suggested that the current catch (124,000 tons) can be increased to the MSY level (167,000 tons), in which case the probability of TB and F violating their MSY levels is less than 50%. Lastly, KAW stock status in the Pacific Ocean remains in a safe situation as the previous assessments. Based on the risk assessment results, the current catch (205,000 tons) needs to be reduced by 20% (164,000 tons) to avoid a 50% risk of TB and F violating their MSY levels. Although the stock status is in the green zone, the current catch (2018) is still higher than the MSY level. That is why the catch needs to be reduced even though the stock status is safe. One catch of pelagic fisheries in the Southeast Asian region is composed

of multiple species. Stocks of these species are widely distributed and homogeneously mixed, which lead to non-selective exploitation. Thus, the implementation of the total allowable catch (TAC) for a specific species in the Southeast Asian region could not be possible (SEAFDEC/MFRDMD, 2019). As kawakawa and longtail tuna are among the most important fisheries resources in the SEAFDEC member countries, stock and risk assessments need to be updated at least every three years (two years for the stocks in the unhealthy status).

Summary of stock status (2018), MSY, current catch level (average of 2016-2018) and suggested TAC (1,000 tons)



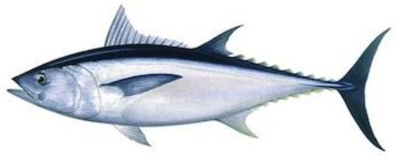
Note The pie chart represents composition (%) of the quadrant of the confidence surface (uncertainties) of the Kobe plot in the final year (2018).

REQUIRED CONSIDERATION BY THE COUNCIL

The Council is invited to endorse the report on Stock and Risk Assessments of Kawakawa and Longtail Tuna in the Southeast Asian Waters and would be circulated to the FCG/ASSP focal persons for endorsement prior to submission to the 29th Meeting of ASWGFi in 2021.

Annex 1

Final Report of the Stock and Risk Assessments of Kawakawa and Longtail Tuna in the Southeast Asian Waters



Stock and risk assessments of kawakawa (*Euthynnus affinis*) and longtail tuna (*Thunnus tonggol*) resources in the Southeast Asian waters using ASPIC[1]
(final)

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January, 2021

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Contents		Page

[1] *This work is based on the SEAFDEC practical workshop on stock and risk assessments of longtail tuna and kawakawa in Southeast Asian Region (10-15 February 2020), held at the SEAFDEC/TD, Samut Prakan, Thailand.*
ASPIC: A Stock-Production Model Incorporating Covariates

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
DNA	Deoxyribonucleic Acid
F	Fishing mortality
FAO	Food and Agriculture Organization
FCG/ASSP	Fisheries Consultative Group of the ASEAN-SEAFDEC Strategic Partnership
Fmsy	Fishing mortality at MSY
GILL	Gillnet fisheries
GLM	Generalized Linear Model
I	Indian Ocean (side)
IOTC	Indian Ocean Tuna Commission
K	Carrying capacity
KAW	Kawakawa
KL	Kuala Lumpur
LOT	Longtail tuna
MFRDMD	Marine Fishery Resources Development & Management Department (SEAFDEC)
MSY	Maximum sustainable yield
mtDNA	mitochondrial DNA (Deoxyribonucleic Acid)
P	Pacific Ocean (side)
PS	Purse Seine fisheries
q	catchability coefficient
Q-Q Plot	Quantile-Quantile Plot
r	Intrinsic growth rate of population
r2	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
SWG	Scientific Working Group
TAC	Total Allowable Catch
TB	Total Biomass
TBmsy	Total Biomass at MSY
TD	Training Department (SEAFDEC/TD)
ToR	Term of Reference
WPNT	Working Party on Neritic Tunas (IOTC)
WS	Workshop

ACKNOWLEDGEMENTS

We sincerely appreciate the following executives and experts who made it possible to implement the SEAFDEC practical workshop on stock and risk assessments of longtail tuna and kawakawa in Southeast Asian Region, held in the SEAFDEC/TD, Samut Prakan, Thailand (10-15 February 2020).

SEAFDEC Secretariat (Bangkok, Thailand)

Malinee Smithrithee	Secretary General
Akito Sato	Deputy Secretary General
Worawit Wanchana	Policy and Program Coordinator

(Secretaries of this workshop)

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SEAFDEC/MFRDMD (Kuala Terengganu, Malaysia)

Raja Bidin bin Raja Hassan	Chief
Masaya Katoh	Deputy Chief

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Member country (alphabetical order)	Data coordinator	Agency
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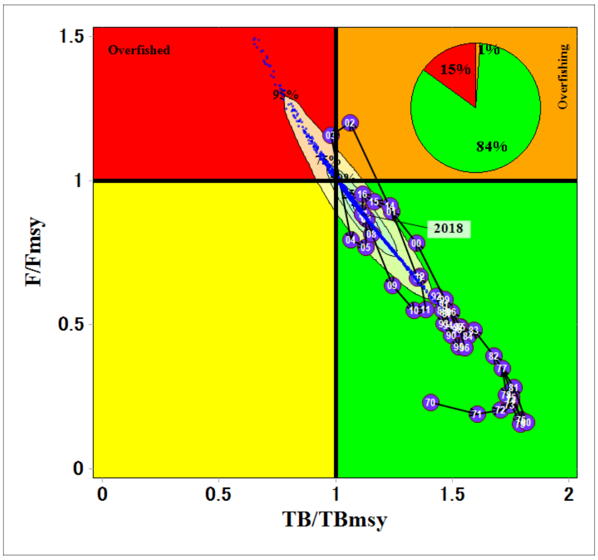
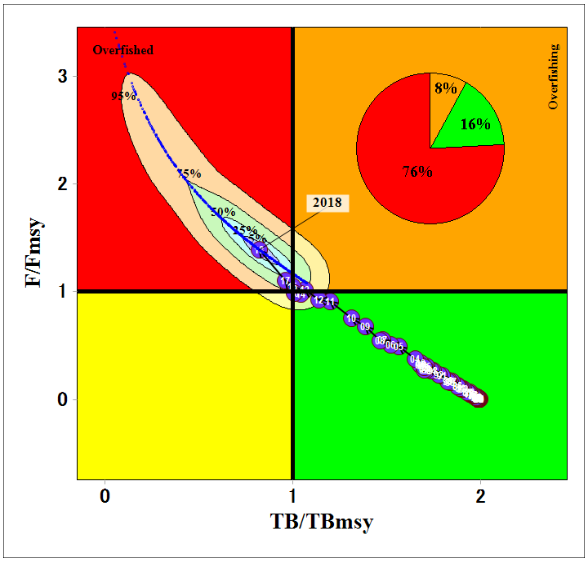
Cambodia	Suy SERYWATH	Fisheries Research and Development Institute
Indonesia	Ali Suman	Research Institute for Marine Fisheries
Malaysia	Sallehudin bin Jamon	Department of Fisheries
Myanmar	Htun Thein	Department of Fisheries
The Philippines	Grace V. Lopez	Bureau of Fisheries and Aquatic Resources
Thailand	Praulai Nootmorn	Department of Fisheries
Viet Nam	NGUYEN Viet Nghia	Research Institute for Marine Fisheries

Summary of stock status (2018), MSY, current catch level (average of 2016-2018) and suggested TAC (1,000 tons)

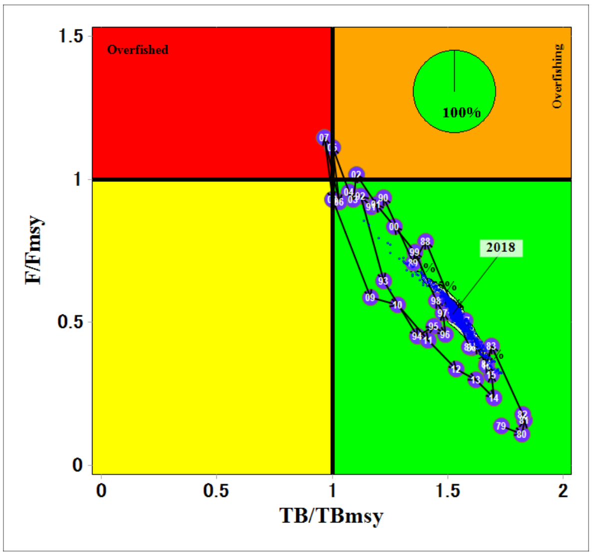
Kawakawa (Pacific Ocean side)
(TB/TBmsy, F/Fmsy) = (1.12, 0.88)
MSY=201, catch=205 and TAC=164



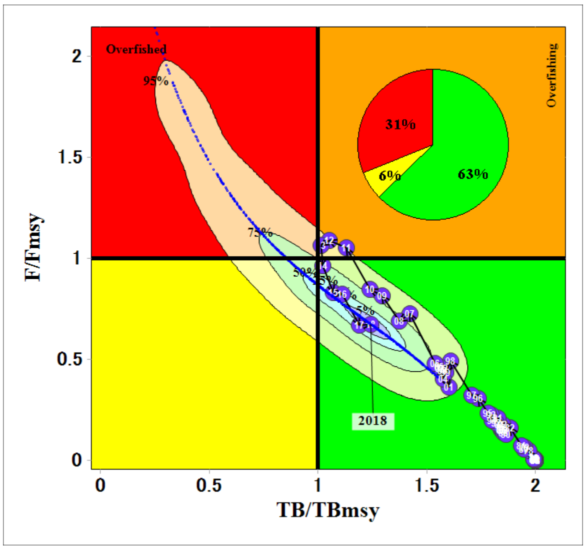
Kawakawa (Indian Ocean side)
(TB/TBmsy, F/Fmsy) = (0.82, 1.39)
MSY=56, catch=62 and TAC=25



Longtail tuna (Pacific Ocean side)
(TB/TBmsy, F/Fmsy) = (1.52, 0.53)
MSY=167, catch=124 and TAC=167



Longtail tuna (Indian Ocean side)
(TB/TBmsy, F/Fmsy) = (1.24, 0.67)
MSY=40, catch=33 and TAC=40



Note The pie chart represents composition (%) of the quadrant of the confidence surface (uncertainties) of the Kobe plot in the final year (2018).

1. INTRODUCTION

We conducted stock and risk assessments of kawakawa (*Euthynnus affinis*) (KAW) and longtail tuna (*Thunnus tonggol*) (LOT) resources in the Southeast Asian waters during the SEAFDEC practical workshop held at the SEAFDEC/TD, Samut Prakan, Thailand (10-15 February 2020). This practical workshop is one of the major activities in the SEAFDEC neritic tuna project. The backgrounds and objectives are available in its home page at http://www.seafdec.or.th/neritic-tunas/. We used ASPIC for stock and risk assessments because it has been recommended by the neritic tuna Scientific Working Group (SWG) since 2015.

During the workshop we produced very preliminary results. After the workshop we spent a lot of time to finalize our works by scrutinizing preliminary results, which are presented in this document. It should be well noted that those results should be looked at with caution, due to uncertainties in data, stock structure, CPUE standardization, factors not incorporated in ASPIC (age structures and biological factors) and environmental factors. Biology and ecology of both species were presented and discussed during the workshop. For details, refer to the SEAFDEC neritic tuna homepage.

Based on the results, we suggested TAC and compared the stock statuses with those in the past and IOTC. As a reference of the SEAFDEC neritic tuna project, we provide the summary of the stock statuses of four neritic tuna species (KAW, LOT, narrow-barred Spanish mackerel and Indo-Pacific king mackerel) including those in the IOTC in Annex A.

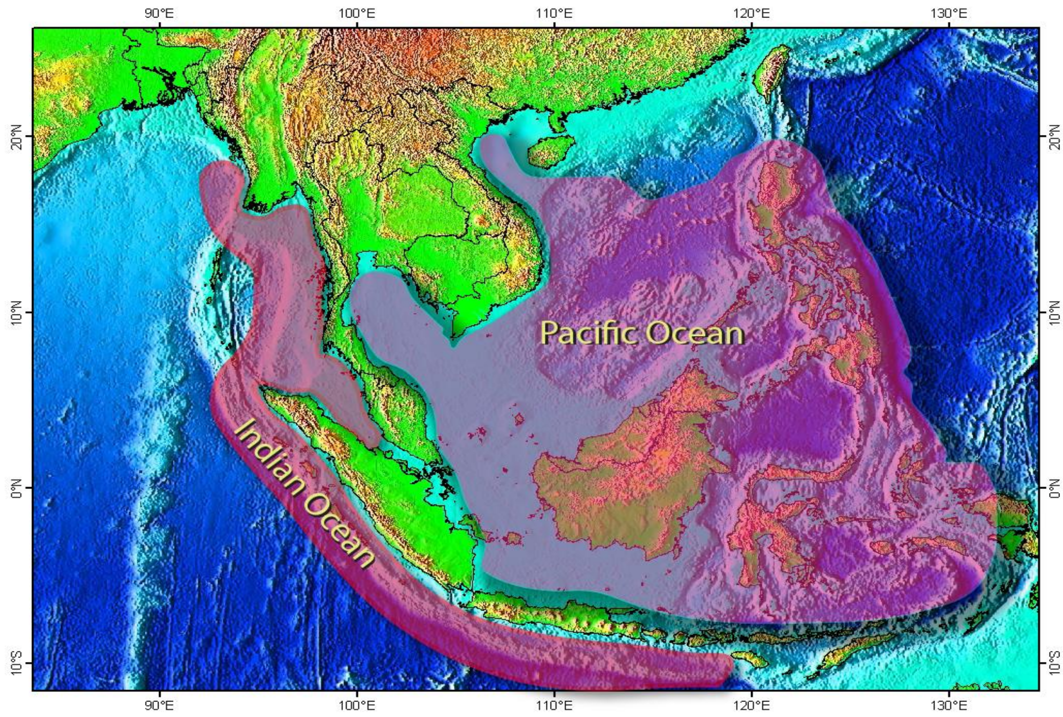
2. STOCK STRUCTURE

In the first risk and stock assessments of KAW and LOT (SEAFDEC, 2017), we assume two stocks for both KAW and LOT, i.e., one for the Indian Ocean side and the other for the Pacific Ocean side (Map. 1). However, the recent population study by Wahidah Mohd Arshaad (SEAFDEC/MFRDMD), based on the genetic analyses on LOT in the Southeast Asian region, suggested a different view and the summary of this study is as follows (quoted from the report of the fifth SWG meeting in 2019):

The aim of the study was to identify the level of genetic diversity and genetic structure of *T. tonggol* (LOT) in the Southeast Asian region. *T. tonggol* population was analyzed using the DNA samples collected from the South China Sea, Andaman Sea, and Semporna-Sulu Sea. Afterwards, laboratory and data analysis were implemented by SEAFDEC/MFRDMD. The results showed that there were five dominant haplotypes found from DNA analysis but there was no significant genetic difference found between the twelve sampling localities based on statistical analysis. Therefore, *T. tonggol* in the South China Sea, Andaman Sea, and Sulu Sea is a single stock. The same results were suggested by another study by Syahida *et al.* (2020).

This issue was discussed during the SWG5 (2019), and it was suggested that these populations should be managed as a single stock. In addition, since this study was based only on one type of DNA marker (mtDNA), it was suggested further studies should be conducted using more variable molecular markers such as microsatellite DNA. Then SWG5 recommended the use of the study results of as reference because genetic stock and fishery stock could be separated considering the issue in light of the management.

Under such circumstances, we followed this recommendation and conducted stock and risk assessments of four stocks, i.e., KAW and LOT in two areas (stocks): Pacific Ocean side and Indian Ocean side (Map 1).



Map 1 Two areas (Pacific Ocean side and Indian Ocean side in the SE Asian waters) used for stock and risk assessments of KAW and LOT.

Please note that the recent genetic study in the whole Indian Ocean (IOTC, 2019) suggests that KAW is likely composed of 2 genetic groups (west/central vs. eastern), while for LOT, a few groups (western, central and eastern). However, results should be referred carefully as there are restrictions on sampling locations and sample sizes. This IOTC study does not suggest any stock structure information of KAW and LOT within the SE Asian waters, for example, Indian Ocean stock vs. Pacific Ocean stocks. Thus, we used our hypothesis of two stock structure (Indian Ocean stock vs. Pacific Ocean stock) in our works.

3. DATA

In ASPIC, catch and CPUE are the input data. The descriptions how we collected and compiled these data are as follows. One of the authors of this document (Muhammad Adam bin Ramlee, Brunei Darussalam) coordinated the data collection as part of capacity building recommended by SWG5 (2019). Data were collected from data coordinators approved by the respective governments of eight member countries (page 3). All collected data belong to the SEAFDEC neritic tuna project.

3.1 Nominal catch

(1) Catch construction

Historical nominal catches were obtained from data coordinators. In addition, published catch data were obtained from IOTC (Indian Ocean Tuna Commission) and FAO (Food and Agriculture Organization of the United Nations). Using these data, we built catch by species and two areas (Pacific Ocean side and Indian Ocean side). The preferentially used catch data are from IOTC (Indian Ocean side) and FAO (Pacific Ocean side) because they are based on the official data submitted by each government. The data obtained from the data coordinators were used if FAO and IOTC catch data are missing. Figs. 1-4 show the resultant catch trends by Indonesia, Malaysia, Thailand and/or Philippines. For KAW (Pacific Ocean side), there are additional catches by other countries (Viet Nam, Cambodia and Brunei Darussalam).

Table 1 lists member countries producing high catches (more than 98%). Among these countries, the Indonesian catches are the highest, i.e., KAW(P) (70% of the total catch), KAW(I) (73%), LOT(P) (54%) and LOP(I) (72%).

Table 1 Member countries producing high catches (> 98% of the total catch) by species and area (listed in order)

KAW			LOT	
P	I		P	I
Indonesia	Indonesia		Indonesia	Indonesia
Philippines	Thailand		Malaysia	Malaysia
Thailand	Malaysia		Thailand	Thailand
Malaysia				

(2) Uncertainties in the catch data

In the catch data construction, IOTC and FAO data are major sources as they have the long time series data. These data are officially provided by SEADEC member countries. However, quality of the data from developing countries is not good in general according to the IOTC data evaluation results (for example, IOTC, 2020) although quality levels vary by country.

Major reasons of the low quality data are: (a) national catch statistics collection system does not cover well spatially and temporally (for example, one sampled data per month are raised to estimate the total monthly landings), (b) in many cases, visual (eye ball) estimations are used, (c) species are often aggregated and disaggregation is conducted very crudely (for example, the same species composition rate is applied to all years and all areas) and (d) data quality control is not sufficient. Thus, it should be well noted that such uncertainties affect the results of stock and risk assessments.

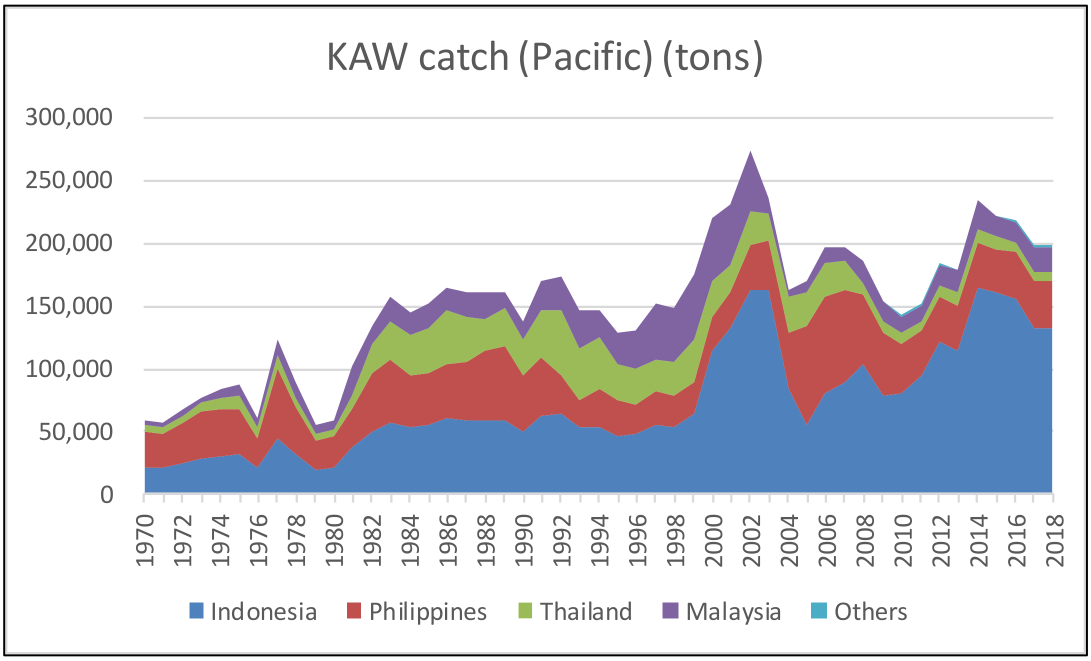


Fig. 1 Catch (KAW) in the Pacific Ocean side by country (1970-2018) (tons)
(Others: Viet Nam, Cambodia and Brunei Darussalam)

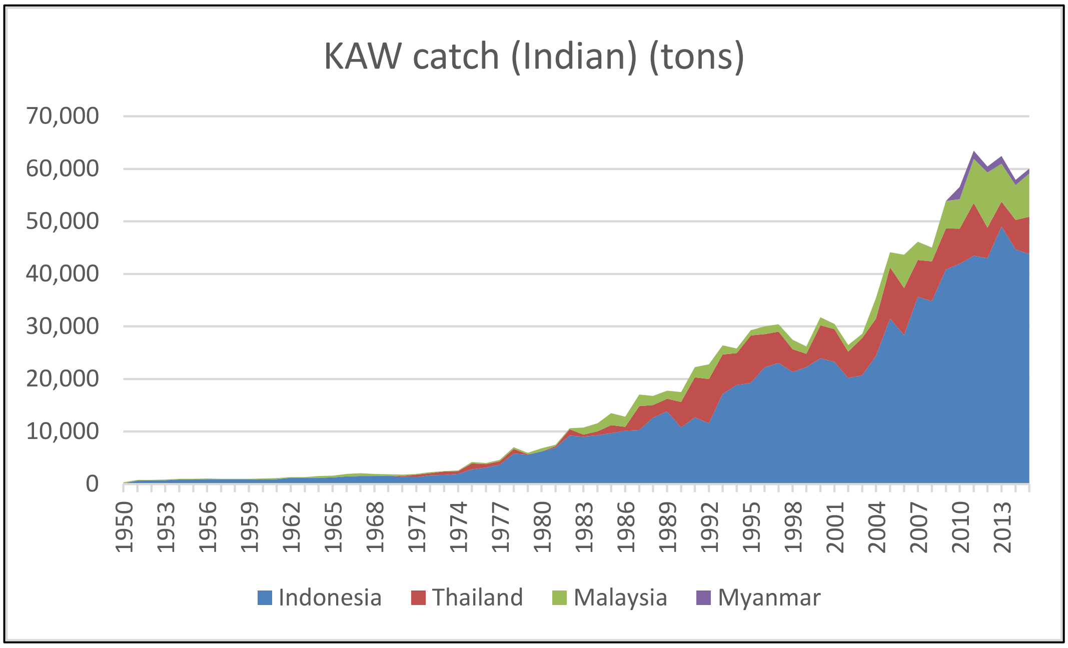


Fig. 2 Catch (KAW) in the Indian Ocean side by country (1950-2018) (tons)

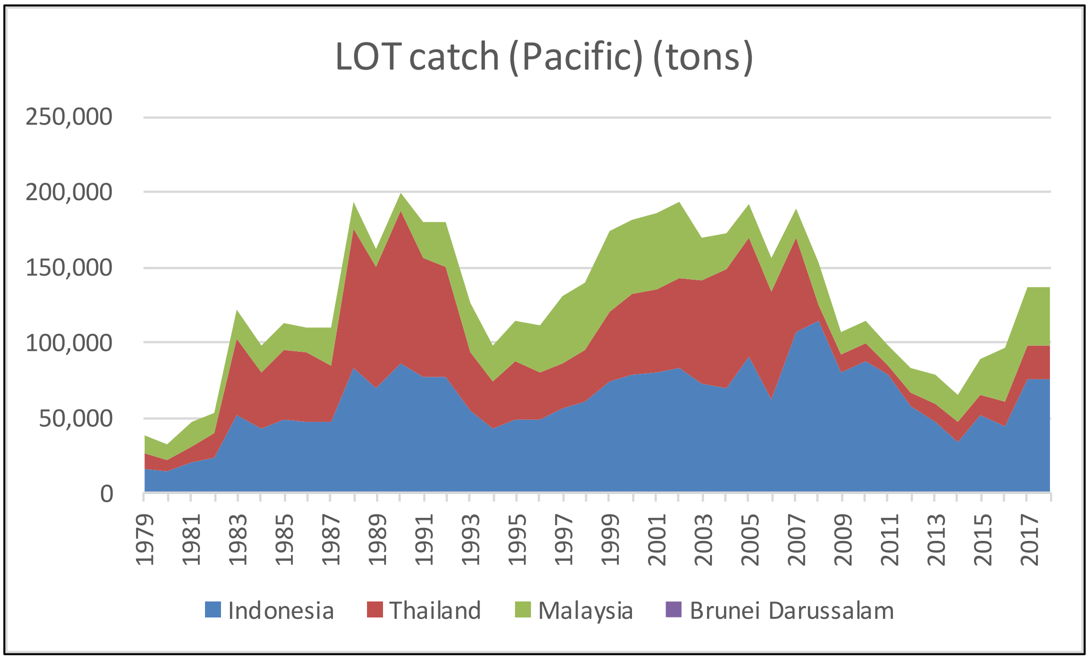


Fig. 3 Catch (LOT) in the Pacific Ocean side by country (1979-2018) (tons)

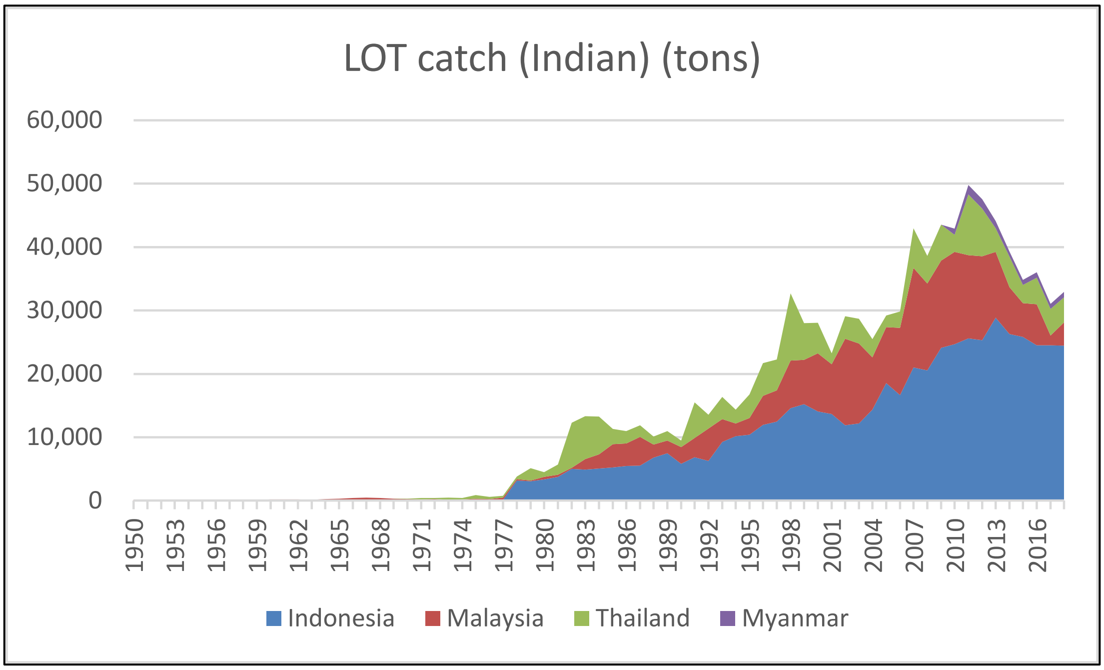


Fig. 4 Catch (LOT) in the Indian Ocean side by country (1950-2018) (tons)

3.2 Nominal CPUE

(1) Collection of nominal CPUE

Nominal CPUE is the essential information for ASPIC. We received nominal CPUE (KAW+LOT) from Thailand, Malaysia, Indonesia, and Philippine. In addition, we also collected nominal CPUE available on the IOTC home page. Table 2 shows a summary of nominal CPUE collected.

Table 2 Summary of the nominal CPUE collected

side		Indian Ocean				Pacific Ocean				
source		IOTC (Thai)	Thai	Thai	Malaysia	Indonesia	Thai	Thai	Malaysia	Philippine
No of gears		1 (GILL)	1 (PS)	1 (PS)	10	2 (PS + GILL)	1 (PS)	1 (PS)	10	45
type		commercial	commercial	survey	commercial	commercial	commercial	survey	commercial	commercial
Resolution	time	month	month	day	month	day	month	day	month	month
	areas	1	5	3	1	1	7	7	5	7
types of fishing effort	hour				(hour*unit)				(hour*unit)	
	day				(day*unit)				(day*unit)	
	haul				(haul*unit)				(haul*unit)	
	trip				(trip*unit)				(trip*unit)	
Available years		1982-2008 (27 years)	1995-2018 (24 years)	2011-2018 (8 years)	2008-2018 (11 years)	2018 (1 year)	1995-2018 (24 years)	2011-2018 (8 years)	2008-2018 (11 years)	2014-2018 (5 years)

(2) Selection of plausible nominal CPUE

There are many nominal CPUE as shown in Table 2. As observed in the last stock assessment (2017), majority of nominal CPUE are not plausible because of poor quality of catch and effort data from artisanal and semi-industrial fisheries. We applied four steps to screen the most plausible nominal CPUE as shown in BOX 1. Table 3 lists six selected nominal CPUE for CPUE standardization.

Box 1 Four steps to screen plausible nominal CPUE

(i) Exclude nominal CPUE for less than ten years.
(ii) Exclude nominal CPUE with abnormal trends.
(iii) Exclude outliers, sudden jumps/drops, zig-zag trends with high magnitudes.
(iv) Select nominal CPUE with relatively high negative correlations between nominal CPUE and catch.

Table 3 Six nominal CPUE selected for CPUE standardization

Species		KAW		LOT			
Area (side)		Pacific	Indian	Pacific		Indian	
Country		Thailand	Thailand	Malaysia	Thailand	Thailand	Thailand
type		commercial	commercial	commercial	commercial	commercial	commercial
Gear		PS	PS	PS	PS	PS	GILL
unit		Kg/hour	Kg/hour	Kg/(hr*unit)	Haul/day	Haul/day	Kg/day
Resolution	time	month	month	month	month	month	month
	areas	Gulf of Thailand	Andaman Sea	Sarawak	Gulf of Thailand	Andaman Sea	Andaman Sea
	statistical area	area 1-5 and A+B	area 6	Sarawak	area 1-5 and A+B	area 6-7 and C-E	area 6-7 and C-E
available year		1995-2007	2001-2015	2009-2018	1995-2018	1995-2015	1987-1999

4. Methods

We use four software to conduct stock and risk assessments, i.e., CPUE standardization, ASPIC original application and the batch job, Kobe plot and risk assessments. For data process and compilation, we use the MS Excel. Fig. 5 shows a flow chart of the procedures.

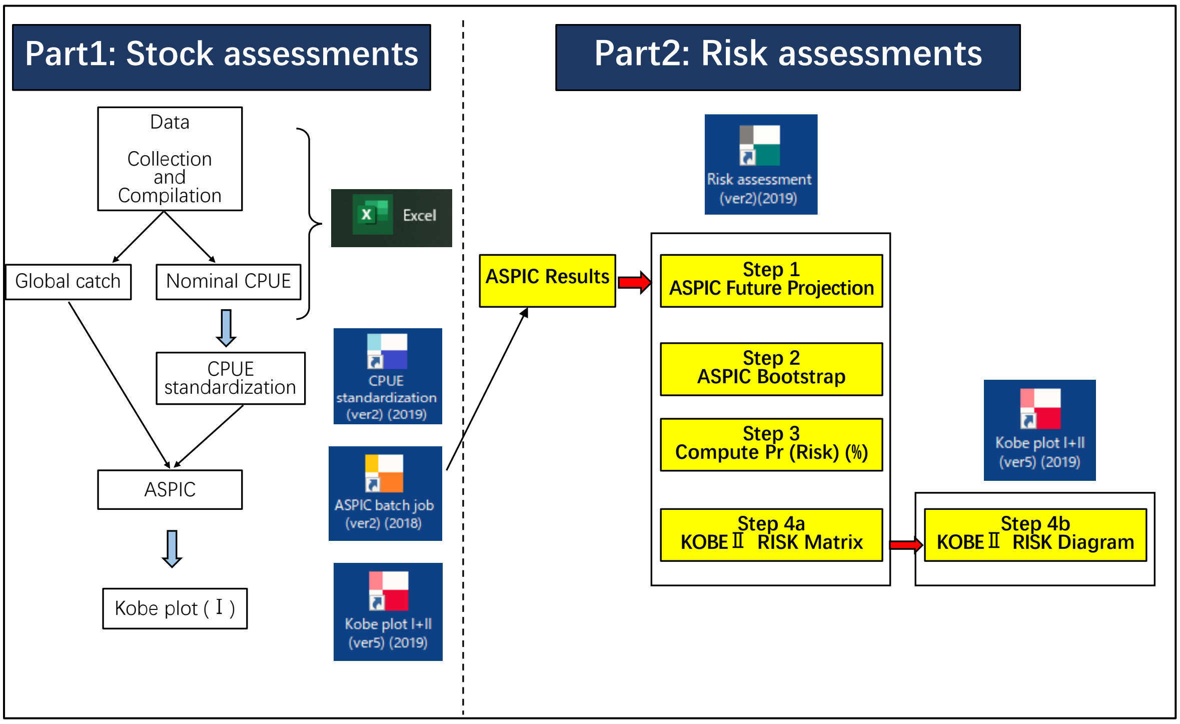


Fig. 5 The procedure of stock and risk assessments using Excel and four software indicated by icons (CPUE standardization, ASPIC batch job, Kobe plot I+II and risk assessment)

4.1 CPUE standardization

We use CPUE standardization software which produces ANOVA table, time series graphs of standardized CPUE with 95% Confidential Intervals (CI) and residual analyses (frequency distributions and QQ plots). For details, refer to the software manual available at the SEAFDEC/TD neritic tuna home page.

4.2 Stock assessment (ASPIC)

(1) Batch job

We use the ASPIC original application and batch job software to implement four stock assessments. We select seeding values for MSY and K (point, minimum and maximum values), B1/K and q using criteria suggested by the resource persons.

We attempted to estimate all four parameters (B1/K, MSY, K and q) in the first attempt. In the batch jobs, in addition to two surplus production models (Schaefer or Fox), four parameters are combined to search the most plausible one. For example, if the settings are B1/K (3 values), MSY (4), K (4), q (2) and production models (2), the total number of combinations is 192 (3x4x4x2x2). This means that the ASPIC catch job automatically executes the batch job (192 runs).

(2) Parameter search

All results are stored in Excel file including four estimated parameters, estimated metrics (total biomass, F, MSY, Fmsy, TBmsy, TB/TBmsy, F/Fmsy and [r] intrinsic population growth rate) and goodness of fit (r^2 and Root Mean Square Error [RMSE]). To select the best combination of parameters, we refer to the values of r^2 (higher is better), RMSE (lower is better) and the optimum [r] value (closer to the optimum value is better). The optimum [r] value is determined by the median of the values available in the literatures, i.e., 0.99 (LOT) and 1.34 (KAW). We also consider their ranges from values available in the literatures.

We proceed with the parameter search using the flag code (flag code =1 to estimate parameters, while flag code= 0, not to estimate parameters, but to provide values) available in ASPIC. The first trail is to set flags for (B1/K, MSY, K and q) to (1111) respectively and estimate all four parameters.

If there are no convergences in (1111), we fix one parameter by setting (0111) or (1101), i.e., B1/K or K is fixed. When we fix, we use several plausible values (scenarios), then run ASPIC by scenario and select the most optimum (plausible) run in all results (scenarios).

If it still does not converge, we re-attempt the estimation by setting to (0101), fixing two parameters (0101), i.e., B1/K and K will be fixed. In this case we also use several values (scenarios) for B1/K and K, i.e., for example, if we have 4 scenarios for each parameter, we will have 16 scenarios. Then run ASPIC by scenario and select the most optimum (plausible) run in all results.

If it still does not converge, we re-check CPUE to see if there are any implausible behaviors (such as sudden jumps/drops, un-realistic trends etc.), then delete such data points if any. Then we re-attempt to run ASPIC runs all over again as before from the beginning with (1111). If it still does not provide any plausible results, we use nominal CPUE. If that still does not provide any plausible results, we consider that the catch and CPUE data do not fit to ASPIC at all and we conclude that no results are obtained.

(3) Kobe plot

Using the most plausible estimated parameters, we make the Kobe plots (trajectories of stock status) and four types of time series graphs, i.e., catch vs MSY, F vs. Fmsy, TB vs. TBmsy and observed vs. predicted CPUE. To estimate uncertainties (confidence surface shaped like a banana) of the final year in the Kobe plot, we use the bootstrap (1,000 times) available in the ASPIC original application. Confidence surface includes five probability contours (5%, 25%,50%,75% and 95%).

4.3 Risk assessment

(1) Strategic risk matrix (Kobe II)

The basic method of risk assessments is one used by the tuna RFMOs i.e., Kobe II strategy management matrix (Kobe II). Kobe II matrix presents the probabilities violating TBmsy (Total Biomass at the MSY level) and Fmsy (F at the MSY level) after 3 and 10 years under nine different catch scenarios (current catch level, ± 10%, ± 20%, ± 30% and ± 40%). This means that if each of the nine different catch levels (scenarios) continues for the next 10 years, Kobe II provides the probabilities violating TBmsy and Fmsy in the 3rd and 10th year. These are the default settings.

Please note that the current catch is not the actual catch of the last year, but is defined as the average for the last three years (2016-2018). This is because the last year's catch (2018 in our case) may not be representative if it were very low/high value by the sudden sharp decrease/increase comparing the catch levels from previous years, which will produce inaccurate results of risk assessments.

In addition to the nine different catch scenarios (as defaults), we added a catch at the MSY level as we are also interested in its risk probabilities. We further added six catch levels, i.e., -80%, -100% (no catch), +50%, +200%, +250% and +300%. This is because when the stock statuses are too good or too bad, we will not able to see the risk levels beyond the default catch level range (-40% to + 40%). As a result, we have a total of 16 catch levels i.e., 9 defaults, 1 at MSY and 6 additions beyond the default levels. All 16 catch levels are available in the risk assessment and Kobe II software. In this way we can select the effective range of catch levels to identify the plausible risk levels.

(2) TAC advice

Using the risk assessment matrix, tuna RFMOs select TAC levels that can sustain TBmsy and Fmsy levels after 3 and 10 years with a minimum risk level around 50% as a default criterion. We also follow this criterion to advise TAC levels. However, this is just a suggestion and not a legally binding recommendation as in RFMOs because SEAFDEC is not a RFMO. Nevertheless, member countries should consider suggestions and hopefully produce some self-measures, especially the member countries with high levels as shown in Table 3.

5 RESULTS

We present the results of stock and risk assessments of KAW (P), KAW (I), LOT (P) and LOT(I) including CPUE standardization, relations between catch vs. STD_CPUE, ASPIC (estimated B1/K, MSY, K, q, TBmsy, TB2018/TBmsy, Fmsy, F2018/Fmsy and [r] (intrinsic population growth rate), goodness of fit (r^2 and RMSE), Kobe plot and Kobe II (risk matrix for TB and F).

5.1 KAW (Pacific Ocean side)

(1) CPUE standardization (Box 2)

CPUE standardization by log normal GLM was conducted using Thai PS nominal CPUE in the Gulf of Thailand. Box 2 shows the results of standardized CPUE including 6 outputs, i.e., (a) trends of standardized CPUE with 95% CI, (b) ANOVA table, (c) frequency distribution of residuals, (d) the QQ plot, (e) time series relation (catch vs. STD_CPUE) and (f) negative correlation (catch vs. STD_CPUE). Standardized CPUE is considered statistically valid thus used for stock and risk assessments. Although the QQ plot shows some biases at both ends which, it unlikely affects the results seriously.

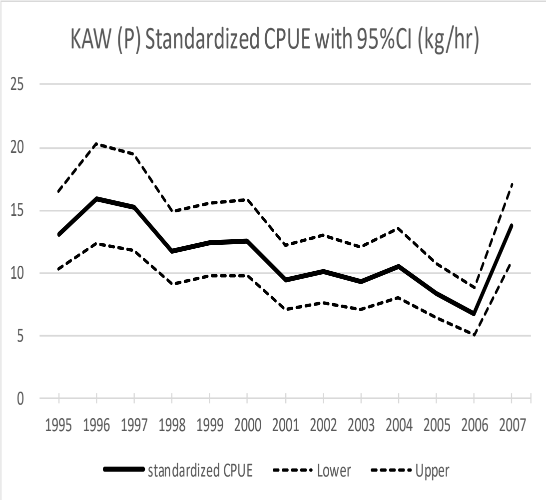
(2) ASPIC (Box3)

ASPIC was conducted using the catch in the Pacific Ocean side and the standardized CPUE of Thai PS in the Gulf of Thailand. All four parameters were estimated with (1111) in the initial attempt. BOX 3 shows five different types of ASPIC results including one table for "estimated parameters and related metrics" and four types of time series graphs for "catch vs. MSY", "F vs. Fmsy", "TB vs. TBmsy" and "observed vs. predicted standardized CPUE".

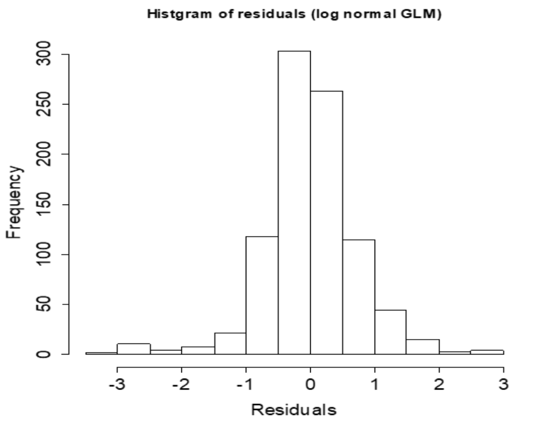
(3) Kobe plot (stock status in 2018) and risk assessments (optimum catch level) (Box 4)

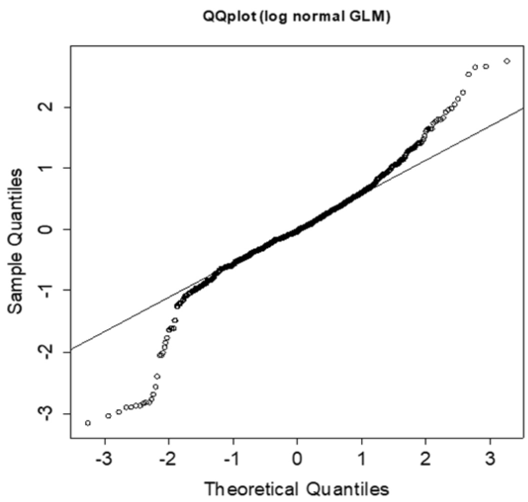
Using ASPIC results, the Kobe plot was created (BOX 4), and risk assessments were conducted for TB and F. Box 4 shows the results suggesting that the stock status of KAW(P) in 2018 is in the green zone of the Kobe plot with a probability of 84%, hence the stock is safe in 2018. Based on the risk assessment results, the current catch (205,000 tons) needs to be reduced by 20% (164,000 tons) to avoid a 50% risk of TB and F violating their MSY levels. Although the stock status is in the green zone, the current catch (2016-2018) is still higher than the MSY level. That is the reason why the catch needs to be reduced even though the stock status is safe.

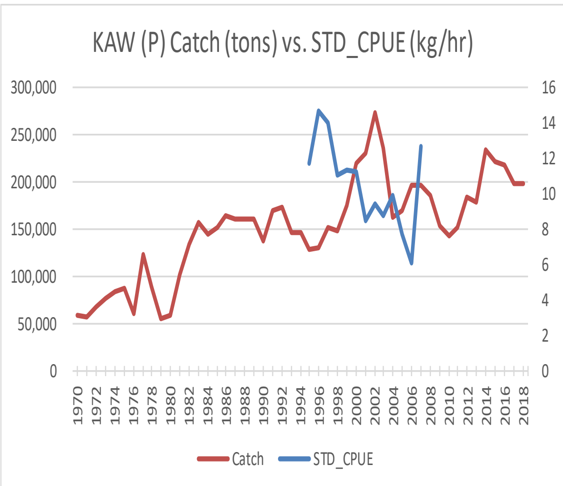
BOX 2 KAW (Pacific side) Results of CPUE standardization and relations with catch

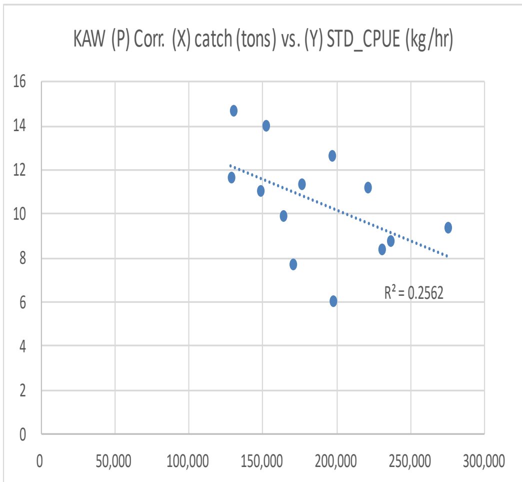


ANOVA (Analysis Of Variance) Table for log normal GLM to test statistical significances				
Adjusted R2 = 0.71				
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	F value	Pr(>F)
Model	75	589.41	13.35	0.00
YR	12	38.05	5.38	0
Q	3	8.83	5.00	0.00
area	6	435.77	123.35	0
YR*Q	36	36.66	1.73	0.01
Q*area	18	70.10	6.61	0









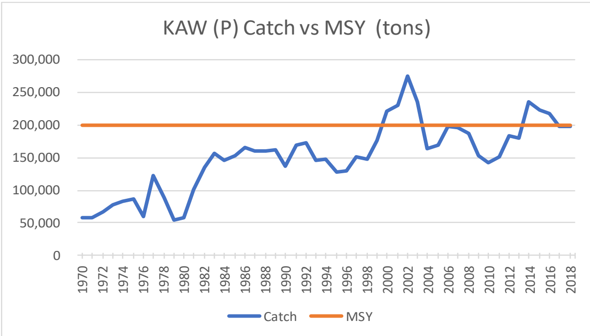
BOX 3 KAW (Pacific side) Results of ASPIC

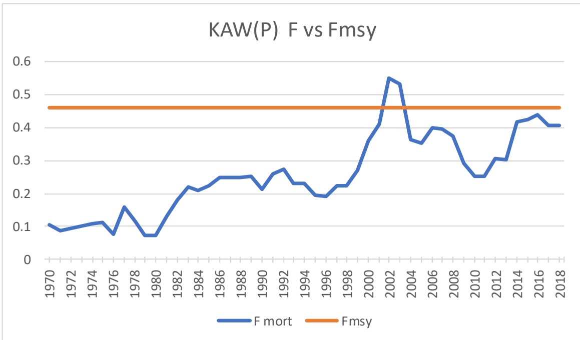
KAW (P) Estimated parameters (1111)* and catch (2018)											
Model	r (0.99)**	q	Fmsy	$TB_{2018}/TBmsy$	$F_{2018}/Fmsy$	TB_{1970}/K	K	TB_{2018}	TBmsy	MSY	C (curr) ***
Schaefer	0.92	1.99E-05	0.46	1.12	0.88	0.56	875	489	438	201	205
							(1,000 tons)				

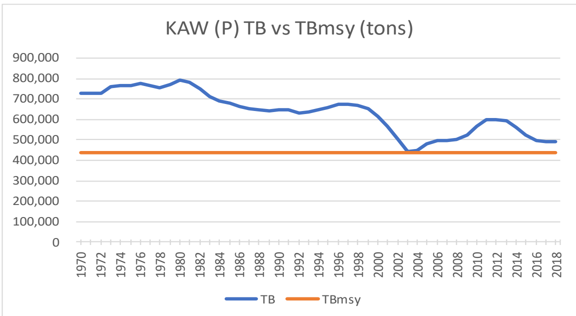
(*) Flag of parameters estimation : 1 (estimated) and 0 (fixed). Four parameters are B1/K, MSY, K and q respectively.

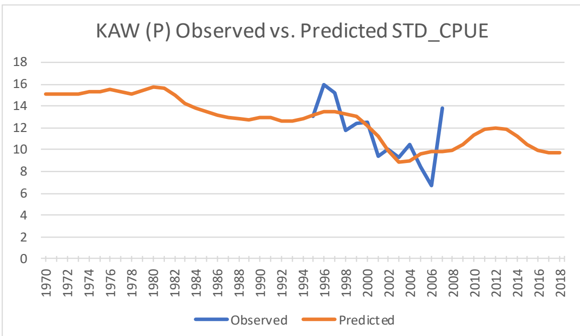
(**) Intrinsic rate of population growth

(***) Catch (curr) : average catch in recent three years(2016-2018)

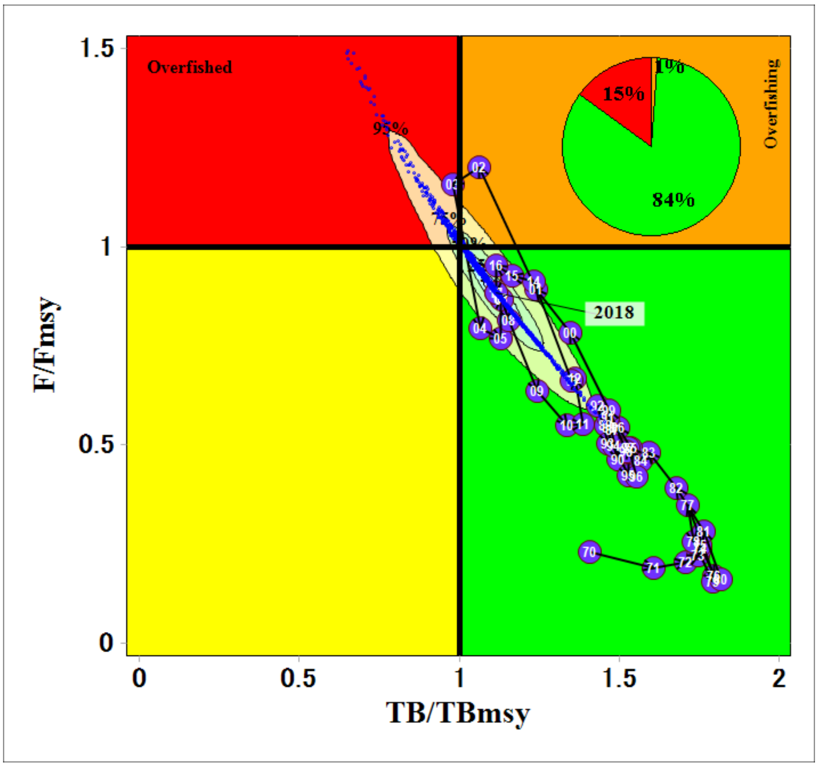








BOX 4 KAW (Pacific side) Kobe plot and results of risk assessment



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

Color legend				
Risk Levels	Low risk	Medium low risk	Medium high risk	High risk
Probability	0 – 25%	25 – 50%	50 – 75%	75 – 100

	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	98% (−2%)	100%	110%	120%	130%	140%
					MSY level	Current catch (*)				
10 catch scenarios (tons)	122,743	143,200	163,658	184,115	200,600	204,572	225,029	245,486	265,944	286,401
TB2021 < TBmsy	62	68	72	76	79	80	83	87	90	93
F2021 > Fmsy	7	18	40	66	78	82	94	98	100	100
TB2028 < TBmsy	35	40	49	66	80	84	95	98	100	100
F2028 > Fmsy	7	14	27	56	80	86	98	100	100	100

(*)The current catch levels the average catch in 3 recent years(2016-2018).

5.2 KAW (Indian Ocean side)

(1) CPUE standardization (Box 5)

CPUE standardization by log normal GLM was conducted using Thai PS nominal CPUE in the Andaman Sea. Box 5 shows the results of standardized CPUE including 6 outputs, i.e., (a) trends of standardized CPUE with 95% CI, (b) ANOVA table, (c) frequency distribution of residuals, (d) the QQ plot, (e) time series relation (catch vs. STD_CPUE) and (f) negative correlation (catch vs. STD_CPUE). Standardized CPUE is considered statistically valid thus it was used for stock and risk assessments. Although the QQ plot shows some biases at both ends, it unlikely affects results seriously.

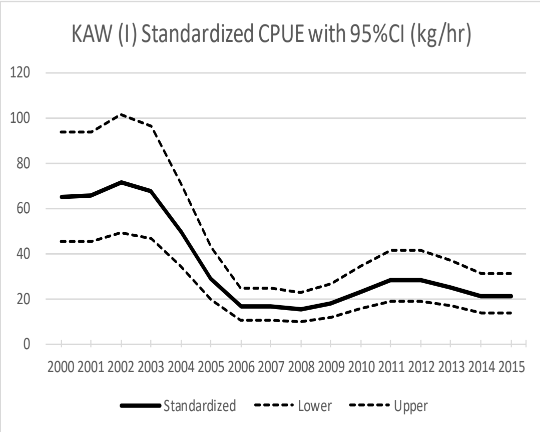
(2) ASPIC (Box 6)

ASPIC was conducted using the catch in the Indian Ocean side and the standardized CPUE of Thai PS in the Andaman Sea. Initially we attempted to estimate all four parameters with (1111), but it did not converge. As the next step, we fixed TB_{1950}/K to 1 (0111), as we considered that TB_{1950} was the virgin stock and close to K. But again, it did not converge again. Then we further fixed K (0101) using four plausible values (15, 20, 25 and 30,000 tons). As a result, the most plausible parameters were obtained with K=20,000 tons. BOX 6 shows five different types of ASPIC results including, one table for “estimated parameters and related metrics” and four types of time series graphs for “catch vs. MSY”, “F vs. Fmsy”, “TB vs. TBmsy” and “observed vs. predicted standardized CPUE”.

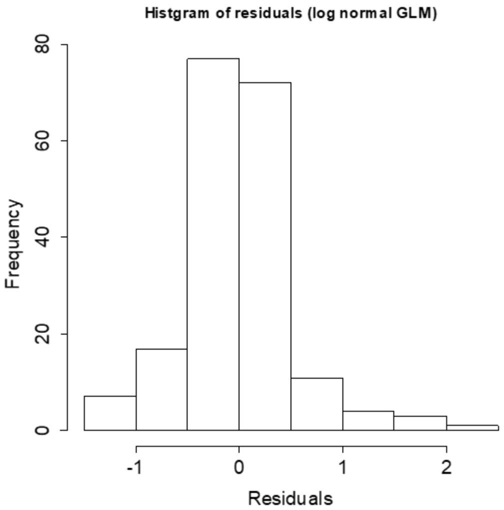
(3) Kobe plot (stock status) and risk assessments (optimum catch level) (Box 7)

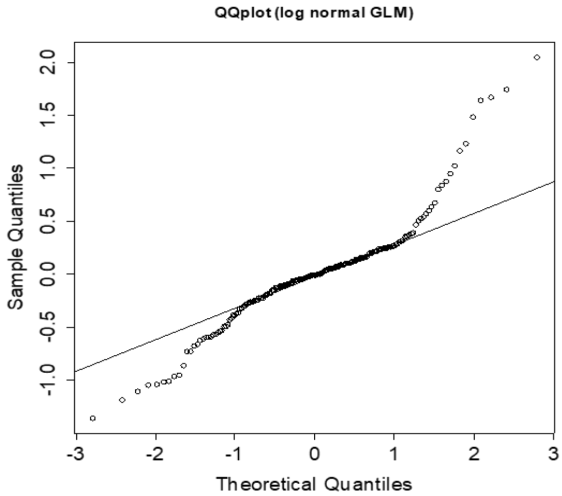
Using ASPIC results, the Kobe plot was created (Box 7), and risk assessments were conducted for TB and F. BOX 7 shows the results suggesting that the stock status of KAW(I) in 2018 is in the red zone of the Kobe plot with a probability of 76%, hence it is in a serious overfished and overfishing situation. Based on the risk assessment results, the current catch (62,000 tons) needs to be reduced by 60% (25,000 tons) to avoid 50% risks of TB and F violating their MSY levels.

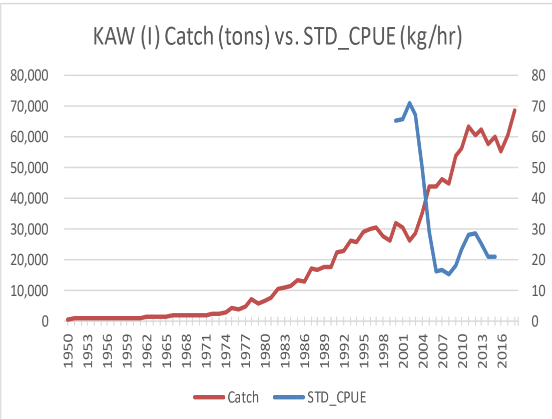
BOX 5 KAW (Indian Ocean side) Results of CPUE standardization and relations with catch

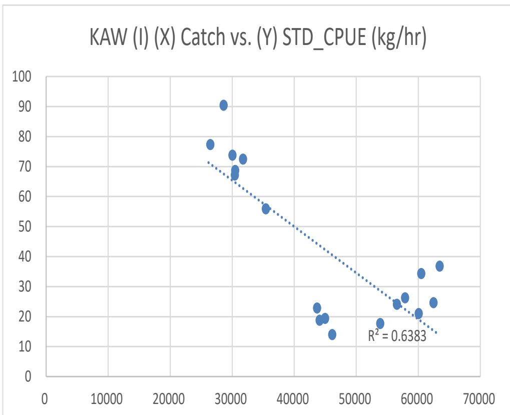


ANOVA (Analysis Of Variance) Table for log normal GLM to test statistical significances				
Adjusted R2 = 0.46				
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	F value	Pr(>F)
Model	63	44.39	1.92	0.00
YR	15	19.86	3.60	0
Q	3	2.26	2.05	0.11
YR*Q	45	22.26	1.35	0.10









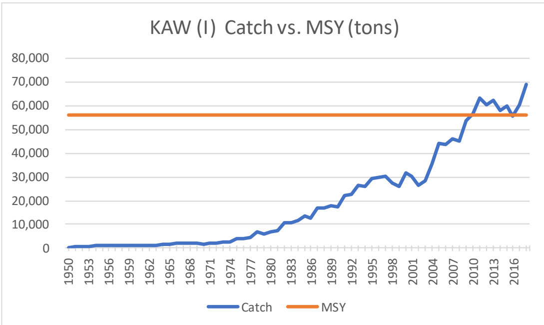
BOX 6 KAW (Indian Ocean side) Results of ASPIC

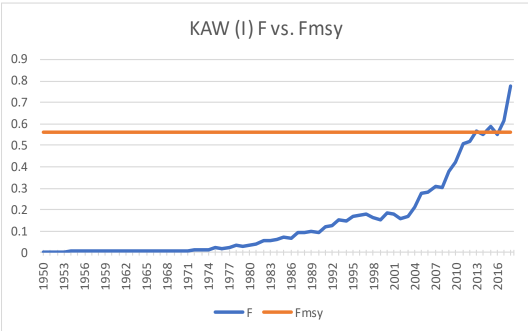
KAW (I) Estimated parameters (0101)* and catch (2018) (TB_{1950}/K and K are fixed)											
Model	r (1.34)**	q	Fmsy	TB_{2018}/TBmsy	F_{2018}/Fmsy	TB_{1950}/K	K	TB_{2018}	TBmsy	MSY	Catch (curr)
Schaefer	1.12	2.25E-04	0.56	0.82	1.39	1	200	96	100	56	62
							(1,000 tons)				

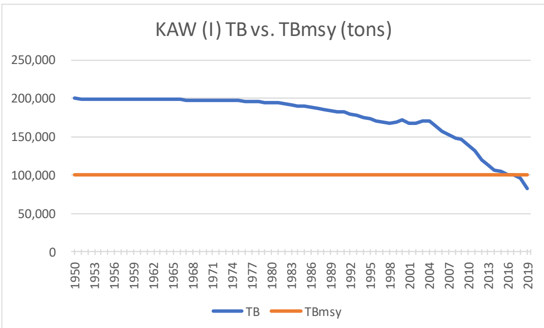
(*) Flag of parameters estimation : 1 (estimated) and 0 (fixed). Four parameters are B1/K, MSY, K and q respectively.

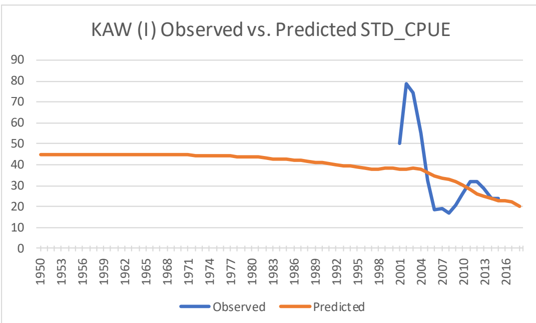
(**) Intrinsic rate of population growth

(***) Catch (curr) : average catch in recent three years(2016-2018)

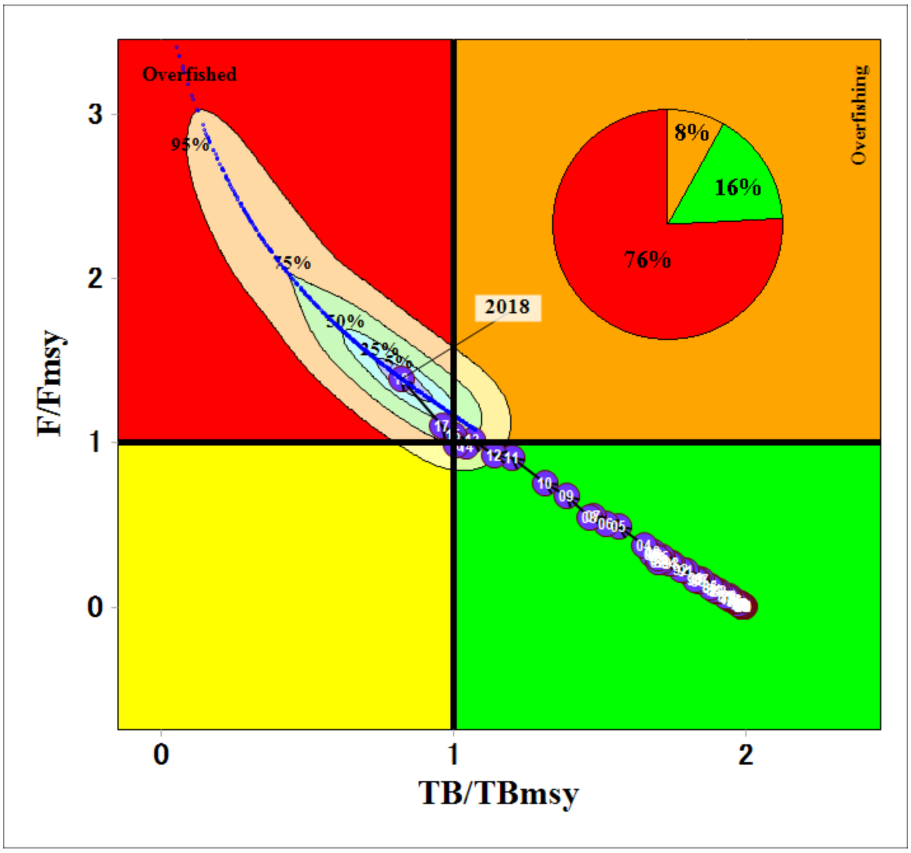








BOX 7 KAW (Indian Ocean side) Kobe plot and results of risk assessments



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

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

	0% (−100%)	20% (−80%)	40% (−60%)	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	91% (−9%)	100%	110%	120%
								MSY level	Current catch (*)		
11 catch scenarios (tons)	0	12,312	24,624	36,936	43,092	49,248	55,404	55,850	61,560	67,716	73,872
TB2021 < TBmsy	56	58	61	67	70	73	76	76	80	84	87
F2021 > Fmsy	0	48	51	56	60	66	75	76	86	98	100
TB2028 < TBmsy	41	48	50	54	57	61	71	72	84	95	100
F2028 > Fmsy	0	48	50	54	57	60	70	72	88	100	100

(*)The current catch levelis the average catch in 3 recent years(2016-2018).

5.3 LOT (Pacific Ocean side)

(1) CPUE standardization (Box 8-Box 9)

Two plausible nominal CPUE were selected for the Pacific Ocean side, i.e., Thai PS (Gulf of Thailand) and Malaysia PS (Sarawak). CPUE standardization by log normal GLM was conducted for both nominal CPUE. Box 8 shows the results of standardized CPUE for both including 4 outputs, i.e., (a) trends of standardized CPUE with 95% CI, (b) ANOVA table, (c) frequency distribution of residuals and (d) time series relations (catch vs. STD_CPUE). Both standardized CPUE is considered statistically valid. Then we combined two STD_CPUE by taking their average of the scaled CPUE (average=1) for each CPUE. Box 9 shows the trend of combined STD_CPUE, the time series relation (catch vs. combined STD_CPUE) and the negative correlation (catch vs. combined STD_CPUE). We used the combined standardized CPUE for ASPIC because it negatively reflected to the catch well.

(2) ASPIC (Box 10)

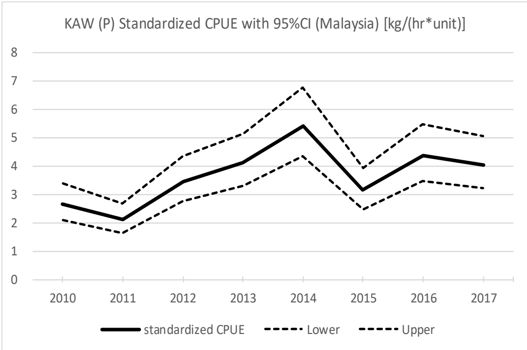
ASPIC was conducted using the catch in the Pacific Ocean side and the combined standardized CPUE. All four parameters were estimated with (1111) on the first attempt. BOX 10 shows five different types of ASPIC results including one table for "estimated parameters and related metrics" and four types of time series graphs for "catch vs. MSY", "F vs. Fmsy", "TB vs. TBmsy" and "observed vs. predicted standardized CPUE".

(3) Kobe plot (stock status) and risk assessments (optimum catch level) (Box 11)

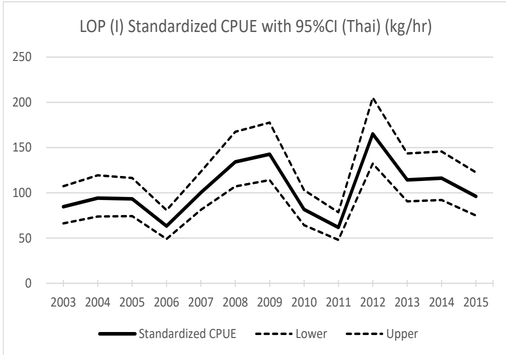
Using ASPIC results, the Kobe plot was created (BOX 11) and risk assessments were conducted for TB and F. BOX 11 shows the results. The size of the confidence surface round the 2018 point is much smaller than normal. The reason is that the data fit to ASPIC very well as shown in the QQ plot. Based on the risk assessment results, it is suggested that the stock status of LOT(P) in 2018 is very healthy as it is in the green zone of the Kobe plot with 100% probability. It is also suggested that the current catch (124,000 tons) can be increased to the MSY level (167,000 tons), in which case the probability of TB and F violating their MSY levels is less than 50%.

BOX 8 LOT (Pacific Ocean side) Results of CPUE standardization (Thailand and Malaysia) and relations with catch

Standardized CPUE (Malaysia)



Standardized CPUE (Thailand)



ANOVA (Analysis Of Variance) Table for log normal GLM to test statistical significances

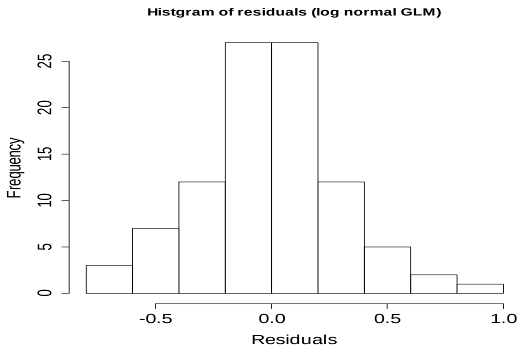
Adjusted R2 = 0.36

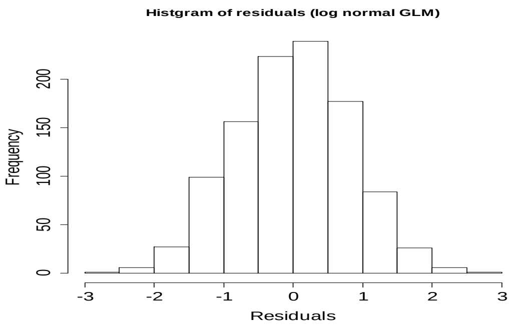
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	F value	Pr(>F)
Model	31	5.34	1.29	0.19
Year	7	1.73	1.85	0.09
Q	3	1.30	3.25	0.03
Year*Q	21	2.31	0.82	0.68

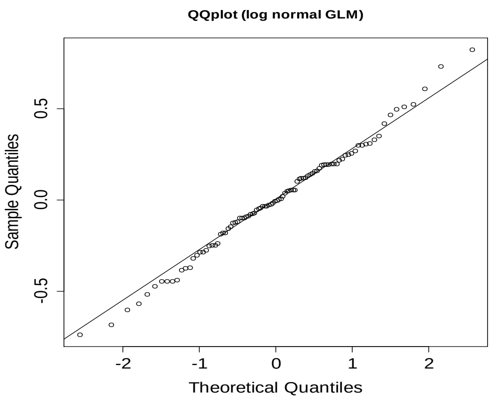
ANOVA (Analysis Of Variance) Table for log normal GLM to test statistical significances

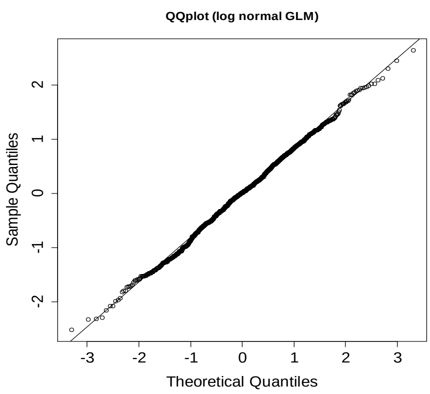
Adjusted R2 = 0.53

Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	F value	Pr(>F)
Model	83	361.43	5.84	0.00
YR	14	47.73	4.57	0
Q	3	7.28	3.25	0.02
area	6	216.80	48.47	0
YR*Q	42	51.58	1.65	0.01
Q*area	18	38.04	2.83	0.00

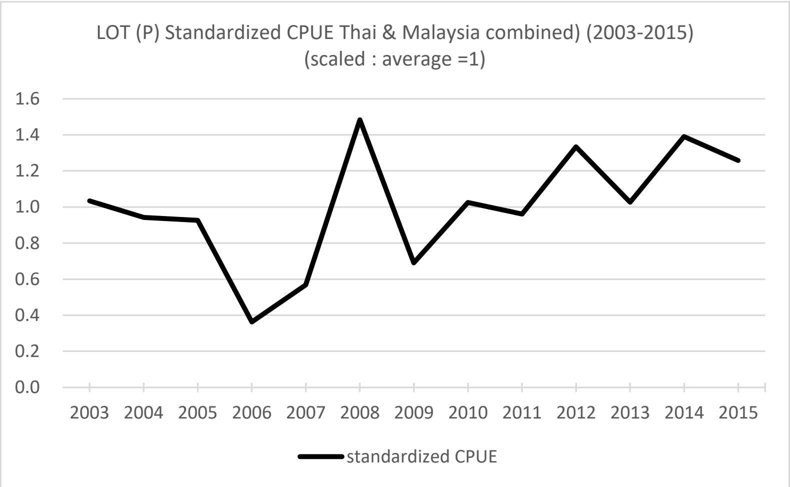


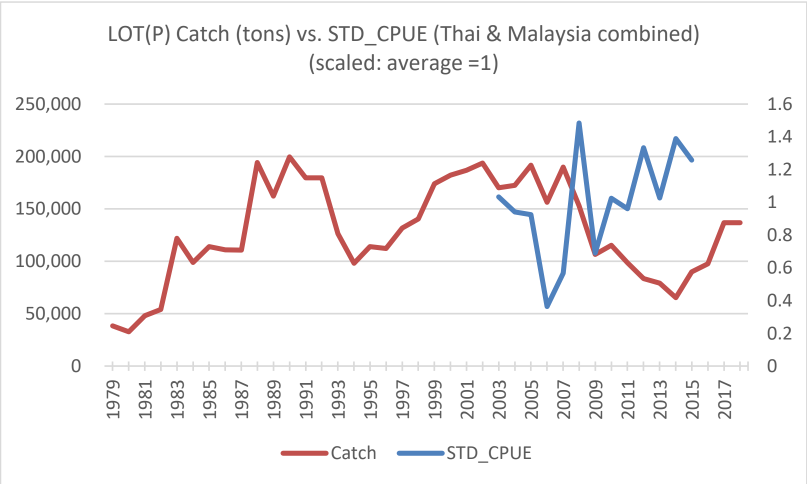


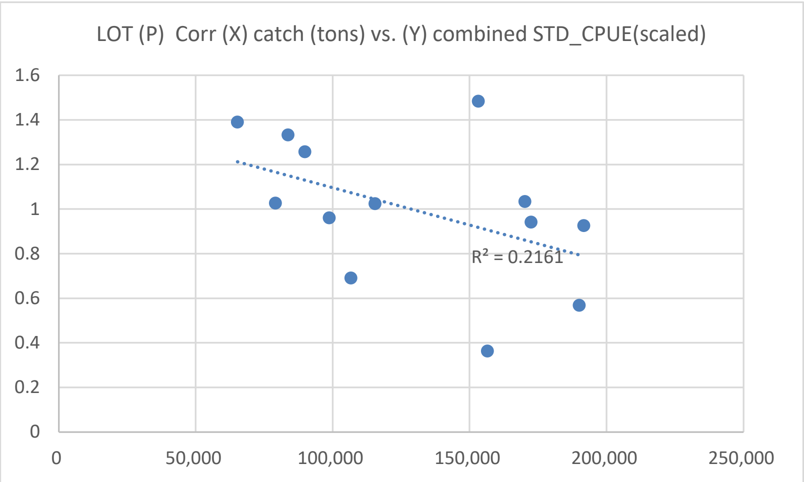




BOX 9 LOT (Pacific Ocean side) Combined standardized CPUE (Malaysia and Thailand PS) and relations with catch







BOX 10 LOT (Pacific Ocean side) Results of ASPIC

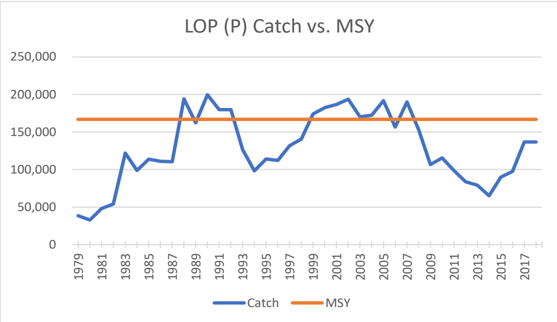
LOT (P) Estimated parameters (1111)* and catch (2018)

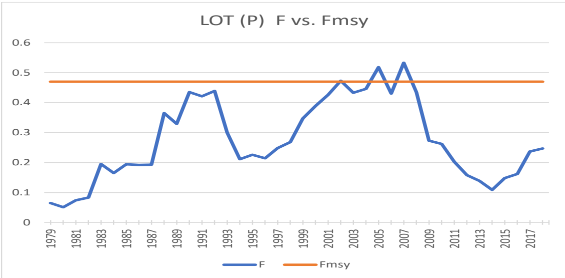
Model	r (0.99)**	q	Fmsy	$TB_{2018}/TBmsy$	$F_{2018}/Fmsy$	TB_{1979}/K	K	TB_{2018}	TBmsy	MSY	Catch (curr)
Schaefer	0.93	2.14E-06	0.47	1.52	0.53	0.79	716	564	358	167	124
							(1,000 tons)				

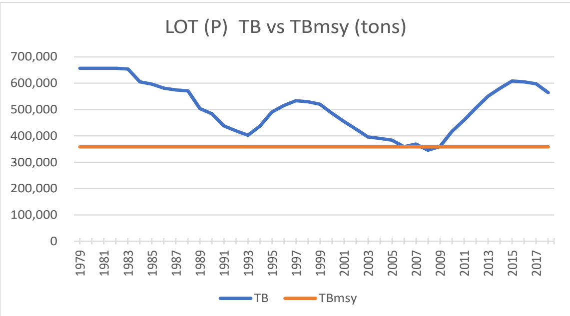
(*) Flag of parameters estimation : 1 (estimated) and 0 (fixed). Four parameters are B1/K, MSY, K and q respectively.

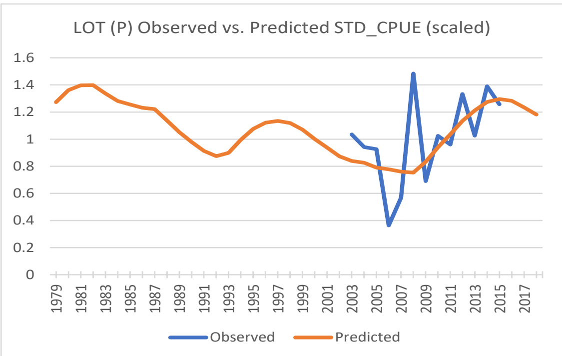
(**) Intrinsic rate of population growth

(***) Catch (curr) : average catch in recent three years(2016-2018)

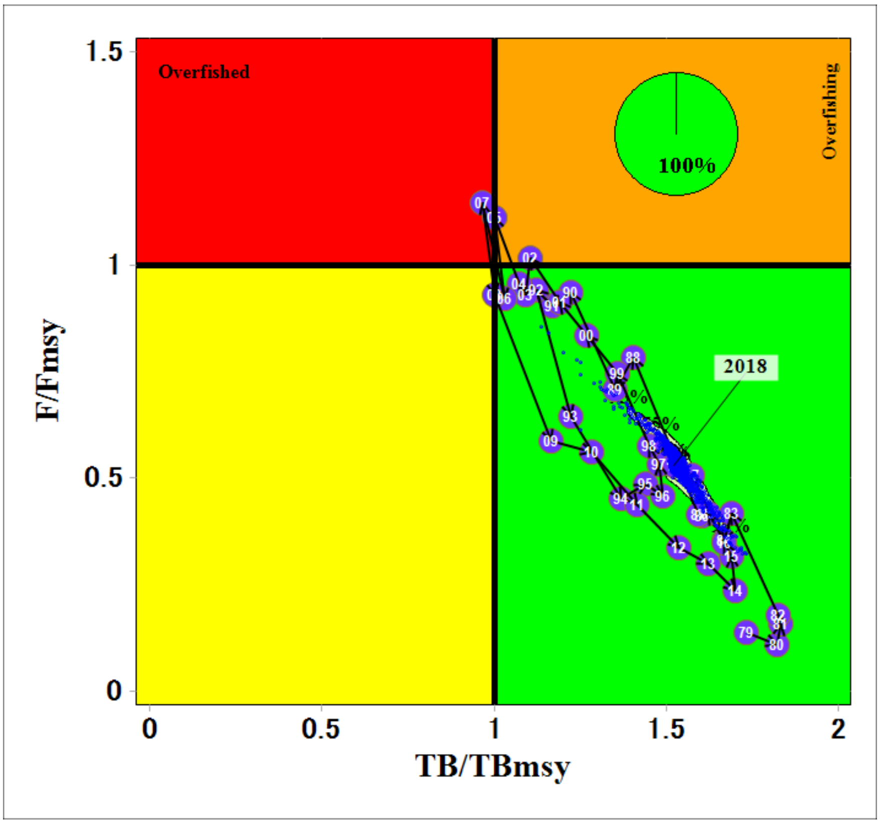








BOX 11 LOT (Pacific Ocean side) Kobe plot and results of risk assessment



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

Color legend				
Risk Levels	Low risk	Medium low risk	Medium high risk	High risk
Probability	0 – 25%	25 – 50%	50 – 75%	75 – 100

	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	100%	110%	120%	130%	135%	140%	150%	200%	250%	300%
					Current catch (*)				MSY level					
14 catch scenarios (tons)	74,259	86,636	99,012	111,388	123,765	136,142	148,518	160,894	166,800	173,271	185,648	247,530	309,412	371,295
TB2021 < TBmsy	21	22	24	26	27	29	32	34	35	35	38	51	63	75
F2021 > Fmsy	0	0	0	4	9	16	24	33	38	42	54	90	99	100
TB2028 < TBmsy	18	20	22	24	27	32	37	46	54	63	78	99	100	100
F2028 > Fmsy	0	0	0	4	9	17	26	43	56	68	86	100	100	100

(*)The current catch levels the average catch in 3 recent years(2016-2018).

5.4 LOT (Indian Ocean side)

(1) CPUE standardization (BOX 12)

Two plausible nominal CPUE in the Andaman Sea were selected, i.e., PS from Thailand and king mackerel gillnet available on the IOTC home page which was originally provided by Thailand. We attempted CPUE standardization, but neither provided statistical significances, indicating no need to use the standardized CPUE. Thus, we decided to use nominal CPUE instead of standardized CPUE.

We combined two nominal CPUE by taking their average based on the scaled CPUE (average=1) for each CPUE. Box 12 shows the trend of combined nominal CPUE, the time series relation (catch vs. combined nominal CPUE) and the negative correlation (catch vs. combined CPUE). Then we decided to use the combined nominal CPUE for ASPIC because it reflected well negatively.

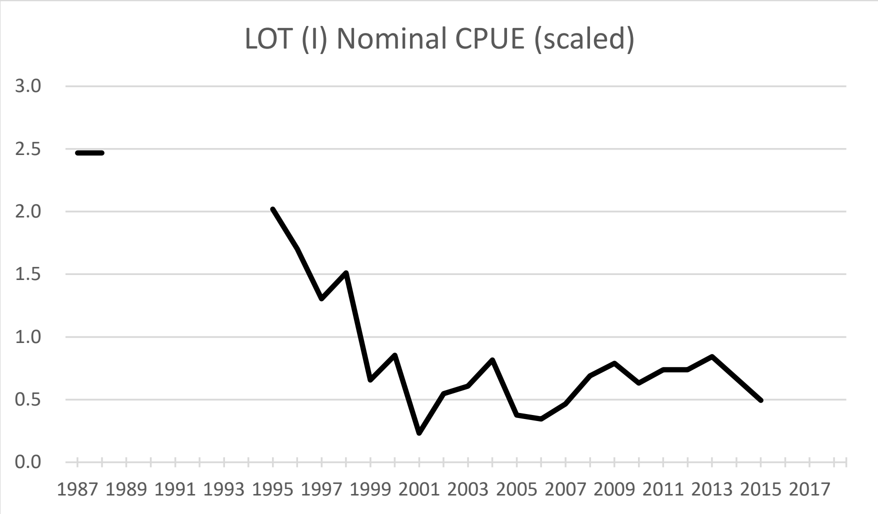
(2) ASPIC (BOX 13)

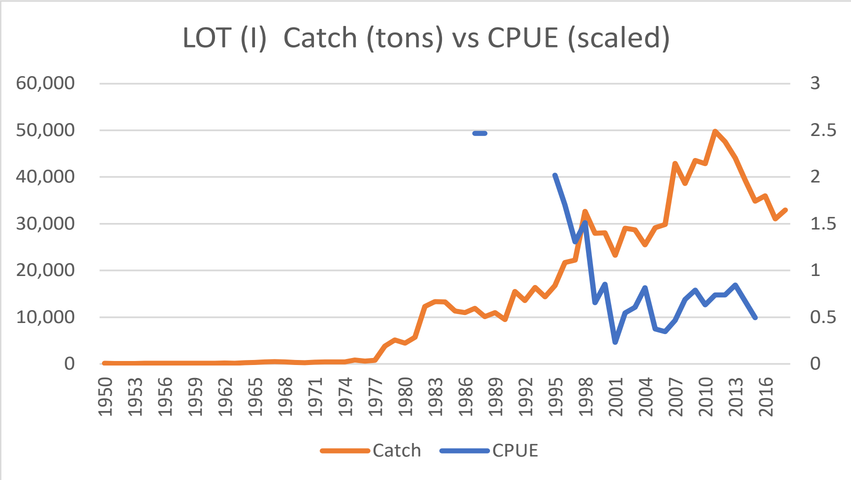
ASPIC was conducted using the catch in the Indian Ocean side and the combined nominal CPUE (PS and GILL) from Thailand. Initially we attempted to estimate all four parameters with the estimation flag set to (1111), which did not converge. As the next step, we fixed TB_{1950}/K to 1 (0111) as we consider that TB_{1950} is the virgin stock and close to K. But it did not converge again. Then we fixed K (0101) and attempted to run ASPIC runs using four plausible K values (15, 20, 25, and 30,000 tons). As a result, the best fit was obtained with K=20,000 tons. BOX 13 shows five different types of ASPIC results, including one table for “estimated parameters and related metrics” and four types of time series graphs for “catch vs. MSY”, “F vs. Fmsy”, “TB vs. TBmsy”, and “observed vs. predicted standardized CPUE”.

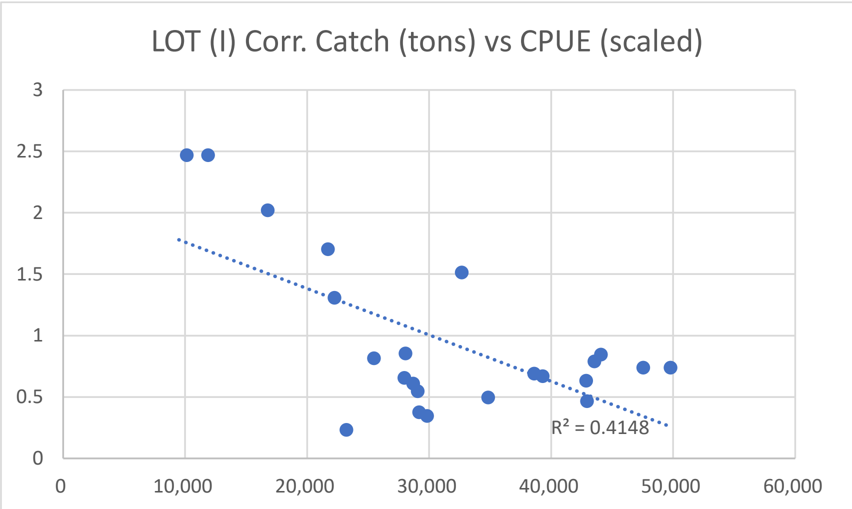
(4) Kobe plot (stock status) and risk assessments (optimum catch level) (BOX 14)

Using ASPIC results, the Kobe plot was created (BOX 14) and risk assessments were also conducted for TB and F. BOX 14 shows the results. The Kobe plot shows that the stock trajectories (2007-2018) move like in a circle from the safe (green) zone to the overfishing (orange) zone, and then return to the recovery trend (green zone). Based on the results, it is suggested that the stock status of LOT(I) in 2018 is in the green (safe) zone of the Kobe plot with 63% probability, and that the current catch (33,000 tons) can be increased by 20% (40,000 tons), in which case the risk probability of TB and F violating their MSY levels are less than 50%.

BOX 12 LOT (Indian Ocean side) CPUE used for ASPIC and relations with catch







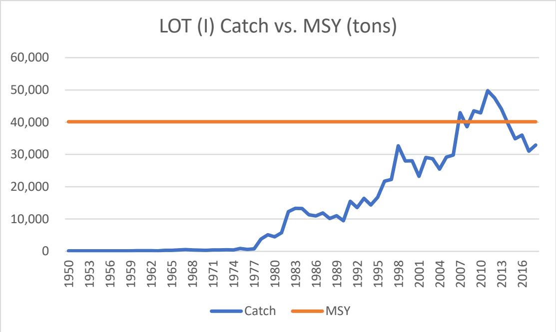
BOX 13 LOT (Indian Ocean side) Results of ASPIC

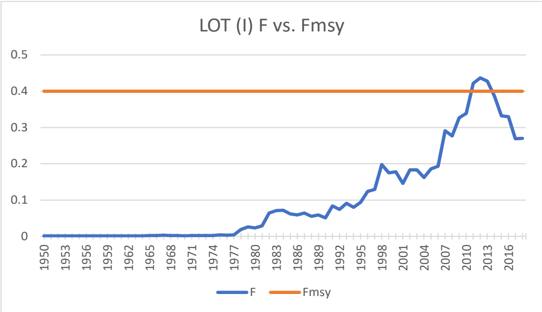
LOT (I) Estimated parameters (0101)* and catch (2018) (TB_{1950}/K and K are fixed)											
Model	r (0.99)**	q	Fmsy	TB_{2018}/TBmsy	F_{2018}/Fmsy	TB_{1950}/K	K	TB_{2018}	TBmsy	MSY	Catch (curr)
Schaefer	0.8	5.43E-06	0.4	1.24	0.67	1	200	124	100	40	33
							(1,000 tons)				

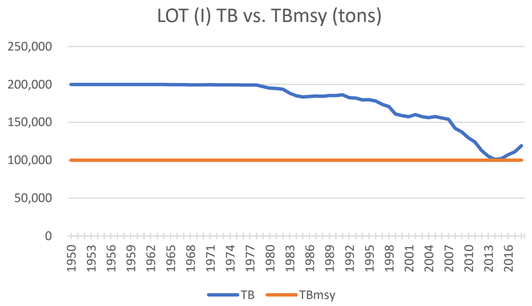
(*) Flag of parameters estimation : 1 (estimated) and 0 (fixed). Four parameters are B1/K, MSY, K and q respectively.

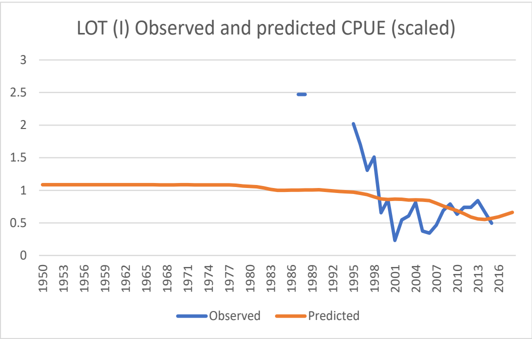
(**) Intrinsic rate of population growth

(***) Catch (curr) : average catch in recent three years(2016-2018)

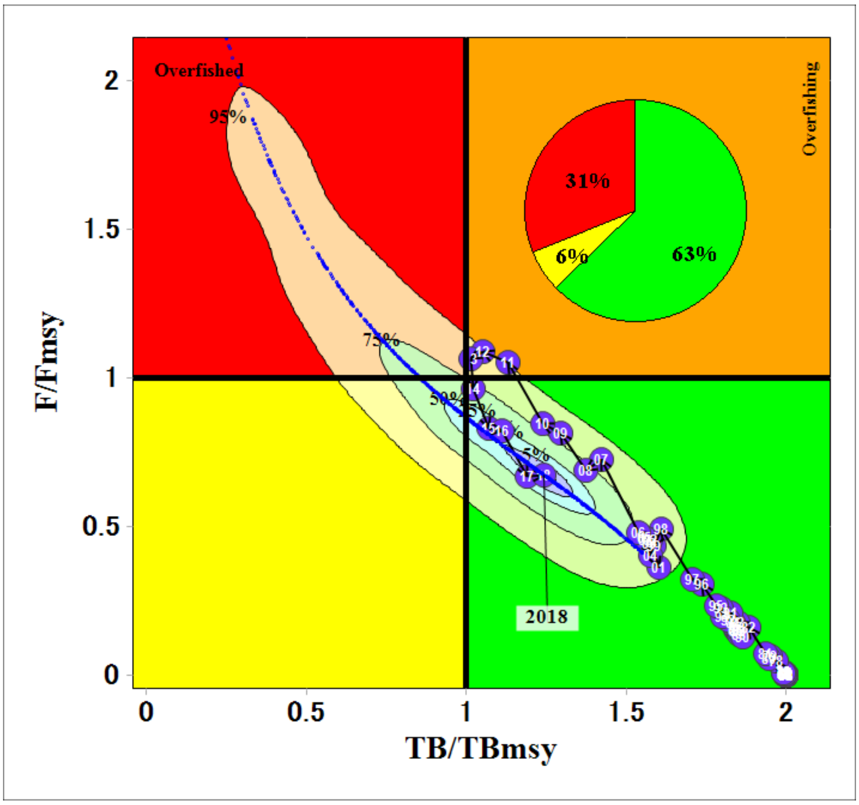








BOX 14 LOT (Indian Ocean side) Kobe plot and results of risk assessment



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

Color legend					
Risk Levels	Low risk	Medium low risk	Medium high risk	High risk
Probability	0 – 25%	25 – 50%	50 – 75%	75 – 100

	60% (−40%)	70% (−30%)	80% (−20%)	90% (−10%)	100% Current catch (*)	110%	120% MSY level	120%	130%	140%
10 catch scenarios (tons)	19,993	23,325	26,658	29,990	33,322	36,654	40,130	39,986	43,319	46,651
TB2021 < TBmsy	27	28	29	30	32	34	36	36	38	40
F2021 > Fmsy	18	20	22	23	26	30	37	37	46	59
TB2028 < TBmsy	18	19	21	23	25	32	44	44	62	73
F2028 > Fmsy	17	18	20	22	24	30	44	44	66	82

(*)The current catch levels the average catch in 3 recent years(2016-2018).

6. Discussion

6.1 Optimum catch levels

Table 4 shows a summary of results of stock and risk assessments with the optimum catch levels (suggested TAC).

Table 4 Summary of results of stock and risk assessments and the suggested optimum catch levels (TACs).

	KAW(P)	KAW(I)	LOT (P)	LOT(I)
Stock status (2018) (color in the Kobe plot)	TB/TBmsy=1.12 F/Fmsy=0.88	TB/TBmsy=0.82 F/Fmsy=1.39	TB/TBmsy=1.52 F/Fmsy=0.53	TB/TBmsy=1.24 F/Fmsy=0.67
MSY (1,000 tons)	201	56	167	40
Current catch level (1,000 tons) (average in 2016-2018)	205	62	124	33
Optimum catch levels (*) (tons) (need update every few years)	164	25	167	40
Reduction (-) or increase (+) from the current to the optimum catch levels	-20%	-40%	+35%	+20%

(*) based on the results of the risk assessment i.e., the risk probability of TB and F violating their MSY levels < 50%. This can be considered as TAC levels.

The optimum catch levels (suggested TACs) are based on the risk assessments, however, these are just references for member countries, especially for those exploiting KAW and LOT largely (see Table 2), to consider. This is because SEAFDEC is not an RFMO and cannot provide legally binding TAC recommendations. Hence, we provide soft suggestions and hopefully they will cooperate with these suggestions.

Please note that the optimum catch levels are different by species, i.e., catch of KAW (I) (unhealthy stock) and KAW(P) (safe but close to the red zone) need to be reduced from the current levels, while LOT (P and I) catch can increase. As KAW and LOT are exploited by multi-gears and multi-species fisheries, if LOT catch (healthy stocks), for example, increase by following our suggestions, KAW stock status will be worse as KAW catch need to be reduced.

Thus, simple increase or reduction of catch would be difficult to undertake because the gears used in the fisheries could catch the other species with healthy and unhealthy stock status respectively. Therefore, especially catch reduction strategies should be developed and implemented holistically considering factors relevant to the fisheries of such species, i.e. species compositions, stock statuses, fishing seasons, fishing grounds, commercial values, and the socioeconomics of fishers. One of the effective strategies is to establish temporal or seasonal closures of the areas where these LOT catches (densities) are high, while KAW, low. Each Member Country should consider such strategy holistically based on its own unique situation of these factors.

6.2 Stock status

We compared stock status available from the past stock assessments by the SEAFDEC based on ASPIC, and by IOTC based on Stock Reduction Analysis (SRA) for the Indian Ocean side.

(1) KAW (P)

Stock status for 2013 and 2018 is available based on ASPIC conducted by the SEAFEDC neritic tuna project (SEADFEC, 2017 and this document) (Fig. 6). The stock status was worsened slightly from 2013 to 2018 within the green zone because the catch level increased slightly from 2013 to 2018 (Fig. 7).

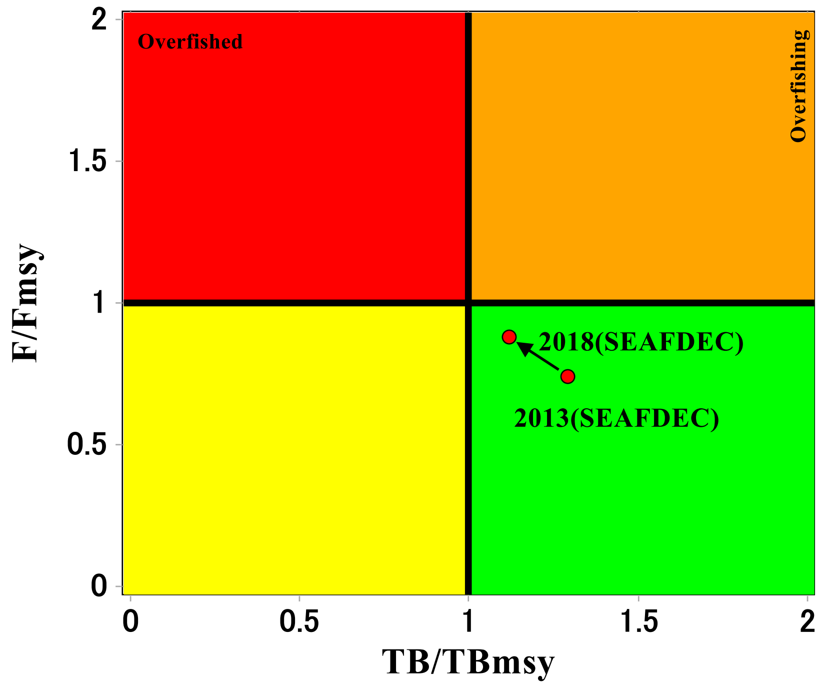


Fig. 6 Comparison of KAW stock statuses (Pacific Ocean side of the SE Asian water) between 2013 vs. 2018

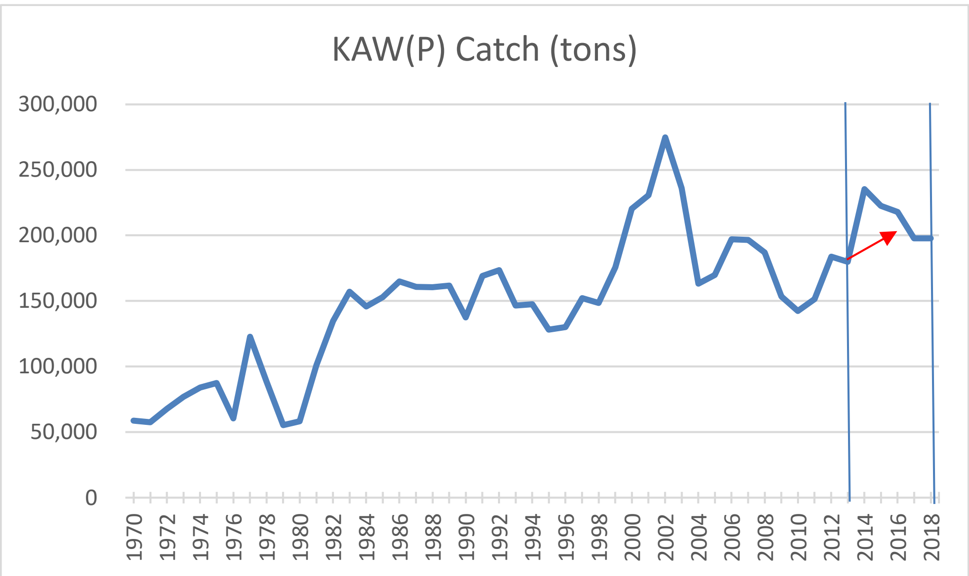


Fig. 7 Catch trend of KAW (P) highlighting two assessed years.

(2) KAW (I)

Stock status is available from results of four stock assessments, i.e. two by IOTC (2013 and 2018) for the whole Indian Ocean based on SRA (IOTC, 2019 and 2020) and two by SEAFDEC (2014 and 2018) for the SE Asian waters based on ASPIC (SEAFDEC, 2017 and this document). Fig. 8 shows the Kobe plot comparing these four points. In the SE Asian waters, the stock status is worsened significantly from 2014 to 2018 (from the green to the red zone), while for the whole Indian Ocean both points are in the green zone although biomass decreased from 2013 to 2018. A possible cause is that the catch in the SE Asian water increased in 2017-2018, while the catch in the whole Indian Ocean were stable (Fig 9). The catch increase in the SE Asian waters are not so large, but the stock status changed significantly. This implies that there may be other factors affecting this significant change, i.e., factors not incorporated into ASPIC such as recruitments, biology and ecology.

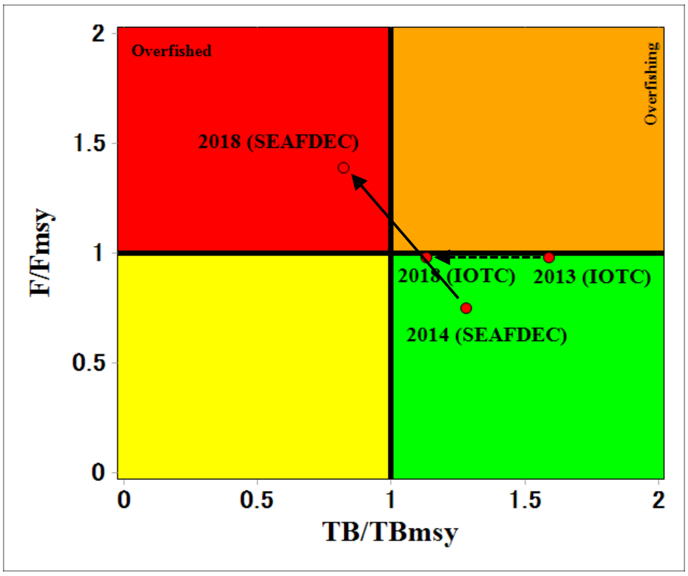


Fig. 8 Comparison of the stock status among 2013/2018 (IOTC) and 2014/2018 (SEAFDEC)

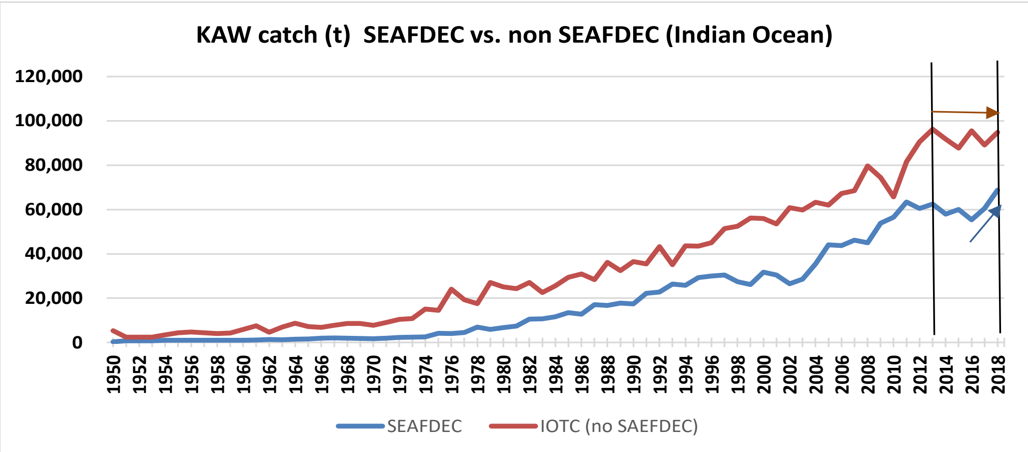


Fig. 9 Catch trends in the SE Asian (SEAFDEC) waters and the other waters in the Indian Ocean. (vertical lines indicate assessed years)

(3) LOT (P)

Stock statuses for 2013 and 2018 for the SE Asian waters bases on ASPIC is available from two practical workshops of the SEAFEC's neritic tuna project (SEAFDEC 2017 and this document respectively). Fig. 10 shows the Kobe plot comparing these two points. The stock status is worsened significantly from 2013 to 2018 due to the significant increases of the catch level (Fig.11), but it is still in the green.

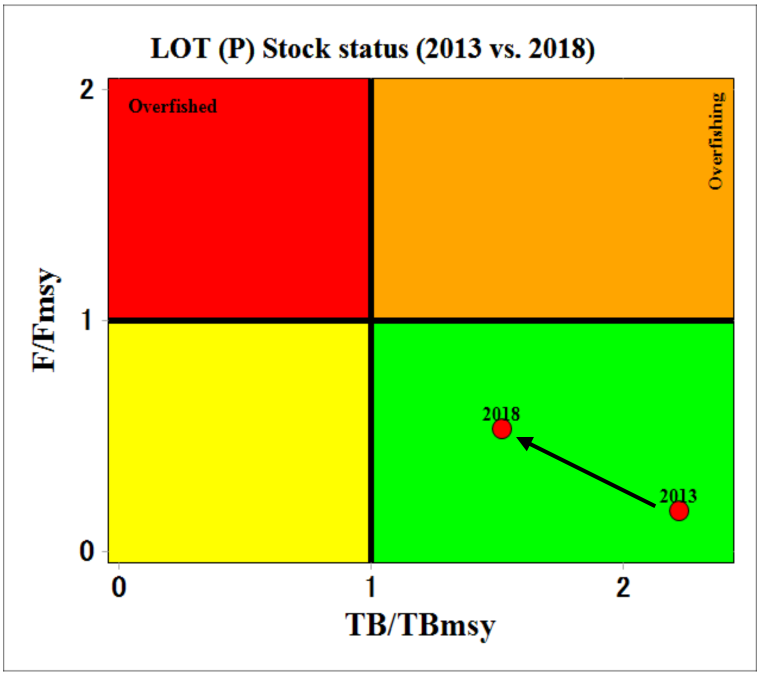


Fig. 10 Comparison of stock status between 2013 and 2018 in SE Asian waters

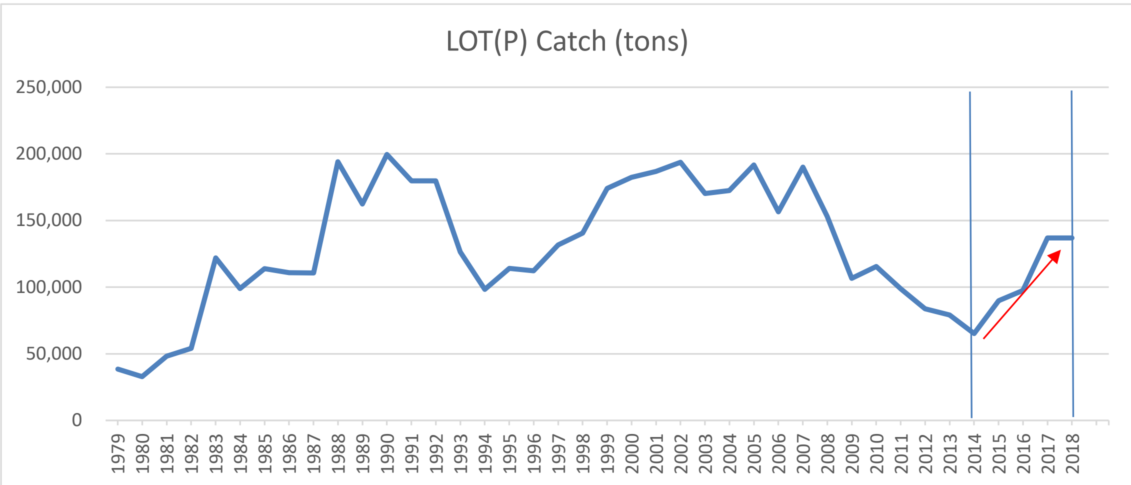


Fig. 11 Catch trend in the SE Asian waters (Pacific side)

highlighting two assessed years (vertical lines).

(4) LOT(I)

Stock status is available from results of three stock assessments, i.e. one by IOTC (2018) for the whole Indian Ocean (IOTC, 2018) and the two by SEAFDEC (2014 and 2018) for the SE Asian water (2017 and this document) and this document). Fig. 12 shows the Kobe plot comparing these three points. In the SE Asian waters, the stock status recovered greatly from 2014 to 2018 (from the red to the green zone) because the catch continuously decreased from 2011 to 2018(Fig. 13). In the whole Indian Ocean, it is in the red zone probably due to the sharp increase of the catch from 2004 to 2012, though the recent catch (2013-2018) shows a declining trend. There are two possible causes for the large discrepancy in stock status in 2018 between IOTC and SEAFDEC i.e. (a) there are less fishing pressure (F) in the SE Asian waters and (b) different stock assessment approaches are used (SRA without CPUE and ASPIC with CPUE).

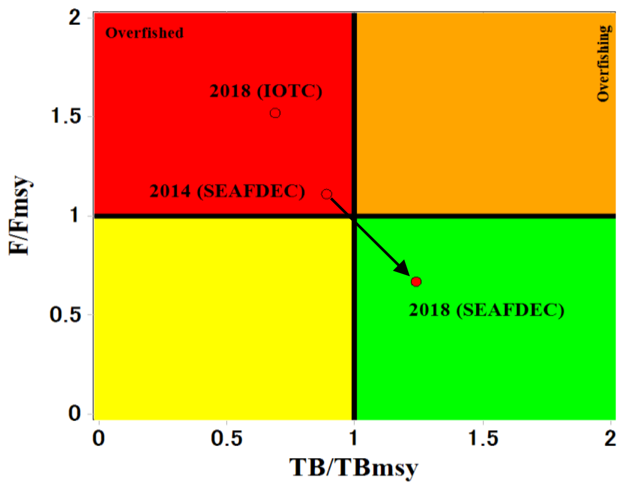


Fig. 12 Comparison of the stock statuses among 2018 (IOTC) and 2014/2018 (SEAFDEC)

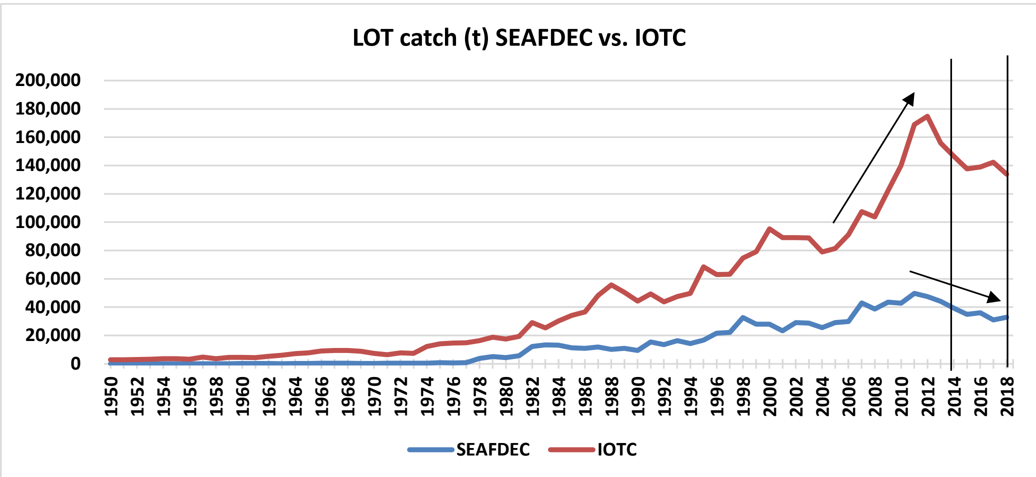


Fig. 13 Catch trends in the SE Asian (SEAFDEC) waters and the whole Indian Ocean (IOTC). (vertical lines indicate assessed years)

7. FINAL REMARKS

Please note that the results should be looked at with cautions due to uncertainties in stock structure, data, CPUE standardization and stock and risk assessments as discussed before. However, there is some consistency between catch trends and stock status as observed in the comparisons between the past and current assessments in the previous section. Therefore, the results are likely plausible to some extent. As the risk assessments for KAW (both Pacific and Indian Ocean sides) suggest reducing the current catch levels, it is hoped that member countries, especially those exploiting KAW largely, will consider reducing the current catch to the suggested levels to conserve resources and to secure sustainable yield for the long-term future.

As kawakawa and longtail tuna are among most important fisheries resources in the SEAFDEC member countries, stock and risk assessments need to update at least every three years (two years for the stocks in the unhealthy status).

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ANNEX A COMPARISONS OF STOCK STATUSES OF FOUR NERITIC TUNA SPECIES (SEAFDEC AND IOTC)

The progress of the SEAFDEC neritic tuna project is provided here by comparing the stock statuses of four neritic tuna species including those in the IOTC. Four species are kawakawa, longtail tuna, narrow-barred Spanish mackerel, and Indo-Pacific king mackerel. Table 5 and 6 show those in the Indian and the Pacific Ocean, respectively. Regarding the stock assessment methods, SEAFDEC used ASPIC, while IOTC, Stock Reduction Analysis (SRA).

In the Indian Ocean, the stock statuses between SE Asian water (SEAFDEC) and the whole Indian Ocean (IOTC) are different. This is likely because the fishing pressure are different between two areas and/or the stock assessment methods (with and without CPUE) are different.

Table 5 Summary and comparisons of four neritic species based on SEAFDEC and IOTC.

(Note) Colors are same as in the Kobe plot and % is the probability in four quadrants of the Kobe plot.

Species	area	Assessed by	Stock status (assessed year)					
			2013	2014	2015	2016	2017	2018
Kawakawa	SE Asian water	SEAFDEC		47%(*)				76%
	Whole area	IOTC	60%					50%
Longtail tuna	SE Asian water	SEAFDEC		62%				63%
	Whole area	IOTC						76%
Narrow-barred Spanish mackerel	SE Asian water	SEAFDEC				25% (*)		
	Whole area	IOTC			89%			73%
Indo-Pacific king mackerel	SE Asian water	SEAFDEC				97%		
	Whole area	IOTC						

(*) These two stock statuses are in the green zone, but probabilities are less than 50%, thus the stock status (safe) is less certain.

According Table 6, stock statuses in the Pacific Ocean side of the SE Asian waters are all in green zones and very healthy conditions except narrow-barred Spanish mackerel (red). This implies that the F in the Pacific side is likely less than in the Indian Ocean side.

Table 6 Summary and comparisons of four neritic species (Pacific Ocean side) based on SEAFDEC.

(Note) Colors are same as in the Kobe plot and % is the probability in four quadrants of the Kobe plot.

Species	Stock status (assessed year)					
	2013	2014	2015	2016	2017	2018
Kawakawa	100%					84%
Longtail tuna	100%					100%
narrow-barred Spanish mackerel				95%		
Indo-Pacific king mackerel				90%		