STOCK AND RISK ASSESSMENT OF

KAWAKAWA
(Euthynnus affinis)

AND

LONGTAIL TUNA
(Thunnus tonggol)

RESOURCES IN THE SOUTHEAST ASIA

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

NERITIC TUNA STOCK AND RISK ASSESSMENT

PART I

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SUPPORTED BY

SEC/SP/160 **February 2017**

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

THIS PAPER WAS ENDORSED BY THE 25TH MEETING OF ASEAN SECTORAL WORKING GROUP ON FISHERIES IN MAY 2017

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PART I

STOCK ASSESSMENT OF KAWAKAWA (*Euthynnus affinis*) AND LONGTAIL TUNA (*Thunnus tonggol*) RESOURCES IN THE SOUTHEAST ASIAN WATERS[1]

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February 2017

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[1] **WP05 (LOT stock assessments) and WP06 (KAW stock assessments)**
3rd Meeting of the Scientific Working Group on Neritic Tunas Stock Assessment in the SE Asian Waters, 27-29 June 2016, Cholburi, Thailand

ACKNOWLEDGEMENTS

We sincerely appreciate following experts and Agencies that made it possible to implement the SEAFDEC Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in Southeast Asian Region (17-25 April 2016), held in SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia.

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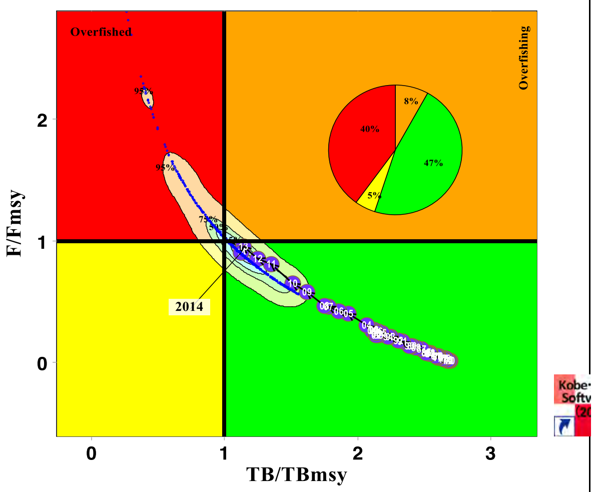
Viet Nam	Mr. Nguyen Viet Nghia

FUNDING AGENCY

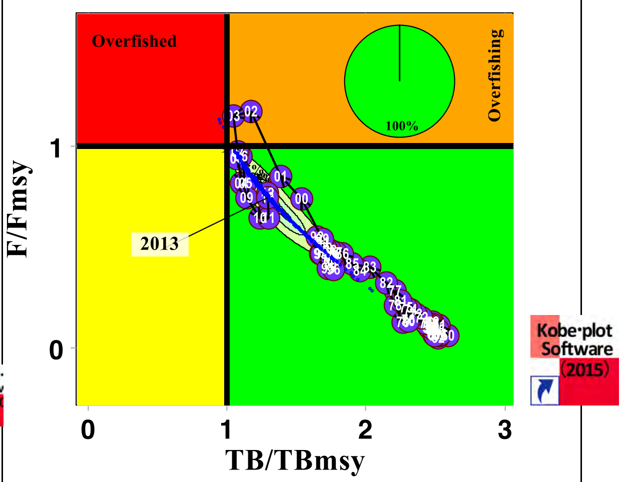
Government of Sweden through the SEAFDEC-Sweden Project entitled "**Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia**".

BOX 1 SUMMARY (STOCK STATUS BASED ON ASPIC)

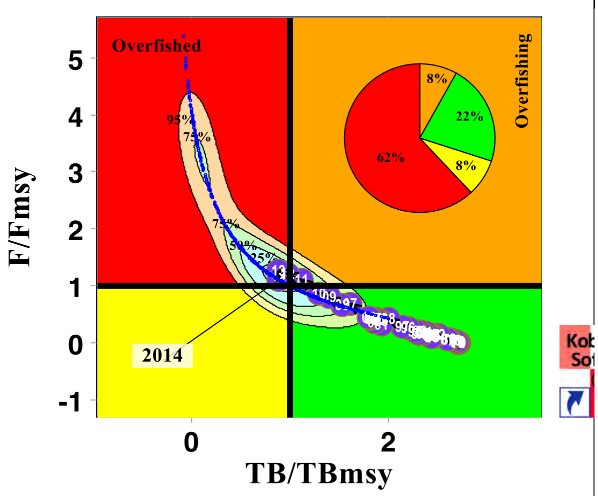
KAWAKAWA (INDIAN OCEAN stock)
Green zone (2014) (47%) (*)
(TB/TBmsy=1.28 + F/Fmsy=0.75)



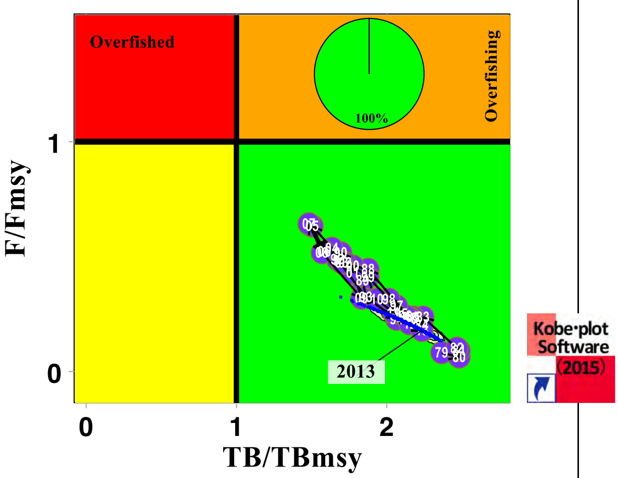
KAWAKAWA (PACIFIC OCEAN stock)
Green zone (2013) (100%) (*)
(TB/TBmsy=1.29 + F/Fmsy=0.74)



LONGTAIL TUNA (INDIAN OCEAN stock)
Red zone (2014) (22%) (*)
(TB/TBmsy=0.89 + F/Fmsy=1.11)



LONGTAIL (PACIFIC OCEAN stock)
Green zone (2013) (100%) (*)
(TB/TBmsy=2.22 + F/Fmsy=0.18)



Note (*): Compositions (%) of the areas of green zones in the areas of uncertainties (banana shape) around the recent points (2013 or 2014).

1. INTRODUCTION

Recognizing the importance of neritic tuna fisheries in the Southeast (SE) Asian Waters, the regional or sub-regional cooperation to promote the sustainable utilization of neritic tuna is therefore needed. In this connection, The Regional Plan of Action on Sustainable Utilization of Neritic Tunas in the Southeast Asian Waters (RPOA-Neritic Tunas) was finalized by all AMSs and later endorsed by the 47th Meeting of SEAFDEC Council on April 2015, the 23rd Meeting of the ASEAN Sectoral Working Group on Fisheries (ASWGFi).

The RPOA-Neritic Tuna was also supported by SSOM 36th AMAF in late 2015. One of the key actions in implementation of the RPOA-Neritic Tunas is to enhance the regional cooperation in which aims to develop/enhance Sub-Regional Action Plans for neritic tuna fisheries, support the assessment of the status and trends of neritic tuna at sub-regional level. In connection to this the Scientific Working Group on Neritic Tuna Assessment was therefore established under the ASEAN-SEAFDEC Strategic Partnership Mechanism (ASSP).

The 1st SWG-Neritic Tunas was held in cooperation with the Department of Fisheries (DOF), Malaysia at BlueWave Hotel, Shah Alam, Selangor, Malaysia from 18 to 20 November 2014. The Meeting reviewed the Updating Status and Trends of Neritic Tuna Fisheries in the Southeast Asian Region especially the status of the longtail tuna, drafting of the Term of Reference (TOR) for long term establishment of the working group in which the Member Countries agreed to support its implementation after the end of the project. The Meeting also discussed the work plan for data improvement, requirement of the capacity building.

The 2nd Meeting of the Scientific Working Group on Neritic Tuna Stock Assessment in the Southeast Asian Waters (SWG-Neritic Tunas) was convened in cooperation with the Directorate of Fisheries Viet Nam (D-Fish) at the Research Institute of Marine Fisheries (RIMF), Hai Phong, Viet Nam from 15 to 17 June 2015. The Meeting was updated on Council's decision pertaining to the Regional Plan of Action for Sustainable Neritic Tuna Fisheries and Management (RPOA-Neritic Tunas) and Terms of Reference (TOR) for SWG-Neritic Tunas. The Meeting discussed on the work plan for genetic study and stock assessment of Longtail tuna (LOT) and Kawakawa, reviewed the country status based on existing statistic data. The Meeting also discussed the prioritization of capacity building programs particularly on the Stock Assessment to support the future effective neritic tuna fisheries management which is aligned with the implementation of the adopted RPOA-Neritic Tunas.

In response to the recommendations, Secretariat in collaboration with TD organized the basic and advance Stock Assessment Training Courses in January and March 2016 under the funding support from Government of Sweden through the SEAFDEC-Sweden project. The training course focused on general stock assessment and was attended by some SEAFDEC Member Countries namely Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam. In addition, Secretariat in collaboration with MFRDMD also conducted the Special Training/Workshop on Stock Assessment of the LOT-KAW using the specific software such as CPUE standardization, A Stock-Production Model Incorporating Covariates (ASPIC)-ver.5, Kobe I (Kobe plot) and Kobe II (Risk assessment) and other relevant software.

The training/workshop could come up with some recommendations that would be useful for further stock assessment of the LOT and KAW of the Southeast Asian region. It is also noted that the genetic studies for LOT and KAW was postponed in 2015 due to the needs to revise of the work plan and process for data collection, to ensure that good quantity and quality of samples are used for genetic analysis.

To follow-up the progress of works implemented during the past years as well as to discuss on the results of the Stock Assessment for LOT and KAW based on the country data compilation and massaging by resources person, the SEAFDEC Secretariat in collaboration with the MFRDMD organized the 3rd Meeting in Bangkok, 25-27 May 2016.

2. OUTLINE

As explained in Introduction, we (nine core persons and the resource person) conducted stock assessments of KAW and LOT in SE Asian Waters (both Indian Ocean and Pacific Ocean sides) along with trainings. In this document, we report results of our works including CPUE standardization, stock assessments by ASPIC and Kobe plots, which also demonstrates our progress of the training and workshop.

2.1 STOCK STRUCTURE

In stock assessments, we assume two existing stocks for Kawakawa and Longtail tuna in the SE Asian Waters, *i.e.*, Pacific and Indian Ocean stocks (Fig. 1). Thus, we conducted 4 stock assessments (2 species for 2 stocks) and report the results in this document.

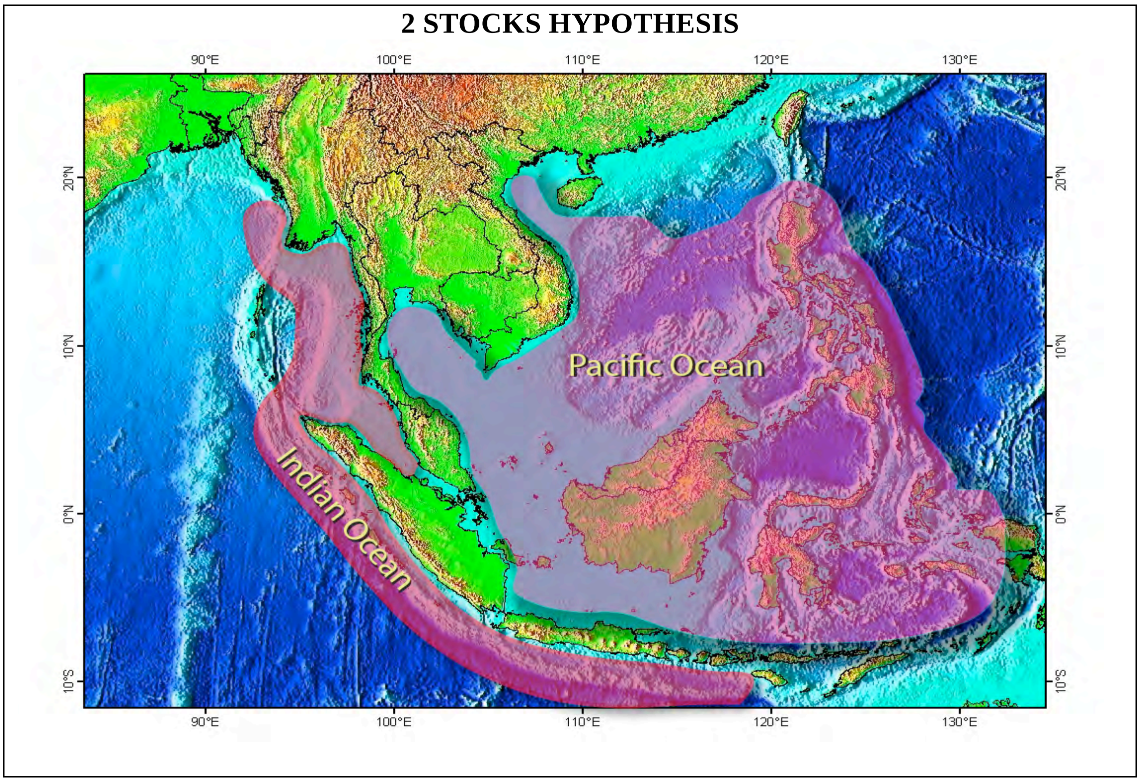


Fig. 1 2 stocks hypothesis in the Southeast Asian Waters for KAW and LOT stock assessments

2.2 DATA

In ASPIC, for each species, we need the global catch (by country) and CPUE (catch and Effort) data by country, gear and area. We now describe how we collected these data.

(1) Historical nominal catch

Historical nominal catch was obtained from data coordinators assigned in each participating country. In addition, published catch data were obtained from IOTC (Indian Ocean Tuna Commission), FAO (Food and Agriculture Organization of the United Nations) and SEAFDEC (Southeast Asian Fisheries Development Center). Using these data, we processed the most plausible catch data sets. In each stock assessment section, resultant catch series are described.

(2) CPUE

Thailand and Philippines provided nominal CPUE for PS (Purse Seine) and multi gears respectively. After we examined CPUE, we realized that CPUE from Thailand satisfied three conditions to estimate reliable and plausible CPUE standardization stated in BOX 2.

Box 2 Conditions on nominal CPUE to estimate reliable and plausible CPUE standardization

(a) data series should be more than 10 years;

(b) compositions of 0 (zero) catch should be less than 30%
(if log normal GLM is applied); and

(c) nominal CPUE trends should be smooth (no sudden jumps or extreme values).

Table 1 shows the structure of the Thailand nominal CPUE. There are data in three periods, i.e., (a) 1991-1994 (annual CPUE from DOF: Department of Fisheries), (b) 1995-2013 (monthly CPUE from DOF) and (c) 2006-2015 (set by set CPUE from AFDEC: Andaman Sea Fisheries Development Center). As the data (a) is the annual basis and we cannot standardize, hence we decided not to use. Regarding the data (b) and (c), these data are collected by different offices (methods), hence they are not same quality. Thus, we decided to use CPUE data from (b) as they have a longer time series data.

Table 1 Specification of Thai CPUE

<table>
<tr><th></th><th colspan="2">DOF/HQs</th><th colspan="2">DOF/AFDEC</th></tr>
<tr><th></th><th>Gulf of Thailand</th><th>Andaman Sea</th><th>Gulf of Thailand</th><th>Andaman Sea</th></tr>
<tr><td>1990</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1991</td><td colspan="2" rowspan="4">(a) PS CE data by year and area (GOT and Andaman Sea) (can not use for CPUE standardization）.</td><td></td><td></td></tr>
<tr><td>1992</td><td></td><td></td></tr>
<tr><td>1993</td><td></td><td></td></tr>
<tr><td>1994</td><td></td><td></td></tr>
<tr><td>1995</td><td colspan="2" rowspan="19">(b) PS CE data by area, year and month (to be used CPUE standardization）</td><td></td><td></td></tr>
<tr><td>1996</td><td></td><td></td></tr>
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<tr><td>2011</td><td colspan="2" rowspan="5">(c) PS set by set CE data by area, year, month, day and boats (to be used for CPUE standardization）</td></tr>
<tr><td>2012</td></tr>
<tr><td>2013</td></tr>
<tr><td>2014</td><td></td><td></td></tr>
<tr><td>2015</td><td></td><td></td></tr>
</table>

2.3 Results

We conducted 4 stock assessments in the Southeast Asian Waters namely (i) Kawakawa (Indian Ocean stock), (ii) Kawakawa (Pacific Ocean stock), (iii) Longtail tuna (Indian Ocean stock) and (iv) Longtail tuna (Pacific Ocean stock). In each stock assessment, we present results as stated in BOX 3.

Box 3 Presentation of ASPIC Results

(1) Historical catch by country;

(2) Nominal CPUE and relations with catch;

(3) CPUE standardization (ANOVA Table, plots of standardized CPUE, residual analyses and QQ plots) and relations with catch;

(4) ASPIC results by Kobe plots (Stock status trajectory); and

(5) Stock status and Management advice.

3. KAWAKAWA STOCK ASSESSMENT IN THE SOUTHEAST ASIAN WATERS (INDIAN OCEAN SIDE)

(1) Catch

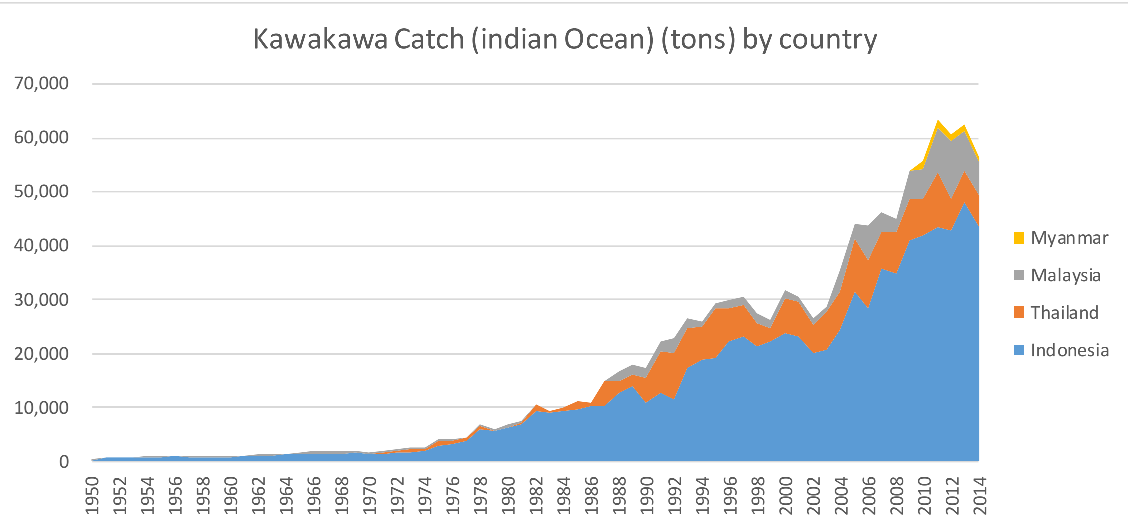


Fig 2. Kawakawa catch trend by country
(Southeast Asian Waters Water in the Indian Ocean side)

Table 2 Kawakawa nominal catch by country in the Southeast Asian Waters (Indian Ocean)

	IOTC(FAO)	IOTC(FAO)	IOTC(FAO)	FAO+data cordinator
	Indonesia	Thailand	Malaysia	Myanmar
1950	111	0	166	0
1951	641	0	111	0
1952	696	0	111	0
1953	707	0	111	0
1954	873	0	111	0
1955	873	0	111	0
1956	926	0	111	0
1957	884	0	111	0
1958	883	0	111	0
1959	884	0	111	0
1960	873	0	166	0
1961	936	0	166	0
1962	1,160	0	166	0
1963	1,182	0	111	0
1964	1,204	0	277	0
1965	1,269	0	332	0
1966	1,469	0	443	0
1967	1,493	0	554	0
1968	1,491	0	443	0
1969	1,545	0	332	0
1970	1,353	145	262	0
1971	1,312	436	183	0
1972	1,636	414	210	0
1973	1,681	680	105	0
1974	1,926	489	167	0
1975	2,783	1,155	272	0
1976	3,102	716	181	0
1977	3,668	647	256	0
1978	5,817	826	363	0
1979	5,561	112	230	0
1980	6,173	53	543	0
1981	6,898	294	286	0
1982	9,205	1,225	194	0
1983	8,987	448	0	0
1984	9,279	742	0	0
1985	9,645	1,539	0	0
1986	10,131	724	0	0
1987	10,283	4,552	0	0
1988	12,609	2,390	1,779	0
1989	13,838	2,392	1,560	0
1990	10,774	4,844	1,849	0
1991	12,696	7,637	1,883	0
1992	11,572	8,380	2,845	0
1993	17,166	7,501	1,753	0
1994	18,858	6,089	867	0
1995	19,227	9,051	1,004	0
1996	22,156	6,359	1,504	0
1997	23,076	5,940	1,395	0
1998	21,327	4,310	1,796	0
1999	22,214	2,566	1,394	0
2000	23,898	6,340	1,491	0
2001	23,240	6,233	1,002	0
2002	20,176	4,983	1,305	0
2003	20,703	7,089	819	0
2004	24,394	7,096	3,934	0
2005	31,459	9,765	2,863	0
2006	28,301	9,011	6,362	0
2007	35,614	7,028	3,487	0
2008	34,854	7,519	2,579	9
2009	40,864	7,832	5,160	0
2010	41,921	6,709	5,598	1,623
2011	43,481	9,997	8,409	1,517
2012	42,896	5,881	10,478	1,319
2013	48,181	5,700	7,259	1,307
2014	43,484	5,642	6,214	909

(2) Nominal CPUE and relation with catch

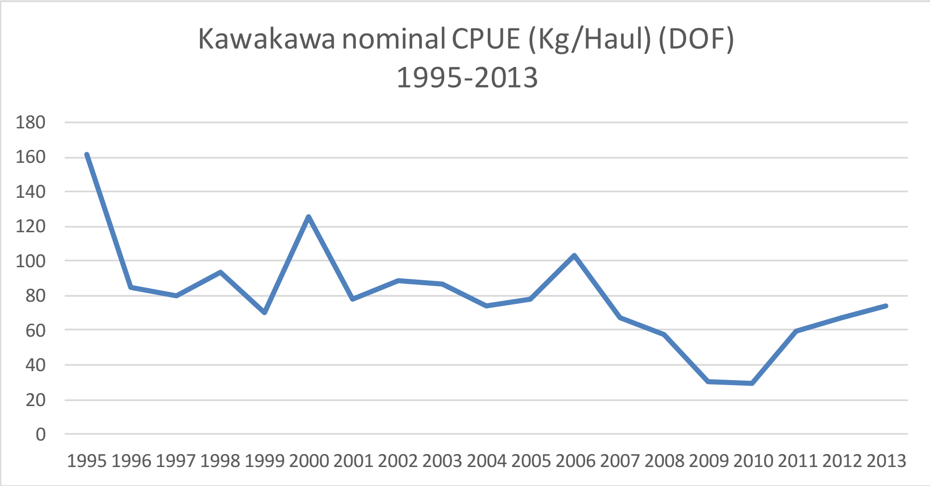
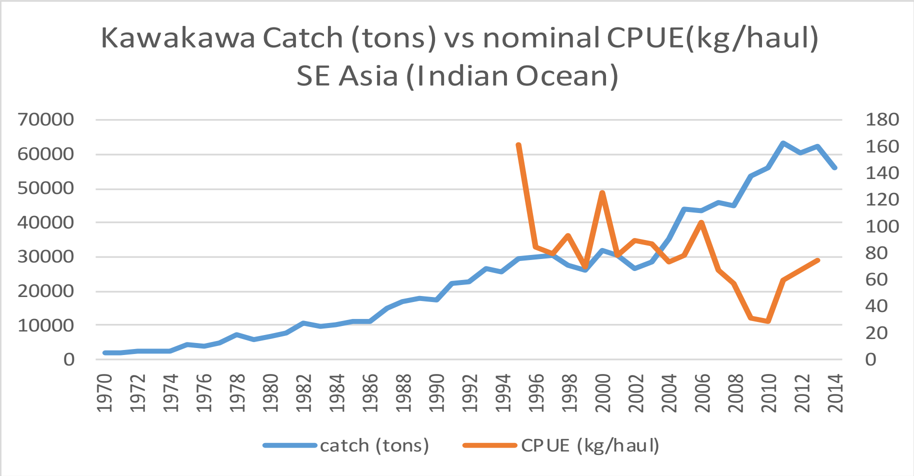


Fig. 3 Trend of nominal CPUE



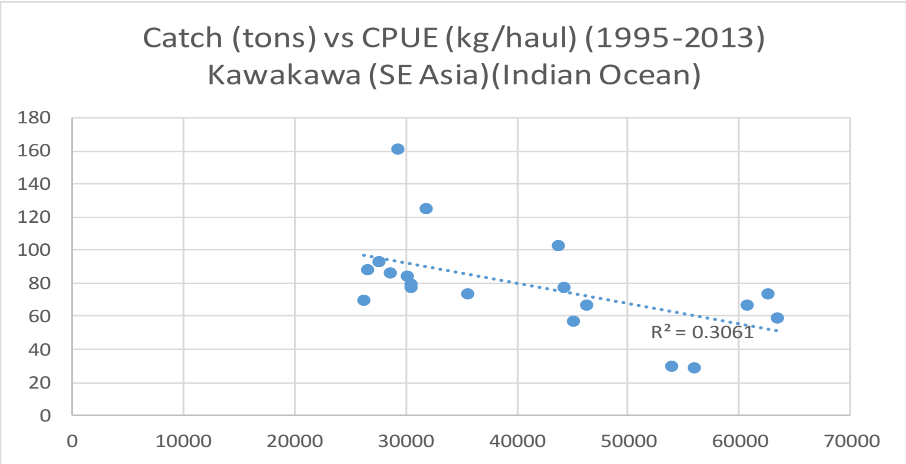


Fig. 4 Relations between catch and nominal CPUE

(3) CPUE standardization (Table 3 and Figs 6-8)

TABLE 3

ANOVA (Analysis Of Variance) Table					
Adjusted R2 = 0.4819					
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	MSE (Mean Squared Error)	F value	Pr(>F)
YR	18	34.39	1.91	2.14	0.00
Q	3	294.08	98.03	109.98	0.00
Area	1	1.20	1.20	1.34	0.25
Residuals	352	313.75	0.89		

Fig 5.

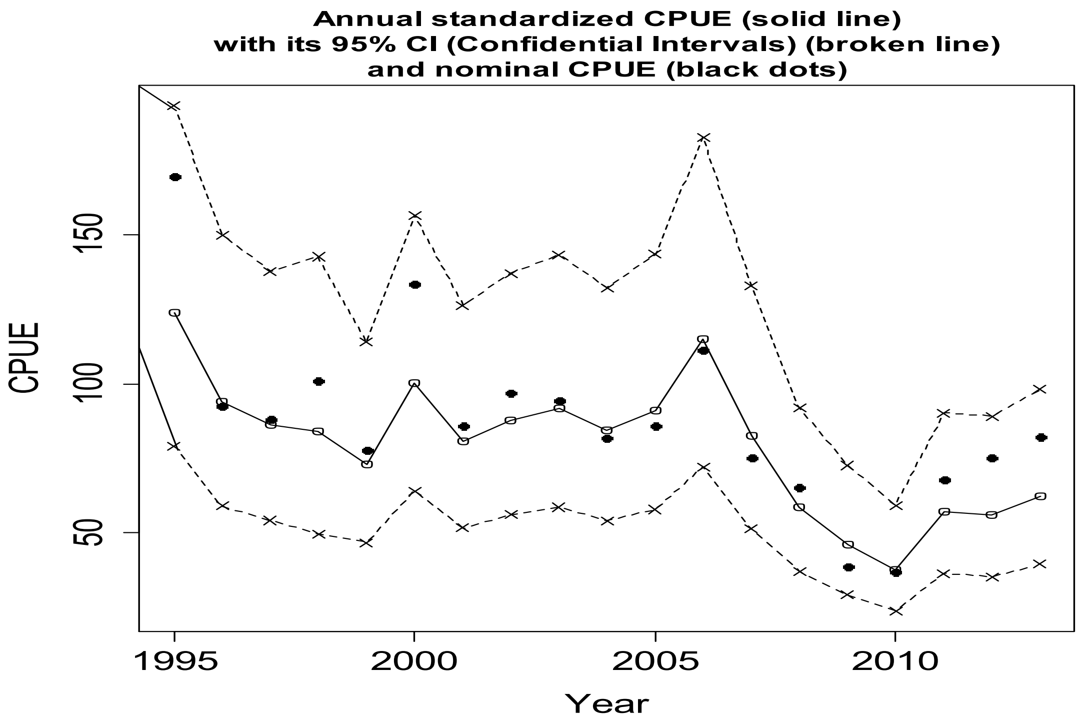
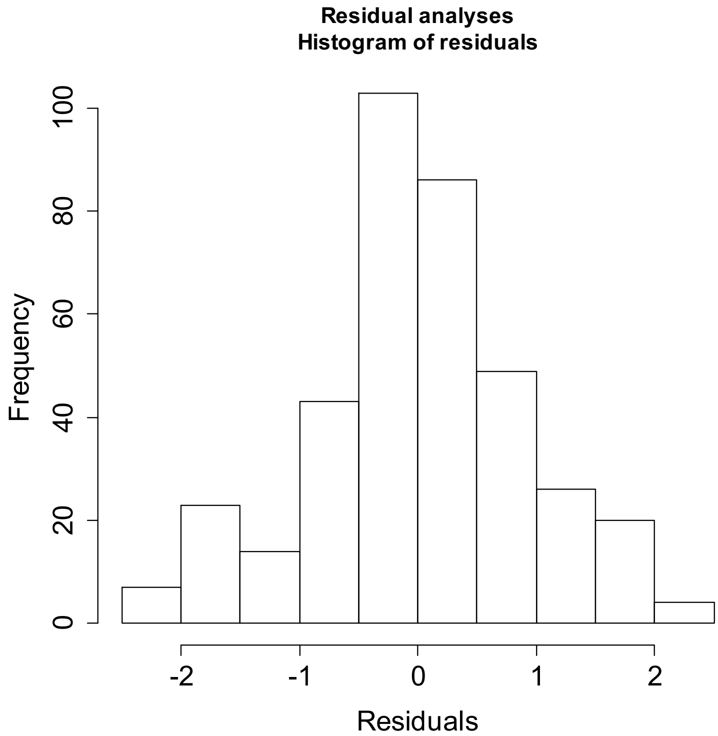


Fig. 6


Residual analyses
Histogram of residuals
Frequency
0
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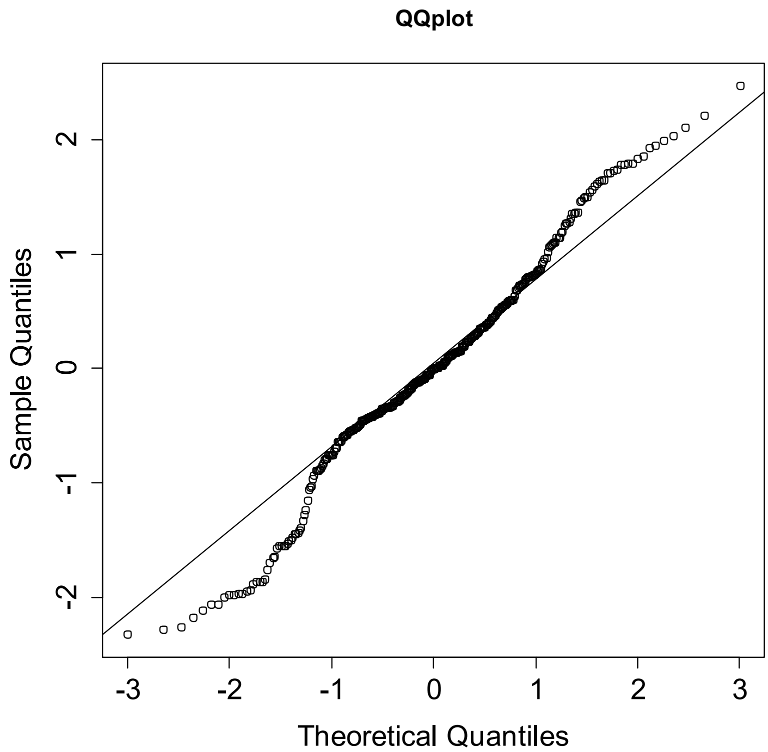
40
60
80
100
-2
-1
0
1
2
Residuals

Fig. 7


QQplot
Sample Quantiles
-2
-1
0
1
2
-3
-2
-1
0
1
2
3
Theoretical Quantiles

(4) ASPIC RESULTS BY KOBE PLOTS (STOCK STATUS TRAJECTORY)

There were no convergences when we attempted to estimate all parameters. Then we assume B0/K=1 and we fixed plausible K values (100, 200 and 300,000 tons). As r values are not realistic for 100 and 300,000 tons, we selected parameters when K=200,000 tons.

Table 4 Results of ASPIC stock assessments on 5 scenarios

Model	K(fixed) (1,000t)	B0/K=1	r	MSY (1,000t)	TB/TBmsy	F/Fmsy	Bmsy	Fmsy	TB	R2	RMS
Fox	100	1	1.76 (too high)	65	1.43	0.61	37	1.45	50	0.23	0.36
Fox	200	1	0.80	59(*)	1.28	0.75	74	0.80	94	0.24	0.37
Fox	300	1	0.48 (too low)	53	1.16	0.91	110	0.48	110	0.25	0.36
Fox	400	1	0.32 (too low)	47	1.07	1.09	147	0.32	167	0.27	0.36
Fox	500	1	0.23 (too low)	42	1.02	1.26	147	0.23	202	0.28	0.35

(*) 59,800 t

(5) STOCK STATUS AND MANAGEMENT ADVICE

Based on the Kobe plots, the 2014 stock status of kawakawa in the **Southeast Asian Waters** (Indian Ocean side) is in the green zone (F/Fmsy=0.75 and TB/TBmsy=1.28), i.e., F is 25% lower than F_{MSY} level and TB is 28% higher than its MSY level. Although Kawakawa stock in the Indian Ocean side is in the safe condition, it is recommended that both fishing pressure and catch should not exceed the 2014 level because 53% of uncertainties around the 2014 point is 53% (Red, Orange and Yellow zone in the Kobe plot), while the 47% is in the safe (green) zone.

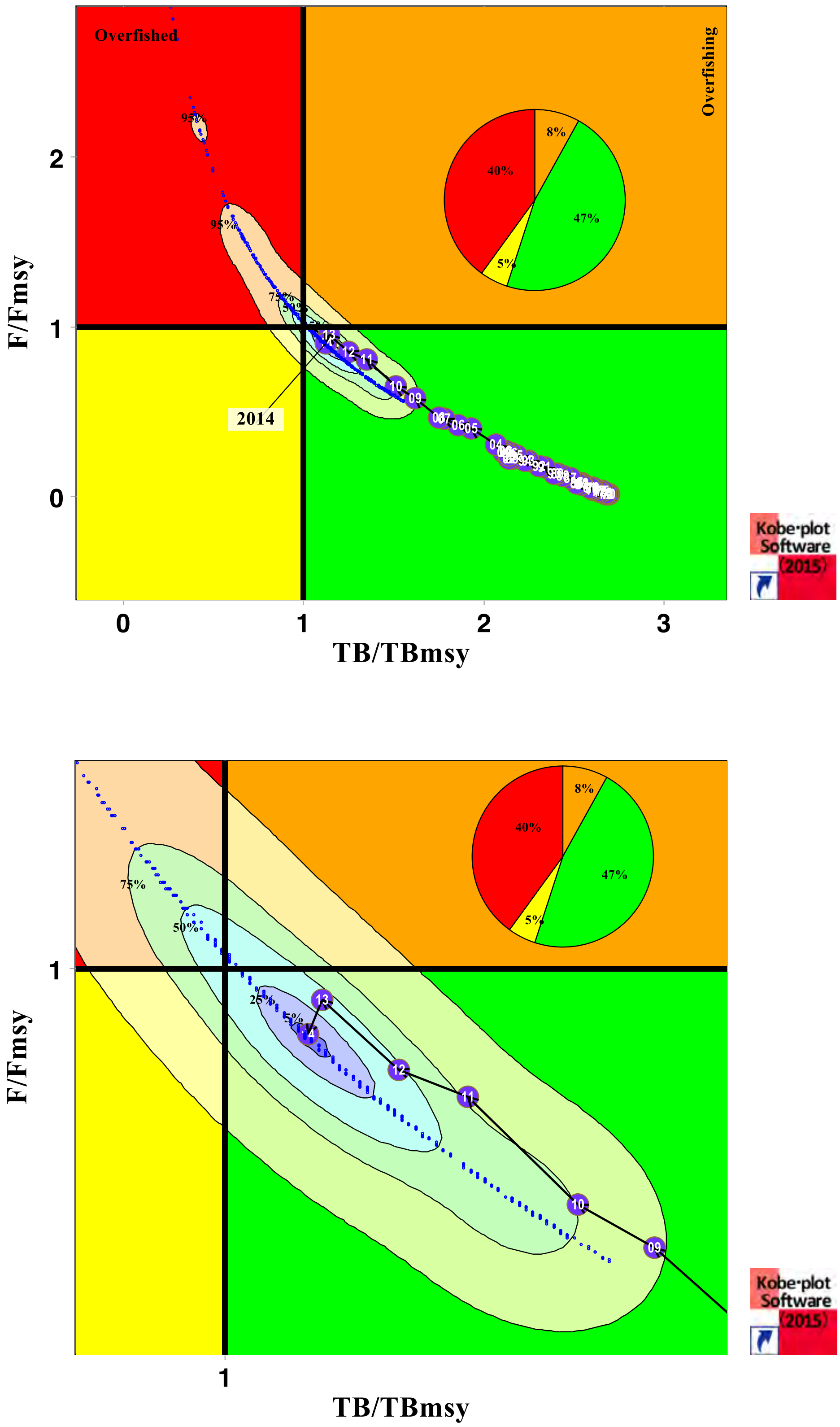


Fig. 8 Kobe plots on KAW stock assessments in the Southeast Asian Waters (Indian Ocean side)

4. KAWAKAWA STOCK ASSESSMENT IN THE SOUTHEAST ASIAN WATERS (PACIFIC OCEAN SIDE)

(1) Catch by country

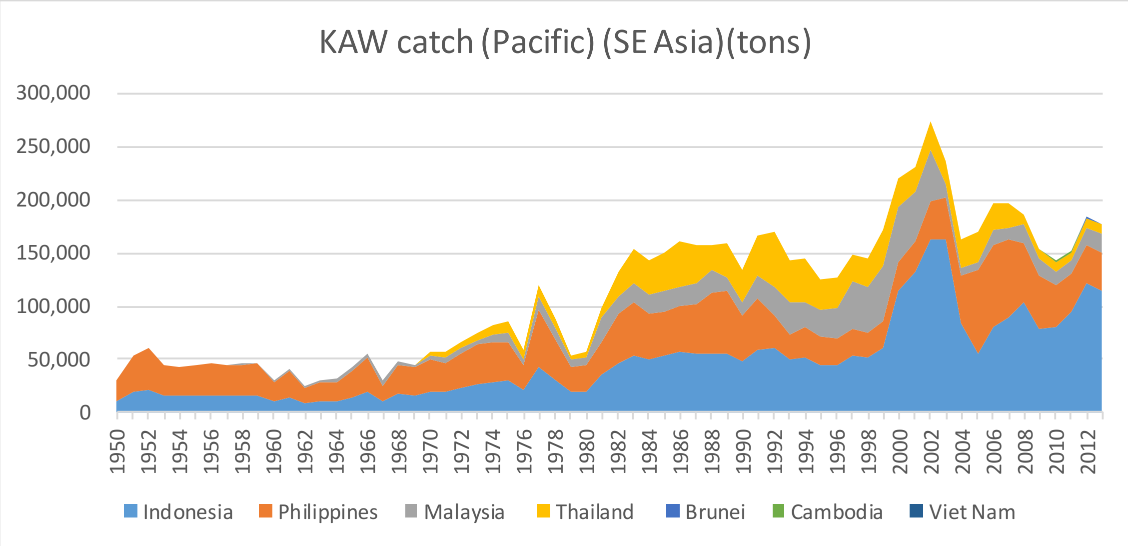


Fig. 9 Kawakawa catch trend by country (SE Asian waters in the Pacific Ocean)

(2) Nominal CPUE

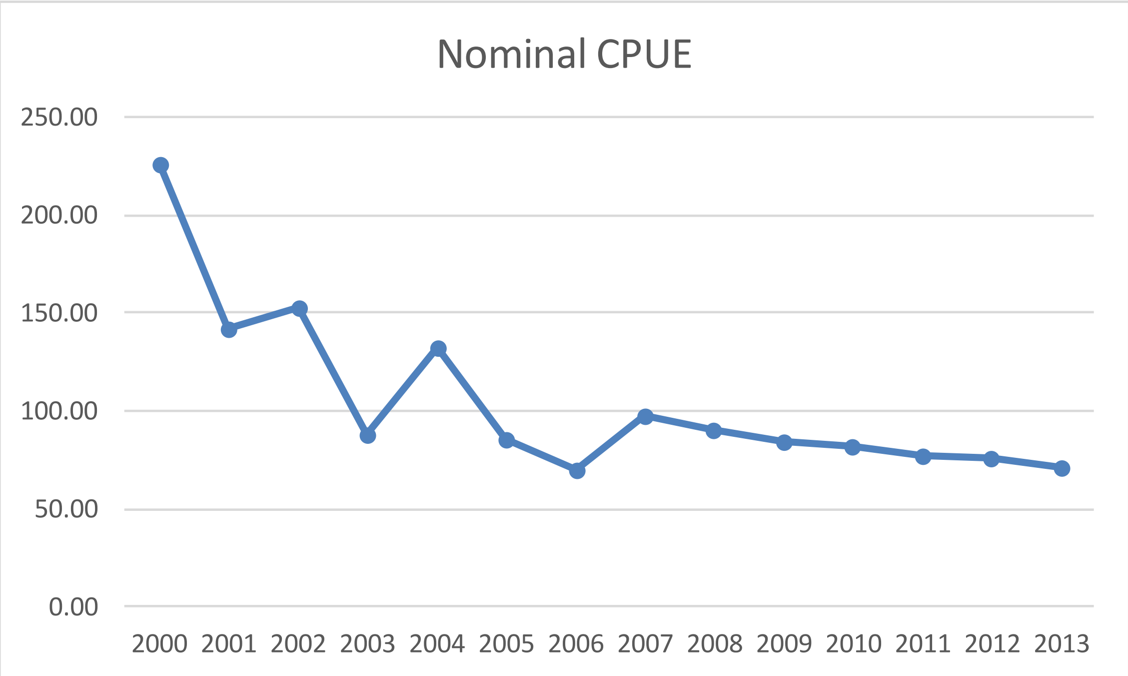


Fig 10 Nominal CPUE

Table 5 Kawakawa nominal catch by country in the Southeast Asian Waters (Pacific Ocean) (1950-2013)

Source	FAO	FAO	FAO	FAO	Cordinator	Cordinator	Cordinator
Country	Indonesia	Philippines	Malaysia	Thailand	Brunei	Cambodia	Viet Nam
1950	10,993	18,900	1,200	0	0	0	0
1951	19,087	34,100	800	0	0	0	0
1952	21,548	38,600	800	0	0	0	0
1953	15,915	28,300	800	0	0	0	0
1954	15,204	27,000	800	0	0	0	0
1955	15,806	28,100	800	0	0	0	0
1956	16,462	29,300	800	0	0	0	0
1957	15,806	28,100	800	0	0	0	0
1958	16,134	28,700	800	0	0	0	0
1959	16,462	29,300	800	0	0	0	0
1960	10,720	18,400	1,200	0	0	0	0
1961	14,493	25,300	1,200	0	0	0	0
1962	8,696	14,800	1,100	0	0	0	0
1963	10,446	18,000	1,100	0	0	0	0
1964	11,102	18,200	2,100	0	0	0	0
1965	14,876	24,700	2,500	0	0	0	0
1966	19,798	32,800	3,400	0	0	0	0
1967	10,610	14,900	4,500	0	0	0	0
1968	17,173	27,700	3,700	0	0	0	0
1969	15,861	26,200	2,800	0	0	0	0
1970	20,375	28,800	4,140	4,315	0	0	0
1971	19,932	27,200	3,820	5,424	0	0	0
1972	23,494	32,500	4,950	5,508	0	0	0
1973	26,623	38,100	4,060	6,519	0	0	0
1974	29,059	37,801	6,617	8,715	0	0	0
1975	30,328	36,199	8,091	11,163	0	0	0
1976	20,912	23,004	6,342	8,890	0	0	0
1977	42,477	54,744	11,626	11,296	0	0	0
1978	30,682	36,341	11,501	8,258	0	0	0
1979	19,168	23,094	7,824	4,130	0	0	0
1980	20,217	24,730	7,303	4,933	0	0	0
1981	35,003	30,891	22,870	10,240	0	0	0
1982	46,717	46,524	15,541	23,355	0	0	0
1983	54,446	48,880	19,121	31,550	0	0	0
1984	50,470	41,899	19,384	30,999	0	0	0
1985	52,946	41,060	20,105	35,644	0	0	0
1986	57,136	42,445	18,049	43,976	0	0	0
1987	55,678	46,934	19,528	35,341	0	0	0
1988	55,605	56,266	21,606	23,799	0	0	0
1989	56,005	57,899	13,457	31,045	0	0	0
1990	47,592	43,762	13,186	30,071	0	0	0
1991	58,585	47,850	23,006	36,263	0	0	0
1992	60,127	31,943	26,809	51,187	0	0	0
1993	50,773	21,714	30,520	40,602	0	0	0
1994	51,124	29,669	22,881	40,927	0	0	0
1995	44,370	27,308	24,948	28,871	0	0	0
1996	45,082	24,345	29,810	28,275	0	0	0
1997	52,685	26,573	44,201	25,557	0	0	0
1998	51,397	24,424	43,126	26,427	0	0	0
1999	60,849	25,406	51,665	34,188	0	0	0
2000	113,738	27,963	51,005	27,654	0	0	0
2001	133,122	27,280	47,133	23,000	1	0	0
2002	163,573	34,681	49,149	27,391	5	0	0
2003	163,159	38,675	12,256	22,016	10	0	0
2004	84,134	44,875	6,202	27,931	77	0	0
2005	56,124	77,674	8,003	27,947	106	0	0
2006	79,894	78,377	13,578	25,273	19	0	0
2007	89,020	73,094	10,897	23,476	7	0	0
2008	103,530	54,907	19,383	9,082	53	0	0
2009	78,849	49,973	15,717	8,478	24	300	0
2010	80,805	38,237	14,004	8,898	64	300	0
2011	95,047	36,403	12,518	7,199	37	300	0
2012	122,230	35,807	16,453	8,862	219	300	0
2013	114,446	36,100	17,947	8,382	160	300	145

(3) Standardized CPUE and relation with catch (Table 6 and Figs 12-14)

Table 6

ANOVA (Analysis Of Variance) Table					
Adjusted R2 = 0.6535					
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	MSE (Mean Squared Error)	F value	Pr(>F)
YR	13	91.52	7.04	11.49	0.00
Q	3	13.73	4.58	7.47	0.00
area	6	1059.19	176.53	288.14	0.00
Residuals	974	596.74	0.61		

Fig. 11

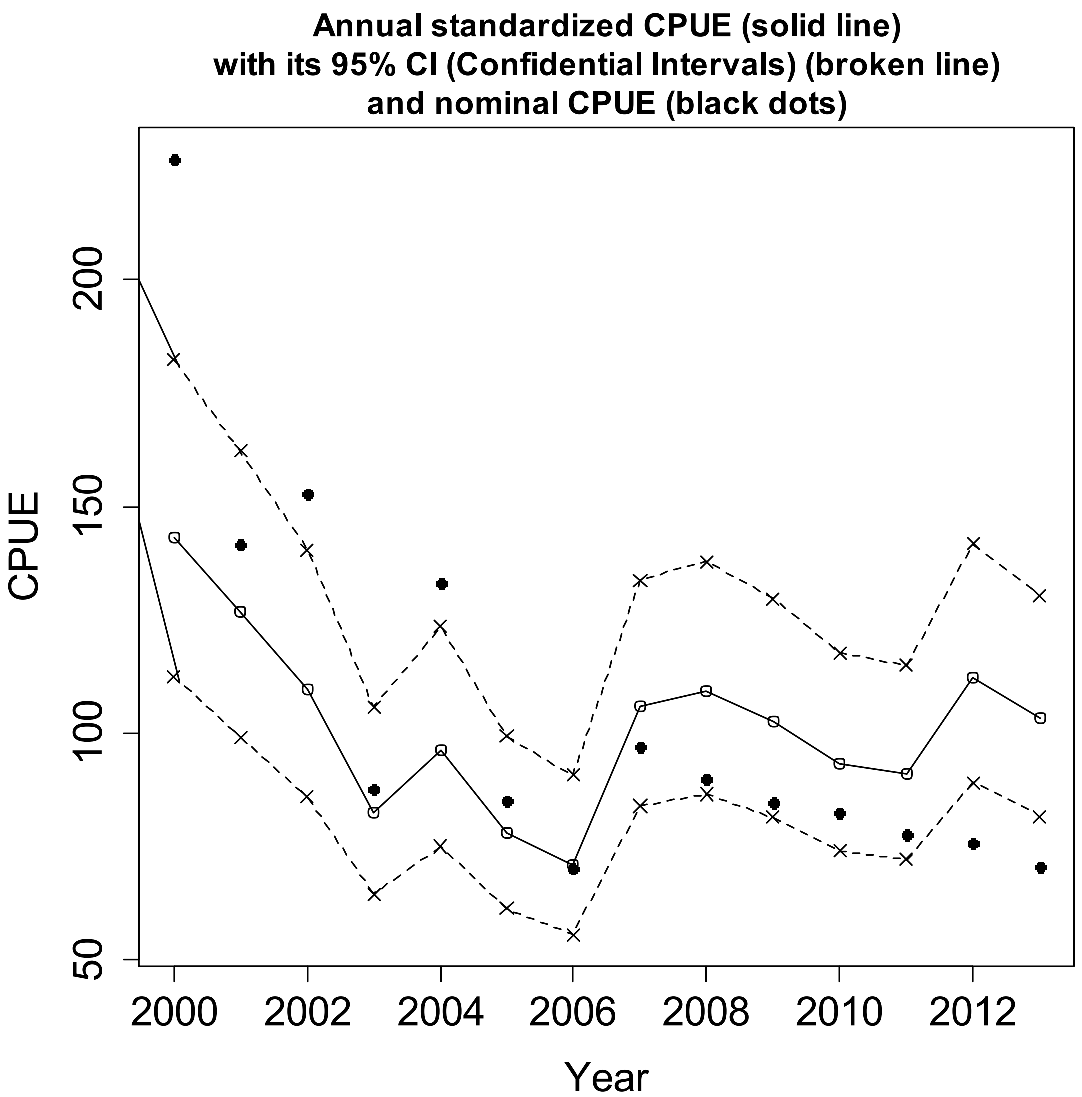


Fig. 12

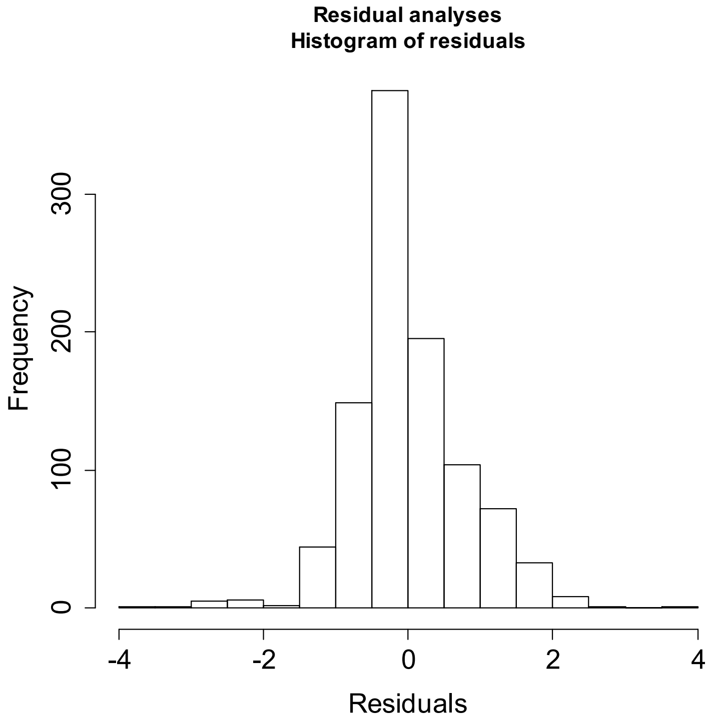
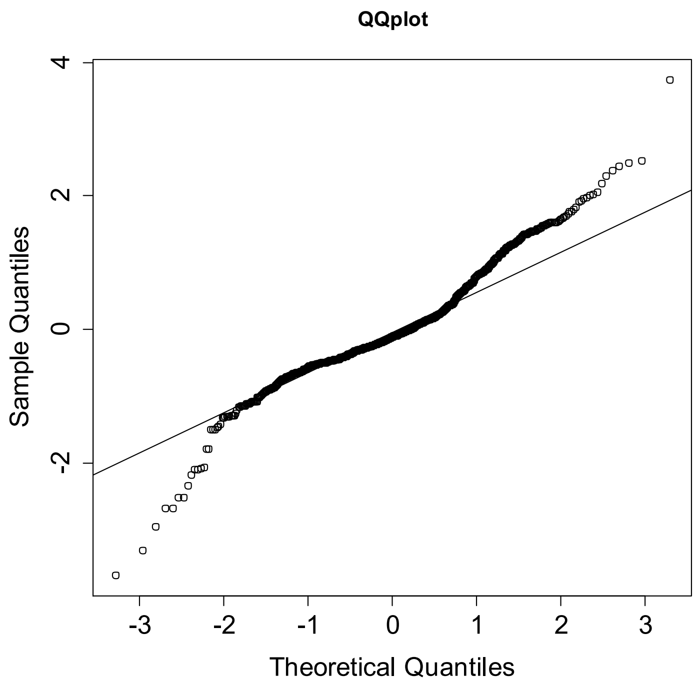

Residual analyses
Histogram of residuals
Frequency
0
100
200
300
-4
-2
0
2
4
Residuals

Fig. 13


QQplot
Sample Quantiles
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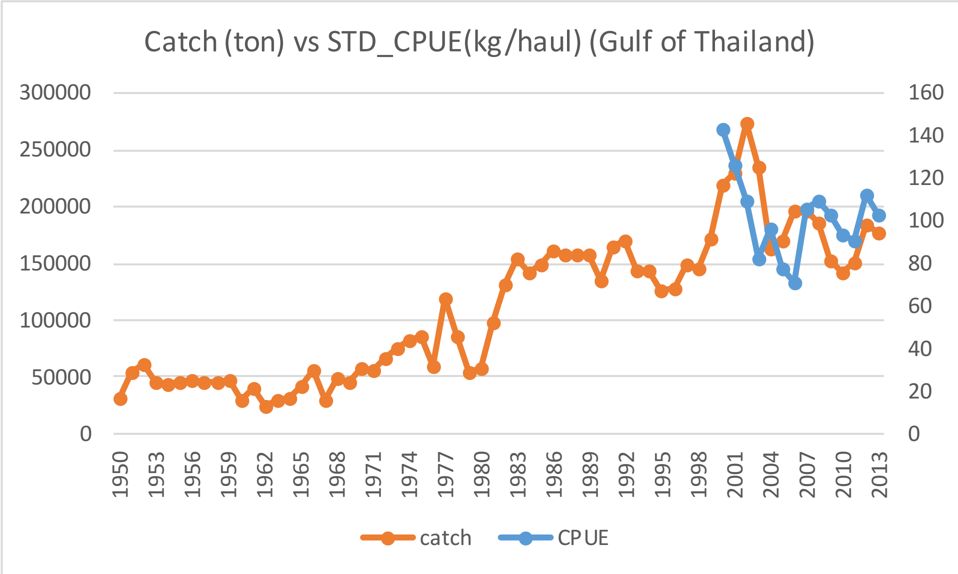
Theoretical Quantiles



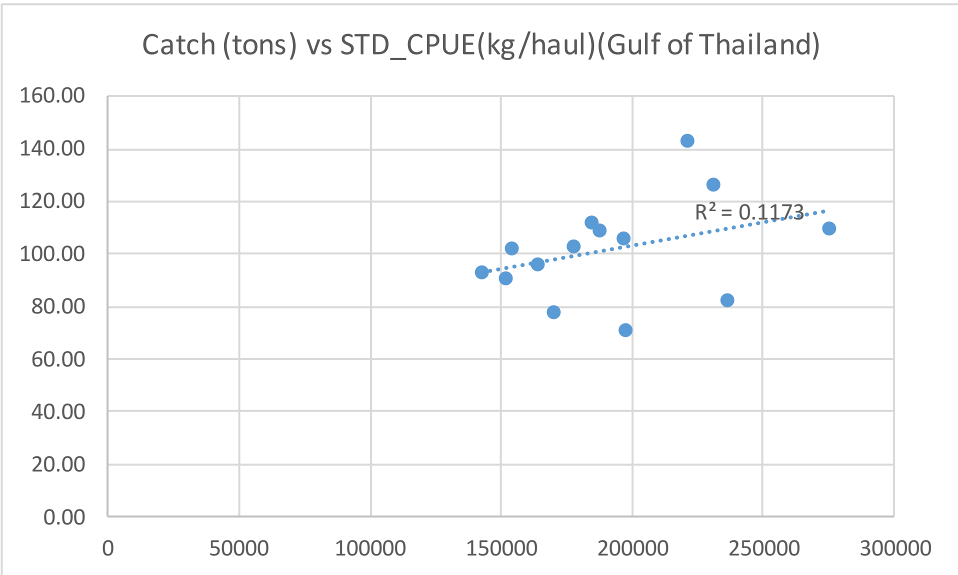


Fig 14 Relation between catch vs standardized CPUE

(4) ASPIC results using the Kobe plots (Stock status trajectory)

All parameters are estimated without any conversion problems.

Table 7 Results of ASPIC stock assessments

Model	K	B0/K=1	R	MSY (1,000t)	TB/TBmsy	F/Fmsy	Bmsy	Fmsy	TB	R2	RMS
Fox	117	0.96	0.42	185.4	1.29	0.74	43	0.43	56	0.57	0.15

(5) Stock status and management advice

The current stock status is in the safe zone (Green in the Kobe plot), i.e., TB/TBmsy=1.29 and F/Fmsy=0.74 implying that TB is the 29% higher than the MSY level and F is 26% lower than the F_{MSY} level. This is because there was significant catch decrease after 2002 (peak level) and the current catch level is low. In addition, the Kobe plot shows that there is no probability that uncertainties in the 2013 estimates fall in the unsafe zone (red, orange and yellow zone in the Kobe plot).

Thus, **there are no problems to maintain the current catch and F (fishing pressure) levels**, but both catch and F (fishing pressure) should be maintained under their MSY levels (185,000 tons and 0.43 respectively)

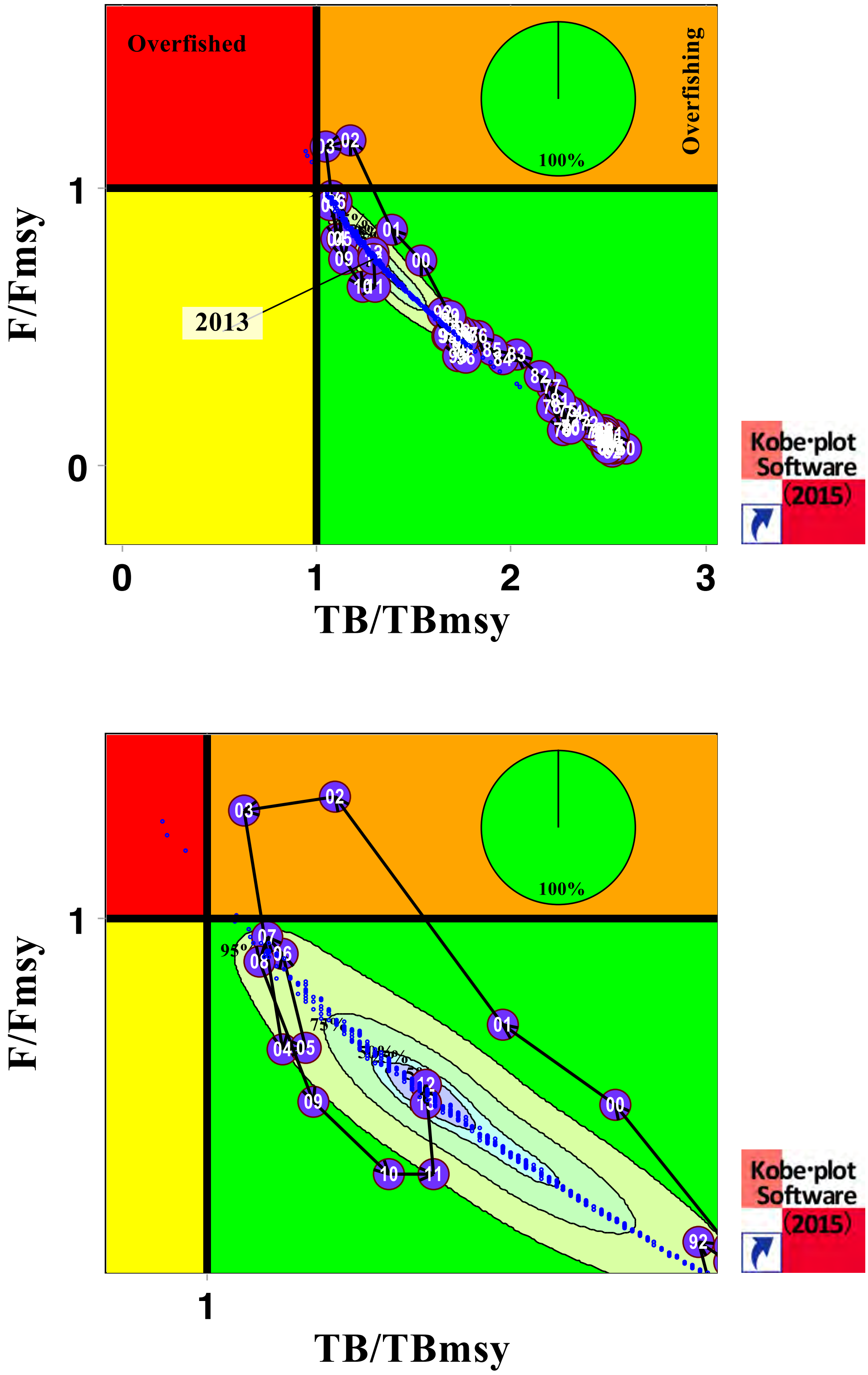
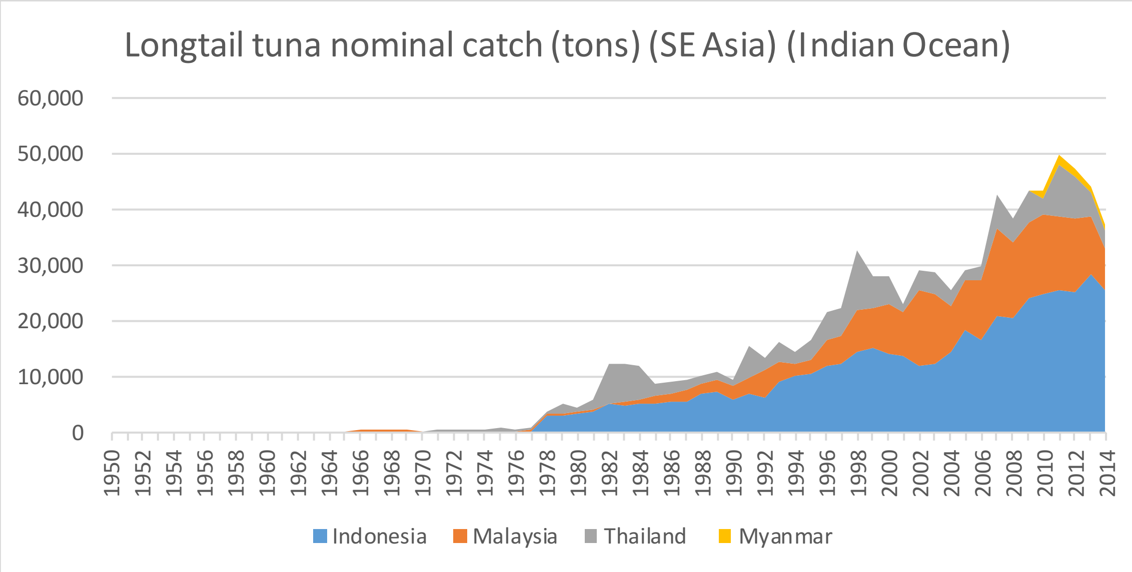


Fig. 15 Kobe plots on KAW stock assessments in the Southeast Asian Waters (Pacific Ocean)

5. LONGTAIL TUNA STOCK ASSESSMENT IN THE SOUTHEAST ASIAN WATERS (INDIAN OCEAN STOCK)

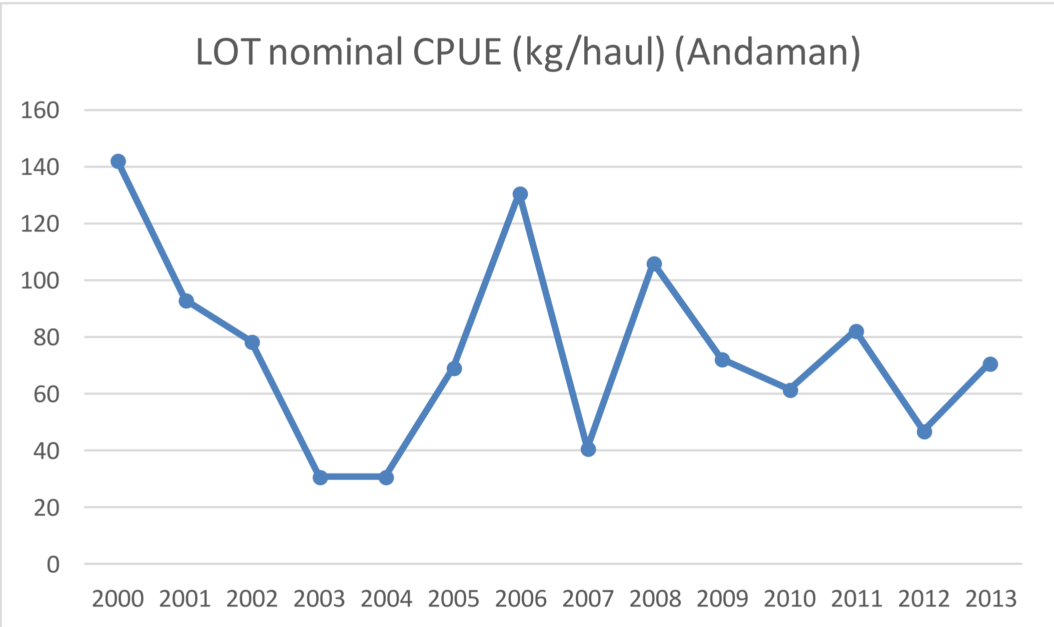
(1) Catch



Note: Based on IOTC and data coordinators.
We used the data from 1970 for stock assessments as the data before 1970 is nil.

Fig. 16 Longtail tuna catch trend by country
(SEAFDEC Southeast Asian Waters in the Indian Ocean)

(2) Nominal CPUE (DOF) (Area 6＋C+D) (2000-2013) (n=343 n(0)=101)

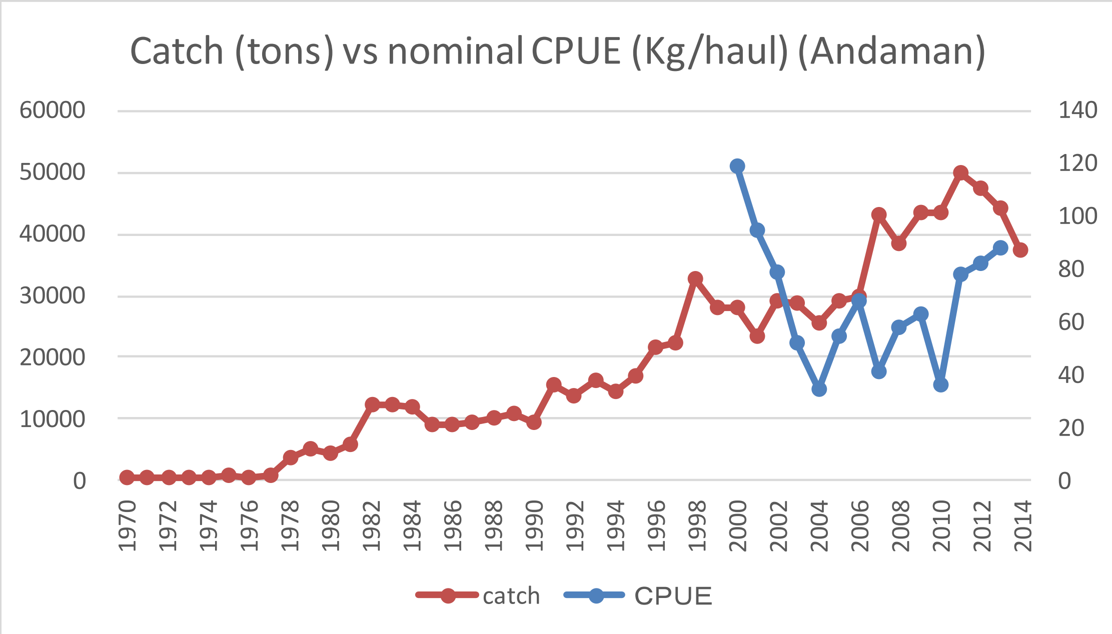


(Note) Outliers (too low values) (1995-1999) and Area 6 (no realistic) are not used.

Fig 17 Trends of nominal Thai LOT CPUE (Andaman Sea)

Table 8 Nominal catch of longtail tuna in Southeast Asian Waters (Indian Ocean side)

Source	IOTC	IOTC	IOTC	Cordinator
Country	Indonesia	Malaysia	Thailand	Myanmar
1950	4	134	0	0
1951	25	89	0	0
1952	28	89	0	0
1953	28	89	0	0
1954	35	89	0	0
1955	35	89	0	0
1956	37	89	0	0
1957	35	89	0	0
1958	35	89	0	0
1959	35	89	0	0
1960	35	134	0	0
1961	37	134	0	0
1962	46	134	0	0
1963	47	89	0	0
1964	48	223	0	0
1965	50	268	0	0
1966	58	357	0	0
1967	59	446	0	0
1968	59	357	0	0
1969	61	268	0	0
1970	54	211	27	0
1971	52	147	205	0
1972	65	168	194	0
1973	59	84	320	0
1974	68	134	227	0
1975	98	218	544	0
1976	109	145	338	0
1977	129	324	305	0
1978	3,175	244	390	0
1979	3,035	162	1,920	0
1980	3,370	386	709	0
1981	3,765	343	1,606	0
1982	5,024	159	7,110	0
1983	4,906	531	6,782	0
1984	5,065	903	5,982	0
1985	5,265	1,230	2,411	0
1986	5,469	1,602	1,922	0
1987	5,551	1,974	1,820	0
1988	6,807	2,023	1,297	0
1989	7,470	1,987	1,529	0
1990	5,816	2,638	1,039	0
1991	6,853	3,017	5,620	0
1992	6,247	5,131	2,169	0
1993	9,267	3,573	3,536	0
1994	10,180	2,007	2,176	0
1995	10,380	2,653	3,731	0
1996	11,961	4,573	5,173	0
1997	12,457	4,935	4,859	0
1998	14,610	7,480	10,593	0
1999	15,218	6,963	5,799	0
2000	14,078	9,142	4,838	0
2001	13,691	7,809	1,726	0
2002	11,886	13,638	3,536	0
2003	12,197	12,599	3,907	0
2004	14,371	8,247	2,864	0
2005	18,533	8,834	1,819	0
2006	16,672	10,601	2,566	0
2007	20,980	15,749	6,218	0
2008	20,533	13,692	4,376	0
2009	24,074	13,764	5,714	0
2010	24,696	14,548	2,701	1,623
2011	25,615	13,122	9,568	1,517
2012	25,270	13,260	7,508	1,319
2013	28,384	10,376	4,244	1,307
2014	25,617	7,372	3,469	909



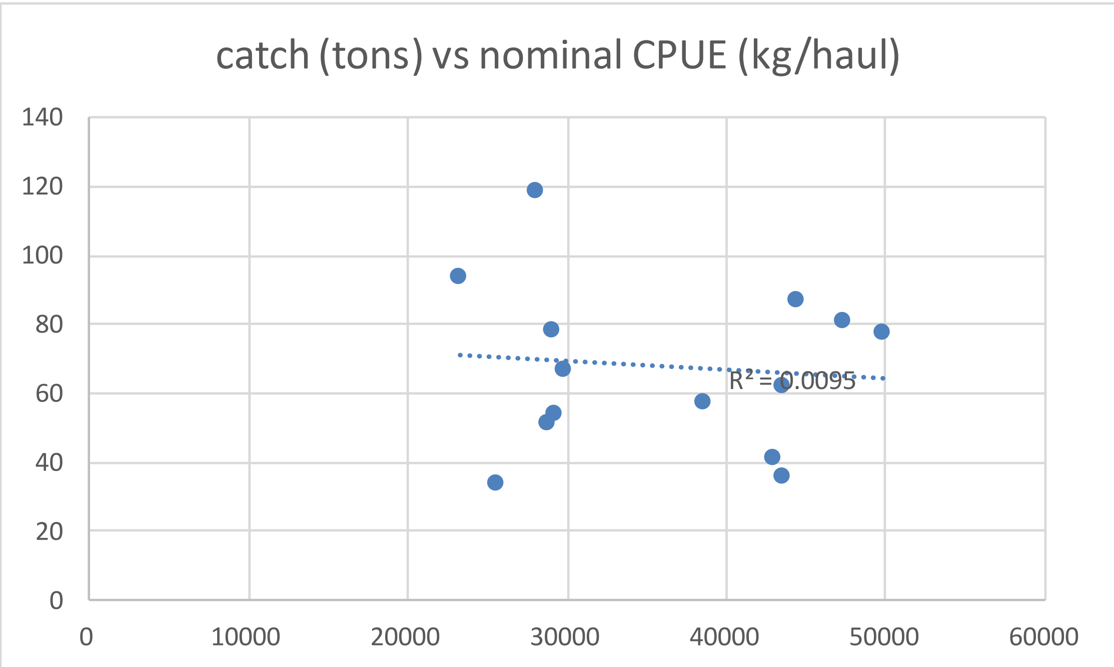


Fig. 18 Relation between LOT catch and nominal CPUE (Indian Ocean side)

(3) CPUE standardization (Table 9 and Figs 19-22)

n=282 and n (0 data) = 84 (35%)

Table 9

ANOVA (Analysis Of Variance) Table					
Adjusted R2 = 0.1161					
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	MSE (Mean Squared Error)	F value	Pr(>F)
YR	13	17.87	1.37	0.86	0.60
Q	3	68.52	22.84	14.26	0.00
area	1	0	0	0	1.00
Residuals	264	422.97	1.60		

Fig. 19

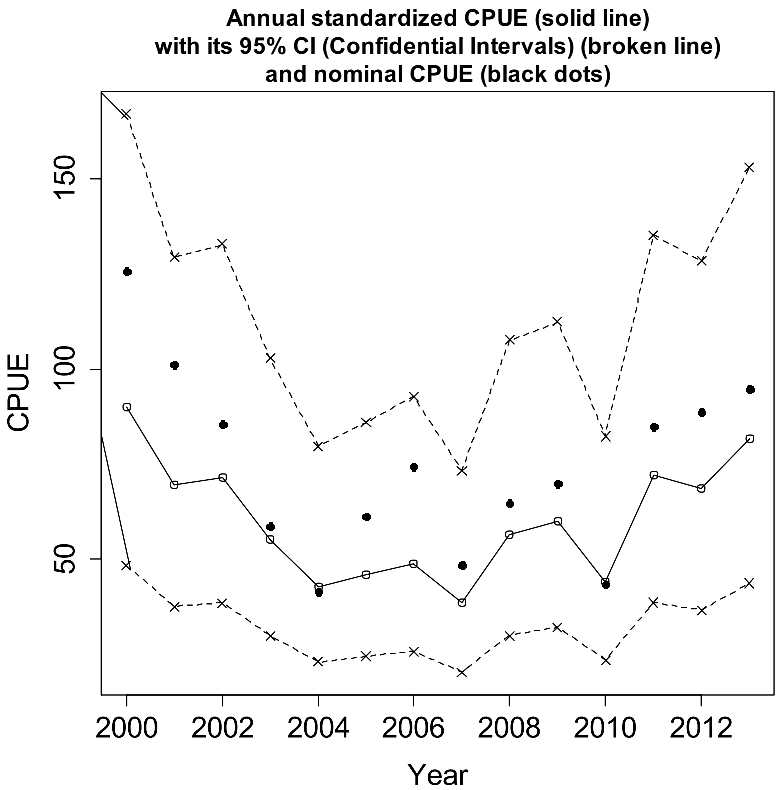
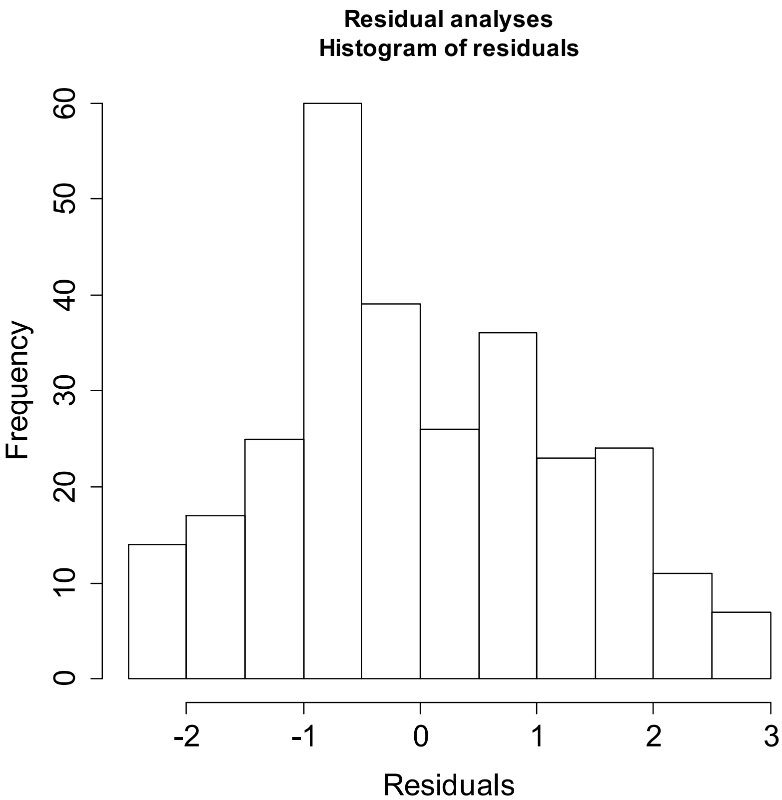


Fig. 20


Residual analyses
Histogram of residuals
Frequency
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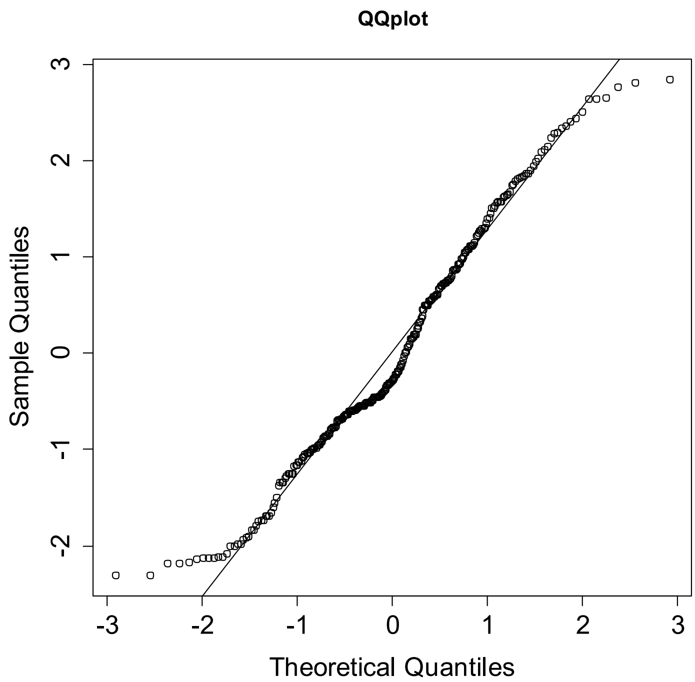
Residuals

Fig. 21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Theoretical Quantiles

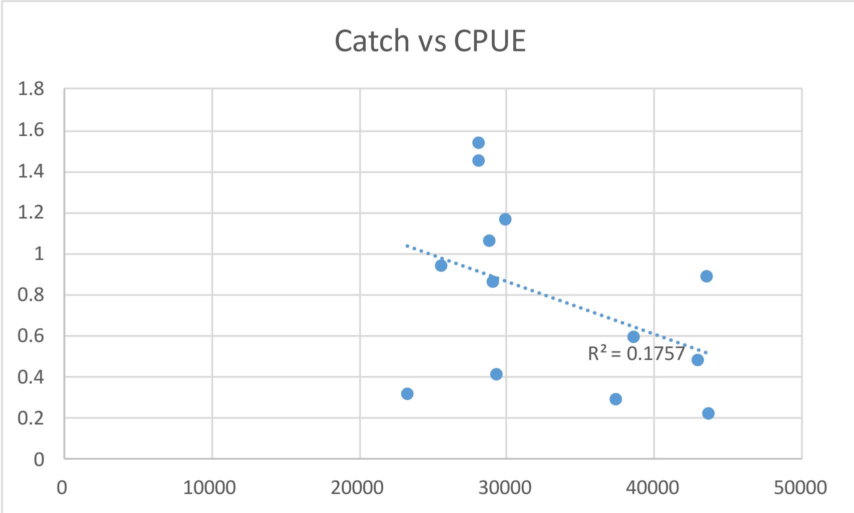


Fig. 22 Relation between LOT catch and standardized CPUE (Pacific Ocean side)

(4) ASPIC Results Using the KOBE PLOTS (Stock Status Trajectory)

In the first attempt using the standardized CPUE, we could not get the convergence, even we fixed some parameters. Hence, we changed to the nominal CPUE for the 2nd ASPIC run.

We set 4 scenarios using K=100,150,200 and 250,000 tons with B0/K=1. After ASPIC runs, we found that parameters with K=200,000 produced most plausible results, although r is a bit low value. Thus, the results should be looked up carefully.

Table 10 Estimated parameters in three scenarios

Model	K(fixed) (1,000t)	B0/K=1	r	q	MSY (1,000t)	TB/TBmsy	F/Fmsy	TBmsy	Fmsy	TB	R2	RMS
Fox	100	1	1.15	0.11E-6	42	1.00	0.89	37	1.15	33 (Too low)	0.13	0.56
Fox	150	1	0.75	7.40E-6	40	0.96	0.99	55	0.73	50 (low)	0.14	0.56
Fox	200	1	0.51	5.00E-6	37(*)	0.89	1.11	66	0.51	66	0.15	0.56
Fox	250	1	0.38 (too low)	4.59E-6	35	0.85	1.23	92	0.38	80	0.17	0.56

(*) 37,580 t

(5) Stock status and management advice

<u>The current stock status (2014) is in the red zone the Kobe plot (overfished and still overfishing),</u> i.e., TB/TBmsy=0.89 and F/Fmsy=1.11 implying that TB is the 11% lower than the MSY level and F is 11% higher than the F_{MSY} level. Catch in 2011 was the peak, but afterwards it decreased to 2014. Hence the stock status has been slightly recovered in 2014.

However, probability of uncertainties in the un-safe zone (red, orange and yellow) of the 2014 point is very high 78%. Thus, **<u>both catch and F (Fishing pressure) should be decreased to their MSY levels, i.e., 37,000 tons and 0.51, respectively.</u>**

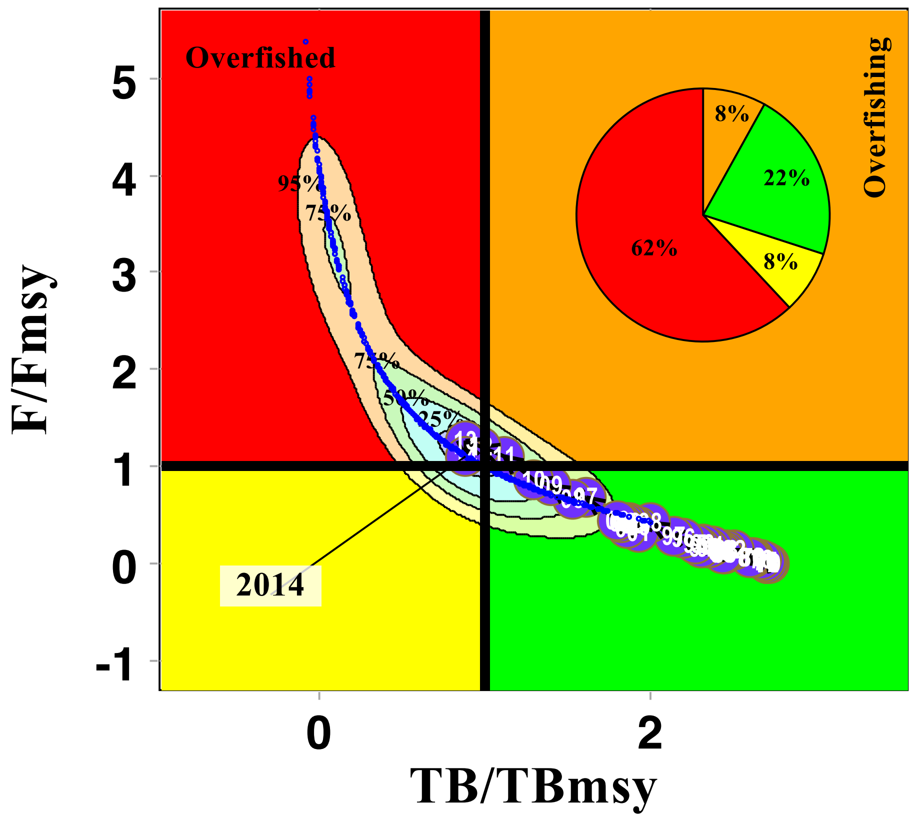


Fig. 23 Kobe plot on the LOT stock assessment results (Indian Ocean side)
(to be continued)

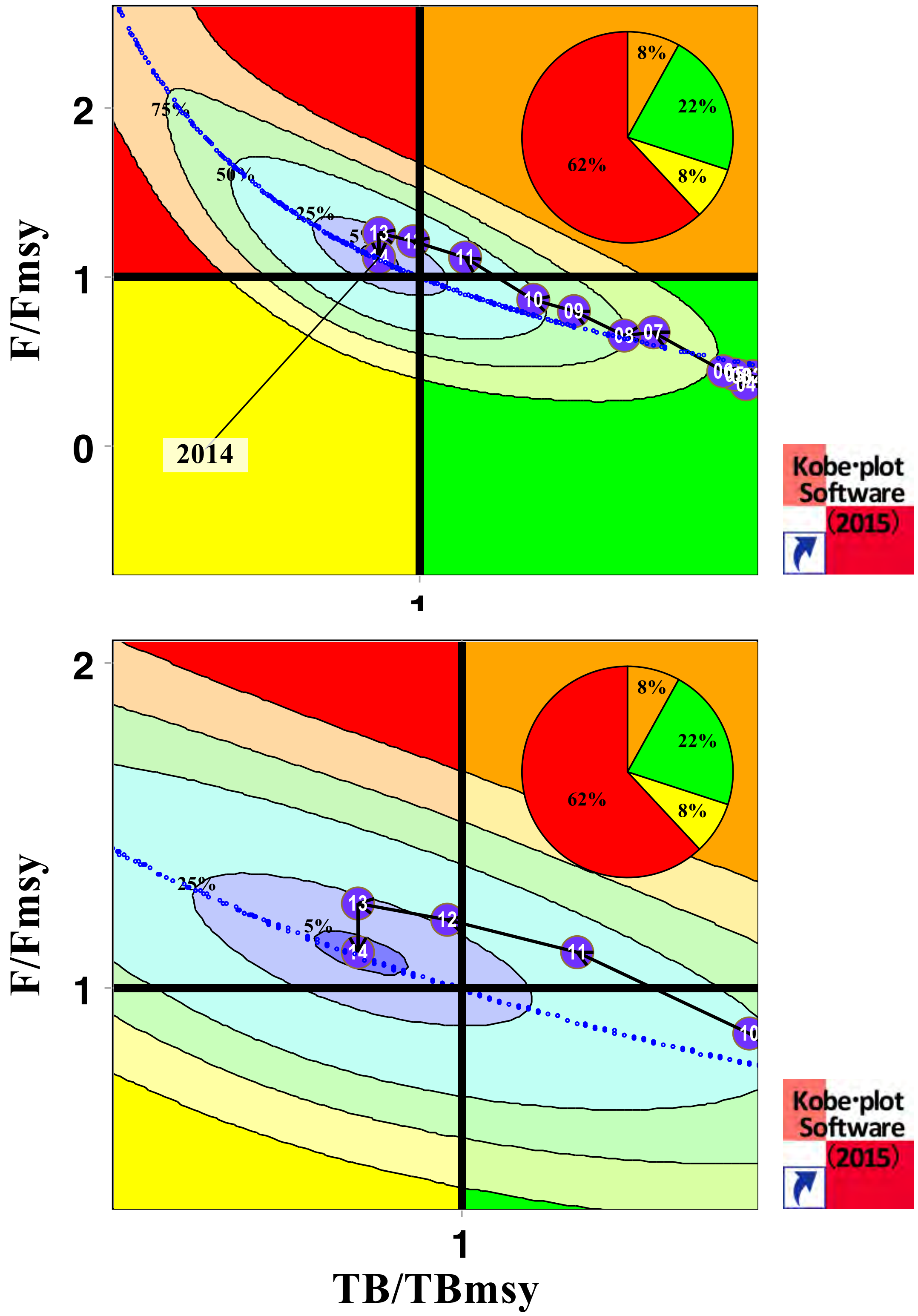
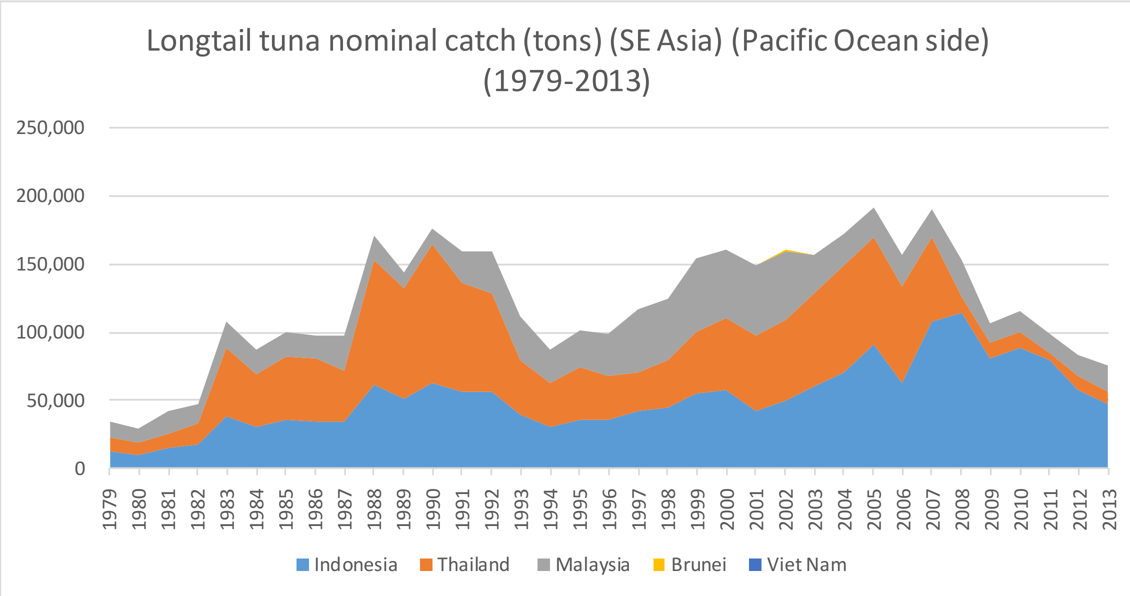


Fig. 24 (continued) Kobe plot on the LOT stock assessment results (Indian Ocean side)

6. LONGTAIL TUNA STOCK ASSESSMENT IN THE SOUTHEAST ASIAN WATERS (PACIFIC OCEAN STOCK)

(1) Catch



Note: *Based on FAO and data coordinators.*
We used the data from 1979 as the data before 1970 are incomplete.

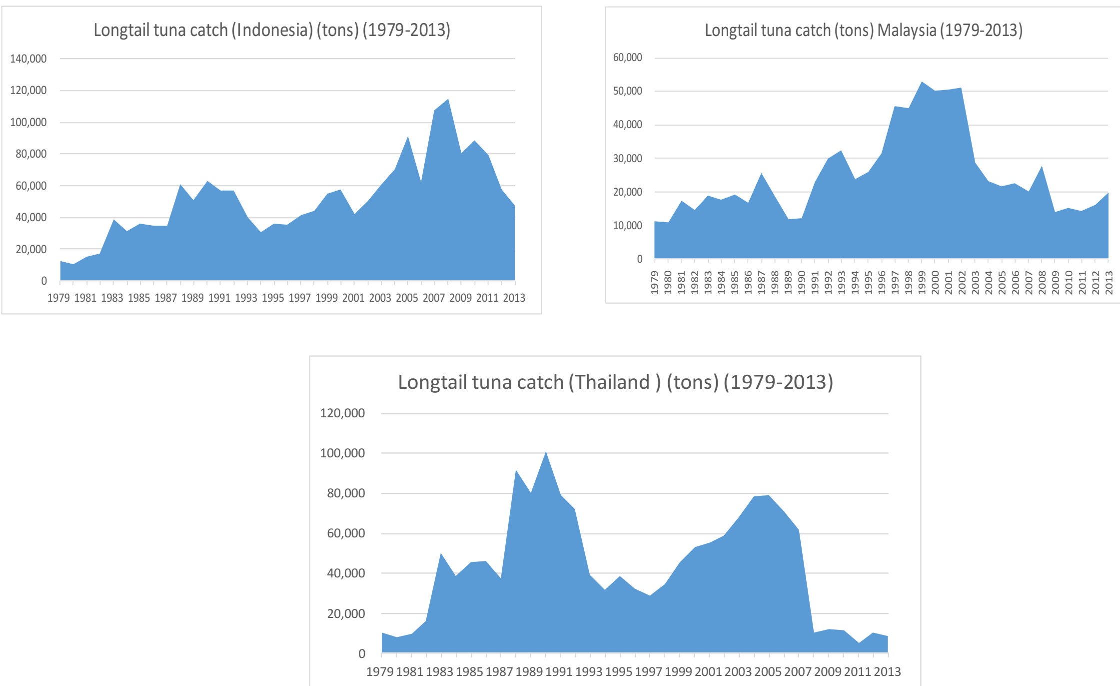


Fig. 25 Longtail tuna catch trend by country
(Southeast Asian Waters in the Pacific Ocean)

Table 11 Longtail nominal catch (tons) by country in the Southeast Asian Waters (Pacific Ocean)

Source	FAO	FAO	FAO	Coordinator	Coordinator
Country	Indonesia	Thailand	Malaysia	Brunei	Viet Nam
1979	12,139	10,583	11,302	0	0
1980	10,352	7,962	10,701	0	0
1981	15,165	9,958	17,382	0	0
1982	17,056	16,306	14,444	0	0
1983	38,432	50,451	18,838	0	0
1984	31,168	38,470	17,723	0	0
1985	35,909	45,589	19,151	0	0
1986	34,943	46,408	16,590	0	0
1987	34,858	37,360	25,484	0	0
1988	61,199	91,628	18,707	0	0
1989	51,160	80,596	11,638	0	0
1990	62,899	101,397	12,002	0	0
1991	56,654	79,227	22,914	0	0
1992	56,659	72,277	29,872	0	0
1993	39,827	39,396	32,407	0	0
1994	30,962	32,006	23,814	0	0
1995	35,968	38,824	26,021	0	0
1996	35,367	32,347	31,415	0	0
1997	41,498	29,127	45,688	0	0
1998	44,286	34,805	45,037	0	0
1999	54,842	45,818	53,056	0	0
2000	57,465	53,407	50,195	0	0
2001	42,420	55,533	50,608	0	0
2002	50,000	59,052	51,021	12	0
2003	60,000	68,147	28,570	16	0
2004	70,735	78,657	23,084	0	0
2005	91,013	79,095	21,616	21	0
2006	62,521	71,213	22,640	98	0
2007	107,672	62,072	20,215	43	0
2008	114,819	10,500	27,801	23	0
2009	80,484	12,309	13,805	73	0
2010	88,468	11,806	15,165	24	0
2011	79,198	5,152	14,362	70	0
2012	57,364	10,175	16,035	99	0
2013	47,197	8,920	19,626	91	145

(2) Nominal CPUE and relation with catch

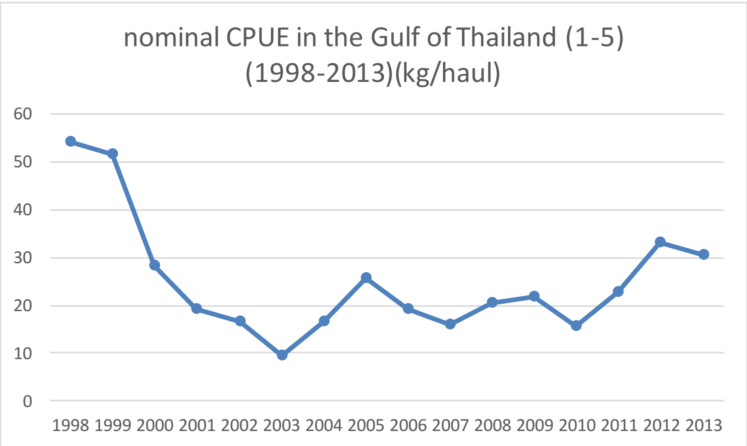
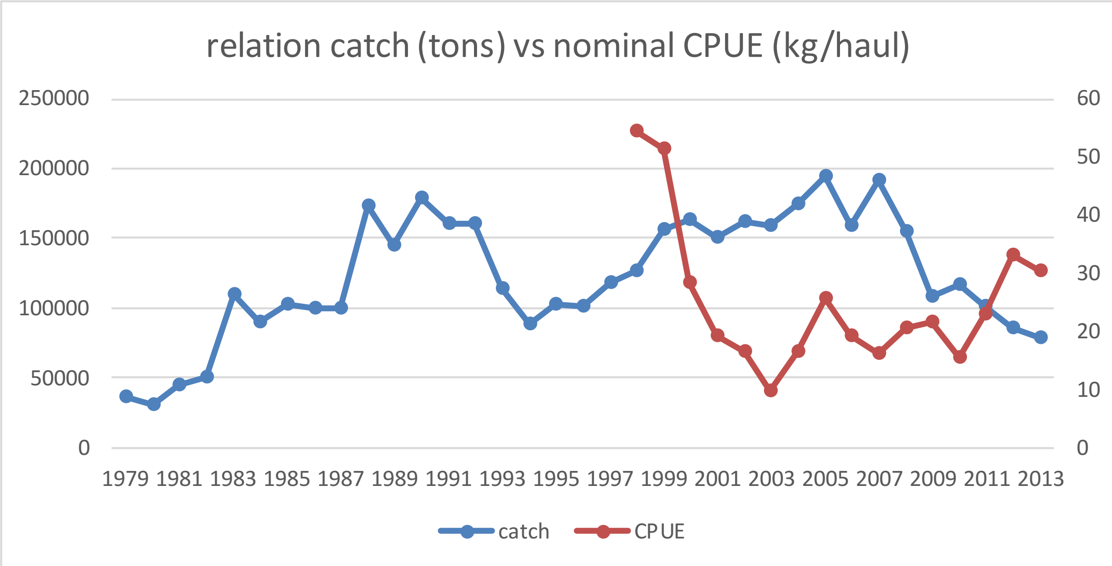


Fig. 26 Longtail tuna nominal CPUE
(SEAFDEC Southeast Asian Waters in the Pacific Ocean)



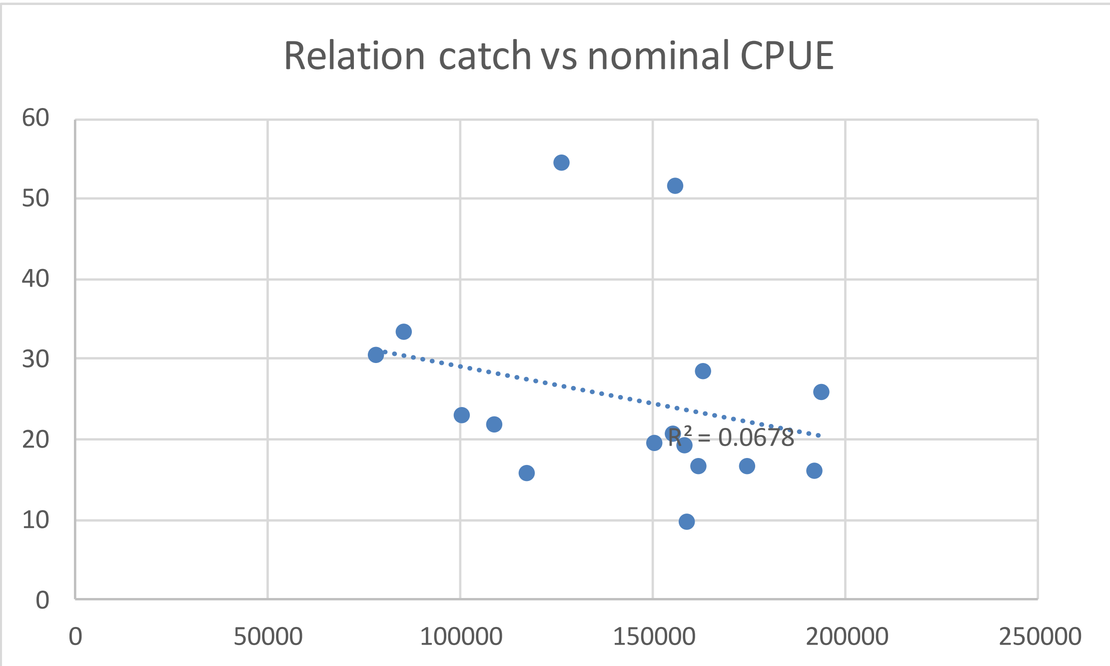


Fig. 27 Relation between Longtail tuna catch and nominal CPUE (Southeast Asian Waters in the Pacific Ocean)

(3) CPUE standardization and relation with catch (Table 12 and Figs 28-30)

Table 12

ANOVA (Analysis Of Variance) Table					
Adjusted R2 = 0.1563					
Factors	DF (Degrees of Freedom)	Type III SS (Sum of Squares)	MSE (Mean Squared Error)	F value	Pr(>F)
YR	15	118.87	7.92	6.20	0.00
Q	3	1.54	0.51	0.40	0.75
area	4	112.61	28.15	22.04	0.00
Residuals	844	1078.01	1.28		

Fig. 28

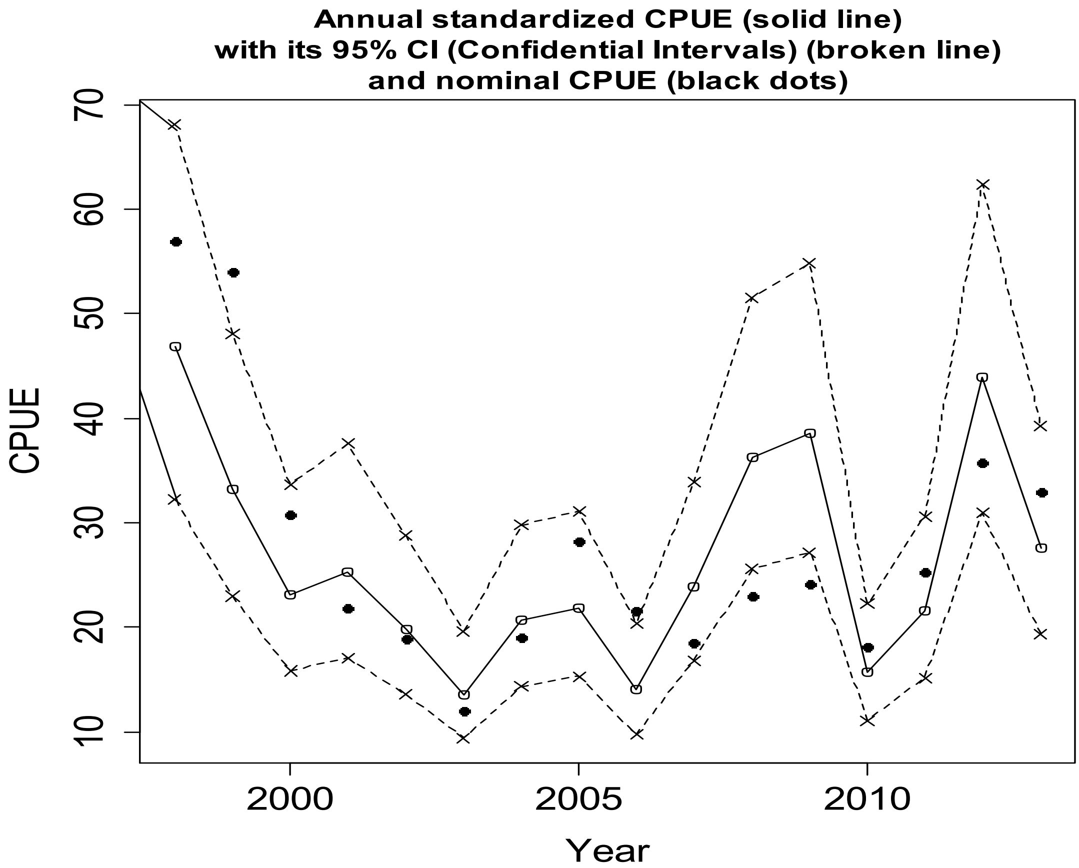
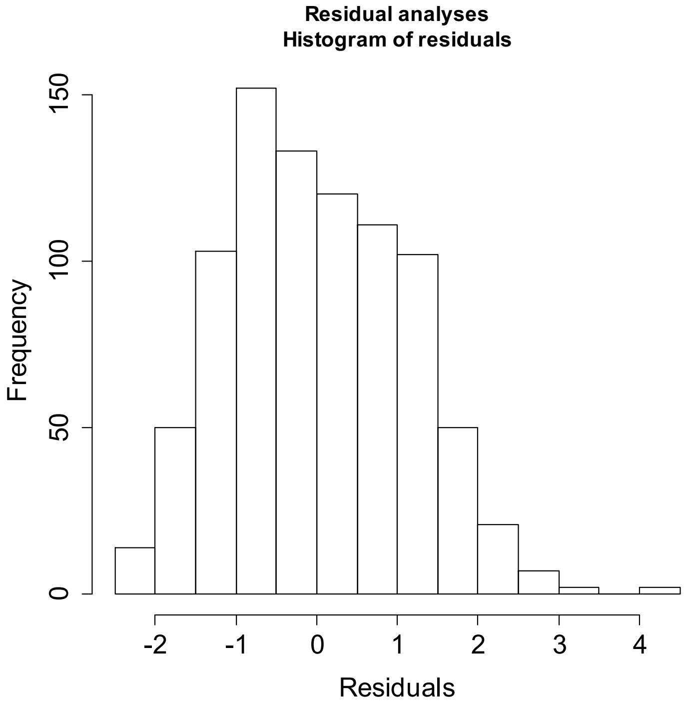


Fig 29



Residual analyses
Histogram of residuals
Frequency
0
50
100
150
-2
-1
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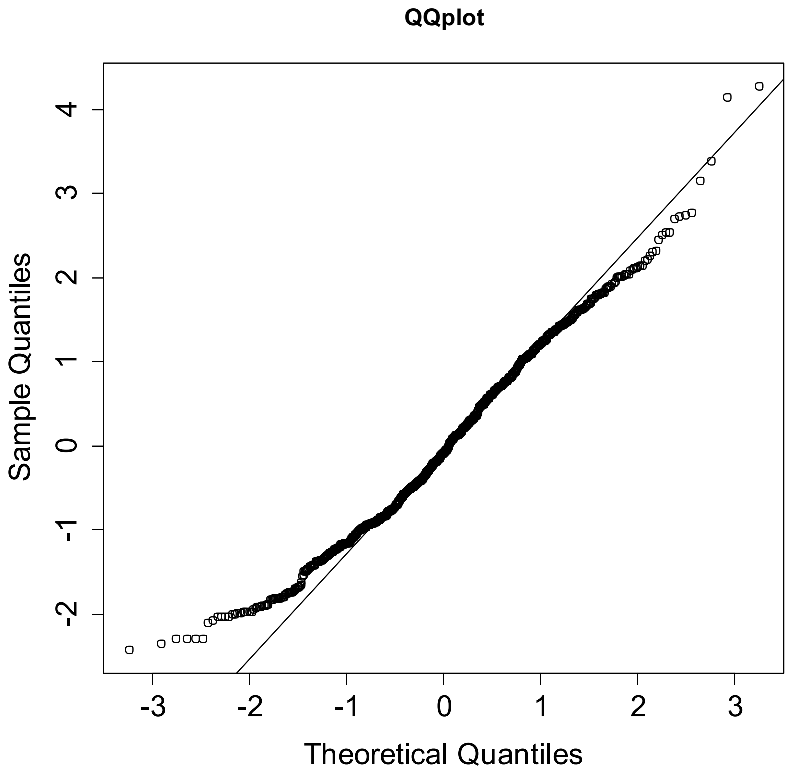
Residuals

Fig 30



QQplot
Sample Quantiles
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Theoretical Quantiles

(4) ASPIC results using the Kobe plots (Stock status trajectory)

We could not get convergence when we attempted to estimate all parameter. Then we assumed that B0/K=1 and explored plausible K values (300, 400, 500, 600 and 700,000 tons). As a result, when K=500,000, we could get the most plausible parameters.

Table 13 Results of ASPIC stock assessments

model	K(fixed) (1,000t)	B0/K	r	MSY (1,000t)	TB/TBmsy	F/Fmsy	TBmsy	Fmsy	TB	R2	RMS
	300	Not converged									
Fox	400	1	1.34 Too high	200	2.25	0.18	150	1.34	320	0.130	0.3796
Fox	500	1	1.07	200(*)	2.22	0.18	180	1.07	400	0.126	0.3800
Fox	600	1	0.89 low	200	2.21	0.18	220	0.89	470	0.120	0.3809
Fox	700	1	0.77 Too low	200	2.19	0.18	260	0.77	540	0.112	0.3821

(*) 196,700 t

(5) Stock status and management advice

The current stock status (2013) is in the green (safe) zone the Kobe plot, i.e., TB/TBmsy=2.22 and F/Fmsy=0.18 implying that TB is the 122% higher than the MSY level and F is 82% lower than the F_{MSY} level. Catch in 2008 was the peak, but afterwards it sharply decreased to 2013 (193,000 tons, the lowest level since 1980's).

That is the reason why the stock status is very safe and the probability of uncertainties in the un-safe zone (red, orange and yellow) around the 2013 point is none (0%). Thus, **both catch and F (Fishing pressure) can be increased more, but should be less than their MSY and Fmsy levels, i.e., 200,000 tons and 1.07, respectively.**

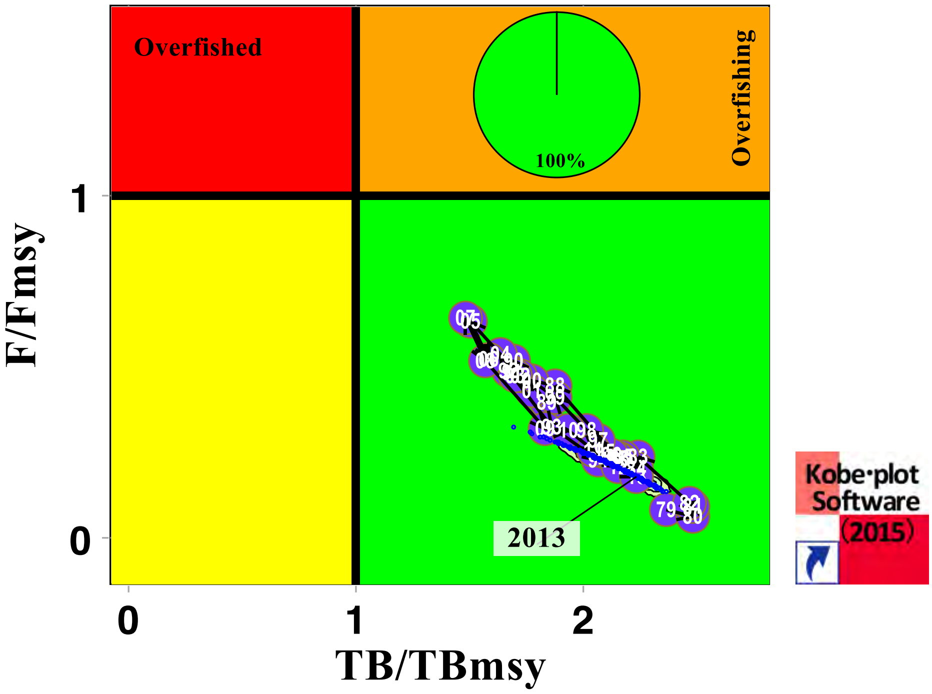
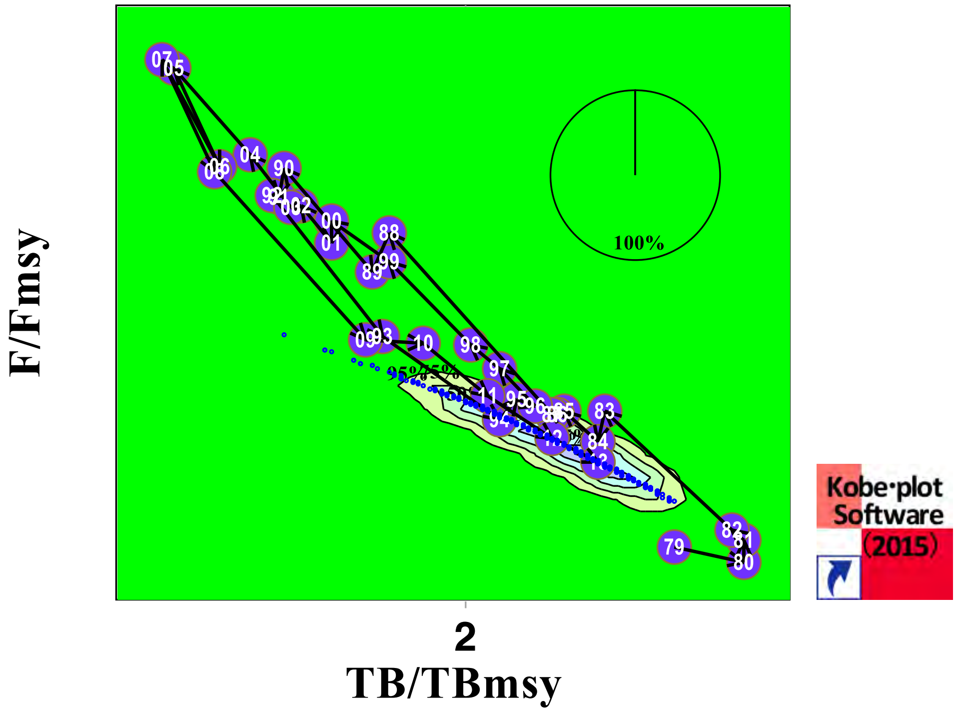


Fig. 31 Kobe plot (to be continued)



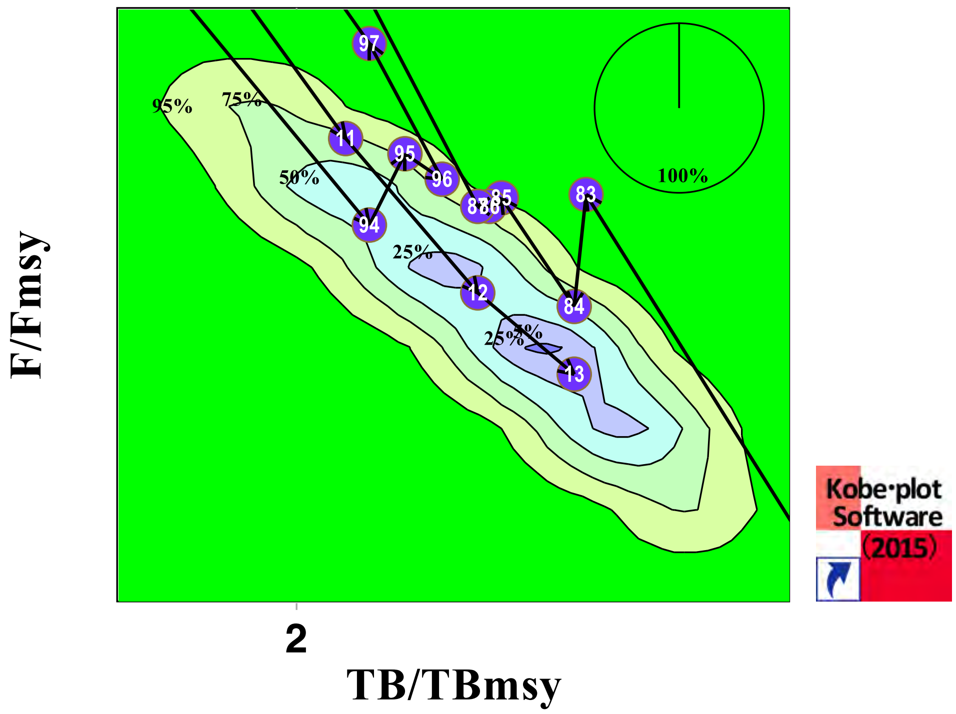


Fig. 32 Magnified Kobe plot on the LOT stock assessment results (Pacific Ocean side)
(continued from the previous page)

7. DISCUSSION AND FUTURE WORKS

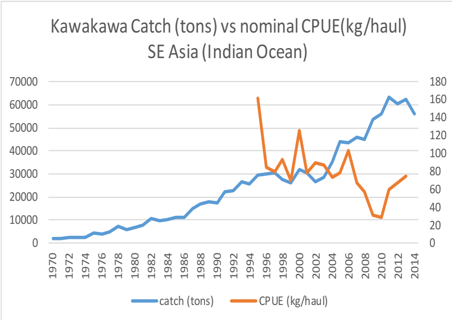
BOX 5 (next page) shows the summary of 4 stock assessments. Results are looked at very carefully as there are numbers of constraints, limitations and uncertainties as shown in Box 4.

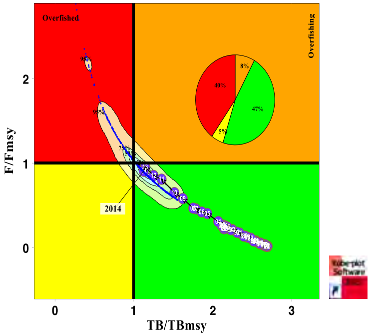
Box 4 Caveats in stock assessments results

- Stock structures are unknown which produce uncertainties in results.
- Catch are based on FAO, IOTC and data coordinators of the SEAFDEC neritic tuna project. This means that almost all data are basically national statistics which have wide range of uncertainties (see IOTC, FAO, BOBP and SEAFDEC publications for details).
- CPUE are based on Thailand DOF information. As other plausible CPUE are not available, we cannot compare with others. This implies that results are mainly driven by Thailand CPUE.
- CPUE series may not be long enough for the reliable stock assessments.
- Some CPUE include 0 (zero) catch more than 30%. In such case, we need to use other suitable models than long normal GLM, such as delta log normal GLM, 0 inflated model, GAM etc.

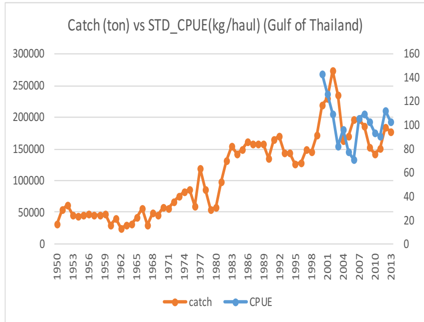
BOX 5 Summary (Catch, CPUE and stock status based on ASPIC)

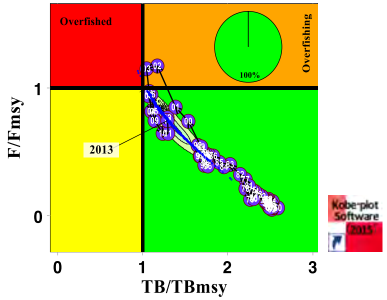
KAWAKAWA (INDIAN OCEAN STOCK) Green zone (2014)
(TB/TBmsy=1.28 and F/Fmsy=0.75)



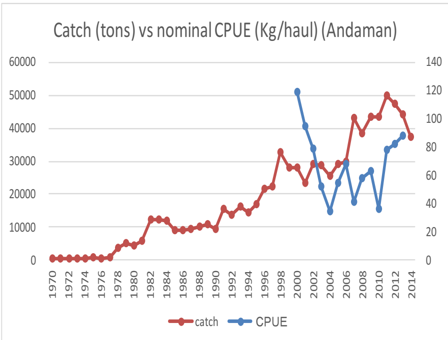


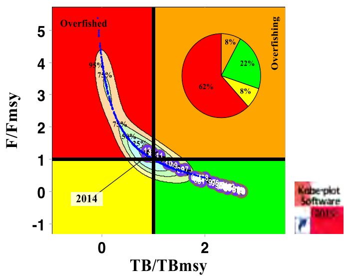
KAWAKAWA (PACIFIC OCEAN STOCK) Green zone (2013)
(TB/TBmsy=1.29 and F/Fmsy=0.74)



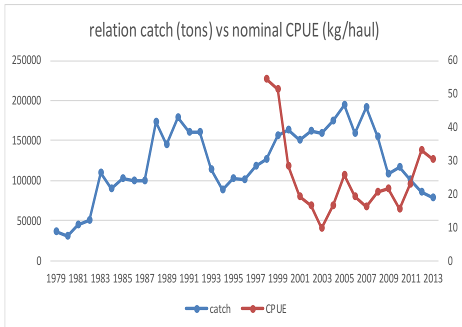


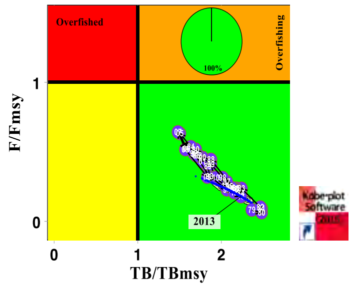
LONGTAIL TUNA (INDIAN OCEAN STOCK) Red zone (2014)
(TB/TBmsy=0.89 and F/Fmsy=1.11)





LONGTAIL (PACIFIC OCEAN STOCK) Green zone (2013)
(TB/TBmsy=2.22 and F/Fmsy=0.18)





Although there are several Caveats, there are some positive evidences that results are likely plausible (realistic) as stated in Box 6. Box 7 lists the future works.

Box 6 Some evidences supporting plausible results of ASPIC stock assessments

- Relation between catch and CPUE (for all four cases) are negatively correlated, which indicate both trends are likely realistic. Hence results of stock assessments are likely plausible.

- Results of stock assessments (Indian Ocean stock) are like those in the whole Indian Ocean based on the stock assessments conducted by IOTC (Boxes 8-9 for Kawakawa and Boxes 10-11 for longtail tuna).

Box 7 Future works

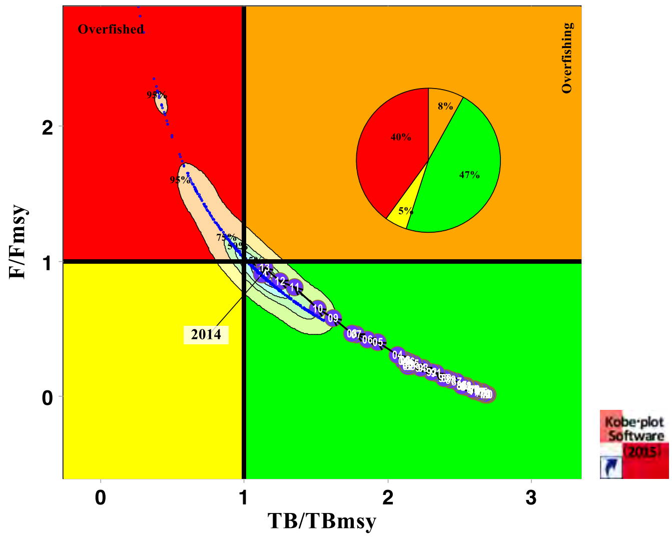
- Re-examine catch data from ALL MEMBER COUNTRIES.
- Explore other standardized CPUE models than log normal GLM for those do not fits well.
- Explore Philippine catch and effort data. We may be able to find some plausible CPUE as data are so details hence some statistical treatment can produce feasible CPUE.
- Thailand (AFDEC) sends additional AFDEC Catch and effort data (2006-2013) recently. But all the stock assessments have completed by that time, thus we could not use these CPUE. We may need to use them in the next chance in the future
- Conduct age/size based stock assessments using biological data (for example Statistical-Catch-At-Age/Size) to compare results by ASPIC.
- Proceed genetic studies for Stock structure by cooperating with the on-going EU funded Stock structure project in the IOTC (for Indonesia, Thailand, Malaysia and Philippines).

BOX 8 Comparison with IOTC assessment results (whole Indian Ocean)

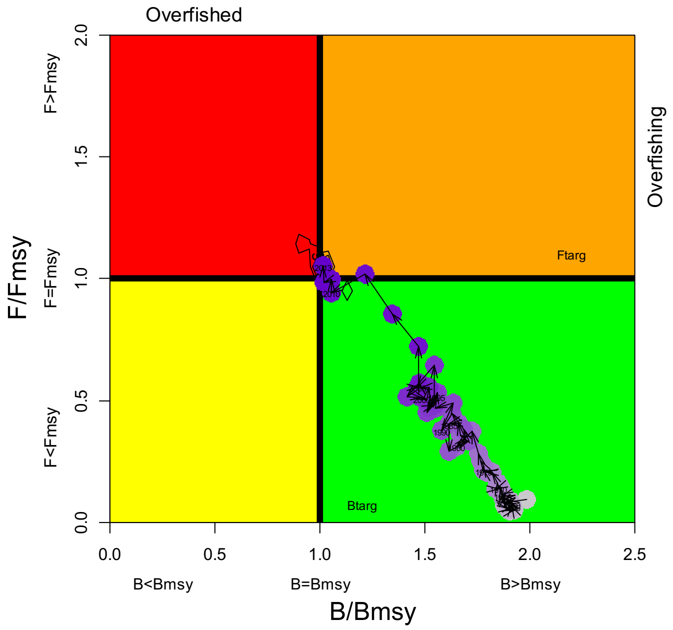
Kawakawa

Both results are very similar (green zone) but very close to MSY (TB and F). Both catch in the whole Indian Ocean and the SE Asia have been increasing, but the catch in SE Asia started to decrease in 2011 (see Box 9, next page).

Southeast Asian region (This document) (Green)



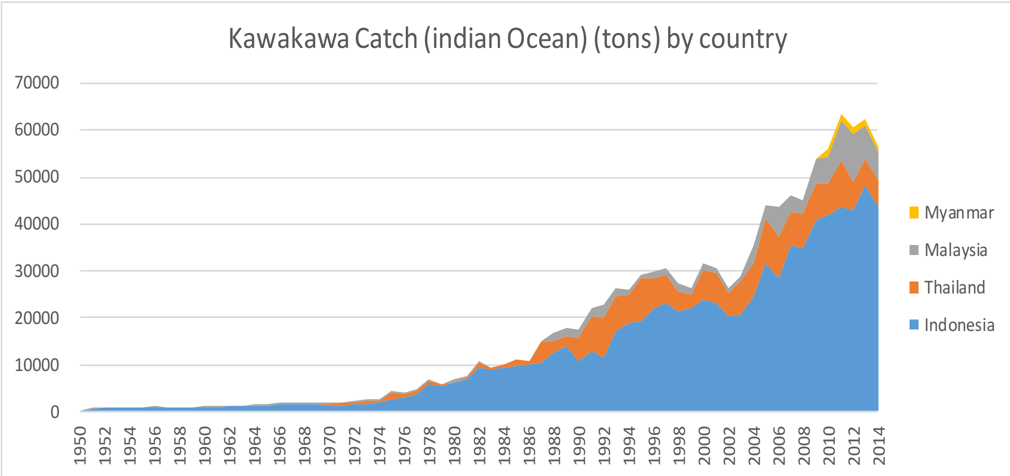
Whole Indian Ocean (IOTC, 2015) (IOTC-WPNT06-2015-21) (Green)



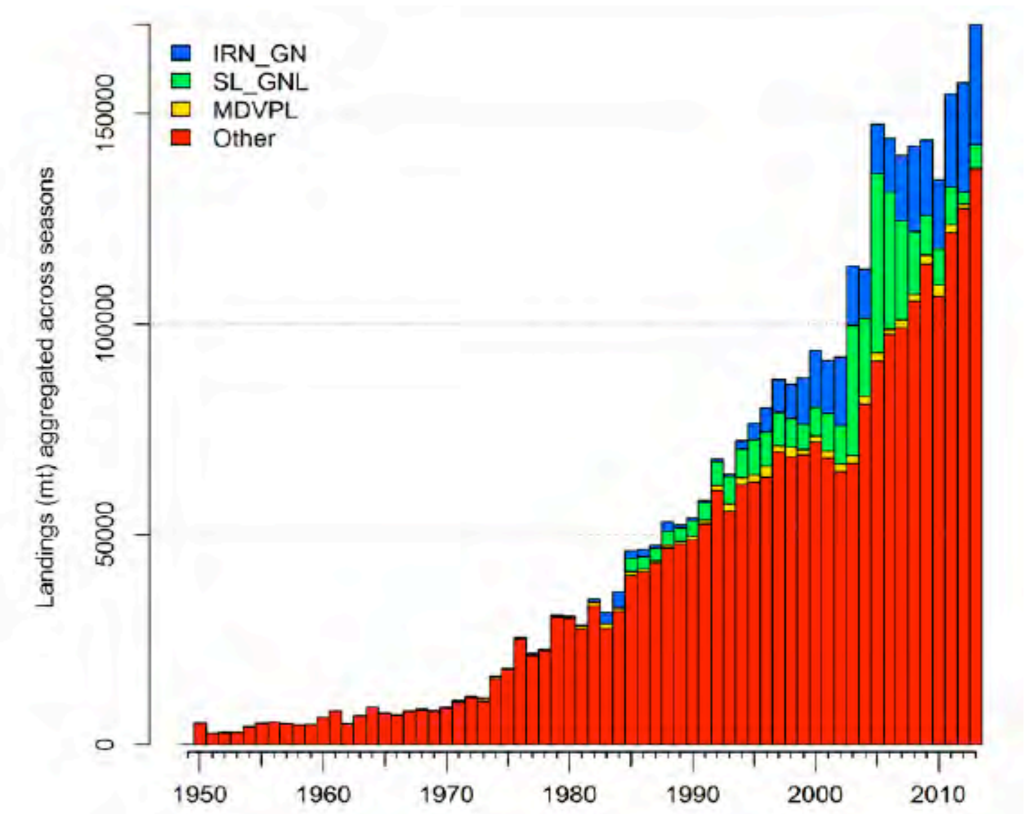
Box 9 Comparison of catch between Southeast Asian Waters (Indian Ocean side) and the whole Indian Ocean

Kawakawa

KAW Catch in the Southeast Asian Waters (Max 62,000 tons)



KAW Catch: whole Indian Ocean (Max 170,000 tons)

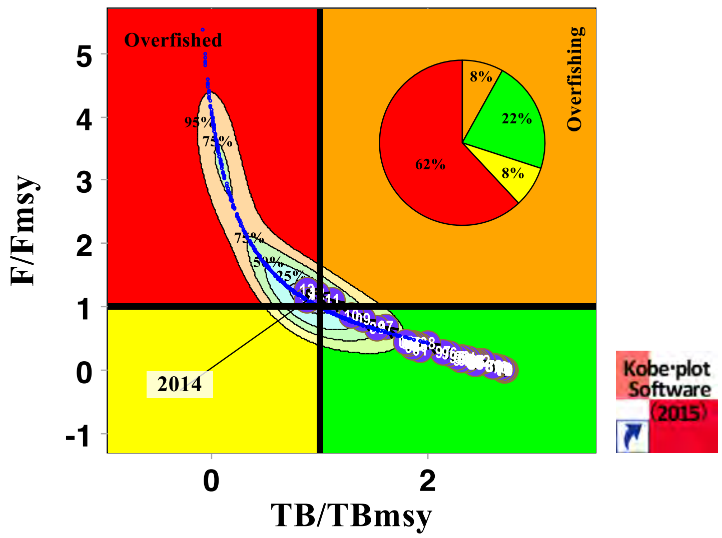


BOX 10 Comparison with IOTC assessment results (whole Indian Ocean)

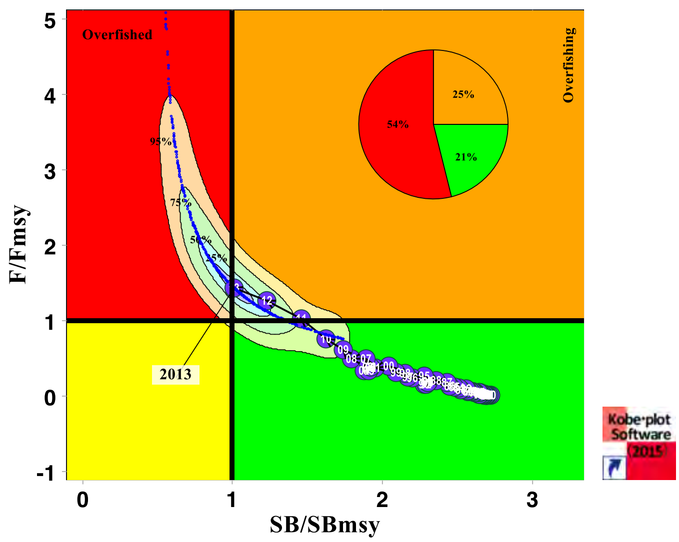
Longtail tuna

Both results are very similar (Red zone) but the one in the whole Indian Ocean is more pessimistic because large catch are mainly from Middle East (especially Iran), which catch have been significantly increasing but started declined in last a few years. Same situation on the LOT in the SE Asia are observed (see Box 11 next page).

Southeast Asian Waters Region (This document)
(Red zone)



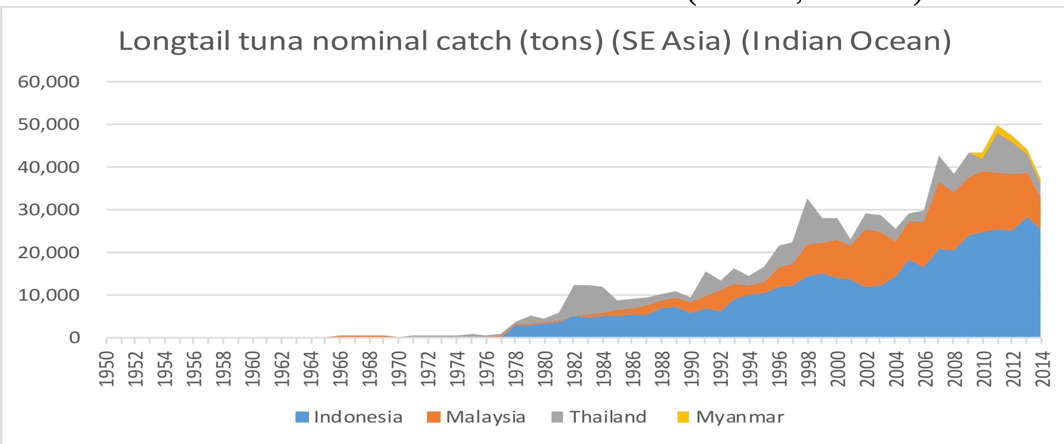
Whole Indian Ocean (Nishida and Iwasaki, 2015) (IOTC-WPNT06-2015-28 Rev_2)
(Red zone)



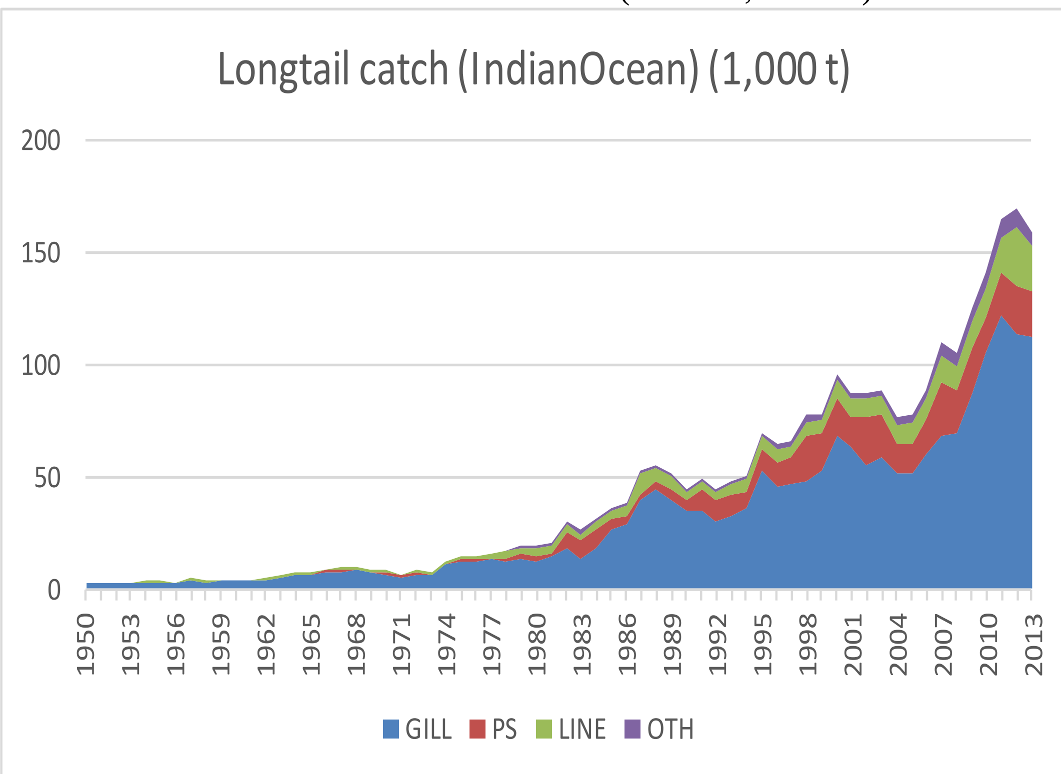
Box 11 Comparison of catch between Southeast Asian Waters and the whole Indian Ocean

Longtail tuna

LOT Catch in the Southeast Asian Waters (Max 50,000 tons)



LOT Catch: whole Indian Ocean (Max 160,000 tons)



NERITIC TUNA STOCK AND RISK ASSESSMENT
Part II

RISK ASSESSMENT OF KAWAKAWA (*Euthynnus affinis*) AND LONGTAIL TUNA (*Thunnus tonggol*) RESOURCES IN THE SOUTHEAST ASIAN WATERS

Supported by

SEC/SP/161 **February 2017**

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

THIS PAPER WAS ENDORSED BY THE 25TH MEETING OF ASEAN SECTORAL WORKING GROUP ON FISHERIES IN MAY 2017

NERITIC TUNA STOCK AND RISK ASSESSMENT

PART II

RISK ASSESSMENT OF KAWAKAWA (*Euthynnus affinis*) AND LONGTAIL TUNA (*Thunnus tonggol*) RESOURCES IN THE SOUTHEAST ASIAN WATERS

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20 February 2017

CONTENTS

Submitted to the Workshop on Managements of Longtail Tuna and Kawakawa Resources in the Southeast Asian Region and Development of Ecosystem Approach to Fisheries Management (EAFM) As the Alternate Approach (December 19-21, 2016) (Furama Hotel, Kuala Lumpur, Malaysia)

ACKNOWLEDGEMENTS

We sincerely appreciate the following experts and Agencies that made it possible to implement the SEAFDEC Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in Southeast Asian Region (17-25 April 2016), at SEAFDEC/MFRDMD (Kuala Terengganu, Malaysia). Without their dedicated efforts, we could not have produced this 2nd part of the document on the risk assessments.

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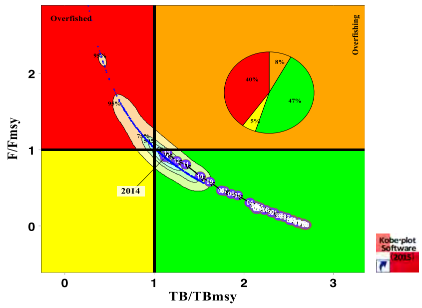
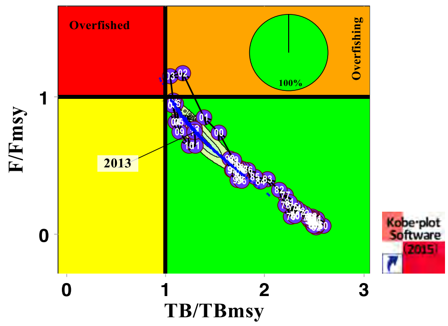
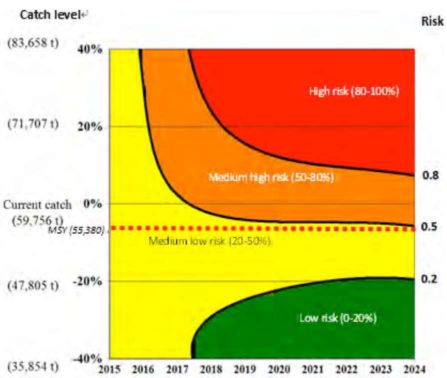
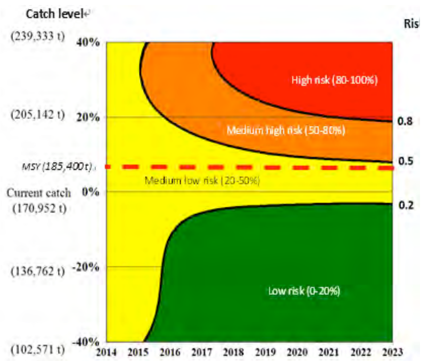
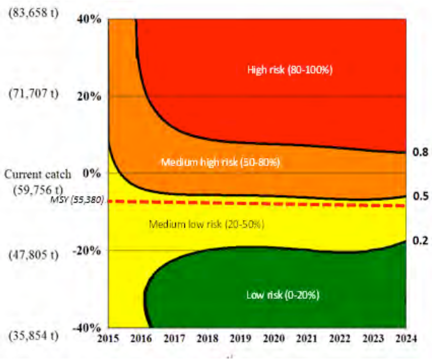
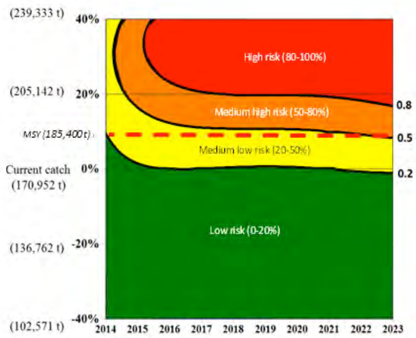
DATA COORDINATORS 16 experts (8 Member Countries)

FUNDING AGENCY

Government of Sweden through the SEAFDEC-Sweden Project entitled "**Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia**".

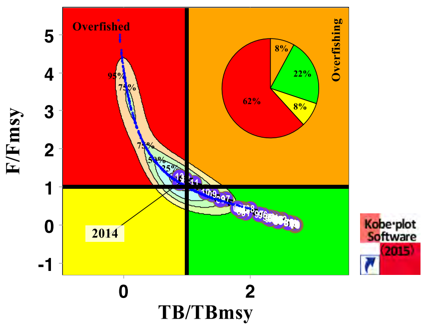
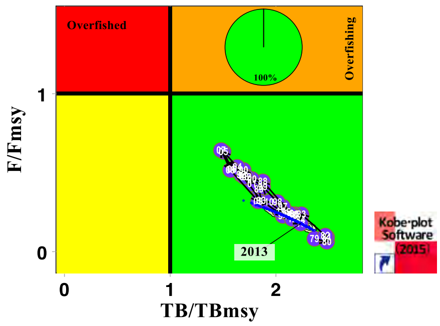
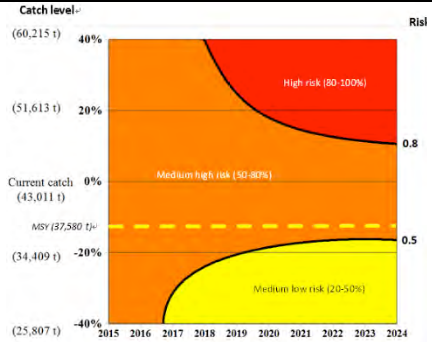
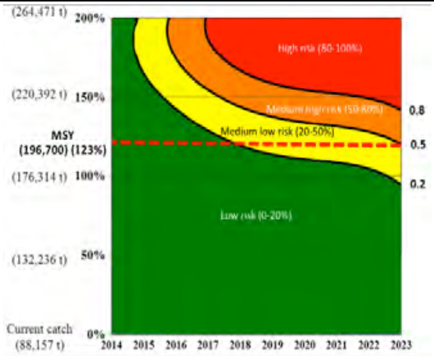
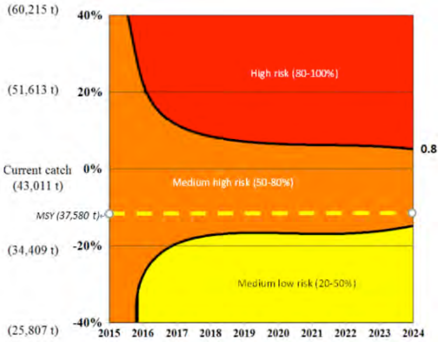
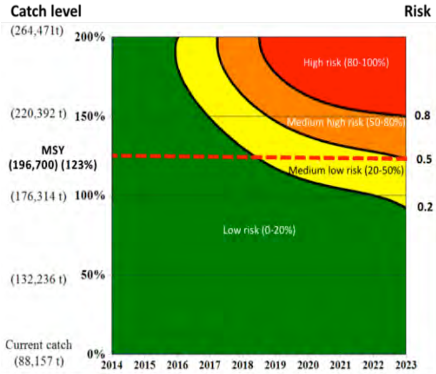
SUMMARY: Recommendations of TAC based on the stock and risk assessments.

KAWAKAWA

	Indian Ocean side (Green)	**Pacific Ocean side (Green)**
Stock status		
Risk assessment **TB (Total biomass)**		
Risk assessment **F (Fishing mortality)**		
TAC *Recommendation*	*TAC should be less than the MSY level (59,800 t). This means that the current catch level (55,380 t) (Average of 2012-2014) should be decreased by 4,400 t (7%).*	*TAC should be less than the MSY level (185,400 t). This means that the current catch level (170,900 t) (Average of 2012-2014) can be increased by 14,100 t (9%).*

SUMMARY: Recommendations of TAC based on the stock and risk assessments.

LONGTAIL TUNA

	Indian Ocean side (Red)	Pacific Ocean side (Green)
Stock status		
Risk assessment **TB (Total biomass)**		
Risk assessment **F (Fishing mortality)**		
TAC *Recommendation*	*TAC should be less than the MSY level (37,580 t). This means that the current catch level (43,000 t) (Average of 2012-2014) should be decreased by 5,400 t (13%).*	*TAC can be increased to the MSY level (196,700 t). This means that the current catch level (88,200 t) (Average of 2011-2013) can be increased by 108,500 t (122%).*

1. INTRODUCTION

Stock assessments of longtail tuna and kawakawa in the Southeast Asian Waters for both Indian and Pacific Ocean sides have been completed during the 3rd Meeting of the Scientific Working Group on Neritic Tunas Stock Assessment in the SE Asian Waters (27-29 June 2016, Cholburi, Thailand) (Nishida, *et al*, 2016). This assessment paper was based on two documents submitted to that meeting, i.e. WP05 (LOT stock assessments) and WP06 (KAW stock assessments). The, risk assessments were requested by SEAFDEC using results of these stock assessments. This document describes methods and results of the risk assessments.

2. METHODS

The basic methods of the risk assessments are those used in the tuna RFMO i.e., Kobe II strategy management matrix (Kobe II). Kobe II presents probabilities violating (not sustaining) TBmsy (Total Biomass at the MSY level) and Fmsy (F at the MSY level) in 3 and 10 years later using 10 different catch scenarios (current catch levels, MSY levels, ± 10%, ± 20%, ± 30% and ± 40%). This means that if 10 different catch levels (scenarios) are continued to next 10 years, Kobe II provides probabilities violating (not sustaining) TBmsy and Fmsy in the 3rd and 10th year.

In this paper, the author produced graphical presentations of Kobe II matrix using the Kobe plot software (Nishida *et al*, 2015). With the graphical presentations, non-technical people (managers, industries and public in general) can easily understand the situation.

In general, tuna RFMOs use catch levels as TAC, which can sustain TBmsy and Fmsy in 10 years later with around 50% (threshold value), which is close to MSY catch levels. However, this workshop (WS) can choose different threshold values. For example, if WS requires more conservative measure, then 40% may be more appropriate, while for the more optimistic measure (good for fishers, but less conservative approach), 60% may be the value to choose.

3. RESULTS

Results of risk assessment of Kawakawa and Longtail tunas are presented as follow:

3.1 Kawakawa (Indian Ocean side of the Southeast Asian Waters)

Fig. 1 shows the Kobe plot (results of stock assessments). Table 1 presents results of risk assessments (Kobe II matrix) and Figs. 2 and 3 show Kobe II graphically for TBmsy an Fmsy respectively. Results suggest that if current (2014) catch (59,756 t) is continued, both the risk violating TBmsy and Fmsy are more than 67% in 10 years, while in case of the MSY level (55,380 t), risk probabilities violating TBmsy and Fmsy are will be less than 45%. **<u>Thus it is recommended that the total catch of Kawakawa in the Indian Ocean (Southeast Asian Waters) should be less than its MSY level (55,380 t).</u>** This means that the current catch level (59,800 t) (Average of 2012-2014) should be decreased by 7%.

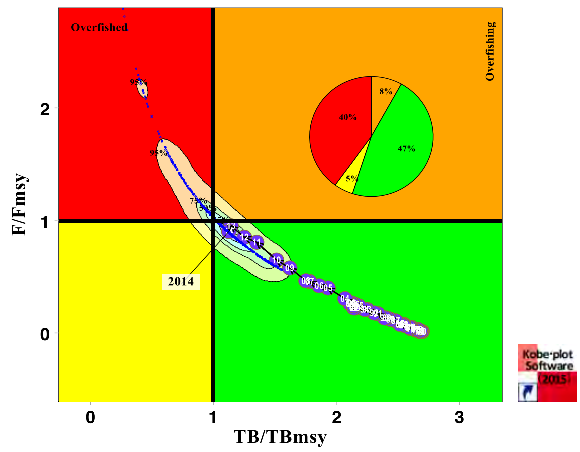


Fig 1. Kobe plot: results of stock assessments
(Kawakawa, Indian Ocean in the Southeast Asian Waters)

Table 1 Probabilities (%) violating TBmsy and Fmsy in 3 years (2017) and 10 years (2024)
(Kawakawa, Indian Ocean side of the Southeast Asian Waters)

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0-20%	20-50%	50-80%	80-100

Catch level	**60%**	**70%**	**80%**	**90%**	**93%**	**100%**	**110%**	**120%**	**130%**	**140%**
					MSY level	Current catch(*)				
10 catch scenarios (tons)	35,854	41,829	47,805	53,780	55,380	59,756	65,732	71,707	77,683	83,658
$B_{2017} < B_{MSY}$	20	24	30	39	41	46	57	64	73	80
$F_{2017} > F_{MSY}$	9	14	20	36	42	59	80	95	100	100
$B_{2024} < B_{MSY}$	7	10	17	36	44	67	87	99	100	100
$F_{2024} > F_{MSY}$	7	9	16	35	45	71	95	100	100	100

(*) The current catch level is the average catch in 3 recent years (2012-2014).

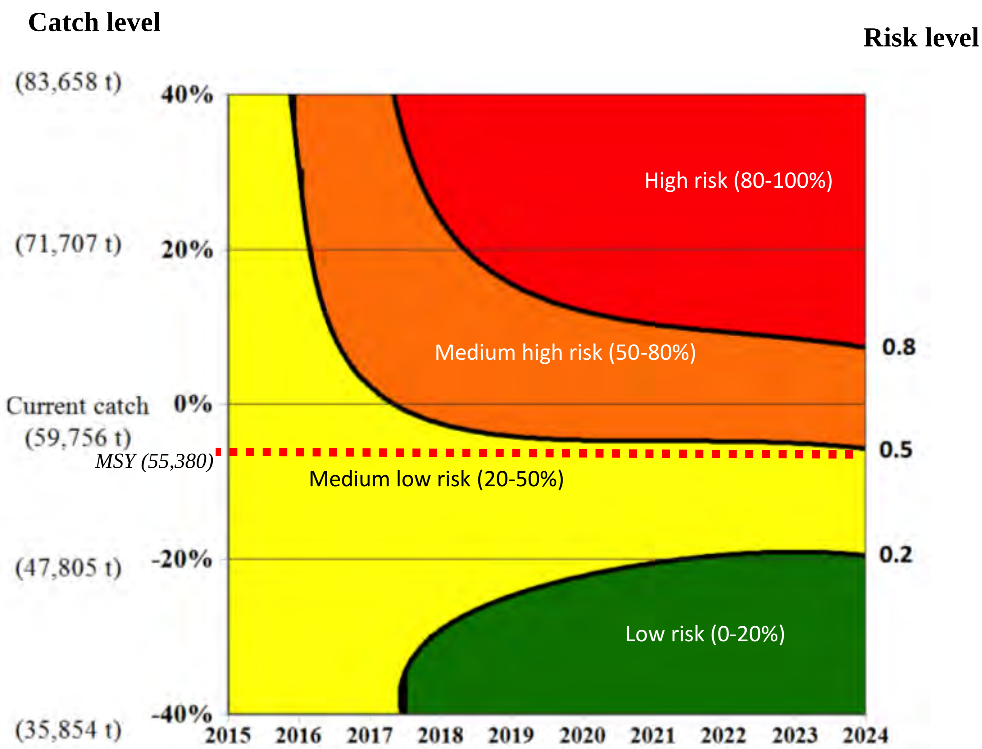


Fig. 2 Risk level (probably) (%) violating TBmsy next 10 years (2015-2024) by different catch levels
(Kawakawa, Indian Ocean side in the Southeast Asian Waters)

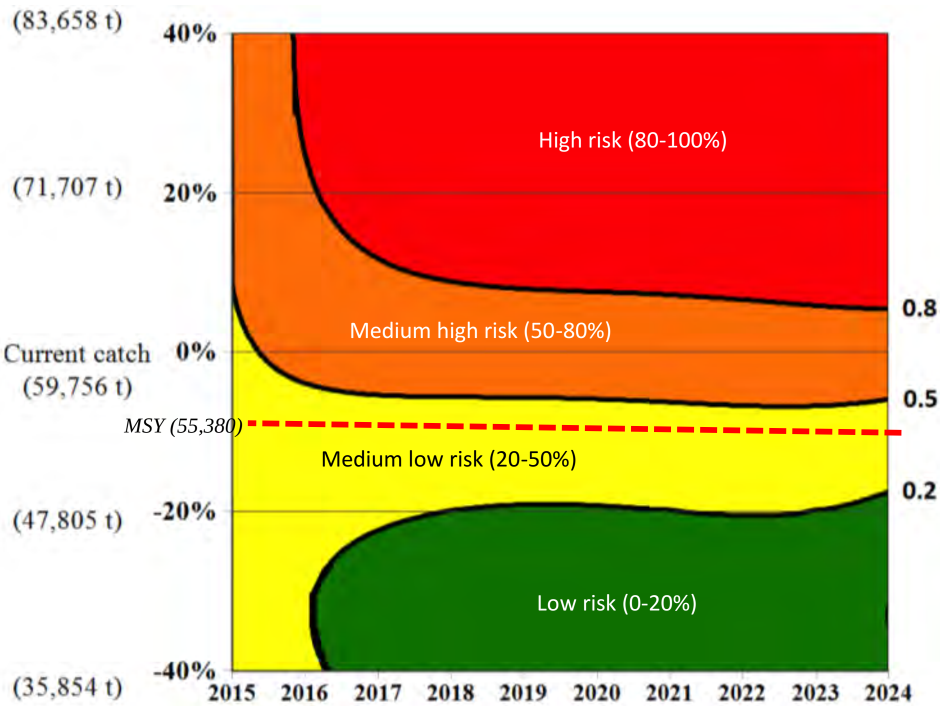


Fig. 3 Risk level (probably) (%) violating Fmsy next 10 years (2015-2024) by different catch levels
(Kawakawa, Indian Ocean in the Southeast Asian Waters)

3.2 Kawakawa (Pacific Ocean side of the Southeast Asian Waters)

Fig. 4 shows the Kobe plot (results of stock assessment). Table 2 presents the results of risk assessments (Kobe II matrix) and Figs. 5 and 6 show graphical risk level for TBmsy and Fmsy respectively. Results suggest that if the MSY level of the catch (185,400 t) were continued, risk probabilities violating TBmsy and Fmsy will be less than 56%. **Thus it is recommended that the total catch of kawakawa in the Pacific Ocean (Southeast Asian Waters) should be less than the MSY level (185,400 t).** This means that the current catch level (171,000 t) (Average of 2011-2013) can be increased by 9%.

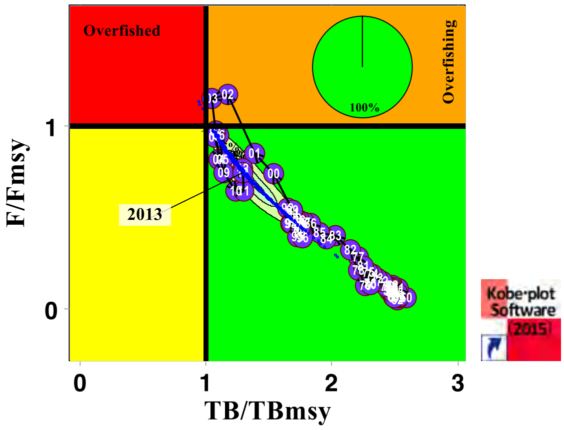


Fig. 4 Kobe plot: results of stock assessments
(Kawakawa, Pacific Ocean side in the Southeast Asian Waters)

Table 2 Probabilities (%) violating TBmsy and Fmsy in 3 years (2016) and 10 years (2023)
(Kawakawa, Pacific Ocean side of the Southeast Asian Waters)

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0-20%	20-50%	50-80%	80-100

Catch level	60%	70%	80%	90%	100%	109%	110%	120%	130%	140%
10 catch scenarios (tons)					Current catch (*)	MSY level				
Projected catch (tons)	102,571	119,666	136,762	153,857	170,952	185,400	188,047	205,142	222,238	239,333
$B_{2016} < B_{MSY}$	5	12	17	26	32	39	40	50	58	65
$F_{2016} > F_{MSY}$	0	0	0	0	16	41	46	73	90	96
$B_{2023} < B_{MSY}$	0	0	0	1	18	56	63	88	96	99
$F_{2023} > F_{MSY}$	0	0	0	0	3	56	66	93	99	100

(*) The current catch level is the average catch in 3 recent years (2011-2013)

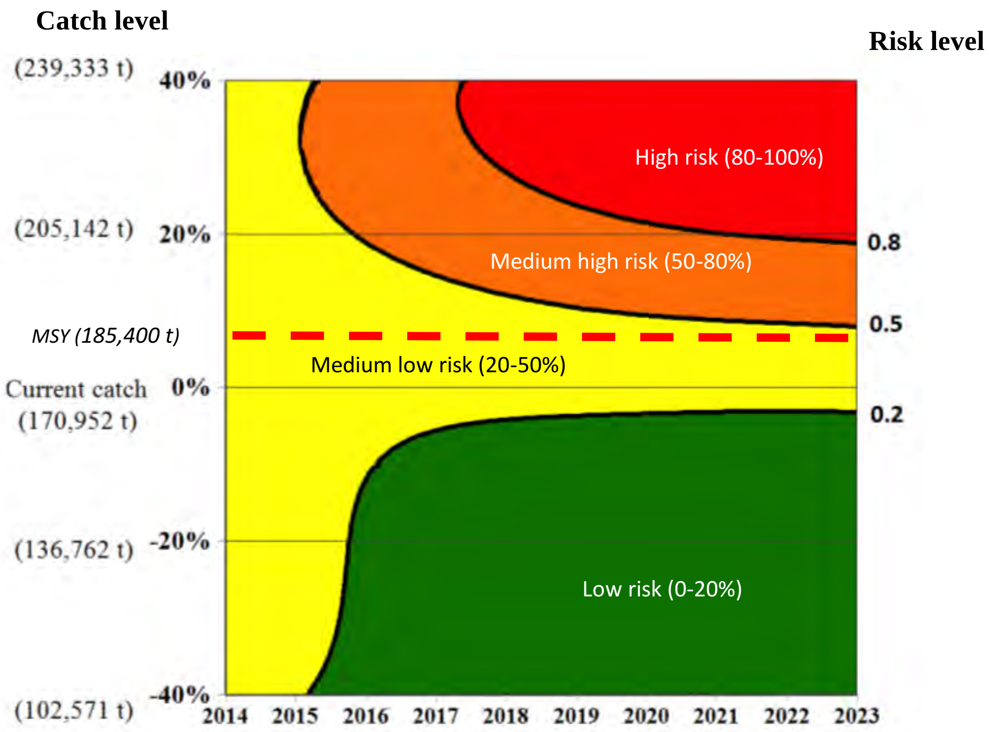


Fig. 5 Risk level (probably) (%) violating TBmsy in 10 years (2014-2023) by different catch levels (Kawakawa, Pacific Ocean side of the Southeast Asian Waters)

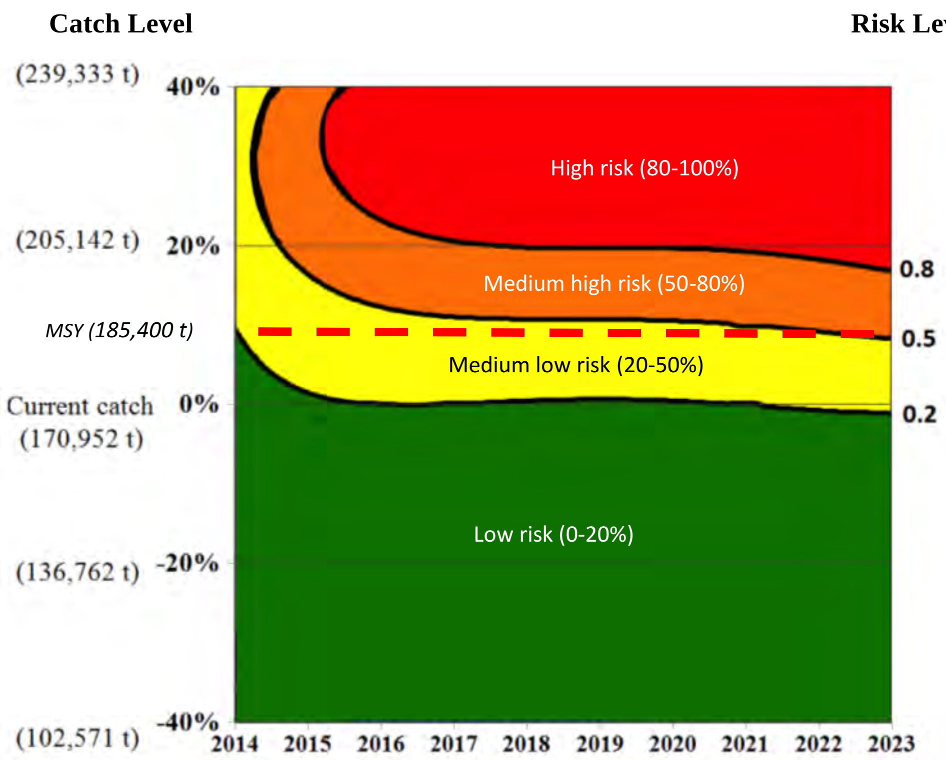


Fig. 6 Risk level (probably) (%) violating Fmsy in 10 years (2014-2023) by different catch levels (Kawakawa, Pacific Ocean side of the Southeast Asian Waters)

3.3 Longtail tuna (Indian Ocean side in the Southeast Asian Waters)

Fig. 7 shows the Kobe plot (results of stock assessments). Table 3 presents results of risk assessments (Kobe II matrix) and Figs. 8 and 9 show results of graphical risk level for TBmsy and Fmsy respectively. Results suggest if the MSY level catch (37,580 t) were continued, risk probabilities violating TBmsy and Fmsy will be less than 53 % in 10 years. **Thus it is recommended that the total catch of longtail tuna in the Indian Ocean (Southeast Asian Waters) should be less than the MSY level (37,580 t).** This means that the current catch level (43,000 t) (Average of 2012-2014) should be decreased by 13%.

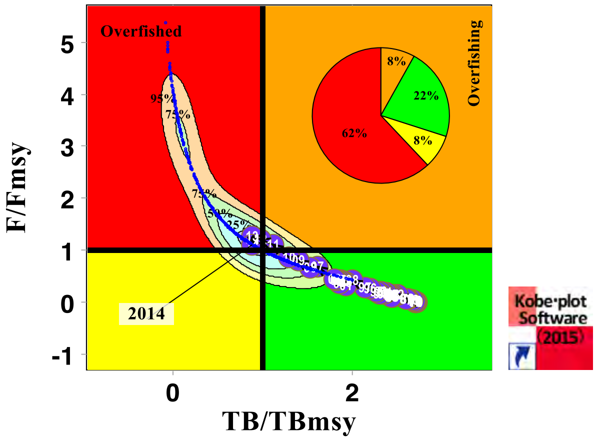


Fig. 7 Kobe plot: results of stock assessments
(Longtail tuna, Indian Ocean side of the Southeast Asian Waters)

Table 3 Probabilities (%) violating TBmsy and Fmsy in 3 years (2017) and 10 years (2024)
(Longtail tuna, Indian Ocean side of the Southeast Asian Waters)

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0-20%	20-50%	50-80%	80-100

Catch level	**60%**	**70%**	**80%**	**87%**	**90%**	**100%**	**110%**	**120%**	**130%**	**140%**
				MSY level		Current catch (*)				
10 catch scenarios (tons)	25,807	30,108	34,409	37,580	38,710	43,011	47,312	51,613	55,914	60,215
$B_{2017} < B_{MSY}$	48	51	55	57	58	61	64	68	71	74
$F_{2017} > F_{MSY}$	35	41	49	56	59	71	79	87	92	96
$B_{2024} < B_{MSY}$	31	36	45	54	57	71	80	87	90	94
$F_{2024} > F_{MSY}$	31	35	42	53	57	75	87	92	96	98

(*) The current catch level is the average catch in 3 recent years (2012-2014)

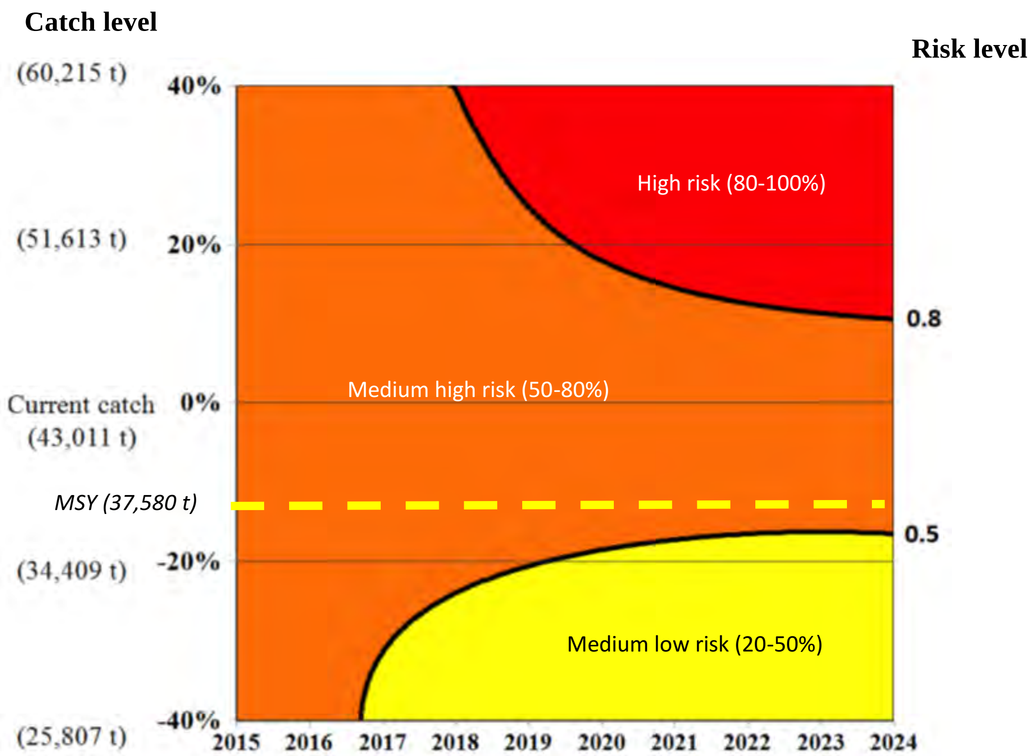


Fig. 8 Risk level (probably) (%) violating TBmsy in next 10 years (2015-2024) by different catch levels (Longtail tuna, Indian Ocean side of the Southeast Asian Waters)

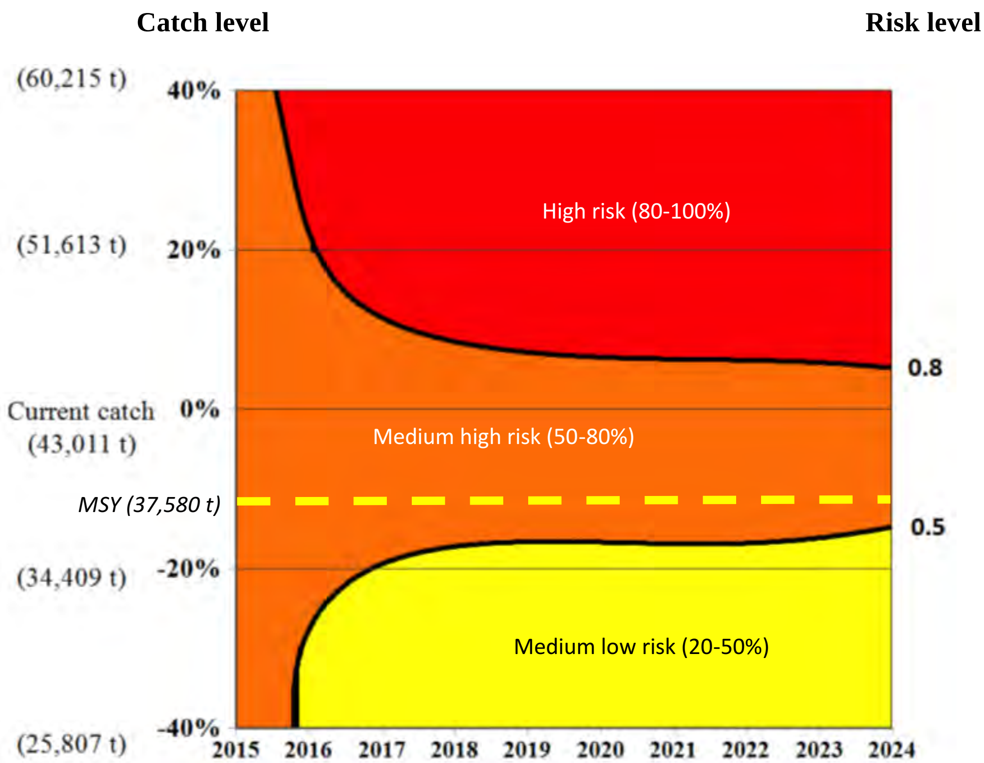


Fig. 9 Risk level (probably) (%) violating Fmsy in 10 years (2015-2024) by different catch levels (Longtail tuna, Indian Ocean side of the Southeast Asian Waters)

3.4 Longtail tuna (Pacific Ocean side of the Southeast Asian Waters)

Fig. 10 shows the Kobe plot (results of stock assessments). Table 4 presents results of risk assessments (Kobe II matrix) and Figs.11 and 12 show results of graphical risk level for TBmsy and Fmsy respectively. From the results, it is not clear the catch level producing 50% probabilities for TBmsy and Fmsy in 10 years later (2023). Thus additional Kobe II table and diagrams are produce in Table 5 and Figs. 13-14 covering increased 50%, 100%, 123%, 150% and 200% of the current catch level. New results suggest that even if the current catch is increased to the MSY level (196,700 t) (123%), risk probabilities violating TBmsy and Fmsy will be around 50 %. **Thus it is recommended that the total catch of Longtail tuna in the Pacific Ocean (Southeast Asian Waters) can be increased to the MSY level (196,700 t) (123%).** This means that the current catch level (88,200 t) (Average of 2011-2013) can be increased by 108,500 t (123%).

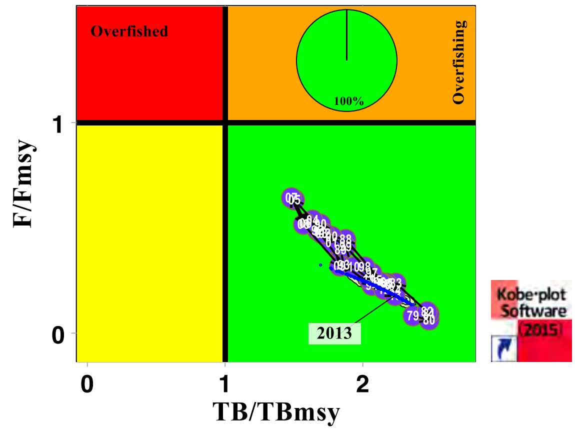


Fig. 10 Kobe plot: results of stock assessments
(Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

Table 4 Probabilities (%) violating TBmsy and Fmsy in 3 years (2016) and 10 years (2023)
(Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

Color legend				
Risk levels	Low risk	Medium low risk	Medium high risk	High risk
Probably	0-20%	20-50%	50-80%	80-100

Catch level increased by	-40%	-30%	-20%	-10%	Current catch(*)	10%	20%	30%	40%	123%
										MSY
10 catch scenarios (tons)	52,894	61,710	70,526	79,341	88,157	96,973	105,788	114,604	123,420	196,700
$B_{2016} < B_{MSY}$	0	0	0	0	0	0	0	0	0	0
$F_{2016} > F_{MSY}$	0	0	0	0	0	0	0	0	0	0
$B_{2023} < B_{MSY}$	0	0	0	0	0	0	0	0	0	52
$F_{2023} > F_{MSY}$	0	0	0	0	0	0	0	0	0	53

(*) The current catch level is the average catch in 3 recent years (2011-2013)

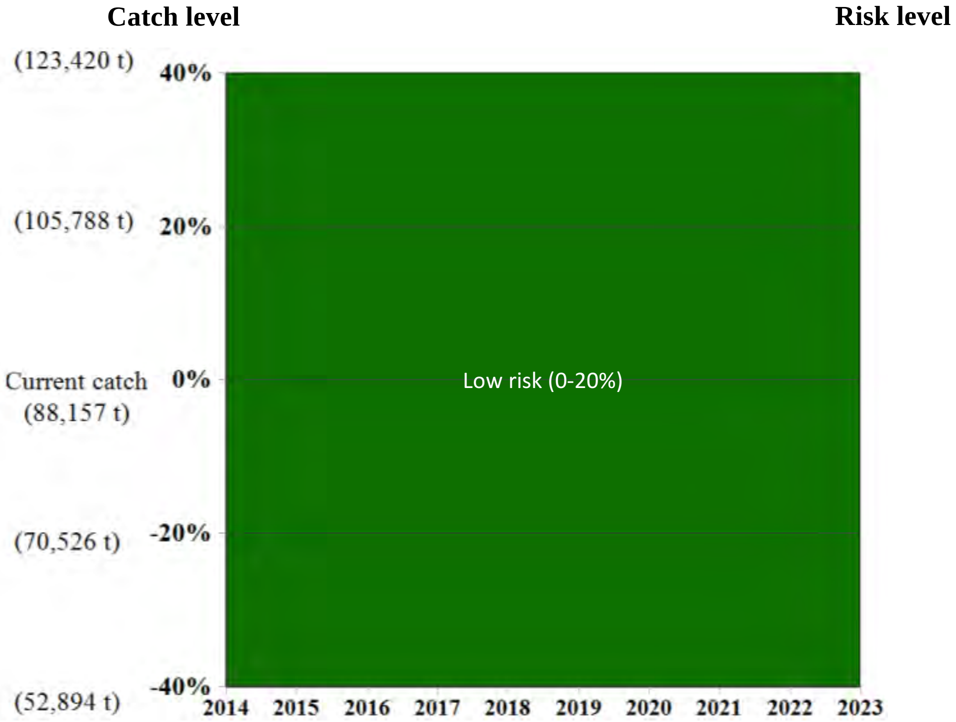


Fig. 11 Risk level (probably) (%) violating TBmsy in next 10 years (2014-2023) by different catch levels (Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

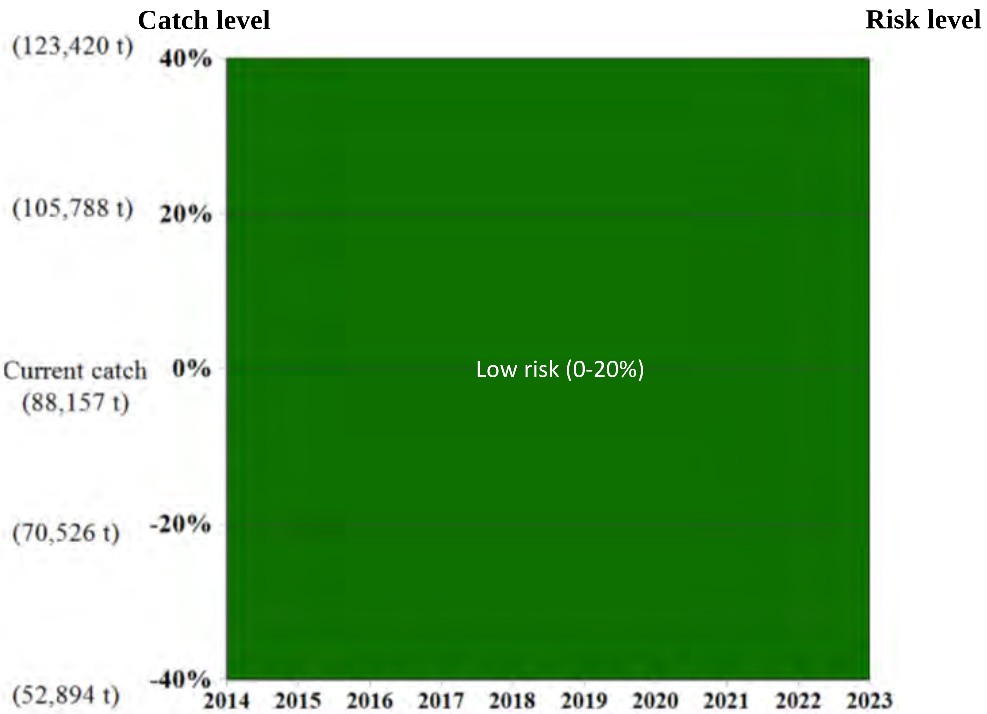


Fig. 12 Risk level (probably) (%) violating Fmsy in next 10 years (2014-2023) by different catch levels (Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

Table 5 Probabilities (%) violating TBmsy and Fmsy in 3 years (2016) and 10 years (2023) if the current catch were increased by 50%, 100%, 150% and 200%
(Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2011–13) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**					
	Current catch (*)			**MSY**		
Catch level Increased by	**0%**	**50%**	**100%**	**123%**	**150%**	**200%**
Projected catch (tons)	88,157	132,236	176,314	196,700	220,392	264,471
$B_{2016} < B_{MSY}$	0	0	0	0	0	0
$F_{2016} > F_{MSY}$	0	0	0	0	0	78
$B_{2023} < B_{MSY}$	0	0	24	52	84	100
$F_{2023} > F_{MSY}$	0	0	19	53	88	100

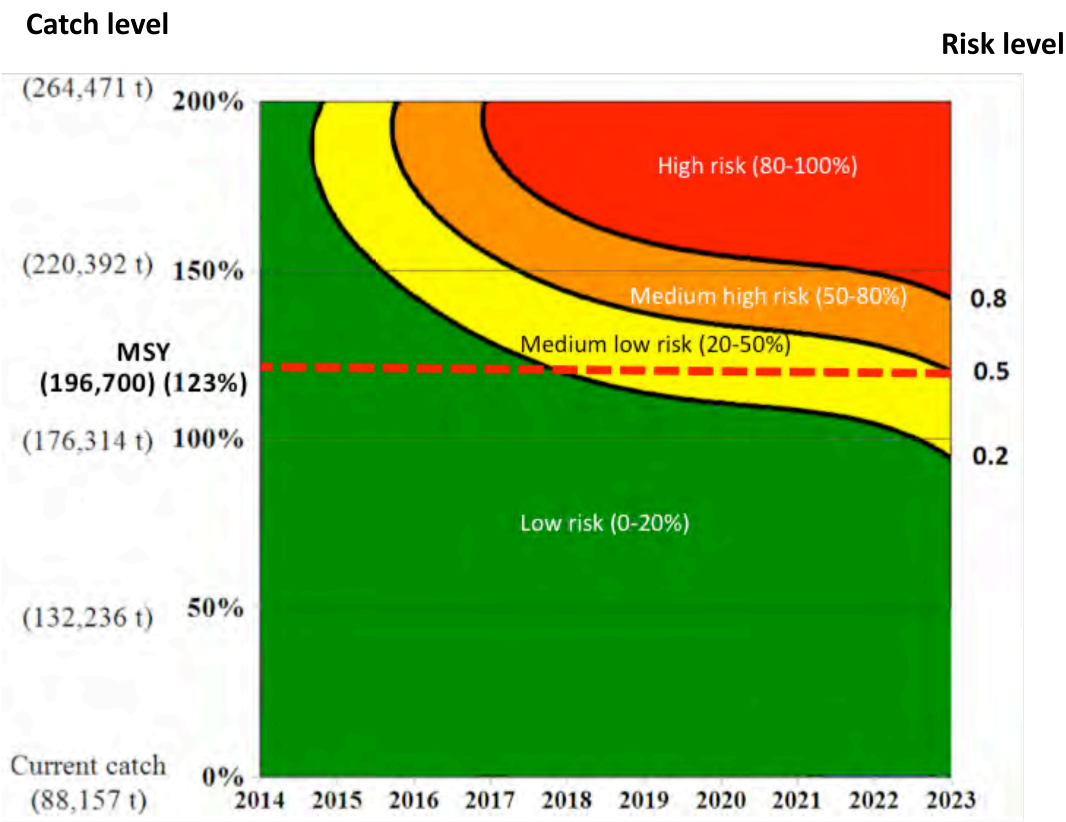


Fig. 13 Risk level (probably) (%) violating TBmsy in next 10 years (2014-2023) by different catch levels (0%, 50%, 100%, 150 and 200%) (Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

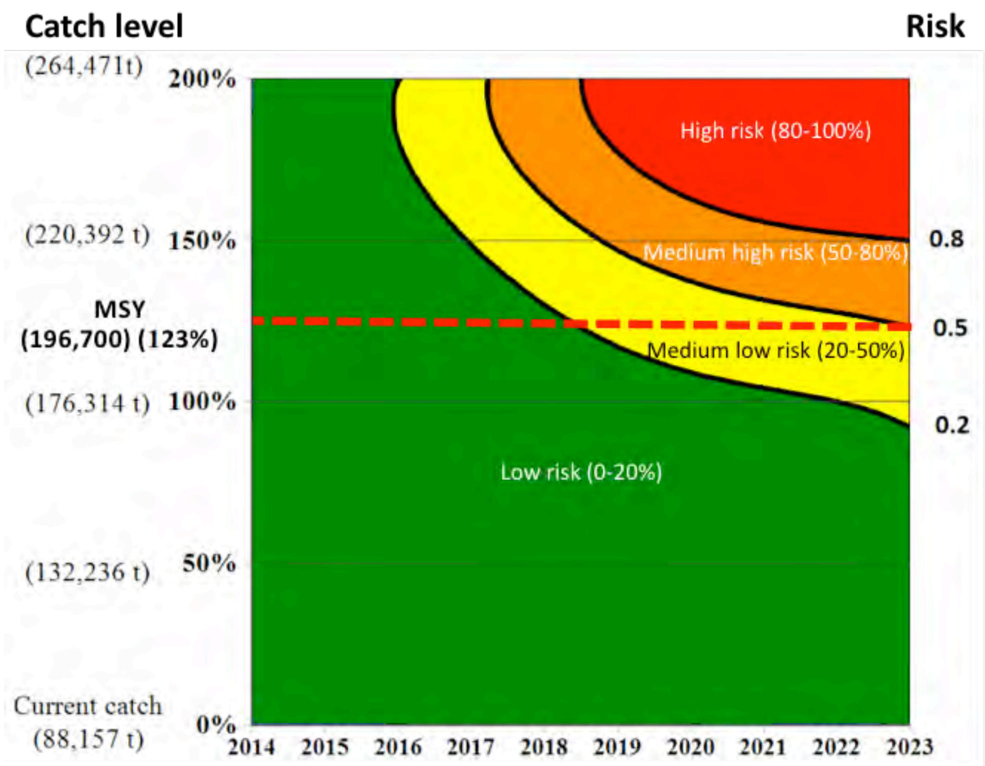


Fig. 14 Risk level (probably) (%) violating Fmsy in next 10 years (2014-2023) by different catch levels (0%, 50%, 100%, 150 and 200%) (Longtail tuna, Pacific Ocean side of the Southeast Asian Waters)

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