Report of the
Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in the Southeast Asian Region

SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia

17-25 April 2016

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SEAFDEC/MFRDMD
in Collaboration with the Secretariat

Supported by
The Swedish Government
Through the SEAFDEC-Sweden Project

SEC/SP/171 **July 2017**

PREPARATION AND DISTRIBUTION OF THIS DOCUMENT

Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in the Southeast Asian Region, SEAFDEC/MFRDMD, in Kuala Terengganu, Malaysia on 17-25 April 2016 was prepared by the Secretariat of Southeast Asian Fisheries Development Center (SEAFDEC). The document is distributed to participants of the meeting, SEAFDEC Member Countries, SEAFDEC Departments and concerned institutions.

BIBLIGRAPHIC CITATION

SEAFDEC. 2016. Report of the Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in the Southeast Asian Region, SEAFDEC/MFRDMD, in Kuala Terengganu, Malaysia on 17-25 April 2016, Southeast Asian Fisheries Development Center. 279 pp.

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CONTENTS

LIST OF ANNEXXES

SESSION I

GENERAL INFORMATION

1.1 Background

Recognizing the regional cooperation to promote the sustainable utilization of neritic tuna in Southeast Asian region, the 45th Meeting of the SEAFDEC Council endorsed the proposal of SEAFDEC Secretariat to conduct regular stakeholders' consultations for the development of the Regional Plan of Action for Sustainable Neritic Tuna Fisheries (RPOA-Neritic Tuna). Thus, SEAFDEC with funding support from the SEAFDEC-Sweden Project organized the "Consultative Meeting on Regional Cooperation on Sustainable Neritic Tuna Fisheries in Southeast Asian Waters" (October 2013 in Songkhla Province, Thailand). Based on the discussion during the above meeting with AMSs and relevant organizations, SEAFDEC developed the zero draft of the RPOA-Neritic Tuna, which was finalized at the "Experts Group Meeting on the Development of Regional Plan of Action on Sustainable Utilization of Neritic Tuna Resources in Southeast Asian Waters" (18-20 June 2014 in Krabi province, Thailand). The RPOA-Neritic Tunas was reported to the 17th Meeting of the FCG/ASSP in December 2014, and then later endorsed by the 47th Meeting of SEAFDEC Council in April 2015. Another output through the above series of the meetings is the establishment of the Scientific Working Group (SWG) on stock assessment of neritic tunas in the ASEAN region. The Term of Reference (TOR) for SWG-Neritic Tunas was formulated in the 1st Meeting of SWG-Neritic Tunas (18-20 November 2014, Shah Alam, Malaysia) and endorsed by the 47th Meeting of the SEAFDEC Council for long term establishment of the working group.

The 1st Meeting of SWG-Neritic Tunas agreed to cover the seven (7) species to be studies in the region, which includes 1) longtail tuna (*Thunnus tonggol*), 2) eastern little tuna/kawakawa (*Euthynnus affinis*), 3) frigate tuna (*Auxis thazard*), 4) bullet tuna (*Auxis rochei*), bonito (*Sarda orientalis*), Indo-pacific king mackerel and narrow barred Spanish mackerel. At the beginning, the Meeting agreed to focus and assess the two (2) neritic tuna species, the eastern little tuna/kawakawa and longtail tuna. The 2nd Meeting of SWG-Neritic Tunas (15-17 June 2015, Hai Phong, Viet Nam) concluded that A Stock-Production Model Incorporating Covariates (ASPIC) would be used as per first phase of the two neritic tuna stock assessment study. In this regard, the participating Member Countries were requested to review all available historical data and information on to Longtail tuna and Kawakawa and submit to SEAFDEC/MFRDMD. The Meeting noted that once historical data has been completed, data quality control and validation would be performed, coordinated by the resource persons. On the other hand, most of the countries requested capacity building on statistics and data collection (including standardizing the stock assessment methodology and data collection) and assessment of CPUE and stock status based on catch data and fishing effort. Therefore, the meeting agreed that SEAFDE would conduct a Training of Trainers (TOT) on CPUE standardization and stock assessment analysis to be held in 2016. Based on the agreement, SEAFDEC/MFRDMD in collaboration with SEAFDEC/Secretariat has convened "the Special Training/Workshop on Stock Assessments of Longtail tuna and Kawakawa in the Southeast Asian Region" on 17-25 April 2016 at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia. The trained trainers in this Special Training/Workshop would have his/her responsibility on conducting training at national level upon completion of the training.

1.2 Objectives of the Special Training/Workshop

1. To transfer specific knowledge to scientist who have experienced on Basic Stock Assessment and IT skills including specific software such as CPUE standardization and stock assessment analysis using ASPIC, Kobe plot (stock status trajectory) decision making tool for management and other relevant program.
2. To train the participant as a trainer who would have his/her responsibility on conducting training for CPUE standardization and stock assessment analysis of neritic tunas at national level upon completion of the training.

1.3 Outlines of the Training/Workshop (Table 1)

DATE		AGENDA
17 April	Sunday	Opening
		Introductions
		Country Report
		Reviews on Biological and Ecological of Longtail Tuna and Kawakawa
		Data Collection and Process
18 April	Monday	CPUE standardization (outlines, initial practices and discussion)
19 April	Tuesday	ASPIC (outlines, initial practices and discussion)
20 April	Wednesday	ASPIC (practices)
21 April	Thursday	Kobe plot (outlines, initial practices and discussion)
22 April	Friday	Excursion to vicinity of Kuala Terengganu
23 April	Saturday	CPUE standardization, ASPIC and Kobe Plot using real data and results of the stock status
24 April	Sunday	
25 April	Monday	Final Practices: Case study presentations: > For Thailand: Case Study ASPIC (LOT)(IOTC) > For Malaysia: Case study ASPIC (KAW)(IOTC) > For Indonesia: Case study (K. Mackerel) (T. Tobago) > For Philippines: Case study (Albacore)(IOTC) > For Brunei Darussalam: Case study LOT NWIO (CPUE+APIC) > For Vietnam: Case study Oman LOT CPUE
		Wrap up (Discussion and Conclusion)
		Closing

1.4 Expected Outputs

1. Increased knowledge and skills on CPUE standardization and stock assessment analysis for neritic tunas using the ASPIC, Kobe plot, and other relevant program.
2. Enhanced capability of scientist as a trainer who would have his/her responsibility on conducting training for CPUE standardization and stock assessment analysis of neritic tunas at national level upon completion of the training.

1.5 Date and Venue

The Special Training/Workshop was held from 17-25 April 2016 at SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia.

1.6 Participants

- A total of 8 core participant from Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand, Viet Nam as well as TD and MFRDMD;
- 12 Observers from Brunei Darussalam (1), Malaysia (1), Philippines (1), Thailand (1), Viet Nam (1) as well as TD (1), and MFRDMD (4);
- 1 Key resource person from Fisheries Research Agency of Japan and another one from the MFRDMD;
- Senior officers from MFRDMD and the Secretariat

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1.7 List of the Training Materials and Software (Table 2)

Topic	Subject	No.	Type of File
Orientation	Orientation	01	Word
Data collection & process	Outline	02	
CPUE standardization	Outline	03	
	Software (Manual)	04	Power Point
ASPIC	Outline	05	Power Point
	Software parameter search (Manual)	06	Word
	Software ASPIC (Manual)	07	Word
Kobe plot	Outline	08	Power Point
	Software (Manual)	09	Word
Case studies	Longtail tuna stock assessments (Nishida and Iwasaki, 2015, IOTC)	10	Word
	Kawakawa stock assessments (Nishida et al., 2014, IOTC)	11	Word
	Kawakawa and Longtail stock assessments (Government of Oman, 2013) (IOTC)	12	Power Point
R	How to install R ?	13	

Software	No.	License by
CPUE (Catch-Per-Unit-of-Effort) Standardization by GLM (Generalized Linear Model)	1	SEAFDEC, 2016
ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5)	2	NOAA,2004
ASPIC: ASPIC (ver. 5.05) Batch (Grid search) Job Software (Menu-driven software) (1st version)	3	NRIFSF, 2016
Kobe I (Kobe plot) +Kobe II (risk assessment) software (New ver. 3, 2014)	4	NRIFSF, 2014
R 3.2.3 (https://cran.r-project.org/bin/windows/base)	5	Duncan Murdoch, 2015

SESSION II

COUNTRY REPORT

2.1 Brunei Darussalam

Neritic Tunas and and sheerfish in Brunei Darussalam waters is prepared and presented by *Mr. Azri Saufi Waliyuddin Haji Nasir* and *Mr. Muhammad Adam Ramlee*. The detailed information are summarized as follows:

- Brunei Darussalam is located in the northwestern part of Borneo with an area of 5,765 km^2 and 161 km long coastline fronting South China Sea.
- The total marine territorial area is estimated about 41,188 km^2 covering the Brunei Fisheries Limits with the potential yield of about 21,300 Metric Tons (MT).
- Neritic tunas (also called coastal tuna) are very important species group for commercial coastal fishing and / or the small-scale fisheries of most nations including Brunei Darussalam.
- The neritic tunas in Brunei Darussalam is very much affected by its neighboring countries since neritic or coastal tunas are highly and moderated migratory species.
- Stock assessment of neritic tunas is not as easy as demersal resources because of the wider area of coverage of this migratory species.
- Therefore it is highly recommended that Brunei actively participate in the RPOA neritic tuna including the coming training course on neritic tuna stock assessment in the region.
- There are 5 main species found in the EEZ such as 1) Lontail tuna (*Thunnus tonggol*), 2) Frigate tuna (*Auxis thazard*), 3) Bullet tuna (*Auxis rochei*), 4) Kawakawa (*Euthynnus affinis*), 5) Narrow-barred spanish mackerel (*Scomberomorus commerson*), and 6) Indo-Pacific king mackerel (*Scomberomorus guttatus*). Most of neritic tunas are caught by purse seine.
- Fishing Areas are separated into 4 zones: namely Zone 1 from 1 to 3nm, Zone 2 from 3 to 20nm, Zone 3 from 20 to 45nm, and Zone 4 is beyond 45nm from the coastal line. **Figure 1** shows fishing area within the EEZ of Brunei Darussalam. **Figure 2** shows the fishing gears specification by Zone.
- **Figure 3** shows the fishing area of commercial purse seiners where their Fish Aggregating Devices (FADs) are being deployed. Mostly zone 2, 3 and 4 are fishing areas of purse seiner.

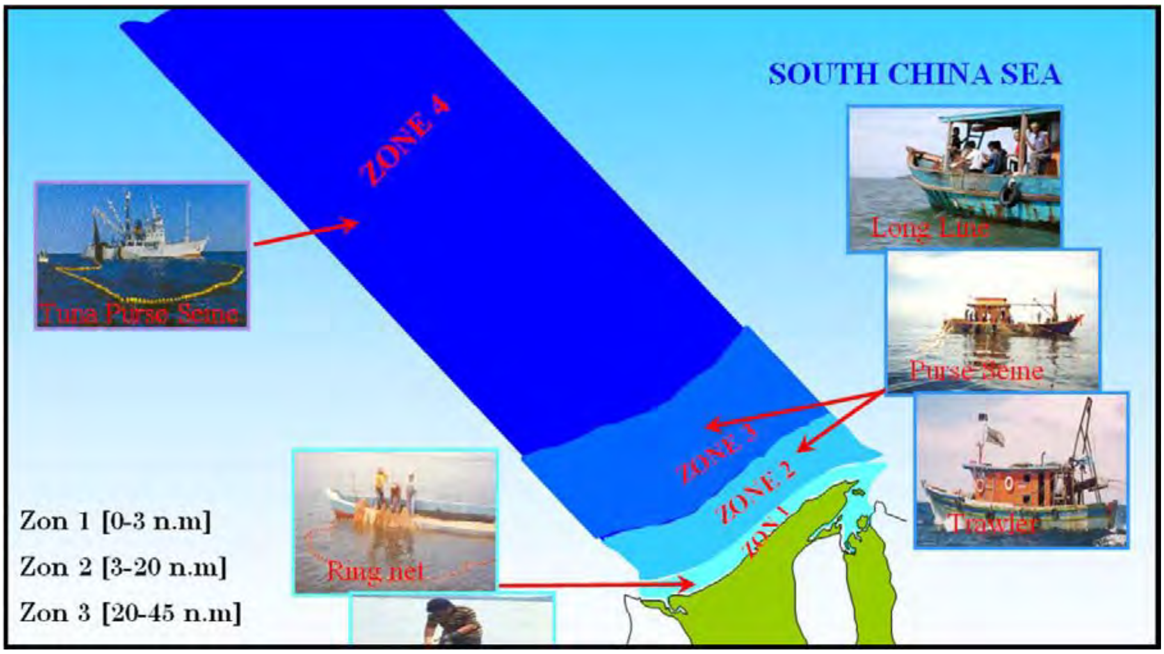


Figure 1

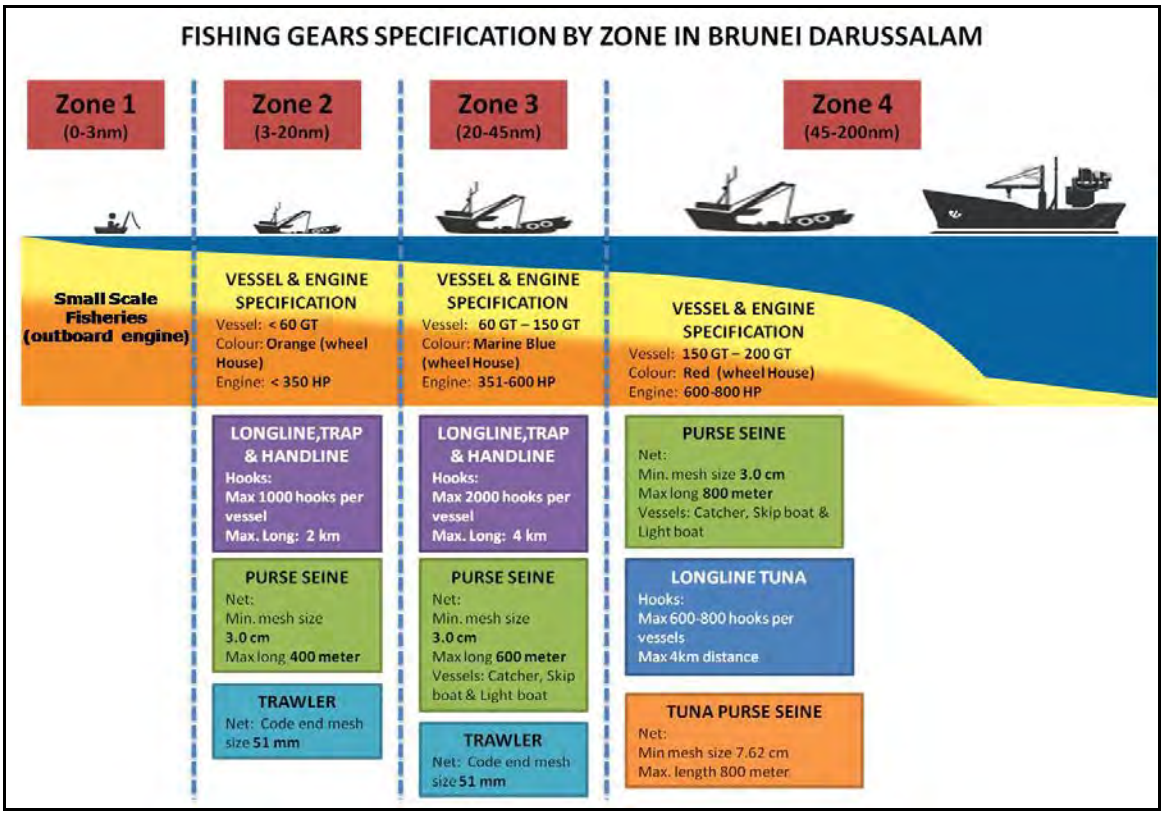
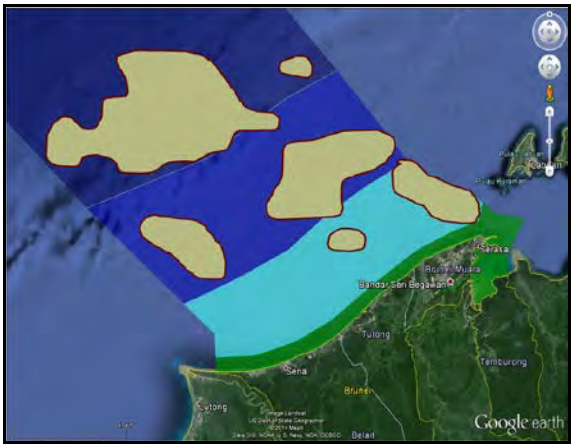


Figure 2



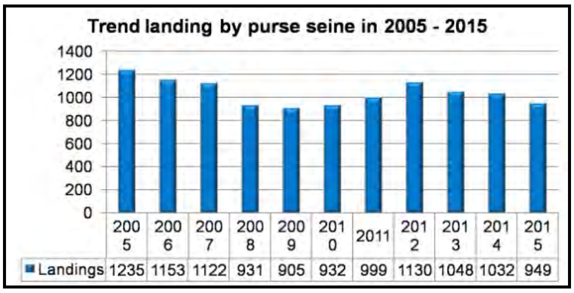


Figure 3 Figure 4

- **Figure 4** shows the total landing in metric tonnes by purse seiners operated in the EEZ during a period from 2005 to 2015, the productions were fluctuation from about 1,235 metric tonnes in 2005 to 949 metric tonnes in 2015.
- Total catch of neritic tunas in kilogram is increased from 87,211kg in 2010 to be 317,306 kg in 2012 and returned to 93,043kg in 2015 as shown in **Figure 5**.
- For Longtail Tuna, a total catch is also varied similar to a total catch of all neritic tunas, the catch of longtail tuna is increased from 23,700 kg in 2010 to about 10,000kg in 2012. The catch is decreased to 10,896 kg in 2015. Most of the catch are caught by purse seine gear as shown in **Figure 6**.
- For the Kawakawa, a total catch is fluctuated from 2010 to 2015, the peak of catch about 218,612 kg in 2012 then slightly decreasing to 160,600kg in 2013 and increasing to 175,954kg in 2014. However, a total catch in 2015 is decreased to be 82,500kg only as shown in **Figure 7**.
- Most of neritic tunas is consumed as fresh in the country, some are export to Thailand and Taiwan as whole frozen fish. In addition, some are processed to smoked fish, fish burger and other valued products. In near future, Brunei Darussalam is planning to export to EU market.

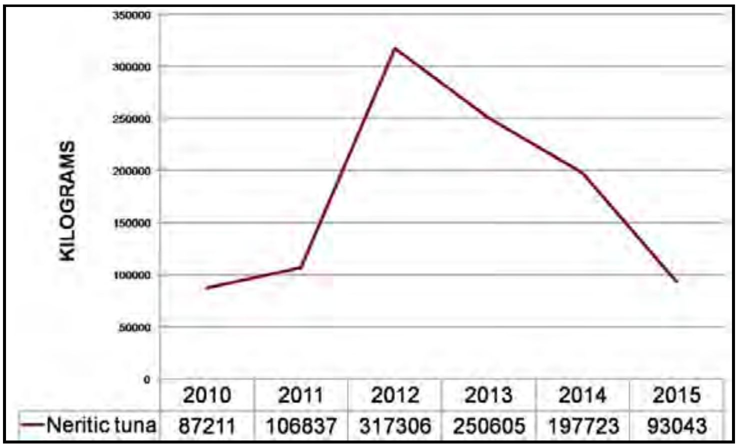


Figure 5

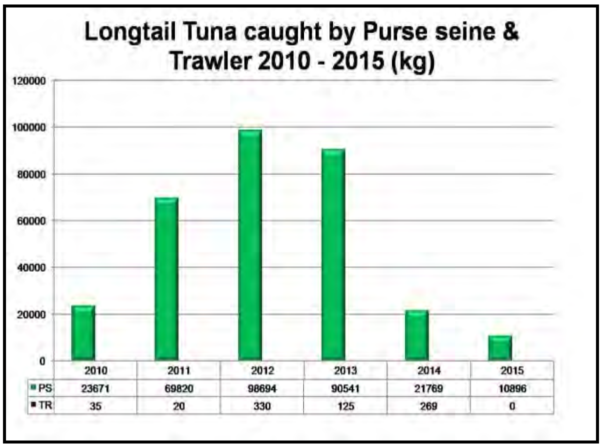


Figure 6

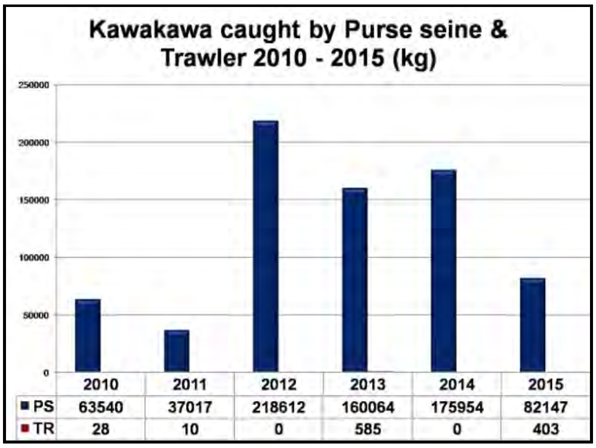


Figure 7

2.2 Indonesia

Neritic tuna fisheries in the Java sea and South China sea is prepared and presented by *Mr. Thomas Hidayat*, a core scientist from Research Institute for Marine Fisheries, Jakarta, Indonesia. In his presentation, the detailed information are summarized as follows:

- Indonesian water divided into 11 Indonesian Fisheries Management Area (IFMA) (Mininsterial Regulation No. 01/MEN/2009).
- There are 6 species of neritic tuna and sheerfish in Indonesia waters. The six species are kawakawa (*Euthynnus affinis*), longtail tuna (*Thunnus tonggol*), frigate tuna (*Auxis thazard*), bullet tuna (*Auxis rochei*), narrow-barred Spanish mackerel (*Scomberomorus commerson*) and Indo-Pacific king mackerel (*Scomberomorus guttatus*). Kawakawa and Longtail tuna are pelagic fish that have economic value in Indonesian fisheries.
- The cacth of neritic tuna and sheerfish reach 588,000 in 2012. The export value is 19,130 ton in 2012 and the import reach 209 ton. The annual catches in metric ton of neritic tuna in the Indonesian waters is shown in **Figure 8**.
- In the Java Sea the neritic tuna mostlty caught as by catch by purse seine, but as main target in drift gill net. In addition, in the South China Sea, Natuna Sea and adjacent water neritic tuna caught by gill net, purse seine and hand line. **Figure 9** show the annual catch of neritic tuna and seerfish operated in Java sea.

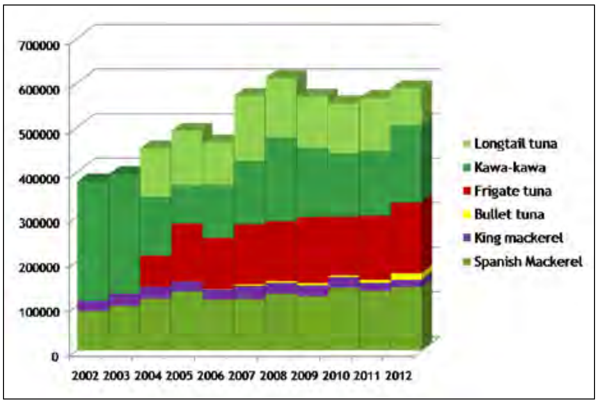
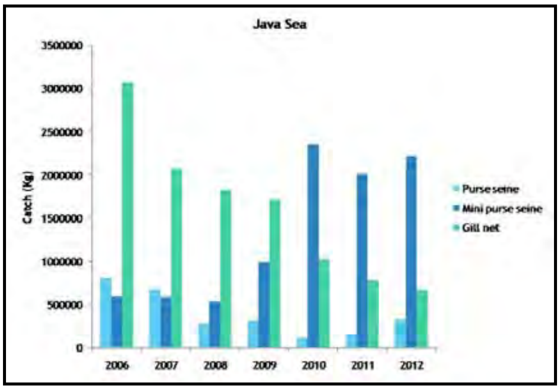


Figure 8 Annual catch of neritic tunas and seerfishes in Indonesia
(Source: Marine Capture Fisheries Statistics of Indonesia 2013)



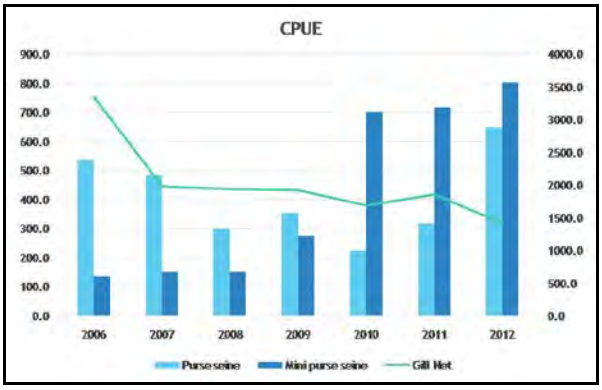
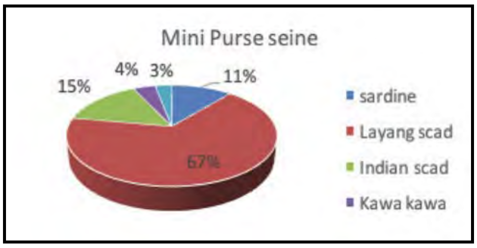


Figure 9 Annual catches of neritic tuna species operated in Java sea landed at Pekalongan Fishing Port

Figure 10 CPUE of Neritic Tuna species landed at Pekalongan Fishing Port

- **Figure 10** show the CPUE of neritic tuna species landed at Pekalongan Fishing Port, the trend of CPUE from three fishing gear in general shows increasing trend. CPUE from purse seine fluktuatif from 2010 to 2012 shows increase with average 650 kg/trip. CPUE mini purse seine shows increase trend, average 800 kg/trip. And gill net shows flat trend, average 1400 kg/trip.
- The catch composition by gear such as Mini purse seine and gill net is shown in **Figure 11** (a and b). The kawakawa is the dominant species of mini-purse seine which is about 67% of a total catch. In addition, for gillnet, kawakawa and longtail tuna are represented as dominant species of about 54% and 36%, respectively.
- The fishing ground of mini-purse seine and gillnet in Java sea is shown in **Figure 12**.
- **Figure 13** shows the annual catches of three neritic tuna species landed at Pemangkat Fishing Port. It is shown that about 84% of three main species of kawakawa, longtail tuna and spanish mackerel, are caught by drift gill net vessels, the remaining 26% was contributed by purse seine vessels.
- **Figure 14** shows the fishing grounds in the South China Sea for different types of gear namely Gillnet from different landing sites and handline.

a)



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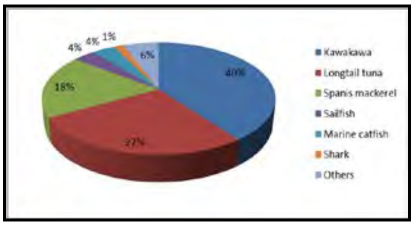


a) Fishing Ground of Mini purse seine

b) Fishing Ground of gill net

Figure 11 Catch composition by gears:
a) mini-purse seine, b) gillnet.

Figure 12 Fishing grounds in Java sea:
a) mini-purse seine and b) gillnet.

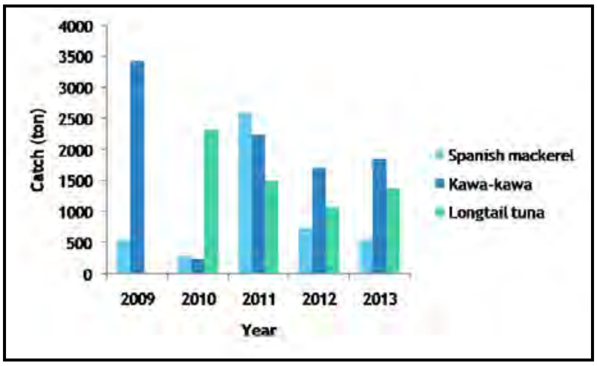


Figure 13 Annual catches of three neritic tuna species landed at Pemangkat Fishing Port

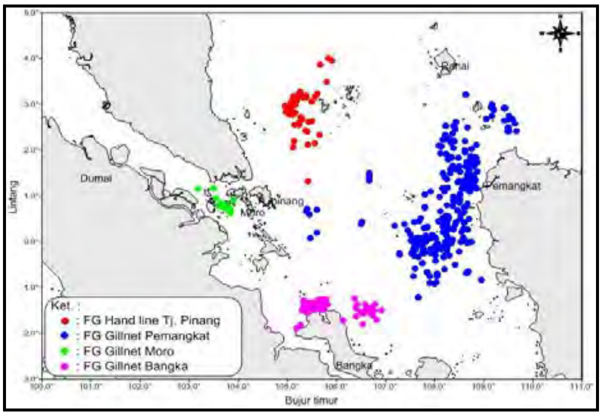


Figure 14 Fishing ground of gill netter in South China/Natuna Sea

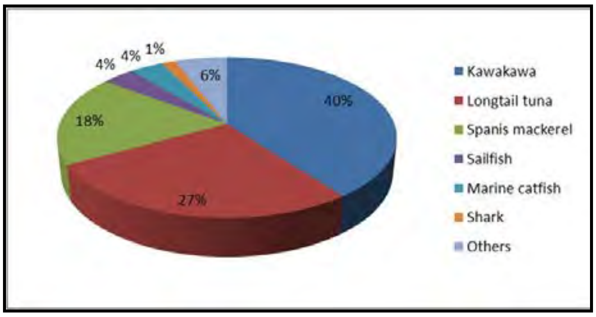


Figure 15 Catch composition of drift gill net landed in Pemangkat fishing port

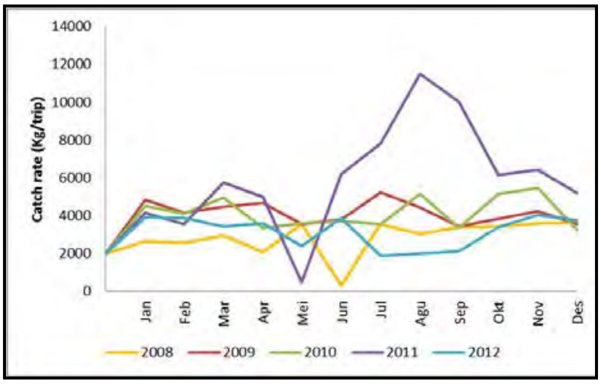


Figure 16 Monthly catch rate of drift gill net

- The catch composition of drift gill net landed in Pemankat fishing port is shown in **Figure 15**, the dominant catch are kawakawa and longtail tunas of about 40% and 27%, respectively. Follow by spanis mackerel of about 18%.
- **Figure 16** show the monthly catch rate from 2008 to 2012 on the catch rate of gill neter in the Pemangkat fishing port is fluctuative each year, from the 5 years series data the average catch rate is 4086 kg/trip with average 10 days each trip.

2.3 Malaysia

Neritic tunas fisheries in Malaysia is prepared and presented by *Mr. Sallehudin bin Jamon Effarina* and *Ms. Effarina binti Mohd Faizal* from Fisheries Research Institute, Sitiawan Perak. The detailed information/presentation are summarized as follows

- In general, fishing areas in Malaysian waters are divided into three main parts namely: 1) Peninsular Malaysia which are included west coast (Malacca Straits) and Andaman Sea, and east coast (South China Sea); 2) Sarawak facing to the South China Sea; and 3) Sabah waters including South China sea on the west coast and the Sulu and Celebes Seas in the east coast. The Malacca Straits is part of the IOTC area of competence.

- Taking into accounts a total marine fishery production of Malaysia, there is not much different for 2013 and 2014, which 1,482,899 MT and 1,440,109 MT were respectively landed. It is also noted that the government plan on development of tuna fisheries cover not only in coastal waters, but also in offshore waters within the Exclusive Economic Zone (EEZ). The second strategic development plan for tuna fisheries was launched at the end of 2013.
- Main species of neritic tunas namely longtail tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*) and, frigate tuna (*Auxis thazard* and *Auxis rochei*) were exploited by main fishing gears *e.g.* purse seine, trawl, hand line and drift net (gillnet). In 1987, when purse seiner were introduced to catching the neritic tunas and start from that the landing of neritic tuna were increased.
- Size of Purse seiners are categorized based on the gross tonnage such as:
  1) 25 – 39.9 GRT (above 8 nm off shore)
  2) 40 – 70 GRT (15 nm off shore) and
  3) Above 70 GRT (above 30 nm offshore)
- At present fishing gears and techniques to catch were developed by using Fish Aggregating Device (FADs) and light luring techniques.
- Number of purse seiners by size category operated in the Peninsular Malaysia (WCPM and ECPM) from 1984 to 2012 is shown in **Figure 17** it was very clear that the purse seiners size larger than 70 gross-tonnages are increasing from 20 vessels in1984 to be about 350 vessels in 2012.
- A total landings of neritic tuna in Malaysia: **Figure 18** shows a total annual landing in metric tons of nertic tunas in which it was ranged from 40,000 MT to 65,000 MT from 1990 to 2014. The highest catch was in 2013 and 2002 (68,000 MT and 62,000 MT, respectively). Decreasing trend found in 2002 to 2005 before an increasing trend until 2014. However, in overall picture, landings of neritic tune in Malaysia appear to have stabilized from 2010 to 2014.
- Total annual production by areas such as Sarawak, Sabah & Labuan were 26,839 MT (1997) and 3,172 MT (1990), respectively. For the ECPM & WCPM, annual production was 50,000 MT (2011) and 11,000 MT (1995).

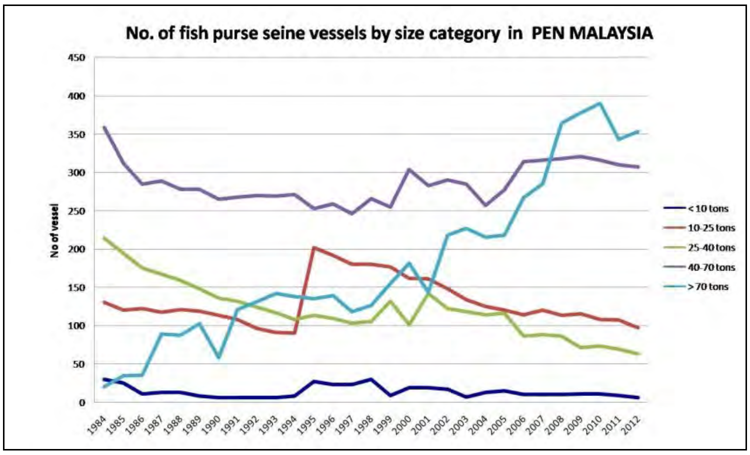


Figure 17
Number of fish purse seiners by size category in Peninsular Malaysia

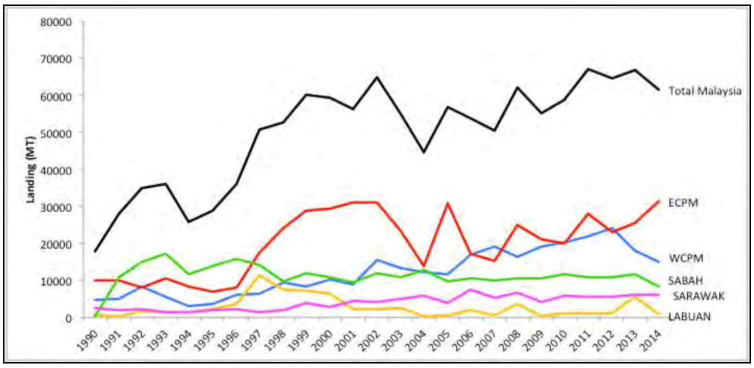


Figure 18
Total landings of neritic tuna in Malaysia based on the Annual Fisheries statistic DoF Malaysia

- Total landing of longtail tuna (LOT) and kawakawa (KAW) in ECPM & WCPM is shown in **Figure 19**. The result shows the highest catch LOT in 2007 which is about 15,000 MT. Increasing trend from 1990 to 2012 and decreasing in 2012 until 2014. For KAW, the highest catch was in 2012 (10,000 MT) and then start to decreasing until 2014.
- Total landing of LOT in Sabah, Sarawak is shown in **Figure 20**. , total catch was decreasing during a period of 2000 until 2015, however landing is stable and fluctuate between 2,400 – 5,400 MT during a period of 2005 - 2015. For Sarawak- Landing was stable during 2003- 2015 (2,900 -1,600 MT). Labuan – The highest landing in 2008 was 2,200 MT.
- For kawakawa in Sabah and Labuan– Decreasing trend was found during a period between 2008- 2015 from 4,600 MT to 615 MT, and 400 MT to 64 MT, respectively. However in Sarawak, during the same period, catch was increased from 646 MT in 2009 to 2,200 MT in 2015 as shown in **Figure 21**.
- Figure 2.3.6 shows the trend of catch landing of LOT and KAW from different types of gears such as Trawl-net (**Figure 22**), Purse seine (**Figure 23**), Gillnet (**Figure 24**), and Handline (**Figure 25**)

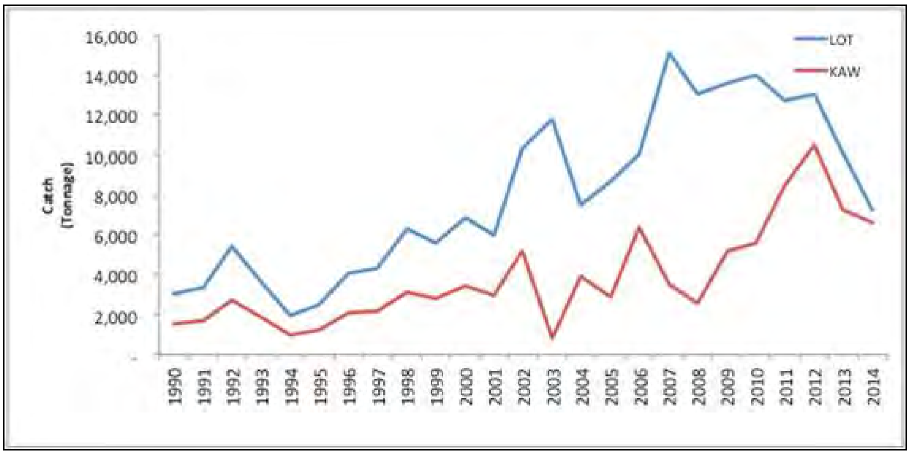


Figure 19
Total landings of LOT & KAW in Peninsular Malaysia

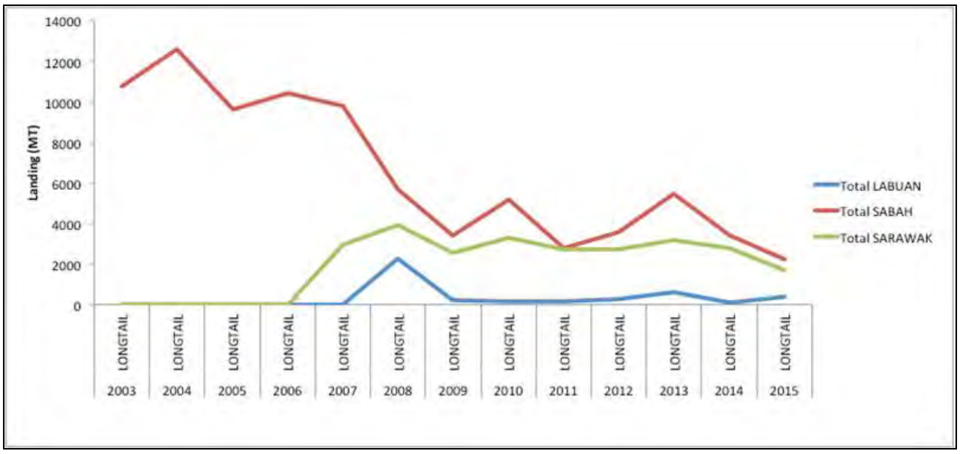


Figure 20
Landings of LOT in Sarawak, Sabah & Labuan

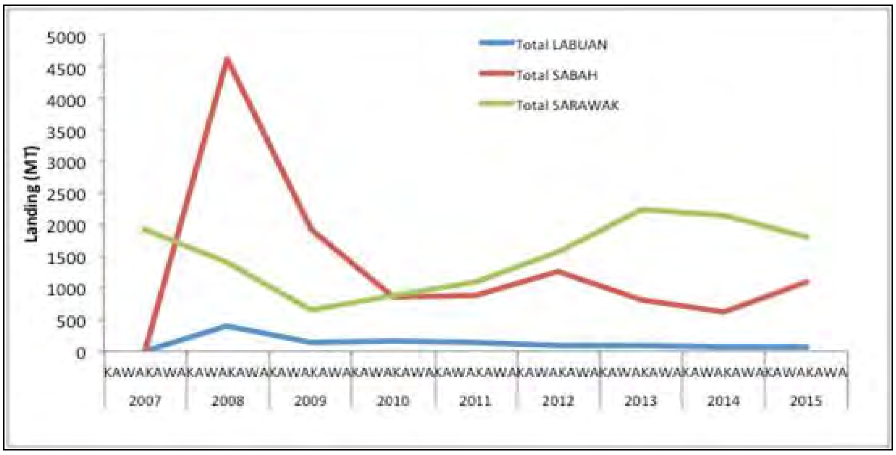


Figure 21
Total landings of KAW in Sarawak, Sabah & Labuan

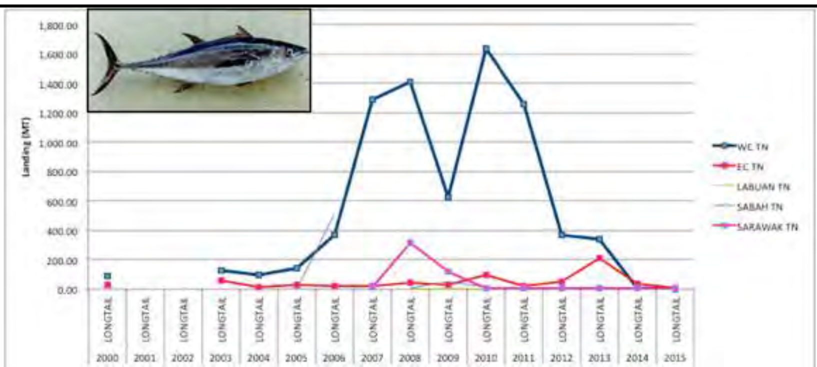
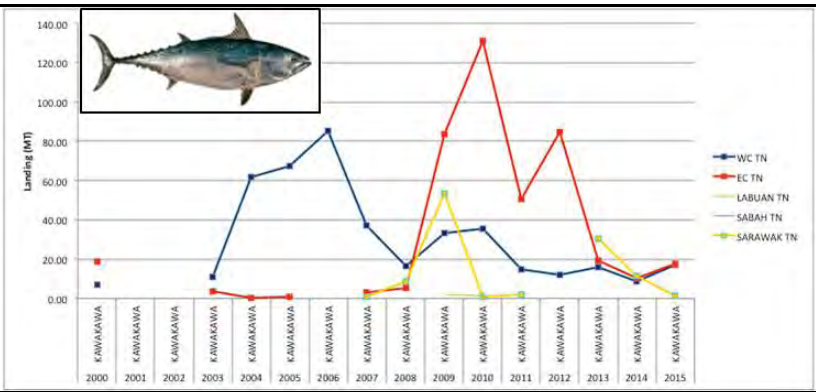
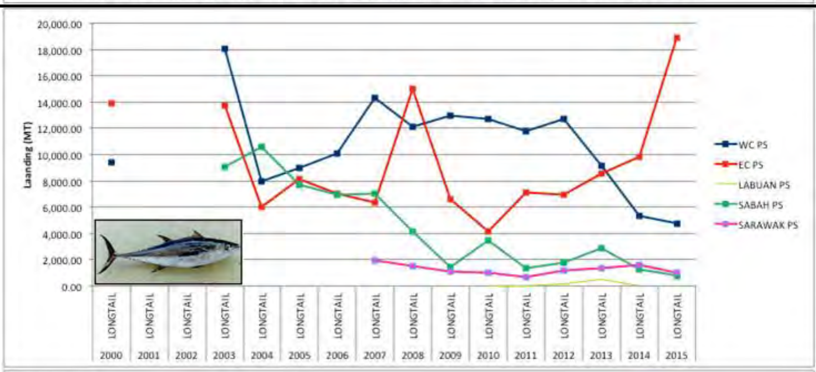


Figure 22
Trend of LOT and KAW from Trawlers





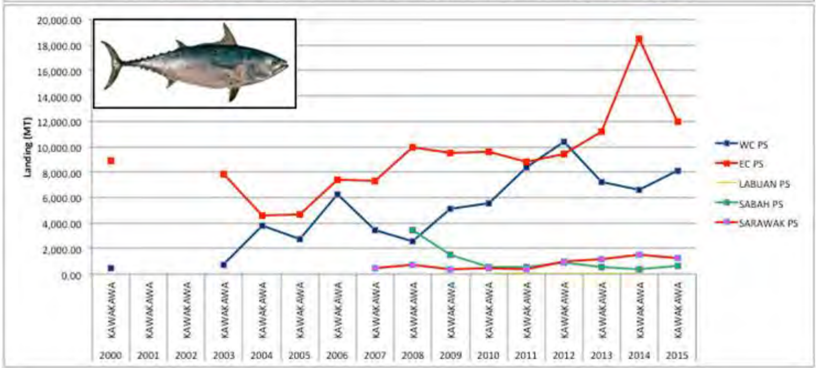


Figure 23
Trend of LOT and KAW from purse seiners

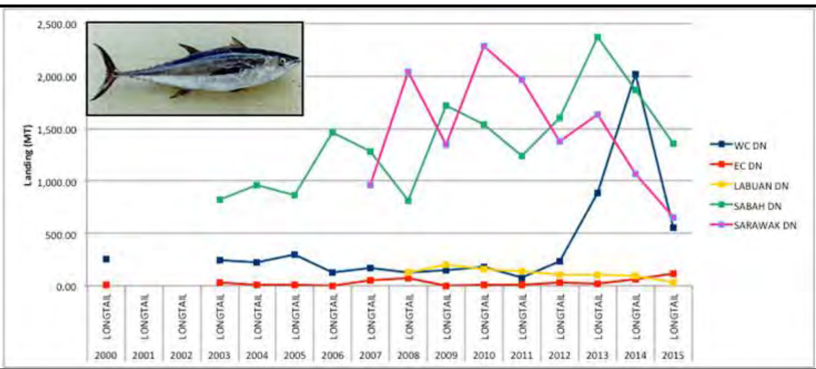


Figure 24
Trend of LOT and KAW from Drift net

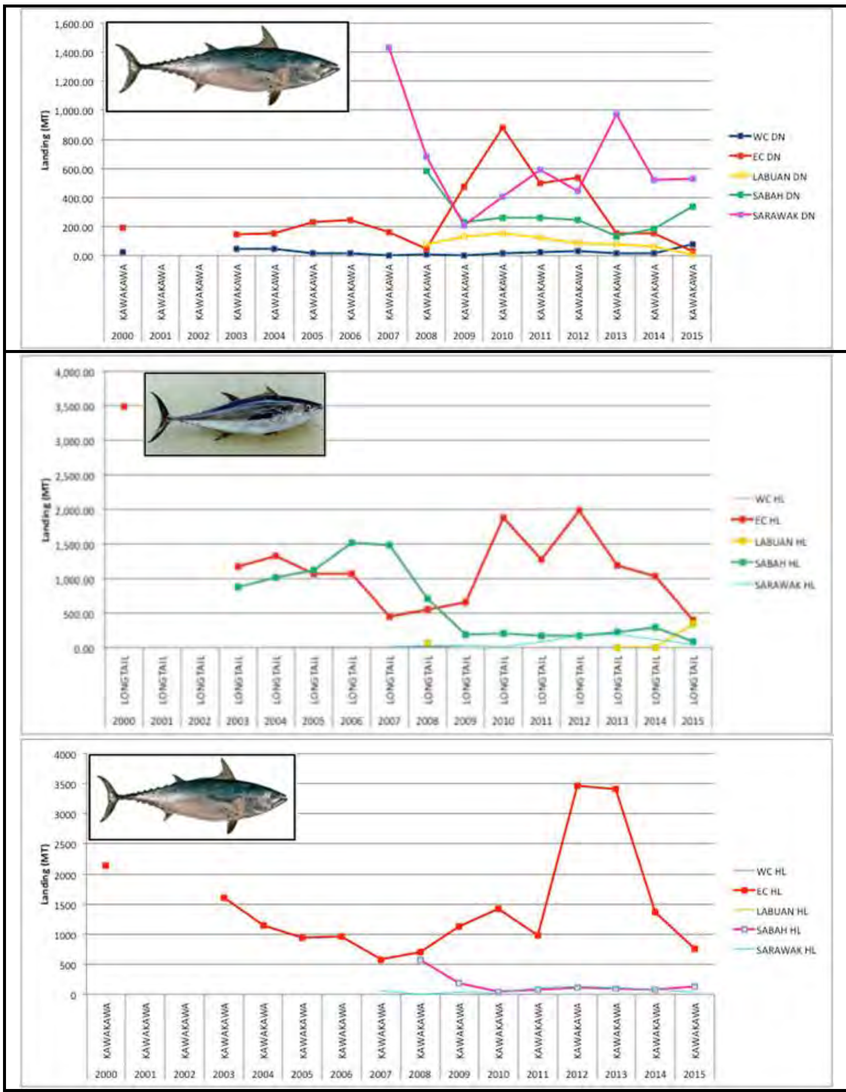


Figure 25
Trend of LOT and KAW from Handline

Utilization of neritic tunas

- The main emphasis of the National Agriculture Policy of Malaysia is to increase food production.
- At the same time, the importance of managing the fishery resources on a sustainable basis is fully recognized.
- In fisheries sector the policy focused on offshore fishing, aquaculture and downstream value-added activities.
- At present fish post harvest and fish processing industries are not adequate to meet the necessity.
- Sabah fisheries commodities of export and imports consist of live fish, live crab, fresh/ chilled and frozen fish, crabs and shrimp, fishmeal, fish fillets , and dried, salted or in brine fish products.
- Most of neritic tuna in Malaysia for domestic market or local consumption *e.g.* Nasi Dagang in ECPM

Conclusion

- The neritic tuna fishery is very much related to the purse seine fishing gears. There is a question of harvesting small pelagic fish including neritic tuna in the South China

Sea and Sulu & Celebes Sea, to what level of the fishing efforts that the present neritic tuna can sustain the exploitation rate.

- There should be a level of exploitation rate set the by the fisheries manager as to ensure that the present resources are exploited at a sustainable level and with a responsible manner.
- The shared stock need shared management among the bordering countries. To implement an effective shared stock management, it needs systematic cooperation and coordination between the ASEAN countries. With the ASEAN Member, SEAFDEC can play the role as a platform to coordinate and assist the Member Countries in research program, managing and streamline data collection format and conducting relevant capacity buildings
- For Malaysia, there is still room to improve the quality of catch and efforts data. With a good data quality, it will provide a good input for scientist to estimate the status of small pelagic fish stocks and at the end it will also assist the fisheries manager in planning and sustainable development of the purse seine fishery.

2.4 Philippines

Neritic tunas fisheries in the Philippines is prepared and presented by GRACE V. LOPEZ (National Fisheries Research & Development Institute, Quezon City) and SHERRYL V. MESA (Bureau of Fisheries and Aquatic Resources, Regional Office No. VI, Iloilo City, Philippines). The detailed information/presentation are summarized as follows:

- Fishery is a key component of the Philippine economy. In addition, a major producer of tuna since the 1970s. Fisheries are most important sector of the fishing industry in terms of volume and value, employment, and export revenues. The Philippine marine fisheries is conventionally subdivided into municipal (small-scale) and commercial fisheries (see **Figures 26**) on the basis of vessel gross tonnage.
    1) **Municipal Fisheries**: includes capture operations using boats less than 3 GT and under the jurisdiction of the Local Government Units (LGUs)
    2) **Commercial Fisheries**: includes capture fishing operations using vessels of 3 GT and above and they are required to fish outside municipal waters, beyond 15 km off the shoreline. In addition, the commercial fisheries required to secure commercial fishing vessel and gear license (CFVGL) at the Bureau of Fisheries and Aquatic Resources (BFAR) which is subject to renewal every three (3) years.

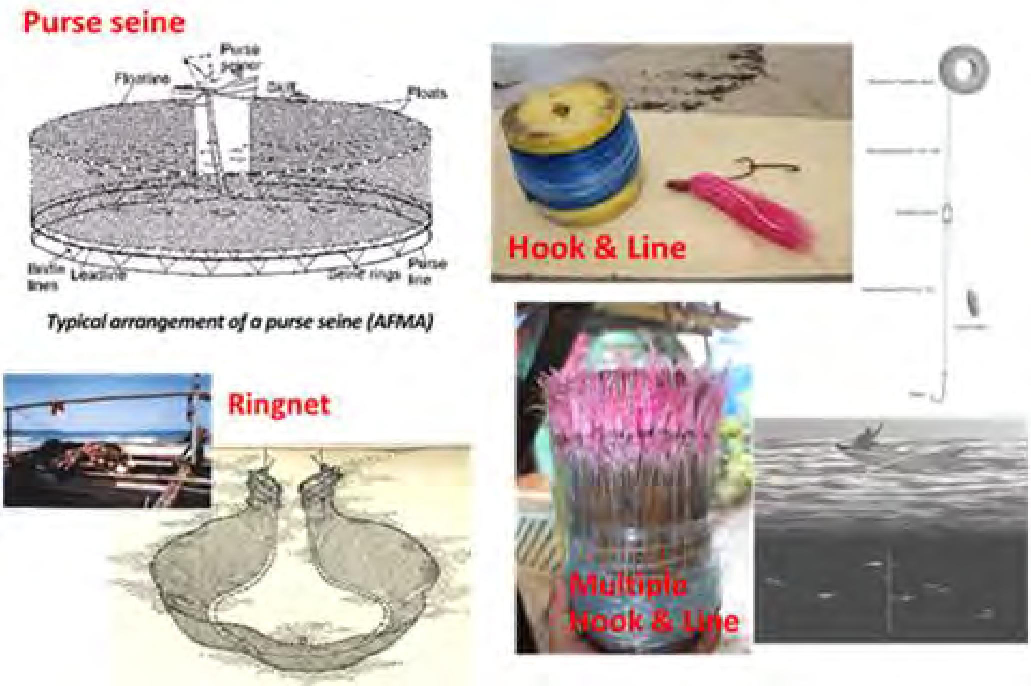
a)

b)

Figure 26

(a) Types of fishing boat operated in the municipal fisheries and (b) Commercial fisheries

- There are 21 species of tuna have been recorded in the Philippine waters but only six are caught in commercial quantity and form the basis of tuna fishing industry, namely oceanic tunas (YFT, SKJ, BET), and Neritic tunas (FRI, BLT, ELT). However, only five are listed in Philippine fisheries statistics
- **Figure 27** shows the common tuna fishing gears in the Philippines for both of municipal and commercial fisheries such as purse seine, ring net, hook and line, multiple hooks and line, etc. In addition, there are also many types of gears catching neritic tunas such as bagnet, gillnets, and fish corral.



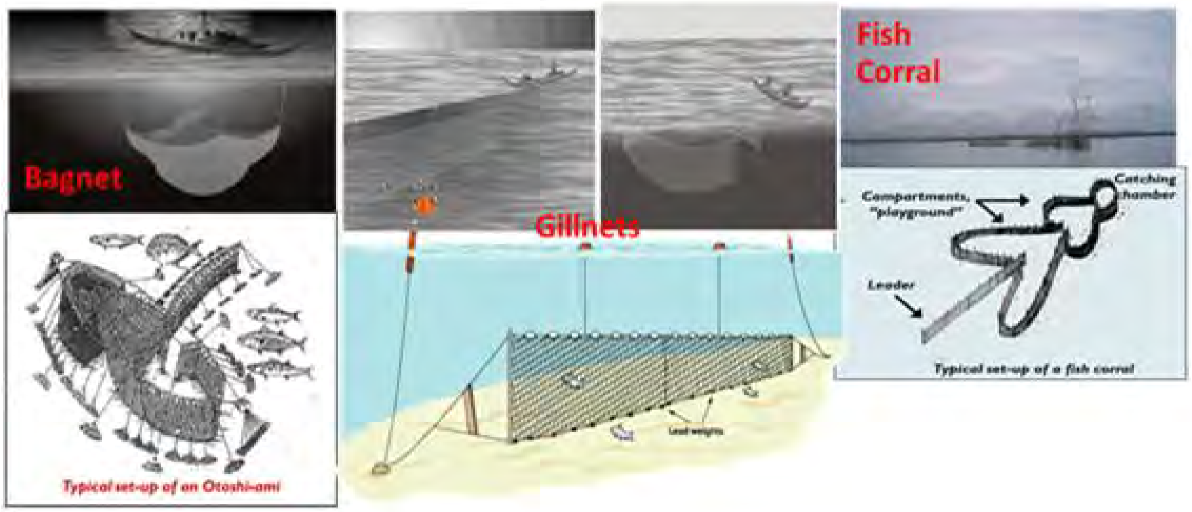


Figure 27
Types of fishing gears for neritic tuna fisheries

- Tuna data collection initiatives by the BFAR can be summarized as followed:

  1. National Stock Assessment Program (NSAP): BFAR/NFRDI initiated the implementation of the NSAP since 1997 as part of the government's efforts to improve the worsening situation of our fisheries resources and the fishing industry in general. NSAP already generated time-series data and have already established trends in catches in terms of catch by gear, catch composition, average sizes, etc.
  2. Philippine Observer Program: The POP where trained fisheries observers go on-board the fishing vessels (purse seine and ringnet), especially during the FAD closure period and in all fishing operations in Celebes Sea, Sulu Sea, South China Sea and the Eastern Pacific Seaboard.
  3. West Pacific East Asia Oceanic Fisheries Management Project (WPEA-OFMP): supports the port samplings for tuna in 2010 (focused Oceanic tuna).

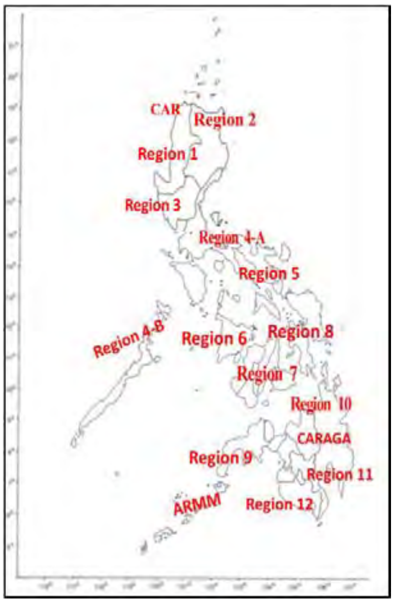


Figure 28
Location of the different Philippines Administrative regions

- NSAP conducts landed catch and effort monitoring in different fish landing sites throughout the Philippines (standard method by FAO) with more sites added under the proposed expansion of study areas. **Figure 29** show the coverage of NSAP.

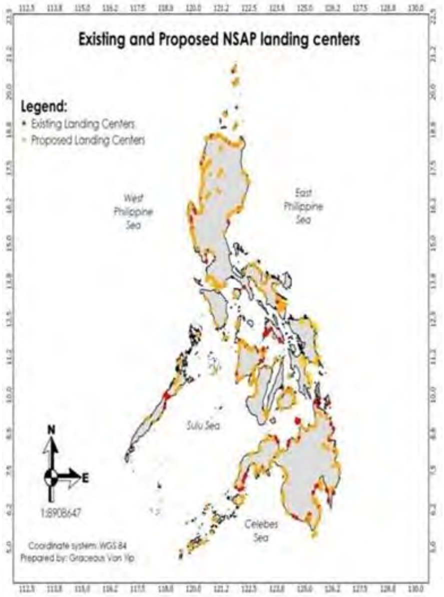


Figure 29

Show the coverage of NSAP.

Status of the Neritic Tunas in the Philippines:

- **Figure 30** shows the Annual catch (MT) of neritic tunas in NSAP -WPEA monitored fishing grounds in the Philippines, 2005-2013.

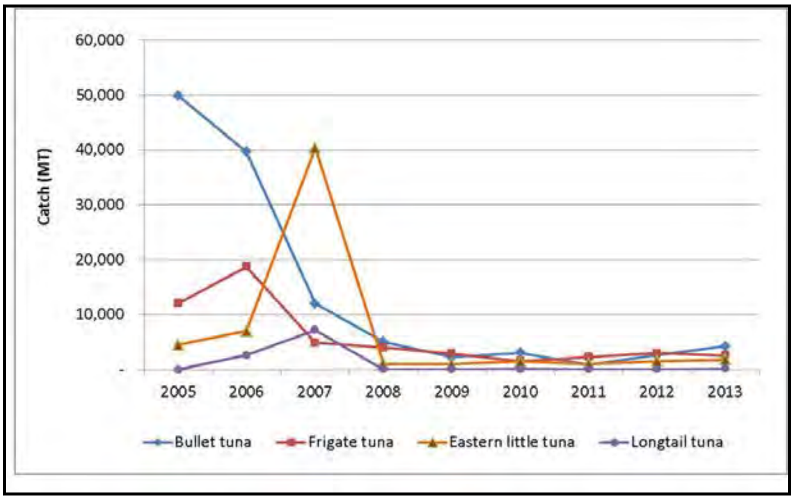


Figure 30

- The Annual catch of neritic tunas namely Bullet tuna, Frigate tuna and Kawakawa (or Eastern little tuna) in the Region VI from 2008 to 2013 are shown in **Table 3** and **Figure 31**.

Annual Catch of Neritic Tunas in Region VI (MT)

SPECIES	2008	2009	2010	2011	2012	2013
Auxis rochei rochei	200.19	293.23	379.47	72.96	460.02	786.10
Auxis thazard thazard	24.88	40.37	30.28	167.68	184.27	41.46
Euthynnus affinis	5.85	10.58	13.40	13.48	42.06	19.99
GRAND TOTAL	**230.92**	**344.18**	**423.15**	**254.12**	**686.35**	**847.55**

Table 3

Relative Abundance of Neritic Tunas in Region VI, 2008-2013

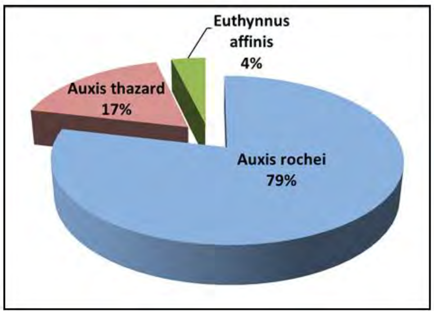


Figure 31

- For Kawakawa, the annual productions in the Philippines from 2005-2013 from both of municipal and commercial fisheries are shown in Table 4. From commercial fisheries the kawakawa was declined from 51,167 MT in 2005 to 22,178 MT in 2013, it was more than 50% reduction from commercial fisheries. The similar trends is also found in the municipal fisheries, where the catch was declined from 26,500 MT in 2005 to be 13,920 MT in 2013. Size ranges of the Kawakawa caught by different types of fishing gears in the Philippines waters from 1999 to 2014 are shown in Table 5.
- The distribution of Kawakawa by statistic fishing ground in the Philippines in 2014 based on the NSAP data is shown in **Figure 32**.

Table 4 Annual Production of Eastern Little Tuna in the Philippines by Region (MT), 2005-2013

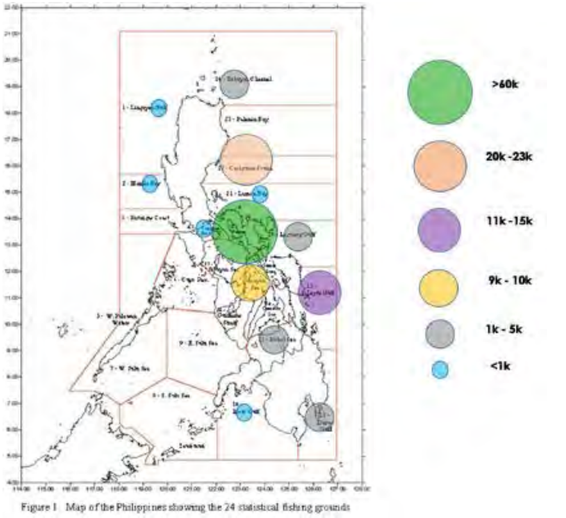
REGION	2005	2006	2007	2008	2009	2010	2011	2012	2013
NCR	144.68	93.12	182.93	35.92	49.60	42.36	67.84	134.60	585.32
I- ILOCOS REGION	48.80	67.14	99.13	86.91	51.22	31.32	5.56	7.29	16.91
II- CAGAYAN VALLEY	25.41	553.00	604.97	533.86	699.31	666.35	542.06	399.35	424.05
III- CENTRAL LUZON	242.21	146.69	182.46	83.48	28.83	281.96	162.57	45.35	181.71
IVA- CALABARZON	5.13	23.66	127.85	182.80	223.00	133.69	3.72	6.12	3.15
IVB- MIMAROPA	81.10	72.74	169.40	136.53	237.74	329.32	323.37	353.81	356.58
V- BICOL REGION	198.00	189.00	169.26	306.15	588.25	641.02	549.71	578.57	441.94
VI- WESTERN VISAYAS	7,234.58	7,662.77	6,742.96	465.41	1,685.04	1,554.51	697.03	403.29	376.68
VII- CENTRAL VISAYAS	637.10	880.84	1,887.63	1,865.88	1,572.85	1,254.85	880.69	825.60	703.00
VIII- EASTERN VISAYAS	721.01	839.98	941.21	999.86	900.07	708.92	673.36	799.80	549.75
IX- ZAMBOANGA PENINSULA	9,453.90	18,309.86	14,196.38	20,215.64	16,802.92	5,471.98	5,889.80	5,021.84	6,126.20
X- NORTHERN MINDANAO	6,376.47	5,459.21	3,726.12	3,022.18	2,358.62	1,742.62	1,358.37	1,387.48	1,028.22
XI- DAVAOREGION	92.86	237.88	382.37	471.19	177.77	220.14	132.15	236.26	175.29
XII- SOCCSKSARGEN	17,409.84	9,729.96	10,558.62	1,300.54	378.03	581.25	476.28	1,512.33	1,087.24
CARAGA	6.73	56.91	20.82	18.97	27.77	28.01	190.62	102.10	75.55
ARMM	8,489.48	8,117.30	7,731.81	8,693.07	8,853.48	9,414.53	9,541.49	9,836.49	10,047.30
TOTAL	51,167.30	52,440.06	47,723.92	38,418.39	34,634.50	23,102.83	21,494.62	21,650.28	22,178.89

REGION	2005	2006	2007	2008	2009	2010	2011	2012	2013
NCR	-	-	-	-	-	-	0.28		0.60
I- ILOCOS REGION	92.47	94.38	146.78	91.37	225.45	85.26	414.08	186.73	90.44
II- CAGAYAN VALLEY	15.34	17.65	28.77	110.44	484.99	581.47	502.43	519.82	528.24
III- CENTRAL LUZON	74.54	77.65	119.08	264.01	93.79	187.42	119.99	97.39	98.99
IVA- CALABARZON	16.45	0.14	80.57	167.88	63.41	0.92	0.65	-	2.09
IVB- MIMAROPA	5,029.91	7,453.24	6,587.31	5,733.34	3,827.37	3,358.55	4,237.27	3,536.12	2,464.23
V- BICOL REGION	753.60	453.00	430.43	436.26	999.09	1,023.10	955.26	1,157.96	1,391.98
VI- WESTERN VISAYAS	4,399.64	3,956.90	5,953.82	679.11	1,859.95	1,793.90	1,781.71	919.77	1,485.59
VII- CENTRAL VISAYAS	2,483.85	548.06	605.77	791.07	704.20	560.85	523.97	451.86	434.40
VIII- EASTERN VISAYAS	790.81	1,059.75	921.53	1,234.40	1,220.45	1,126.19	969.91	959.75	757.52
IX- ZAMBOANGA PENINSULA	8,217.55	7,020.86	5,665.71	3,010.54	2,510.53	2,468.03	1,574.13	2,923.37	3,201.12
X- NORTHERN MINDANAO	733.55	763.25	877.35	844.53	607.67	611.07	588.04	379.51	308.64
XI- DAVAOREGION	249.66	96.77	259.69	327.49	310.66	393.14	287.15	111.99	138.97
XII- SOCCSKSARGEN	1,635.17	2,061.58	1,465.22	343.96	103.12	164.17	229.50	145.72	187.33
CARAGA	863.63	915.53	415.75	272.07	244.48	324.99	323.67	223.17	227.51
ARMM	1,150.56	1,418.45	1,811.84	2,182.57	2,083.35	2,455.07	2,400.26	2,543.28	2,603.99
TOTAL	26,506.73	25,937.21	25,369.62	16,489.04	15,338.51	15,134.13	14,908.30	14,156.44	13,921.64

Table 5 Size ranges of *Euthynnus affinis* caught by gear in the Philippines (1999-2014)

Fishing Gear		Size Ranges (cm)
Bagnet	BN	9.0-52.0
Beach seine	BS	24.0-35.0
Danish seine	DS	23.5-50.4
Fish corral	FC	25.0-69.5
Bttom gillnet	BGN	26.0-49.0
Drift gillnet	DGN	16.0-67.3
Encircling gillnet	EGN	16.7-25.0
Gillnet	GN	20.0-78.0
Surface gillnet	SGN	16.3-70.0
Hook & Line	H&L	16.1-56.7
Handline	HL	10.0-68.0
Longline	LL	23.4-64.5
Multiple hook & line	MH&L	12.0-57.0
Multiple handline	MHL	10.6-59.0
Multiple troll line	MTL	15.3-63.5
Single hook & line	SH&L	21.0-59.5
Single handline	SHL	22.0-60.0
Troll line	TL	13.8-81.3
Purse seine	PS	8.0-49.0
Ringnet	RN	9.0-66.0
Trammel net	TN	44.0-55.0

Figure 32 Abundance Distribution of Kawakawa by Statistical Fishing Grounds, 2014



For Longtail tuna, Table 6 shows the size range of *Thunnus tonggol* caught by different types of gears during 2008-2014. Their distribution based on the statistical fishing grounds in 2014 is also shown in **Figure 33**.

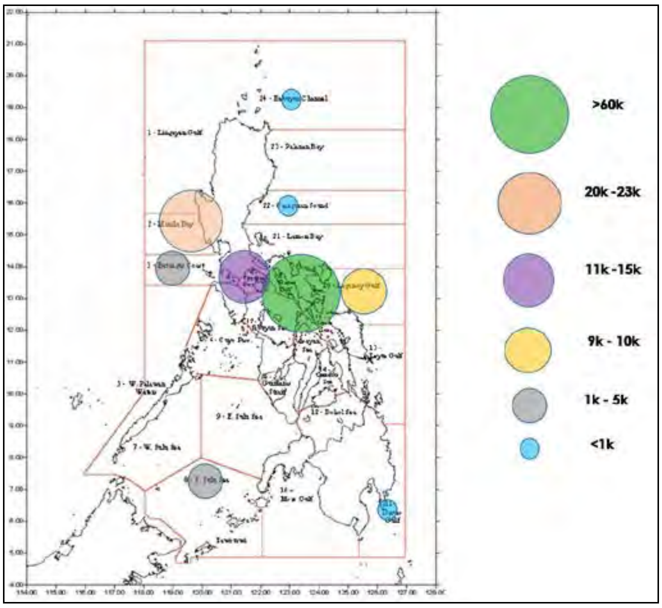


Figure 33
Abundance Distribution of Tonggol tuna by Statistical Fishing Grounds, 2014

Fishing Gear		Size Ranges (cm)
Drift gillnet	DGN	25.0-72.0
Surface gillnet	SGN	20.3-25.4
Hook & Line	H&L	30.0-111.0
Handline	HL	16.0-46.0
Multiple Hook & Line	MH&L	17.4-98.0
Multiple handline	MHL	12.0-50.0
Single Hook & Line	SH&L	23.1-190.0
Single Handline	SHL	57.8-178.7
Troll Line	TL	22.1-91.0
Purse seine	PS	31.0-41.0
Ringnet	RN	18.0-64.5

Table 6 Size ranges of *Thunnus tonggol* caught by gear in the Philippines (1999-2014)

Distribution and Market of Tuna Catches

- Catch from commercial fisheries such as purse seine and ringnet, mostly delivered to canneries.
    - Yellowfin and bigeye tunas - target the export market, while Skipjack - goes to the canneries
    - Neritic tunas *i.e.* eastern little tuna/kawakawa - consumed locally.
- Catch from municipal fisheries, mostly landed as wet fish in different landing sites of the country.
    - Some are processed by drying, salting, smoking etc. and
    - Some would enter large scale commercial processing.

2.5 Thailand

Status of Neritic Tunas and Fisheries in Thailand was reported by *Ms. Praulai Nootmorn* and *Mr. Chalit Sa-nga ngam* from Department of Fisheries Thailand.

Introduction:

- Marine fisheries play a very important role for the economy in Thailand. Neritic tuna fisheries is one of the There are three main neritic tuna species, *i.e.* longtail tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*), and frigate tuna (*Auxis thazard*).
- Neritic tunas become the main target species because the attractive prices offered by tuna canneries. However, it was reported that the Neritic tunas in Thai waters were overexploited.
- Three main fishing gears are common used to catch neritic tunas (see **Figure 34**)as follows:
    1) Thai Purse Seine (TPS)
    2) Luring Purse Seine (LPS)
    3) Luring Purse Seine with FADs
    4) Tuna Purse Seine (TUN)

1)

2)

3)

4)

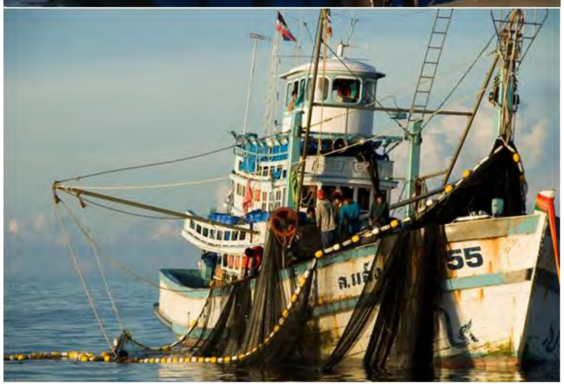


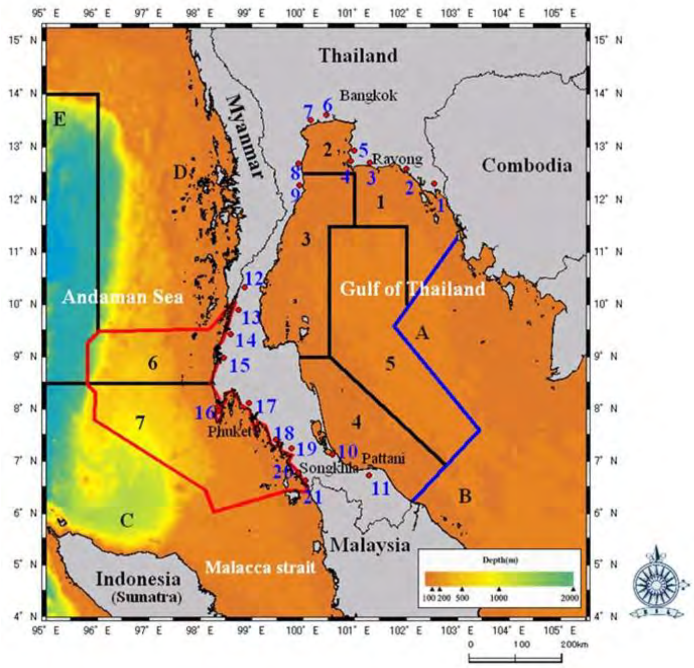
Figure 34

Types of common fishing gears (purse seine net) for catching neritic tunas in Thailand

- In general, size of fishing boat (Thai purse seiner) mostly are ranged from 18-25 m (LOA), the engine of 200-300Hp with Nylon net of 500-1,200 m (long) and

50-150 m (depth). Mesh size 25 mm and number of crews are 25-40 persons. But tuna purse seine for neritic tunas mostly are more than 44 m (LOA) with the larger engine of 400-500Hp, the Nylon net of 1,200 - 1,600 m in length and 120-150 m in depth. TUN normal uses mesh size of 94 mm and number of crew operation is about 35-45 persons.

- Department of Fisheries categorized the fishing zones into two main areas: 1) Gulf of Thailand where consists of 7 sub-areas and 2) the Andaman Sea where consist of 4 sub-areas as shown in **Figures 35** Important landing sites located on the map are the important landing.



The Gulf of Thailand	The Andaman Sea
1. Laem Ngop, Trat	12. Muang, Ranong
2. Thamai, Chanthaburi	13. Kuraburi, Phang-nga
3. Muang, Rayong	14. Takuapa, Phang-nga
4. Sattahip ,Chonburi	15. Taimuang, Phang-nga
5. Sriracha, Chonburi	16. Muang, Phuket
6. Pak Nam, Samutprakan	17. Muang, Krabi
7. Muang, Samutsakhon	18. Kantang, Trang
8. Cha-Um, Phetchaburi	19. Palian, Trang
9. Pranburi, Prachuap Khiri Khan	20. La-ngu, Satun
10. Muang, Songkhla	21. Muang, Satun
11. Muang, Pattani	

Figure 35
Map of fishing ground/areas and main landing sites in the Gulf of Thailand and Andaman Sea

Status and Trends of Neritic Tunas Fisheries:

- Three main species of neritic tuna namely tonggol tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*) found within the EEZ of Thai waters. Especially tonggol tuna abundantly found in deeper water for example their distribution at deeper than 20m during in Jan. - Mar. in the Gulf of Thailand. In addition, tonggol tunas are found in deeper than 40 m. during Nov. to May. in the Andaman Sea. The number of purse seiners registered during 2006 to 2010 shown that the number were increasing from 1,164 vessels in 2006 to be 1,371 (**Table 7**).

Place/Year	2006	2007	2008	2009	2010
The Gulf of Thailand	537	548	501	210	531
The Andaman Sea	627	642	681	696	840
Total	1,164	1,190	1,182	1,206	1,371

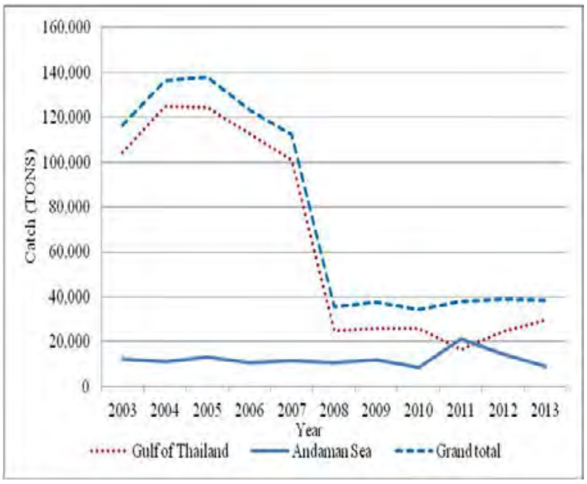
Table 7 The number of purse seines registered during 2006-2010

Table 8 Total catch (tons) of neritic tuna in the Gulf of Thailand and the Andaman Sea, 2000-2011

Year	Species	The Gulf of Thailand	The Andaman Sea	Total
2000	Longtail tuna	53,407	4,838	58,245
	Kawakawa&Frigate	46,054	7,374	53,428
2001	Longtail tuna	55,533	1,726	57,259
	Kawakawa&Frigate	38,400	7,250	45,650
2002	Longtail tuna	59,052	3,536	62,588
	Kawakawa&Frigate	45,691	5,798	51,489
2003	Longtail tuna	68,147	3,916	72,063
	Kawakawa&Frigate	36,616	8,249	44,865
2004	Longtail tuna	78,657	2,874	81,531
	Kawakawa&Frigate	46,631	8,256	54,887
2005	Longtail tuna	79,095	1,819	80,914
	Kawakawa&Frigate	46,647	11,357	58,004
2006	Longtail tuna	71,213	2,056	73,269
	Kawakawa&Frigate	42,073	8,385	50,458
2007	Longtail tuna	62,072	4,974	67,046
	Kawakawa&Frigate	39,076	6,524	45,600
2008	Longtail tuna	10,500	3,623	14,123
	Kawakawa&Frigate	15,132	7,088	22,220
2009	Longtail tuna	12,309	4,548	16,587
	Kawakawa&Frigate	14,128	7,313	21,441
2010	Longtail tuna	11,806	2,161	13,967
	Kawakawa&Frigate	14,828	6,257	21,085

Figure 36 Trends of neritic tuna in the Gulf of Thailand and the Andaman Sea, 2003-2013

**noting that the drastically drop of production since 2008 was due to exclusion of the imported neritic tunas in the national statistic*



- A total production/catches of neritic tunas in different fishing areas in the Gulf of Thailand and Andaman sea are shown in **Table 8** as well as in the **Figure 36**.
- Refers to the study of neritic tunas made in 2012 found that the distribution of the tonggol tuna and its CPUEs in the Gulf of Thailand is shown in **Figure37** Based on the survey found that good fishing areas are in the coastal and offshore areas of Sonkhla and Pattani provinces near by the border of Thai-Malaysian transboundary areas.

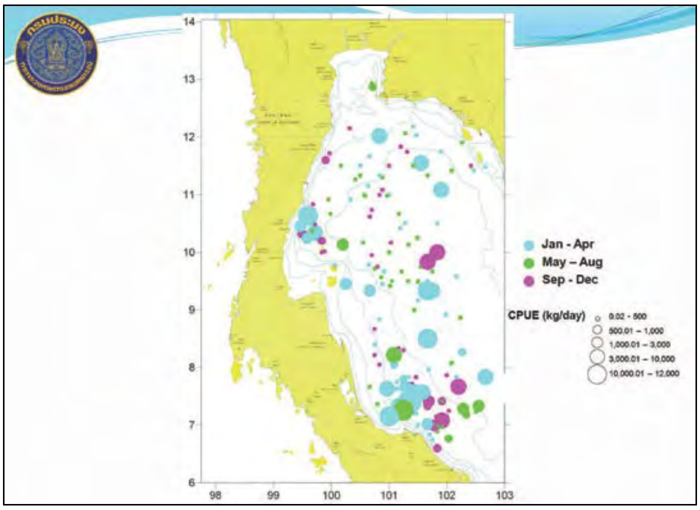


Figure 37
CPUE (kg/day) of longtail tuna from purse seines in the Gulf of Thailand (2012)

- Catch composition between kawakawa and toggol tunas landed in Thailand is shown in **Figure 38**. It was very clear that almost 60% of tonggol tunas are landed before 2008, after 2008 it is about 20% of tonggol are disappeared from the statistic, remaining about 40% of a total catch of two species when compared with kawakawa.
- **Figure 39** shows total catch of the tonggol (longtail) tunas landed in Thailand (a), catch of longtail tuna by gears in the GOT (b), and the Andaman sea (c). Figures show the large quantity of tonggol tunas are from the gulf of Thailand rather than from the Andaman Sea. However, taking into consideration the drastically drop of productions in 2008 due to many reasons which are related to the record that excluding in national fisheries statistic of imported fishes from neighboring countries such as Indonesia, Malaysia, etc. The figure also shows important fishing gears for catching the toggol tunas particularly purse seine rather than king mackerel gillnet.

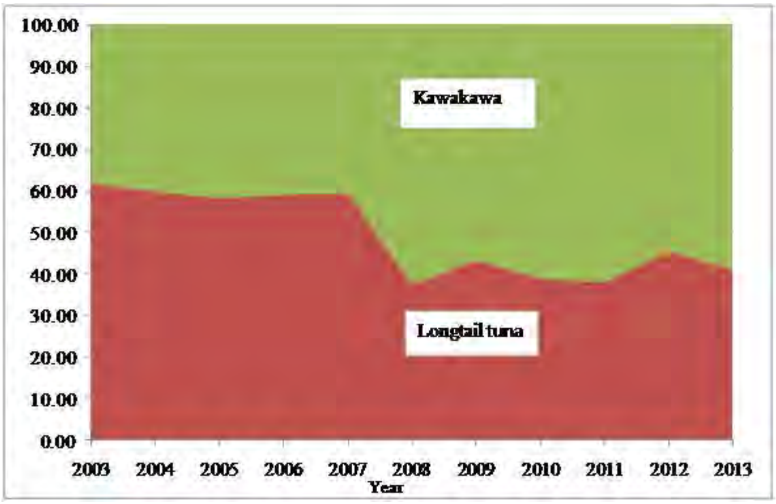


Figure 38
Catch composition between longtail tuna and kawakawa landed in Thailand.

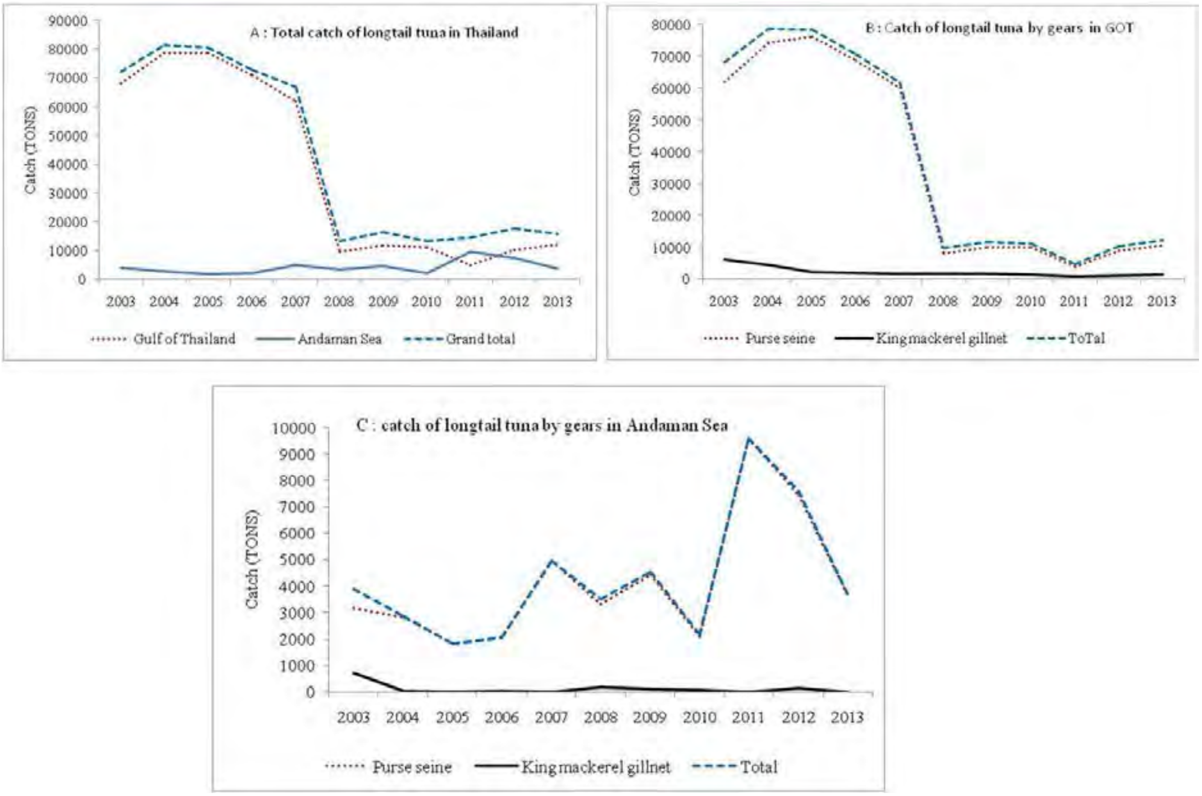


Figure 39
Total catch of the tonggol (longtail) tunas landed in Thailand (a), catch of longtail tuna by gears in the GOT (b), and the Andaman sea (c).

Resources Management Measures

None of fishery law or regulations specially governing neritic tuna fisheries. A number of legislation essentially enforced by six Marine Fisheries Management Centers as follows:

- Notification of the Ministry of Agriculture and Cooperatives Re: Prohibition of certain kinds of fishing appliances in spawning and breeding seasons in some localities of Prachuap Khiri Khan, Chumphon and Surat Thani Provinces, given on 24 January B.E. 2550 (2007);
- Notification of the Ministry of Agriculture and Cooperatives Re: Prohibition of certain kinds of fishing appliance in spawning and breeding seasons in some localities of Phuket, Phang-nga, Krabi and Trang Provinces during specified period, given on 24 October B.E. 2551(2008);
- Notification of the Ministry of Agriculture and Cooperatives Re: Prohibition of surrounding nets having meshes of smaller than 2.5cm in width in fishing at night, given on 14 November B.E. 2534(1991).
- Thailand has “the Marine Fisheries Management Plan of Thailand (FMP)” in October 2015. FMP 2015-2019 outlines the nature of the management as follows:
  1. FMP required to transform an open-access fishery into a limited-access fishery based on balancing the fishing effort with the productivity of the resources (MSY).
  2. FMP closely linked to the National Plan of Action to NPOA-IUU
  3. FMP will implement the e-logbook, e- licencing and Port State Measure (PSM) in 2016 and catch quota of longtail tuna in 2018

4. FMP covers the work on the VMS system on all fishing vessels (> 30 gross ton) in 2015 and observe programme in 2015 (Department of Fisheries, 2015).

- Thailand ratified the United Nations Fish Stocks Agreement (UNFSA) and agreed on Port State Measures (PSM) in 2016 (Department of Fisheries, 2015).

National Technical Study on Neritic Tunas Resources in Thailand

- Research Project 1: Reproductive Biology of the Eastern Little Tuna, Frigate Tuna and Longtail Tuna in the Gulf of Thailand.
- Research Project 2: Reproductive Biology of the Eastern Little Tuna, Frigate Tuna and Longtail Tuna in the Andaman Sea Coast of Thailand.
- Research Project 3: The Status of Neritic Tuna Resources and Fisheries in the Gulf of Thailand.
- Research Project 4: The Status of Neritic Tuna Resources and Fisheries in the Andaman Sea Coast of Thailand.

2.6 Viet Nam

The status of neritic tuna fisheries in the Viet Nam waters was prepared and present by *Mr. Pham Quoc Huy* from the Research Institute for Marine Fisheries (RIMF) and *Ms. Nguyen Thi Hong Nhung* from the Sciences Technology and International Cooperation Department.

Introduction:

- Viet Nam has a long coastline of 3,260 km. and a large Exclusive Economic Zone (EEZ) of more than 1 million km^2. Fisheries sector contributed about 3.0% GDP and provide of 40% animal protein consumption;
- The marine waters are divided into 4 management areas, including: Tonkin Gulf, Central, Southeast and Southwest coverage the 28 coastal provinces;
- Main fishing gears: Gillnet (35.7%), Trawl (17.3%), Purse seine (4.8%), Hooks and Line (17.3%), others (24.9%), small scale, multispecies;
- Most of the oceanic tuna fisheries are located in the central of Viet Nam such as Binh Dinh, Phu Yen, Khanh Hoa. But for neritic tuna fiseries, the fishing grounds are located from North to the South.
- Five neritic tunas are found in Viet Nam namely Frigate tuna (*Auxis thazard*), Bullet tuna (*Auxis rochei*), Kawakawa (*Euthynnus affinis*), Stripped bonito (*Sarda orientalis*), and Long tail tuna - (*Thunnus tongol*).
- **Figure 40** shows the type of fishing gears and fishing efforts in Viet Nam. From a total number of commercial fishing vessels of 117,631 vessels, 36% is represented by gillnet fishing boat following by other types, Trawl, Longline/handline, purse seine, and falling net of about 25%, 17%, 17%, 5% and less than 1%, respectively. The main fishing gears for harvesting neritic tunas are purse seine and gill net in which many types of gears based on size of fishing vessels (**Figure 41**).
- Purse seine fisheries are categorized into two namely:
  1. Luring Purse Seine: such as Anchovy purse seine, small pelagic fishes purse seine.

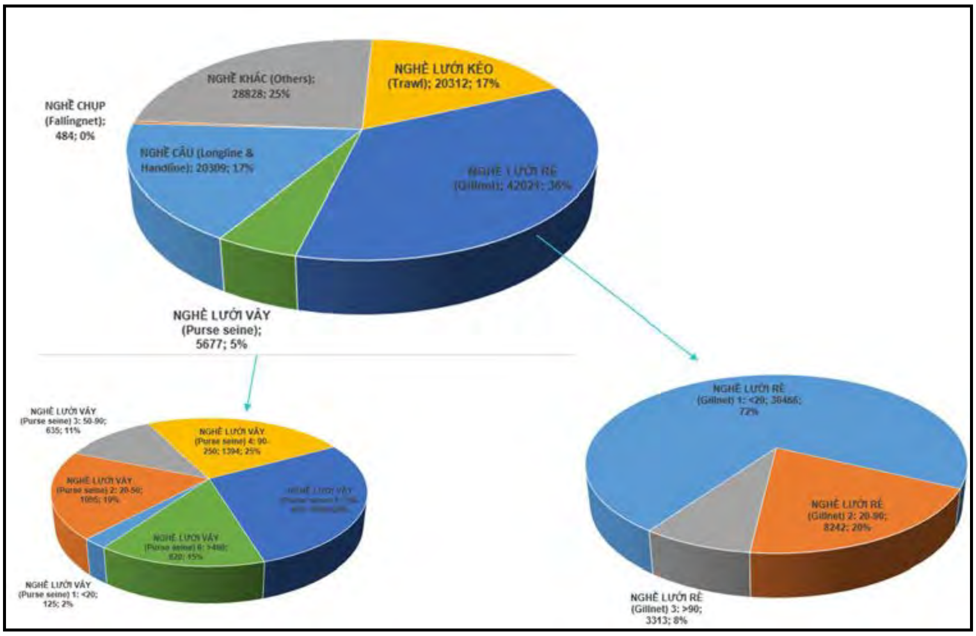


Figure 40

Type of fishing gears and fishing efforts in Viet Nam

Figure 41

Purse seine and Drift gillnet for small-pelagic species and neritic tuna operated in the Viet Nam

2. Searching Purse Seine: such as small pelagic fish purse seine and tuna purse seine.

- Drift Gill-net fisheries targeting for small pelagic species in coastal areas but for tuna and large oceanic tuna in the offshore areas.

Fishing Ground of Neritic Tunas

- **Figure 42** shows the fishing ground of neritic tunas during the southwest and northeast monsoon seasons. It is clearly shown that during the southwest monsoon neritic tuna fisheries could be operated in all coastal areas from the south to the north. But during the Northeast monsoon season most of fishing activities are conducted in the northern area when compare to the south.

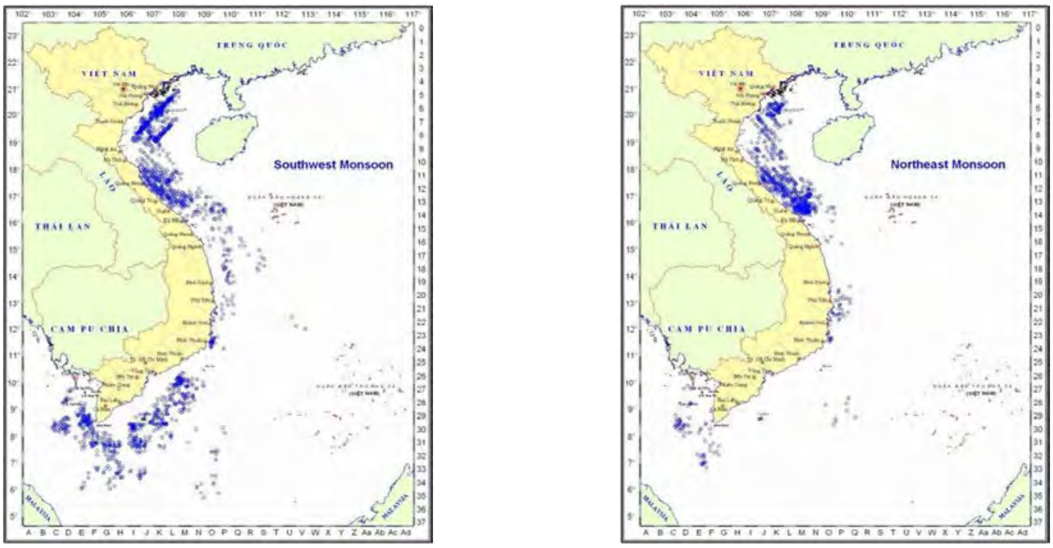


Figure 42
Fishing ground of neritic tunas during the southwest and northeast monsoon seasons

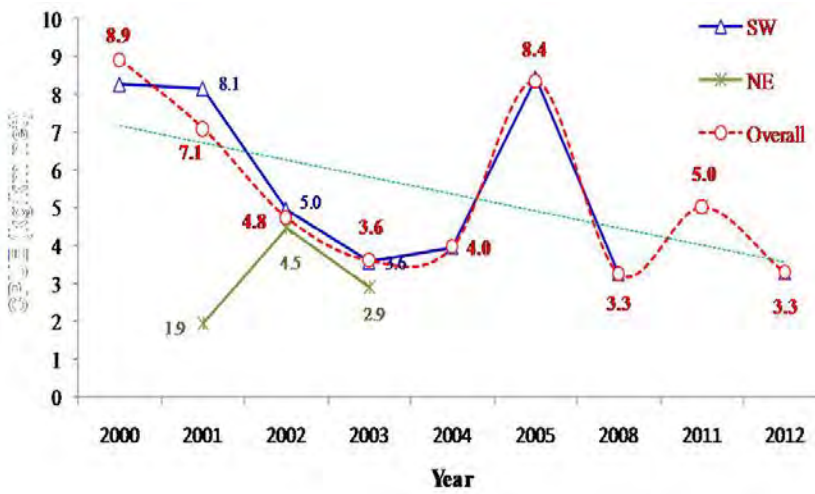
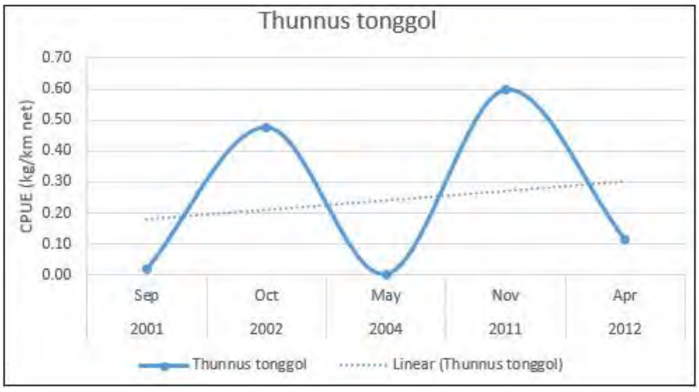


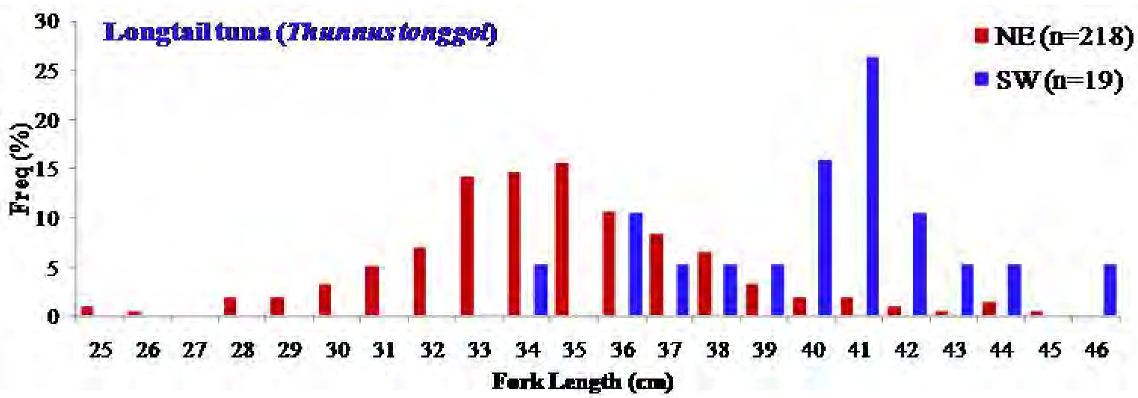
Figure 43
Average CPUE of the group of neritic tunas during the southwest and northeast Monsoons

- The average CPUE of the group of neritic tunas regardless of sampled gears varied from 3.3 to 8.4 kg/km, mean value of 5.5 kg/km in the southwest monsoon. Similarly, it varied from 1.9 to 5.0 kg/km, average of 3.6 kg/km in the northeast monsoon as shown in **Figure 43**.
- The CPUEs and length frequency of tonggol tuna (a) and kawakawa (b) during different monsoon seasons are shown in Figure 2.6.6. For Kawakawa, the CPUEs

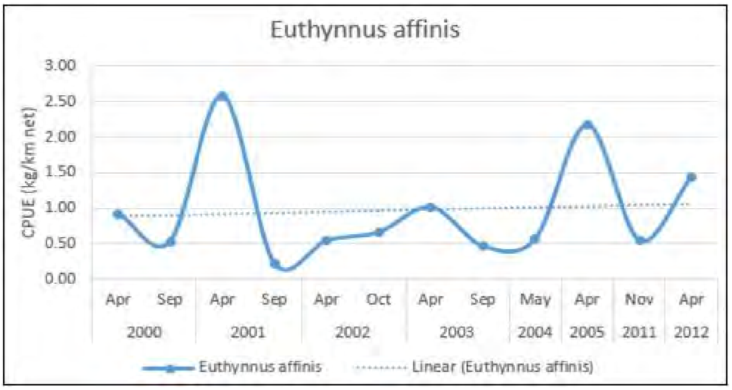
for drift gillnet were mostly ranged between 0.5 to 1 kg/km net during 2000 - 2005. However, the CPUEs were peak in April 2001 and in 2005 which was about 2.3-2.5 kg/km net. Comparison with the toggol tuna, the CPUEs was quite low which were less than 0.6 kg/km net. The size in total length of kawakawa was ranged from 17 to 59 cm while the tonggol was in the ranged from 25 to 46 cm. The size of both kawakawa and tonggol tuna are larger during the southwest monsoon season when compared to the northeast monsoon (**Figure 44**).



a)



b)



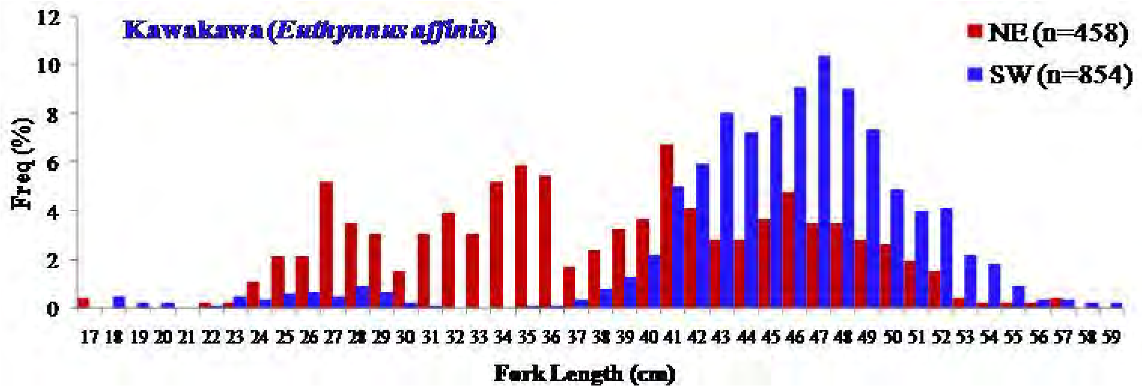


Figure 44
CPUEs and length frequency of (a) tonggol tuna and (b) kawakawa during southwest and northeast monsoon seasons

Fisheries Management Measures and Issues:

- Lack of specific legal framework for tuna fisheries management;
- Weak and poor essential resources, minor role/power and involvement of FAs;
- VMS, under MOVIMAR project, 3,000 units of offshore fishing vessels installed VMS, not all fishers comply and willingly to use;
- Poor handling practices and high proportion of post harvest lost;
- Poor infrastructure for fishery;
- Middlemen play an important role and take the most benefit while fishermen normally fishing with loss or marginal benefit;
- Weak enforcement of current regulations;
- Overfishing capacity;
- Mostly, fisheries resources are being overfished;
- Logbook applied but poor coverage and unreliable information received;
- Port sampling (ALMRV, 1996 to 2005), un-continuous after project ended;
- On boat observers not implemented as routine works;
- Database is not updated;
- "Top down" approach in data collection;
- Stock assessments with high variation and uncertainty

Needs and Way Forward

- Need to collect data, gather information as routine tasks;
- Promote port sampling and biological sampling for better fish stock assessments and monitoring purposes;
- Strengthening the collaboration between countries in stock assessment, data collection and experiences shared in relevant areas;
- Pilot study for data collection, stock assessment for neritic tunas should be implemented;
- Annual meeting on tuna fisheries management should be alternatively organized in Member Countries;
- A network of neritic tuna fishery managers in the region should be established.

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SESSION III

REVIEW OF BIOLOGY AND ECOLOGY OF LOT TUNA AND KAW

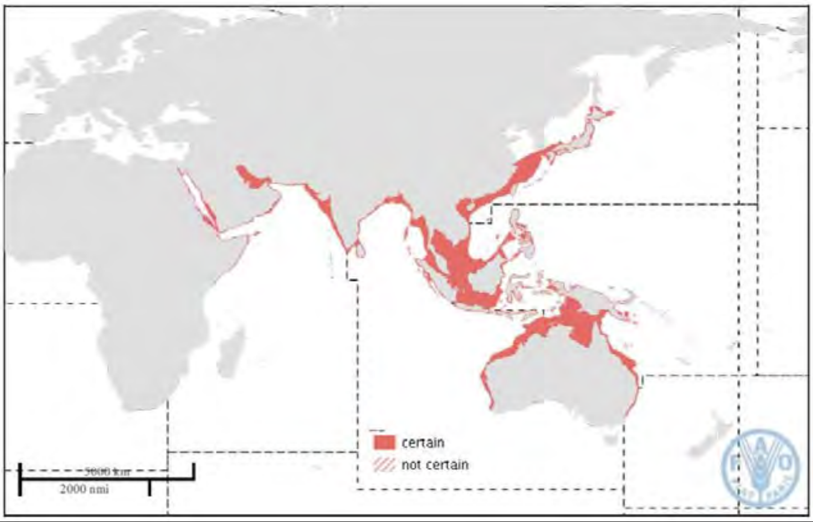
By *Dr. Osamu Abe*

1. Longtail Tuna, *Thunnus tonggol* (Bleeker, 1851)

a. Diagnostic Features

- A small tuna species. In the Indian Ocean; Commercial size is FL 40~70 cm (Silas & Pillai, 1982). Biggest record is 35.9 kg, 136 cm FL in New South Wales, Australia, 1982.
- Body is covered with very small scales behind corselet;
- Pectoral fins are short to moderately long; 22~31% FL (< 60 cm FL), 16~22% FL in larger individuals;
- Fin rays 30 to 36; 2nd dorsal fin higher than 1st dorsal fin;
- 2nd dorsal and anal fins never greatly elongate, < 20% FL;
- No black spots on body; back dark blue without any striped pattern;
- Lower sides and belly; silvery white with colorless elongate oval spots arranged in horizontally oriented rows;
- Dorsal, Pectoral and Pelvic fins; Blackish;
- Caudal fin blackish, with streaks of yellowish green;
- Tip of 2nd Dorsal and Anal fins; Washed with yellow;
- Anal fin silvery;
- Finlet; Yellow with greyish margins;
- Gillrakers; comparably few, 19~27 on first arch;
- Vertebrae; 18 + 21 = 39;
- Liver; ventral surface not striated, right lobe >> left/central lobes;
- Swimbladder; absent or rudimentary;
- Two important key to identify Longtail tuna from other tuna species;
- Number of gillrakers;
  - >31; northern and southern Bluefin tuna
  - 26~34; yellowfin tuna
  - 23~31; albacore, bigeye tuna
  - 19~28 (mostly <25); longtail tuna
- Shape of liver
- Ventral surface of liver with prominent striations, Center lobe > Left/Right lobes; northern and southern bluefin tuna, albacore, bigeye tuna
- Ventral surface of liver without striations, Right lobe > Central/Left lobes; yellowfin tuna, longtail Tuna, blackfin Tuna

b. Distribution



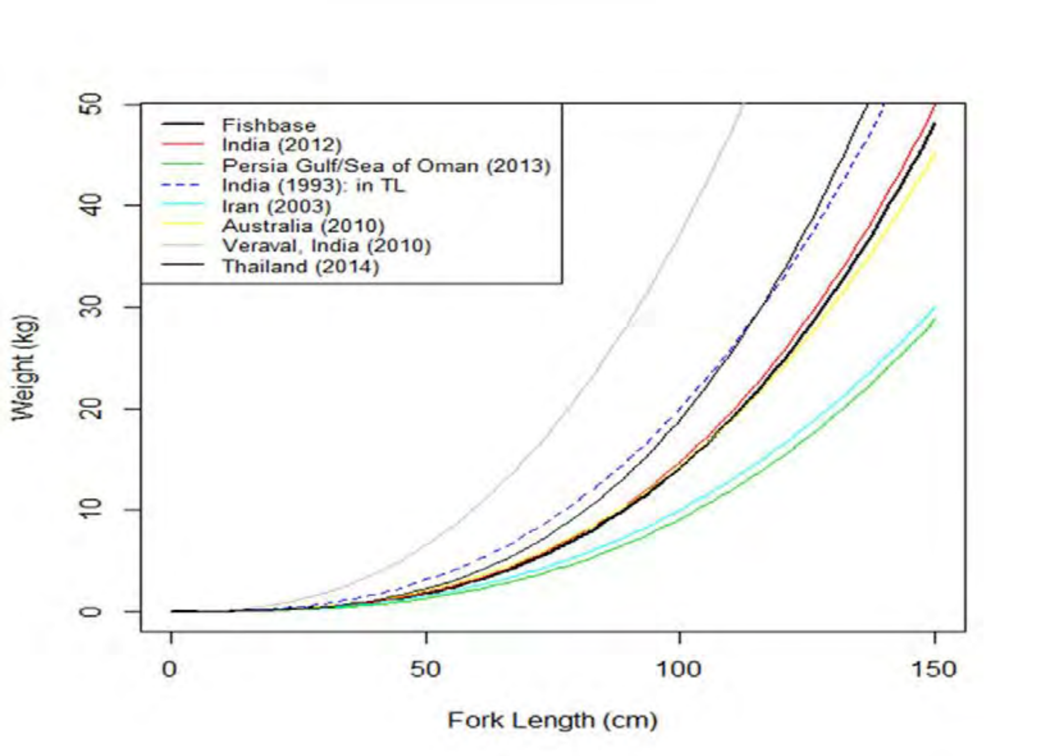
Longtail Tuna is an epipelagic species inhabiting tropical to temperate provinces of the Indo-Pacific, almost exclusively in the neritic waters close to the shore, south from Japan, all ASEAN waters to Papua New Guinea, New Britain, and Australia except for the most northern area, both coasts of India, southern Arabian Peninsula, the Red Sea and the Somalia coast.

c. Length and Weight

Length-Weight parameters are estimated as below:

$$W = a * L^b$$

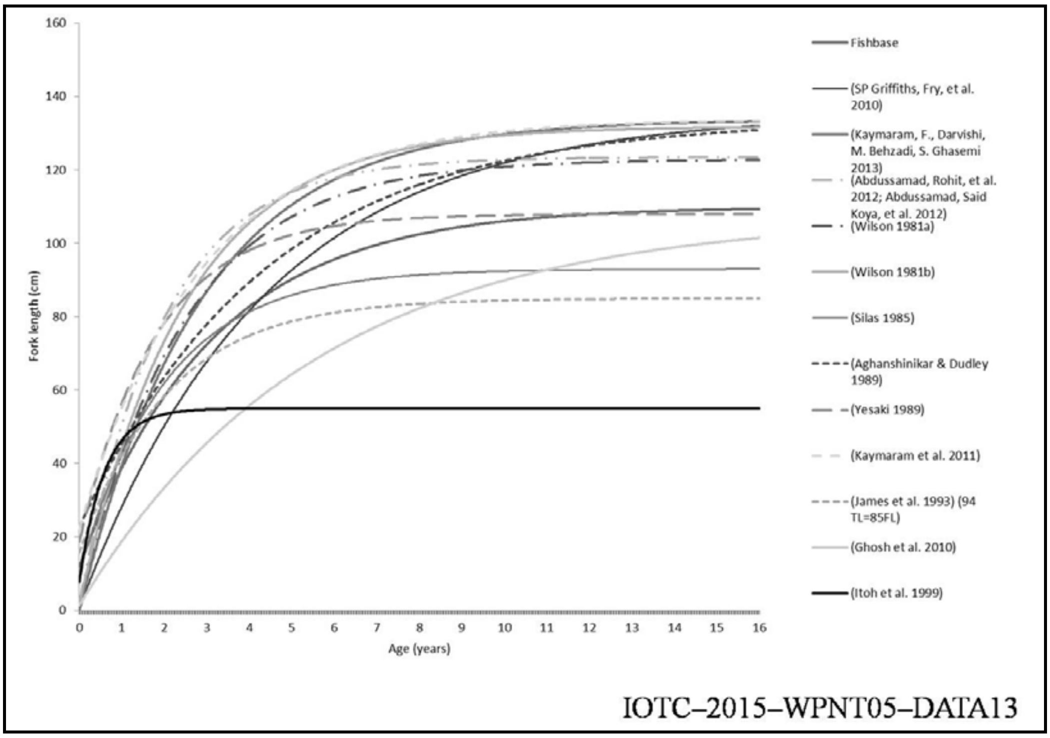
Region	a	b	Units	Reference
	0.01427	3.00	(FL) cm – g	Fishbase
India	0.01480	3.00	(FL) cm – g	Abdussamad et al, 2012
Persia Gulf / Sea of Oman	0.00002	2.83	(FL) cm – kg	Kaymaram et al, 2013
India	0.00008	2.70	(TL) cm – kg	James et al. 1993
Iran	0.00004	2.70	(FL) cm – kg	Darvishi et al, 2003
Australia	0.00005	2.82	(FL) mm – g	Griffiths et al, 2010
Veraval, India	0.357	2.51	(FL) cm – g	Ghosh et al. 2010
Thailand	0.012	3.10	(FL) cm – g	Hassadee et al, 2014



d. Age estimation

$$L_t = L_\infty\left(1 - e^{-k(t-t_0)}\right)$$

Region	L_∞ (FL: cm)	k (year^{-1})	t_0 (years)	Aging Method	Reference
Australia	110	0.32	-0.36		Fishbase
Australia	135.4	0.23	-0.02	Otoliths	Griffiths et al, 2010
Persian Gulf / Sea of Oman	133.72	0.35	-	LF	Kaymaram et al, 2013
India	123.5	0.51	-0.0319	LF	Abdussamad et al, 2012
Papua New Guinea	122.9	0.41	-0.032	LF	Wilson 1981a
Papua New Guinea	131.8	0.40	-0.035	Otoliths	Wilson 1981b
India	93.0	0.49	-0.240	LF	Silas 1985
Oman	133.6	0.23	-	LF	Aghanshinikar & Dudley 1989
Gulf of Thailand	108.0	0.55	-	LF	Yesaki 1989
North Persian Gulf / Sea of Oman	133.8	0.35	-	LF	Kaymaram et al. 2011
India	85	0.48	-	LF	James et al. 1993
Veraval, India	107.4	0.18	-0.0729	LF	Ghosh et al. 2010
Japan	55.0	1.7	-0.089	Otoliths	Itoh et al. 1999



e. Maturation

- The length-at-first maturity;
    - Australia: 37 cm FL. (Griffiths et al, 2007)
    - Thailand: 43 cm FL (Yesaki, 1982)
- 50% Maturity;
    - Gulf of Thailand: 396mm (Cheunpan, 1984)
- Most probably LTT matures at age 1.
- Fecundity:
    - ~ 1.9 million eggs (43.8 to 49.1 cm FL) (Klinmuang, 1978)
    - 0.8 ~ 1.9 million eggs (75.5 to 98.0 cm FL) (Wilson, 1981)
- Probably spawns more than once a year, like other tunas.

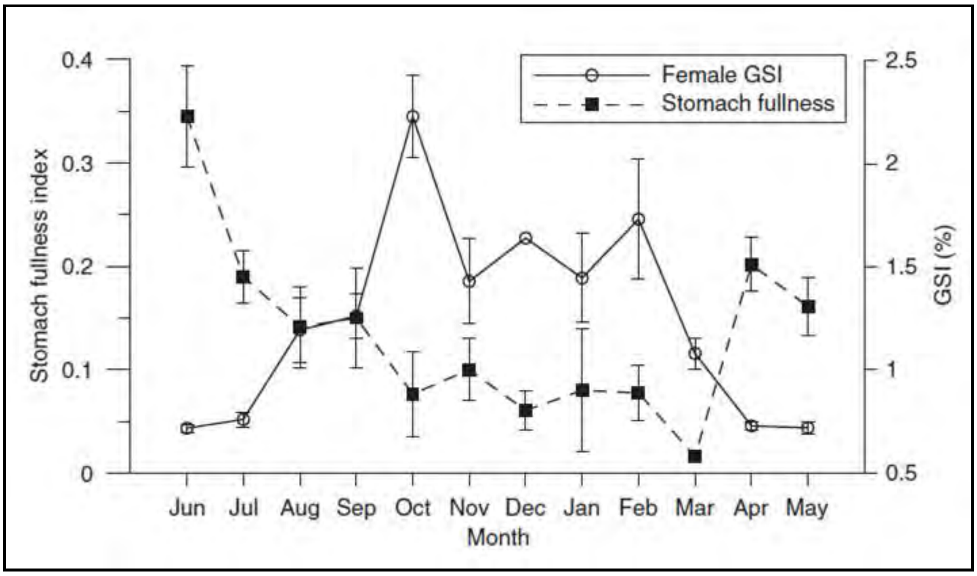
f. Spawning Seasons

- West coast Thailand: two spawning seasons (Yesaki, 1982)
    - spawn principally in the outer-neritic regime
    - major spawning during the NE monsoon (Jan~Apr)
    - minor spawning during the SW monsoon (Aug~Sep)
- Gulf of Thailand: two spawning season (Cheunpan, 1984)
- March-May, July–December

g. Life History

- Little information of distribution of LTT larvae
- Gulf of Thailand: January~June (Chamchang and Chayakul, 1988)
- West coast of Thailand: February~April (Boonragsa, 1987)
- Preadults
- ~20cm: captured by luring purse seines off the west coast of Thailand.

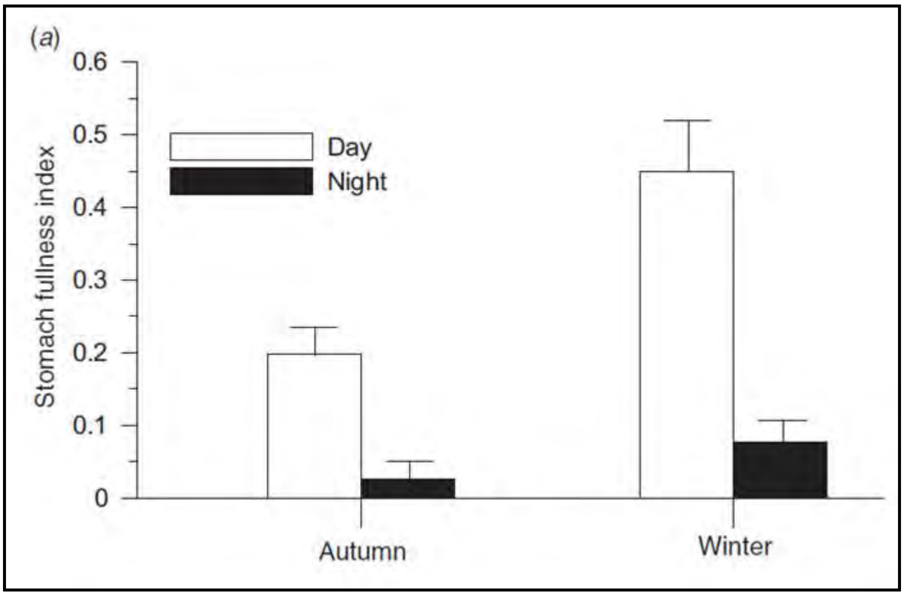
• Longtail tuna may form schools of varying size.
• Little information of migration and sub-populations



Stomach fullness index:

- Highest April ~ July
- Lowest October ~March
- Inverse relationship with GSI

(Griffiths et al, 2007)



Feeding primarily during the day; LT rely heavily on their high visual acuity to capture prey. (Griffiths et al, 2007)

h. Feeding

• Australia; (Griffiths et al, 2007)

- Northern region most diverse diet in autumn and winter (47 and 27 taxa) and the least diverse diet in summer (7 taxa).

- The same trend was apparent in the eastern region, where fish had the most diverse diet in autumn and winter (29 and 17 taxa) and the least diverse diet in summer (7 taxa)
- Fish size: 60~115cm; Prey size in length: mostly ~200mm; Little change of prey size in relation with fish size

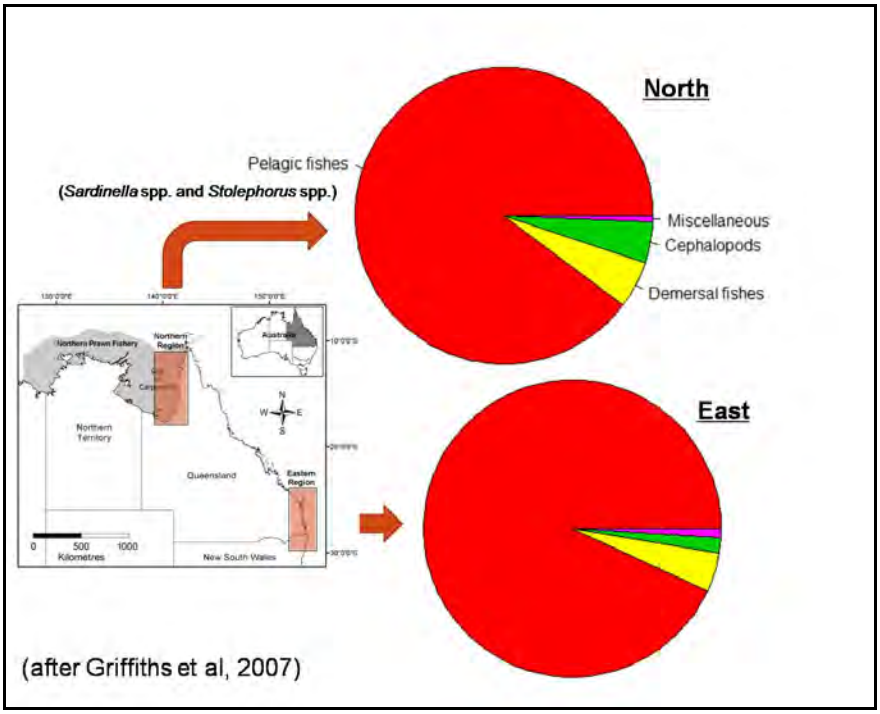
• Gulf of Papua (Wilson, 1981)

- 31 prey taxa; teleosts (85% by vol), crustaceans (8%) and cephalopods (6%)
- Engraulids are the most predominant prey item overall

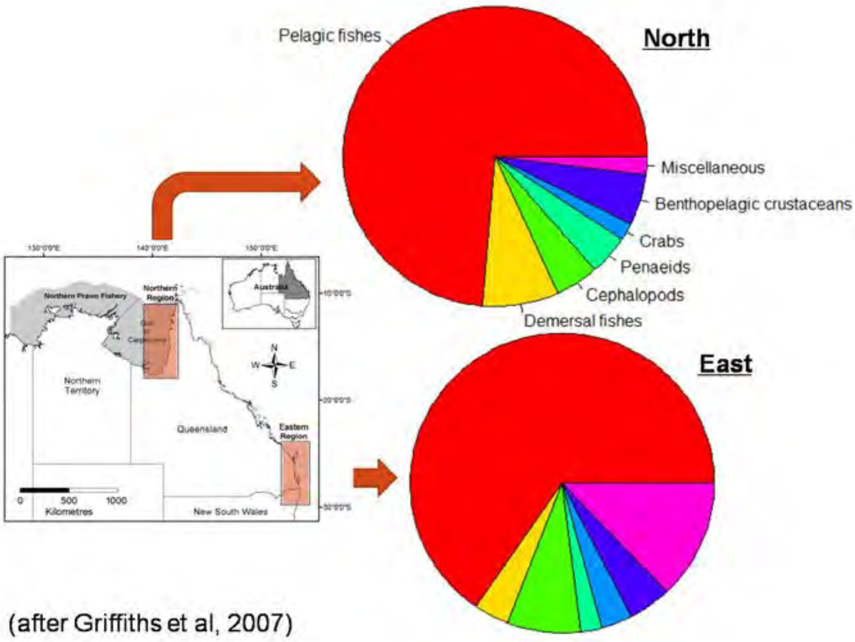
• Malaysia (Silas 1967)

- Pelagic & demeral fishes: engraulids, clupeids, sygnathids and scombrids;
- Squids and crustaceans (stomatopods,mysids and megalopa) were the predominant prey in terms of frequency of occurrence.

• These variety of prey species suggest opportunistic foraging behavior of LTT.



The feeding ecology of longtail tuna was studied in northern and eastern Australia.
By % dry weight, small pelagic fishes covers almost 90% or more of stomach contents in both regions, followed by demersal fishes and cephalopods.



(after Griffiths et al, 2007)

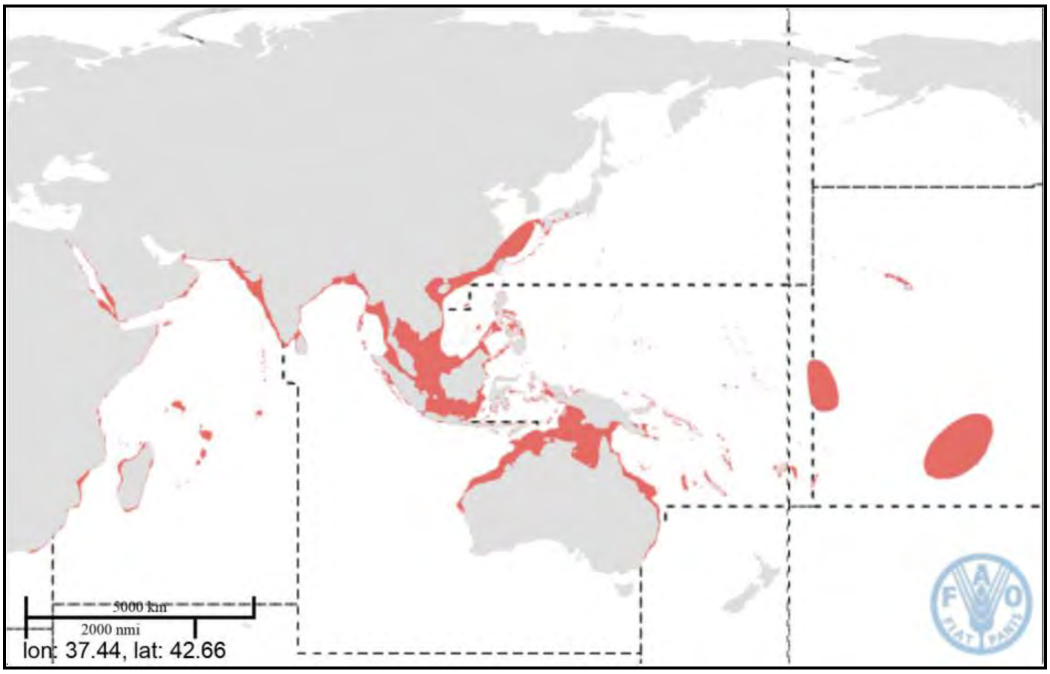
By % frequency of occurrence, small pelagic fishes covers 70-75% also in both regions, followed by demersal fishes and cephalopods, and then Penaeids (shrimp), crabs, benthopelagic crustaceans. In terms of prey variety, even 25-30% however, the contribution of demersal and benthic prey is relatively high comparing to the oceanic tunas, owing to their preference for relatively shallow neritic waters.

2. Kawakawa, *Euthynnus affinis* (Cantor, 1849)

a. Diagnostic Features

- Body naked except for corselet and lateral line;
- Maximum; Females and males 100 cm FL; weight 14 kg. The all-tackle
- Max record; 96.5 cm FL, 11.80 kg (Merimbala, New South Wales, 1980)
- Pectoral fin rays 25-29; Dorsal spines (total): 10-15; Dorsal soft rays (total): 11-15; Anal spines: 0; Anal soft rays: 11-15;
- Anterior spines of first dorsal fin much higher than those mid-way.
- Bony caudal keels on 33 and 34 vertebrae;
- Severa1 black spots usually present between pectoral-and pelvic-fin bases;
- Back dark blue-green with a complex striped pattern under dorsal fin bases;
- Gillrakers 29 to 33 on first arch; gill teeth 28 or 29;
- Vomerine teeth absent? (FAO, 1983); present? (Nakabo, 2001)
- Vertebrae 39;
- Swim bladder absent.

b. Distribution



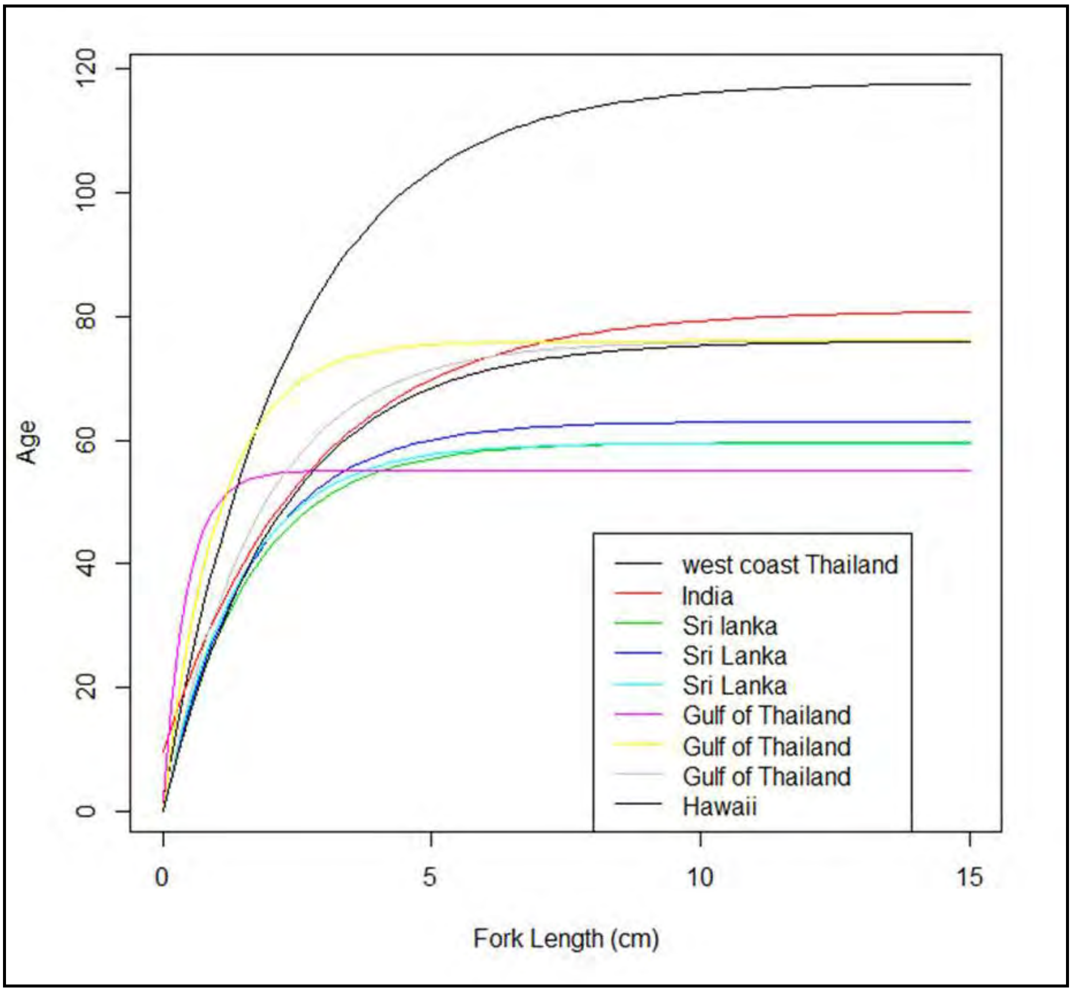
Kawakawa is distributed throughout the warm waters of the Indo-West Pacific, including oceanic islands and archipelagos. A few stray specimens have been collected in the eastern tropical Pacific.

c. Age estimation

$$L_t = L_\infty\left(1 - e^{-k(t-t_0)}\right)$$

Region	L_∞ (FL: cm)	k (year^{-1})	t_0 (years)	Aging Method	Reference
west coast Thailand	76	0.46	-	Modal progres.	Yesaki, 1982
India	81	0.37	-0.344	ELEFAN	Silas et al., 1985b
Sri lanka	59.6	0.63	-	ELEFAN	Joseph et al., 1987
Sri Lanka	63	0.61	-	ELEFAN	
Sri Lanka	59.5	0.69	-	Bhattacharya	
Gulf of Thailand	55.1	2.23	-0.015	Modal progres.	Supongpan and Saikliang, 1987
Gulf of Thailand	76	0.96	-	Modal progres.	Yesaki, 1989b, 10-day intervals
Gulf of Thailand	76	0.56	-	Modal progres.	Yesaki, 1989b, monthly intervals
Hawaii	117.8	0.42	-0.03	otoliths	Uchiyama, 1980

$$L_t = L_\infty\left(1 - e^{-k(t-t_0)}\right)$$



d. Maturation

- The smallest mature females
  - Philippines: 38.5 cm (Ronquillo, 1963)
  - Gulf of Thailand: 37.0 cm (Klinmuang, 1978)
  - Gulf of Thailand: 33.4 cm (Cheunpan, 1984)
  - West coast Thailand: 38 cm (Yesaki, 1982)
  - Papua New Guinea: 48.9 cm(Wilson, 1981)
- 50% Maturity:
  - Gulf of Thailand: 40 cm (Cheunpan, 1984)
  - Mangalore, India: 43-44cm (Muthiah, 1985)
  - Most probably Kawakawa start maturation from age 1.
- Fecundity:
  - India: 210,000 ~680,000/spawning (48.5 ~ 65.0 cm FL) (Rao, 1964)
  - India: 202,000 ~1,570,000/spawning (39.4 ~ 67.0cm FL) (Muthiah, 1985)
  - South China Sea: av.1,730,000/spawning (39.5 to 51.0cm) (Klinmuang, 1978)
- Kawakawa is a multiple spawner releasing ova at frequent intervals during a spawning season.

e. Spawning Season

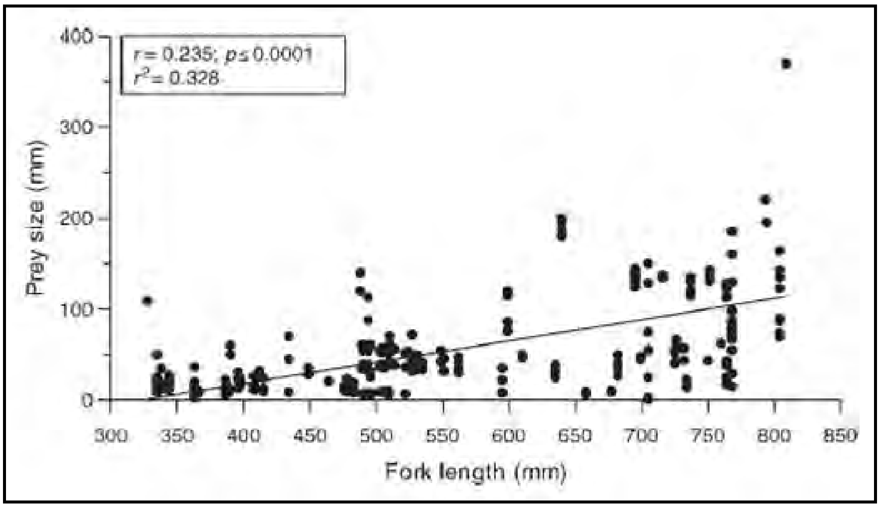
- Philippine waters; March ~ May
- Seychelles; during the period of the NW monsoon (October/November ~ April/May)
- off East Africa; from the middle of the NW monsoon period to the beginning of the SE monsoon (January ~ July)
- off Indonesia ; probably from August ~ October

f. Life History

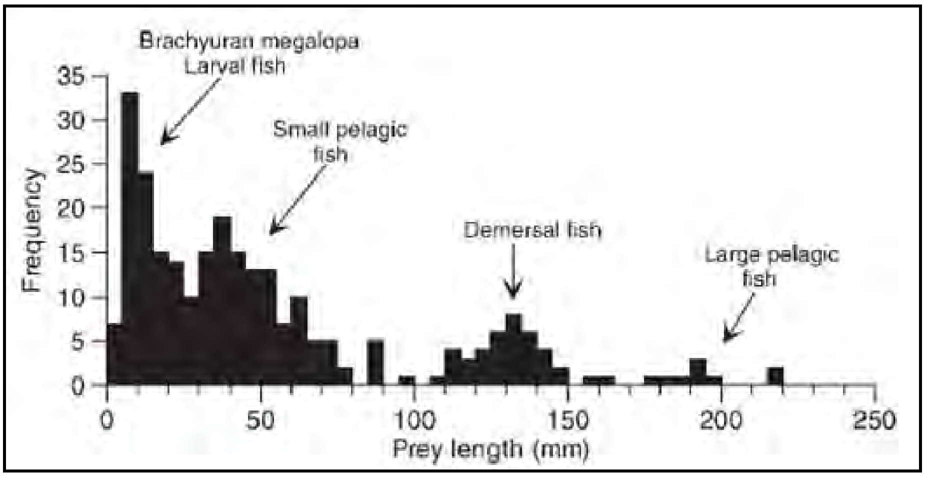
- An epipelagic, neritic speciesinhabiting waters temperatures ranging from 18 to 29° C.
- Occurs in open waters but always remains close to the shoreline. The young may enter bays and harbors.
- Like other scombrids, E. affinis tend to form multispecies schools by size, comprising from 100 to over 5 000 individuals.
- Kawakawa are captured with;
    - Thunnus tonggol and Auxis thazard throughout much of the Indo-Pacific region
    - Sarda orientalis off the north coast of Australia;
    - Megalaspis cordyla in the Gulf of Thailand;
    - T. albacares and Katsuwonus pelamis in the coastal waters of Sri Lanka;
    - K. pelamis and Elagatis bipinnulata off Papua New Guinea
    - All these species are probably competitors of kawakawa.

g. Feeding

- Diet Composition:
    - Australian neritic waters; Overall 43 prey taxa (Griffiths, et al, 2009)
        - Primarily pelagic clupeoids (78% by WW; 71% by FO); demersal fish (19% WW; 32% FO).
    - Seasonal Change
        - Autumn; virtually only engraulids
        - Other seasons; engraulids were still the dominant, but a greater variety of other prey were consumed.
    - Size difference
        - Small tuna; small pelagic crustaceans and teleosts
        - Medium/large tuna; larger pelagic and demersal teleosts



Fish size: 33~80cm; Moderate correlation between prey size and fish size



Prey size in length: mostly ~200mm;
Prey types consisting of four distinct prey size modes (Griffiths et al, 2009)

h. Predation

- Kawakawa is a highly opportunistic predator feeding indiscriminately on fish, shrimps and cephalopods. In turn, it is preyed upon by other predators.
- Number and incidence of kawakawa juveniles in the stomachs of predators sampled from tropical waters (modified from Argue et al., 1983, below).

Predator	Predators examined for full stomach tuna content	juveniles	No of juveniles	Predators with juveniles	Juveniles per 100 predators	% predators with juveniles
Katsuwonus pelamis	3,896	8,175	31	19	0.38	0.23
Thunnus albacares	1,018	1,711	30	2	1.75	0.12
Euthynnus affinis	145	233	2	1	0.90	0.45

SESSION IV

TRAINING/WORKSHOP PROGRAM

Topics	**Subjects**	**References**
Orientation	Orientation	Annex 1
Data collection & process	Outline	Annex 2
CPUE standardization	Outline	Annex 3
	Software (Manual)	Annex 4
ASPIC	Outline	Annex 5
	Software parameter search (Manual)	Annex 6
	Software ASPIC (Manual)	Annex 7
Kobe plot	Outline	Annex 8
	Software (Manual)	Annex 9
Case studies	Longtail tuna stock assessments (Nishida and Iwasaki, 2015, IOTC)	Annex 10
	Kawakawa stock assessments (Nishida et al., 2014, IOTC)	Annex 11
	Kawakawa and Longtail stock assessments (Government of Oman, 2013) (IOTC)	Annex 12
R	How to install R ?	Annex 13

Group photo of the Special Training/Workshop on Stock Assessments of Longtail Tuna and Kawakawa in the Southeast Asian Region on 17-25 April 2016 at SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia

SESSION V

TRAINING PROGRAM EVALUATION

The evaluation of this training course program are based on the surveying 16 people including 8 core participants and 8 observers from SEAFDEC Member Countries namely Brunei Darussalam, Indonesia, Malaysia, Philippines, Thailand and Viet Nam as well as SEAFDEC staffs from MFRDMD, TD and Secretariat.

Figure 45 shows about the knowledge of the participants before after the training and the interactive during the training. First column shown that most of the trainer had the level knowledge of the training before the training has score 1 (poor). After the trainer attend the training has score of the knowledge giving during 3-5 (good-excellent). Most of the participants had participate and interaction during the training gave the score 4 (very good). However, the participants suggested the participant needs more training on ASPIC and training should be clearer probably due to language barrier and instruction.

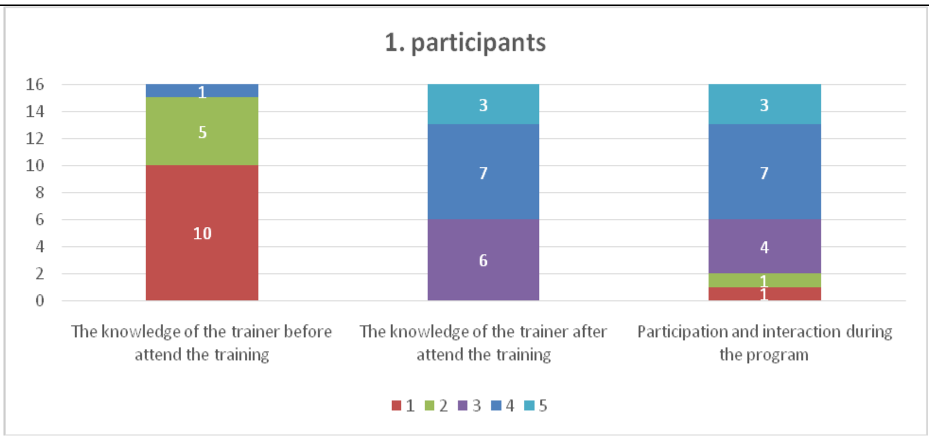


Figure 45

Figure 46 shows the evaluation on the curriculum contents. The majority of the participants prefer to the topics covered were relevant to your work, material distributed were helpful, and this training experience will be useful in their work has score 5 (excellent).

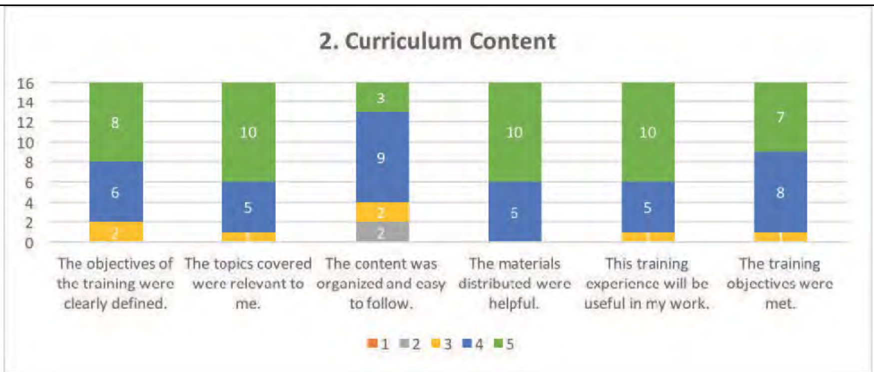


Figure 46

Figure 47 shows the useful of the software for stock assessment. The majority of the participants prefer to the software of Kobe I (Kobe Plot) and Kobe Plot II (Risk Assessment) had most useful for stock assessment. However, participants need more time to practice using the software and country data set needs to prepare good data for stock assessment analysis. Most of the participants prefer the level of the resource person of this training giving the score 4-5 (good-excellent) on the knowledge and the clarification contents in response questions.

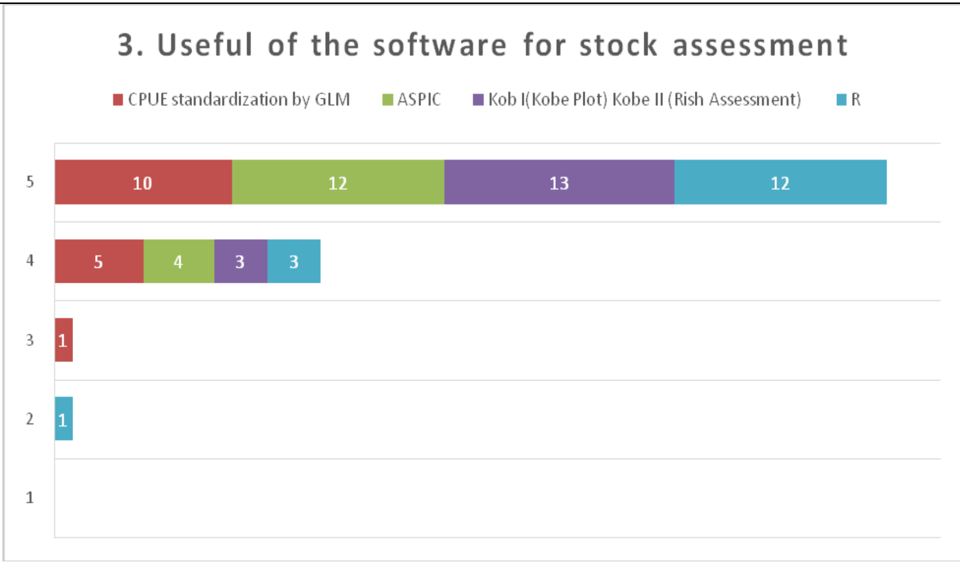


Figure 47

Figure 48 shows the results of the facilities during the training on the comfortable and provided the adequate space and the adequate and appropriate for each session gave score 4-5.

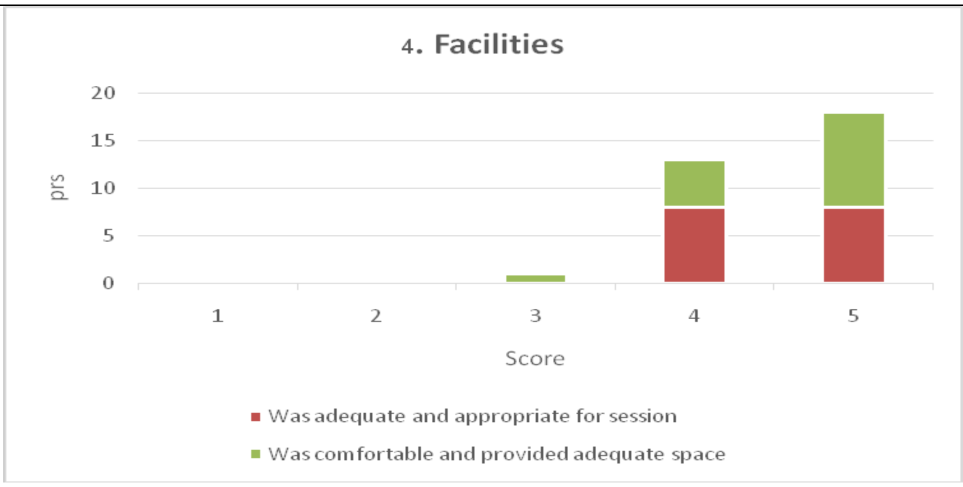


Figure 48

In this training, shows 100 % of the participants prefer to this program will enhanced your professional expertise and they will intend to encourage higher authority to conduct the country training on this similar program and 93% of the participant will recommend this program to others. The participants suggested that SEAFDEC should be supported and conducted the training on stock assessment in Member Countries especially ASPIC software and also should be involving person from manager because statistic data will provide by them and that they can make the proper data statistic to conduct the stock assessment. In addition, the participants also suggested that SEAFDEC should be continued the training for them about risk assessment.

Annex 1

Orientation

The Special Training/Workshop on Stock Assessments of Longtail tuna and Kawakawa in the Southeast Asian Region"
17 - 25 April 2016
SEAFDEC/MFRDMD in Kuala Terengganu, Malaysia

April 17 (Sun) 0920-1020

Orientation

This is not formal meeting.. Feel free to ask..

Please raise you hands and ask questions for discussion, so that other participants and instructors will also understand and learn further in depth.

Contents

1. Self-introduction
2. Backgrounds
3. Objectives
4. List of training materials
5. Check participant's PC
6. Software
7. Outline of the training
8. Copies of training materials

1. Self introduction

- ONE CORE participant per country.
- Observers
- Organizers (SEAFDEC HQs and SEAFCEC/MFRDMD)
- Resources persons

Who is the (crazy) instructor (Tom Nishida)? self introduction

Profile

- Made in Japan
  (but father made in USA ➔ Hilo, Hawaii)
- Retired scientists ➔ Associate Scientist
- National Research Institute of Far Seas Fisheries （NRIFSF）
- Fisheries Research Agency (FRA)
- Tuna and demersal fish stock assessments

Backgrounds

- BS University of Hokkaido (Oceanography)
- BS Univ. of Washington (Stock assessments)
- MS Univ. of Washington (Stock assessments)
- PhD Tokyo University
  ➔ Indian Ocean yellowfin tuna
  stock assessments

Work experiences

University of Washington (USA)
(Research assistant)(salmon)
BOBP+FAO(Sri Lanka)
(Fisheries statistician) (Indian Ocean)

National Research Institute of Far Seas Fisheries (Japan)
Indian Ocean (IOTC)
Tuna, Billfish, neritic tuna stock assessments
+
Atlantic Ocean (NAFO+SEAFO)+ Indian (SIOFA)
Demersal fish Management

Important : 2 way talk (instructor vs. participants)
(not to baby nor between wrestlers)

2. Background (1)

SEAFDEC neritic tuna stock assessments project

- 1st Meeting (Selangor, Malaysia) (November, 2014)
  SWG (Scientific Working Group) established
  (8 member countries)

- 2nd Meeting (Hai Phong, Viet Nam) (June 2015).

2. Background (2) 2nd meeting agreed

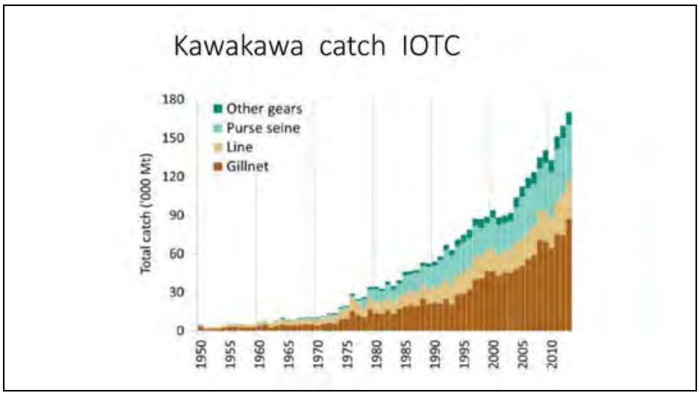
- ASPIC for Kawakawa+Longtail tuna
  as a first step to evaluate their stock statuses.
- Two stocks hypothesis (Indian and Pacific stock)
  for each species.

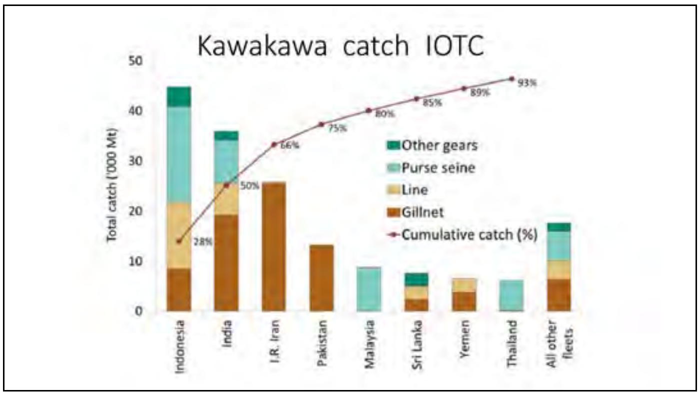
➔4 stock assessments need to be conducted.
➔ For Training purpose

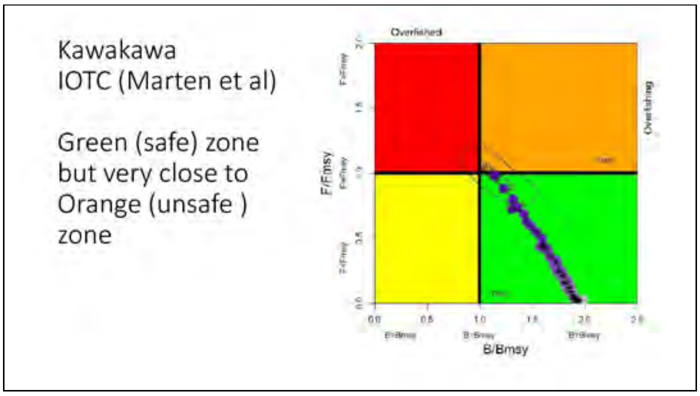
Background

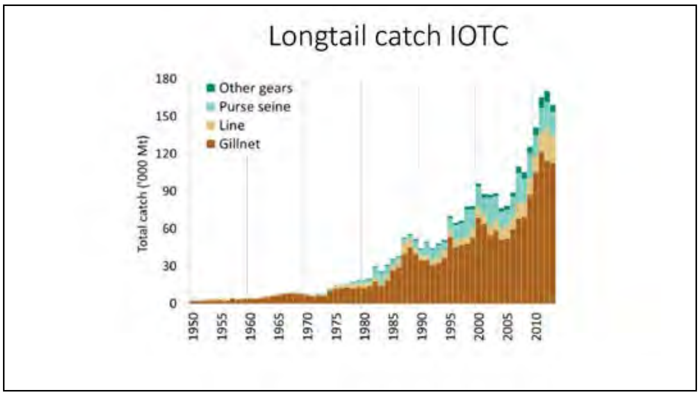
Why longtail and Kawakawa were selected ?

Important food resources in the SE Asia (for a long time)(BOBP+IPTP)
High catch : important for industry (commercially important)
⬇
We concern their Stock status

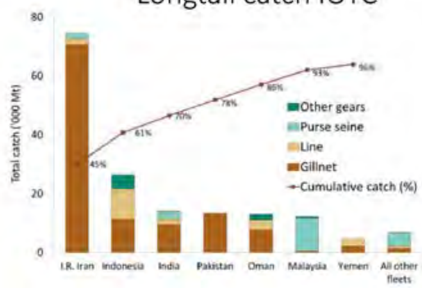

Kawakawa catch IOTC
Other gears
Purse seine
Line
Gillnet
Total catch ('000 Mt)
180
150
120
90
60
30
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Kawakawa catch IOTC
Total catch ('000 Mt)
50
40
30
20
10
0
28%
50%
66%
75%
80%
85%
89%
93%
Other gears
Purse seine
Line
Gillnet
Cumulative catch (%)
Indonesia
India
I.R. Iran
Pakistan
Malaysia
Sri Lanka
Yemen
Thailand
All other fleets


Kawakawa
IOTC (Marten et al)
Green (safe) zone
but very close to
Orange (unsafe)
zone
Overfished
Overfishing
F/Fmsy
B/Bmsy
0.0
0.5
1.0
1.5
2.0

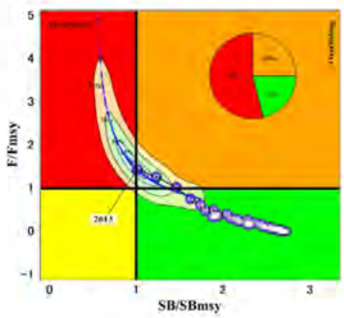

Longtail catch IOTC
Other gears
Purse seine
Line
Gillnet
Total catch ('000 Mt)
180
150
120
90
60
30
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Longtail catch IOTC



Longtail tuna
IOTC (Nishida et al) (2015)

red (unsafe) zone
F is very high



3. Objectives (Kawakawa and Longtail tuna in SE Asia) (1)

- To learn
  - Biology and Ecology
  - Data process (CPUE standardization + stock assessments)
  - CPUE standardization
  - Sock assessments (ASPIC)
  - Kobe Plot (Management tool)
- To enhance
  - Discussion and Presentation skill

3. Objectives (very important) (2)

- **Style of the training: Training of Trainer style**
- One core person from each country.
- Core persons will be trained to learn all materials as perfect as possible, so that they can train same materials to their colleagues in their home countries.

➔ **focus ONLY for core person**

Observers ➔ self learning

4. List of training materials (20 items) 4 is not ready (later)

Files will be provided by USB memory stick

(00) List of training materials (Rev_2) (final)	2016/04/15...	Microsoft Word Document	17 KB
(00) Orientation	2016/04/16...	Microsoft PowerPoint Presentation	5,957 KB
(01) Data collection and process	2016/04/16...	Microsoft PowerPoint Presentation	5,416 KB
(02) (not ready) CPUE standardization (Outline)	2016/04/13...	Microsoft PowerPoint Presentation	1,688 KB
(03) Manual CPUE standardization by GLM soft	2016/04/15...	Microsoft Word Document	469 KB
(04) (not ready) ASPIC outline	2016/04/16...	Microsoft PowerPoint Presentation	299 KB
(05) ASPIC parameter search soft (manual)	2016/04/15...	Microsoft Word Document	449 KB
(06) ASPIC manual	2016/04/01...	Adobe Acrobat Document	175 KB
(07) Kobe plot (Manual)	2016/04/01...	Microsoft Word Document	1,915 KB
(08) (not ready) Kobe plot (PowerPoint)	2016/04/13...	Microsoft PowerPoint Presentation	1,509 KB
(09) Case study ASPIC (LOT) (IOTC)	2016/04/01...	Microsoft Word Document	1,702 KB
(10) Case study ASPIC (KAW) (IOTC)	2016/04/01...	Microsoft Word Document	2,519 KB
(11) Case study (Oman)	2016/04/01...	Microsoft Word 97 - 2003 Document	16,342 KB
(12) How to install R	2016/04/01...	Microsoft PowerPoint Presentation	100 KB
(13) Case study (K. Mackerel) (T Tobago)	2013/05/26...	Microsoft PowerPoint 97-2003 Presentati...	1,479 KB
(14) (not ready) Stock structure	2016/04/16...	Microsoft PowerPoint Presentation	2,169 KB
(15) Kobe plot case study SC15 report	2012/05/06...	Microsoft PowerPoint 97-2003 Presentati...	3,425 KB
(16) Case study Albacore (IOTC)	2012/02/26...	Microsoft PowerPoint 97-2003 Presentati...	1,559 KB
(17) Case study LOT NW IO (CPUE+ASPIC)	2015/02/11...	Microsoft PowerPoint Presentation	1,956 KB
(18) Oman LOT CPUE	2015/02/09...	Microsoft PowerPoint Presentation	5,998 KB
(19) QS	2014/08/26...	Microsoft PowerPoint 97-2003 Presentati...	2,828 KB

4 Software will be provided by USB memory stick
(as it may be difficult to download using the internet in MFRDMD)

- CPUE standardization by GLM (Menu-driven software)(51 MB)
- ASPIC (original program by Prager) (1MB)
- ASPIC (grid parameters search) (Menu-driven software)(50 MB)
- Kobe plot (Menu-driven software) (5MB)

5. Check participant's PC

- Lap top PC per person (windows 7 or higher) (64 bits).
- R should be pre-installed.
- No MAC/Apple PC nor Tablets because of software compatibility problems.
- Hard Disk
  (enough space : more than 20% should be available)

Important note

Normally it will **take several years**
to learn CPUE standardization by GLM and ASPIC
if you are the beginners and don't know any programs

You need to learn in several days !

How?

Don't worry
We prepare easy (menu driven) software

- CPUE standardization
- Stock assessments (ASPIC) (2)
  - Original by Prager (2004)
  - Grid (parameter) search
- Kobe plot
  - I Kobe plot
  - II Risk assessments (not covered this time)

How long dose it take to learn with and without software ? Merit and Demerit ?

	Merit	Demerit
• If you use the program (no software) a few years	flexible (output)	take time (difficult) to learn (only limited person)
• If you use software → 0.5 years	easy to do for anyone	output (FIXED)(not flexible)

Best way : 1st by software later challenge programs (R, SAS, C, etc.)

6. Outline of the training (revised)

National Report important to learn the current situation

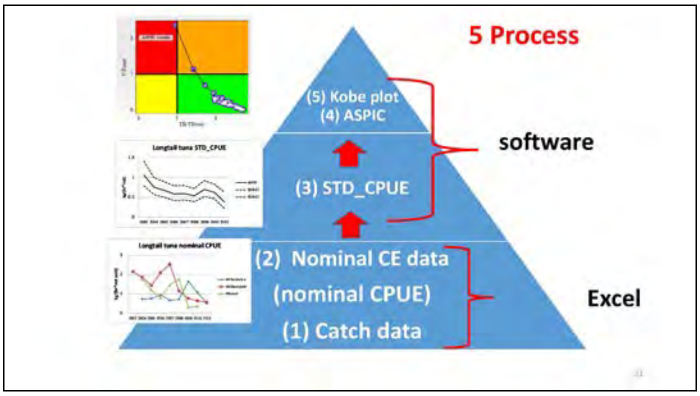
April		Plan
17	Sun	Openings
		Orientations
		National Report
		Biology and Ecology of kawakawa and longtail tuna
		Data collection and process
18	Mon	CPUE standardization (outline initial practice)
19	Tue	ASPIC(outline initial practice)
20	Wed	Kobe plot (outline initial practice)
21	Thu	case study presentations (participants)
22	Fri	OFF
23	Sat	CPUE standardization、ASPIC and Kobe plot using real data and results of the stock status
24	Sun	
25	Mon	Final Practice
		Wrap up (Discussion and Summary)
		Closings

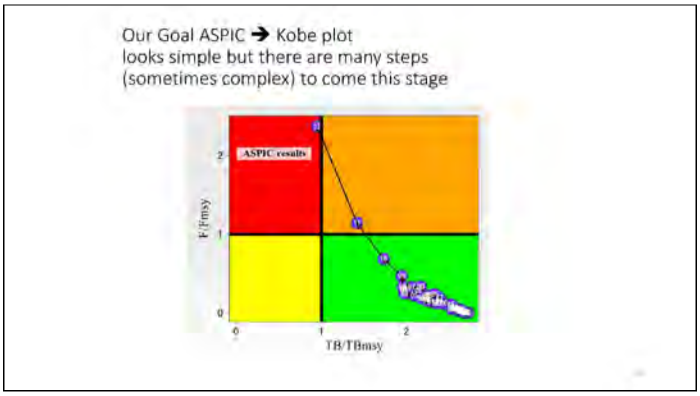
April 21 (Thu) Case study presentation

(to understand CPUE standardization＋ASPIC) (20-30 minutes)

- (09) Case study ASPIC (LOT) (IOTC) — Thailand
- (10) Case study ASPIC (KAW) (IOTC) — Malaysia
- ~~(11) Case study (Oman)~~
- ~~(12) How to install R~~
- (13) Case study (K. Mackerel) (T Tobago) — Indonesia
- ~~(14) (not ready) Stock structure~~
- ~~(15) Kobe plot case study SC15 report~~
- (16) Case study Albacore (IOTC) — Philippines
- (17) Case study LOT NW IO (CPUE+ASPIC) — Brunei
- (18) Oman LOT CPUE — Viet Nam


Need user's friendly software for beginners
(no MATH nor programming)
Beginners
Aged (traditional) person
Special Marks to put on car in Japan


5 Process
(5) Kobe plot
(4) ASPIC
software
(3) STD_CPUE
(2) Nominal CE data
(nominal CPUE)
(1) Catch data
Excel


Our Goal ASPIC ➔ Kobe plot
looks simple but there are many steps
(sometimes complex) to come this stage
ASPIC results
F/Fmsy
TB/TBmsy

Annex 2

Data Collection & process

Document (01) Data Collection & process
15:30-17:00 April 17 (Sunday)

Outline and general views

Progress on actual data collection and process
for longtail tuna and kawakawa
will be presented in sessions on
CPUE standardization and ASPIC

Contents

- Data collection (general)
- Data collection (ASPIC)
- Progress of the data collection
- Data processing skill
- Data message and massage?
- Sample size
- Data catalogue

Document (01) Data Collection & process
15:30-17:00 April 17 (Sunday)

Starting point
Most basic work
before CPUE standardization+ stock assessments

Why

Without data, you can not do (analyses) anything.

Data collection (general)

What do you need to collect ? Depending on the Objectives

Government (Management) :
➔ Catch for national statistics and planning
Research

Research	catch	nominal CPUE (C•E)	Biology	Ecology	Environment
CPUE standardization					
Biological study					
stock assessments					
Stock structure					
habitat					

Data collection

How to collect ?

- Port sampling (sub sample, interview, eye ball..)
- Observer program (human and video system) link..
- Logbook (paper and Electronic logbook)
- Catch report from fishing company

How detail we need to collect

- Ideally set-by-set data is perfect
  ➔ less bias to estimate for catch, CPUE Stock structure etc..

➔ Information by species, gear, area, year, month, day, boat and set

- But if we can not.. We collect aggregated data

For example by species, gear, area, year and month.
(normal situation)

Data collection for ASPIC

What do we need to collect for our case
CPUE standardization + stock assessments (**ASPIC**)
by stock and species

CPUE standardization➔ Nominal CPUE (catch and Effort)
by set (gear, fishing area, year, month, day, boat and set)

ASPIC➔ Annual **global Catch** by country
+ standardized CPUE

How about our case ? Not real data collection → Compilation

→ Collect & compile available historical catch +CPUE (ASPIC)(8 countries)

- Data collection (catch)
  - Annual total catch by Country and Ocean (Indian and Pacific)
    - → no need by gear and area
    - → ASPIC needs the annual global catch

- Data collection : CPUE (catch and effort) (set by set)
  - by gear, Ocean, area, year, month, day and Boat
    - → CPUE standardizations needs fine scale data
    - → if not available, aggregated data OK

Quiz

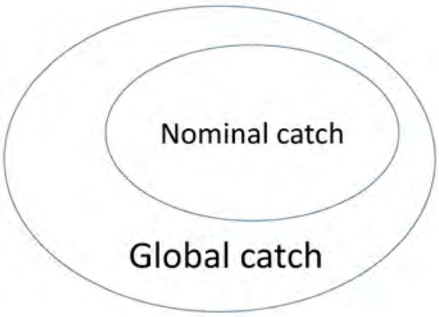
Global catch [1/]

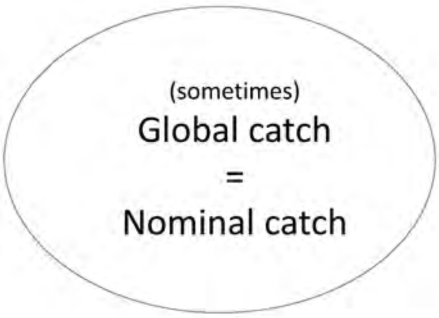
vs nominal CPUE (nominal Catch [2/] and effort)

What are differences between

Global Catch [1/] and nominal Catch [2/]

Same ?





Progress of the data collection

Data collection by through coordinators in 8 member countries (completed in December, 2015)

ONLY Thailand and Philippines long time series of CPUE
(key parameters for ASPIC)

Special mission (further investigations) (Jan/Feb, 2016)
Nishida+ Sweetness (SEAFDEC)

Data coordinators (8 member countries) (Completed in Dec., 2015)
What is the stock (1 or 2)

No	Country	Stock	Member country	Coordinators	Post	Agency	e-mail
1	Brunei	1	Brunei	Ms Noorizan Karim	Head	Capture Fisheries Industry Division	noor6263@gmail.com
				Mr Matzaini Juna	Head		matzaini.juna@fisheries.gov.bn
2	Cambodia	1	Cambodia	Mr. Suy Serywath	Director	Fisheries Research and Development Institute, Fisheries Administration (FiA)	serywath@gmail.com
				Mr. Kao Monirith	Deputy Director		kaomonirith@yahoo.com
3	Indonesia	2	Indonesia	Dr Khairul Amri	Chief scientist	Research Institute for Marine Fisheries	Kh_amri@yahoo.com
				Mr Thomas Hidayat	Researcher		hidayatthomas245@gmail.com
4	Malaysia	2	Malaysia	Mr Samsudin Bin Basir	Chief scientist	Department of Fisheries	s_basir@yahoo.com
				Mr Sallehudin Jamon	Scientist		dinjamon@rocketmail.com
							sallehudin_jamon@dof.gov.my
5	Myanmar	1	Myanmar	Dr Htun Thein	Assistant Director	Marine Resources Survey & Research Unit, Department of Fisheries	htunthein.akyab@gmail.com
				Mr Nay Myo Aye	Assistant Fisheries Officer		nvnghia@rimf.org.vn
6	Philippines	1	Philippines	Mr Noel Barut	Director	Bureau of Fisheries and Aquatic Resources (BFAR)	noel_c_barut@yahoo.com
				Ms. Grace Lopez	Aquaculturist II		gmslopez@yahoo.com
7	Thailand	2	Thailand	Ms. Suwantana Tossapornpitakkul	Fishery Biologist	Marine Fisheries Technology Research and Development Institute, Department of Fisheries	tsuwantana@yahoo.com
				Mr. Chalit Sangangam	Fishery Biologist		chalitter@gmail.com
8	Viet Nam	1	Viet Nam	Mr Nguyen Viet Nghia	Deputy Director	Research Institute for Marine Fisheries	nvnghia@rimf.org.vn
				Mr Pham Hung	Officer	Research Institute for Marine Fisheries	hunglam83@gmail.com

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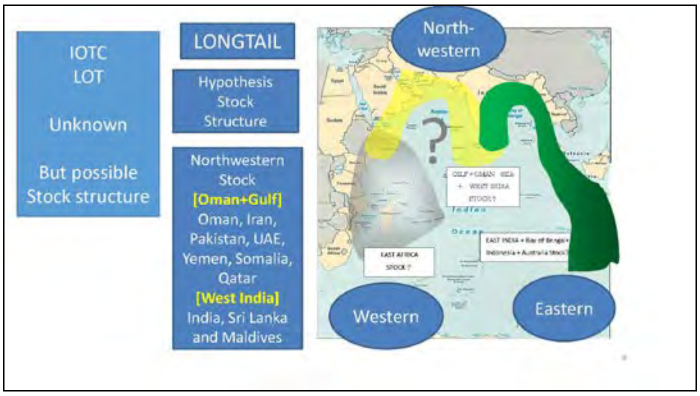
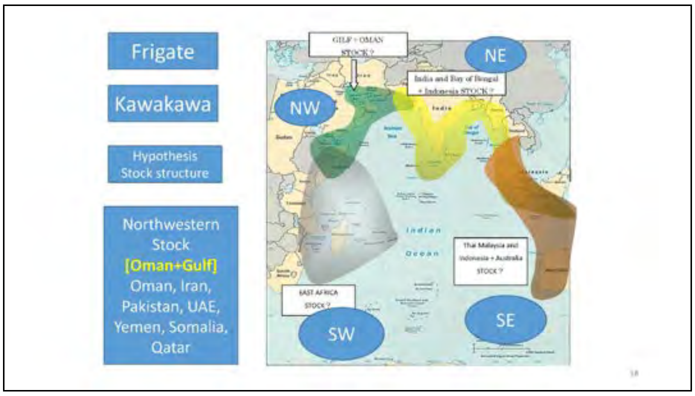
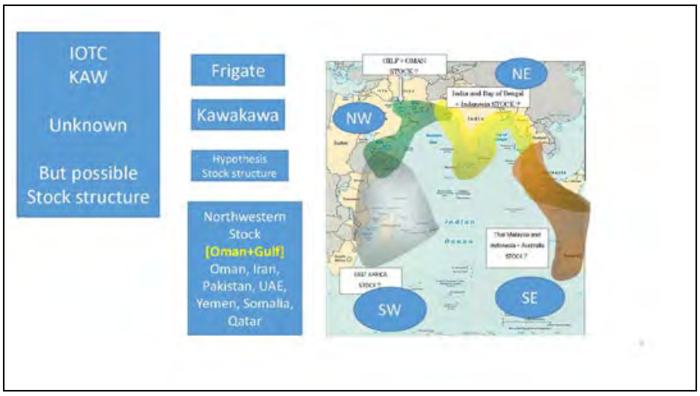
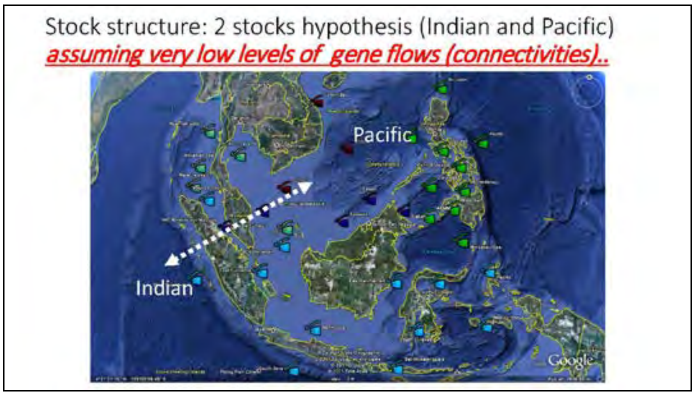
Stock structure


IOTC
LOT
Unknown
But possible
Stock structure
LONGTAIL
Hypothesis
Stock
Structure
Northwestern
Stock
[Oman+Gulf]
Oman, Iran,
Pakistan, UAE,
Yemen, Somalia,
Qatar
[West India]
India, Sri Lanka
and Maldives
North-
western
?
Indian
Ocean
EAST AFRICA
STOCK ?
Western
Eastern


Frigate
Kawakawa
Hypothesis
Stock structure
Northwestern
Stock
[Oman+Gulf]
Oman, Iran,
Pakistan, UAE,
Yemen, Somalia,
Qatar
GULF + OMAN
STOCK ?
NE
India and Bay of Bengal
+ Indonesia STOCK ?
NW
Indian
Ocean
EAST AFRICA
STOCK ?
SW
SE


IOTC
KAW
Unknown
But possible
Stock structure
Frigate
Kawakawa
Hypothesis
Stock structure
Northwestern
Stock
[Oman+Gulf]
Oman, Iran,
Pakistan, UAE,
Yemen, Somalia,
Qatar
NE
NW
SW
SE


Stock structure: 2 stocks hypothesis (Indian and Pacific)
assuming very low levels of gene flows (connectivities)..
Pacific
Indian
Google

Stock strcture➔Management unit

We need to do the stock assessments by stock

In our case we don't know the Stock structure

⬇

Simple hypothesis (Indian vs. Pacific)

⬆

Geographical feature

Gene flow (connectivity)

Data collection by stock (some country covers 2 stocks)

	(a) Pacific stock FAO 71 area	(b) Indian stock FAO 57 area
(1) Brunei		
(2) Cambodia		
(3) Indonesia (2 stocks)		(Malacca)
(4) Malaysia (2 stocks)		(Malacca)
(5) Myanmar		(Bay of Bengal and Andaman)
(6) Philippines		
(7) Thailand (2 stocks)		(Andaman)
(8) Viet Nam		

Template to collect catch data (1)

(1) Annual total catch by species, stock, country, year and gear

Example 1

Stock Pacific

Country Thailand (Gulf of Thailand)

Species longtail tuna

Template (Excel file)

year	Catch by Gear (tons)			
	Troll line	Gillnet	Purse seine	Total
1976	235	678	123	1,036
1977	367	89	239	695
	⬇		⬇	
2014	110	44	333	487

Note: if species are aggregated, you can indicate as follows (example):
Longtail + Kawakawa (combined), all neritic tuna (combined) etc

Template to collect catch data (2)

Example 2

Stock Indian

Country Myanmar (Bay of Bengal + Andaman Sea)

Species Longtail tuna + Kawakawa (combined)

Template (Excel file)

year	Catch by Gear (tons)		
	Troll line	Other gears	Total
1990	1,235	234	1,469
1991	367	1,234	1,601
	⬇	⬇	
2014	110	744	854

Note: if species are aggregated, you can indicate as follows (example):
Longtail + Kawakawa (combined), all neritic tuna (combined) etc

Template to collect CPUE (Catch+Effort) data (1)

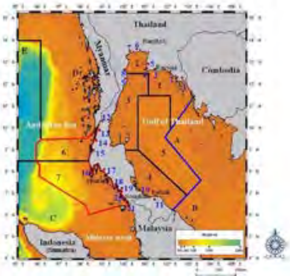
By gear, area, year, month, day and boats **including 0 catch(important)**

For example.. for GILL and Moro Gulf (**Statistical area 10**) ...

				← catch		→	← effort		→
Year	**Month**	**Day**	**Boat**	**KAW**	**LOT**	**OTH**	**hour**	**haul**	**day**
1999	12	25	Val-maru	0	0	2,345	23	5	2
2012	1	19	Grace maru	33	0	568	12	☐ (no data)	☐ (blank)

Template to collect CPUE (Catch+Effort) data (2)

Example of fishing Grounds



Fishing ground (statistical area) in Thai waters
(Example of the fishing ground)
If you don't have fishing ground information, then you can use the landing site.

Important : 0 (zero catch)

If you don't report 0 catch , we will have overestimated nominal CPUE then Standardized CPUE

				← catch		→	← effort		→
Year	**Month**	**Day**	**Boat**	**KAW**	**LOT**	**OTH**	**hour**	**haul**	**day**
1999	12	25	Val-maru	(0)	(0)	2,345	23	5	2
2012	1	19	Grace maru	33	(0)	568	12	☐ (no data)	☐ (blank)

Need the Data processing skill using..

- Excel/ACCES : good for data process for **small + medium size data**

Various functions (sort, filter, pivot tables....) → useful and Powerful

- Users friendly

If you need to process **large data (e.g. million data set),** you need special programs such as Java, C++, Script, SQL-like Query...

Don't try data process of large data by excel..
Otherwise you will get stiff shoulder
and may get troubles with your partners.

Another important points data process

- Don't forget data MASAAGE (QC)
  (Former SEAFDEC SG loves this word. Maybe the new SG, too?)

Range Check: year, month, day, latitude, longitude..
GIS check locations

GIS mapping (important)

Visualization of the data → Important
(one of data massage techniques)

After mapping your data
You may find Kawakawa at Mt. Pinatubo??
(barbequed kawakawa)

Barbecued Kawakawa (location errors)

(location errors)
you may find Pacific Yellowfin tuna on Mt Fuji

Data need massage to release stiff shoulder (errors)
then you (data) will be happy for accurate analyses
such as CPUE standardization＋ASPIC

CPUE: Sample size is also important

If you have catch and effort data for many years,
but some might be from a very few sampling or bycatch

Then you can not use such CPUE

We need to investigate sample size
before CPUE standardization

Some example : Philippines CPUE data west Philippines Sea
investigation on sample size by gear type PS looks OK

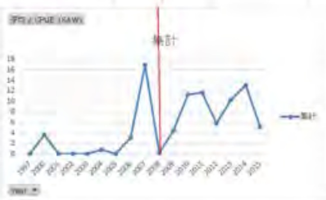
Year	Dagnet	Bottom gillnet	Danish seine	Drift gillnet	Handline	Jigger	Multiple Handline	Multiple hook and line	Other trawl	Purse seine
1997										23
1998	118									
1999	252									
2000	191				4					88
2001	205				16					80
2002										106
2003	87								117	105
2004	213		20						17	119
2005	279	15	76	1	7	9		25	26	175
2006	38		13							88
2007	169		7				8			227
2008	68		71						1	309
2009	47		103							181
2010	43		77							256
2011			59							185
2012			50							121
2013			42							108
2014			51		146		158			153
2015			44		118	1	97			211

Processed nominal CPUE data
PS data n=2,692 16 years data (1997 and 2001-2015) : LOOKS fine

ground_des	landing_center	gear_des	Year	Month	Day	vesselname	Effort	UnitEffort	KAW	LOT	OTHER	CPUE (KAW)
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	01	EO CLAIMS	1	days	0	0	850	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	01	EO CLAIMS	2	days	0	0	6375	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	01	EO CLAIMS	3	days	0	0	818.125	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	01	EO CLAIMS	4	days	0	0	244.375	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	04	EO CLAIMS	1	days	0	0	1735.423	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	04	EO CLAIMS	2	days	0	0	2163.571	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	07	EO CLAIMS	1	days	0	0	2571.431	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	07	EO CLAIMS	2	days	0	0	[illegible]	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	07	EO CLAIMS	3	days	0	0	1718.574	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	07	Saint Joseph 1	1	days	0	0	931.0073	0
West Philippine Sea	Balogo_Macalvis, Masinloc, Zambales	Purse seine	1997	04	07	Saint Joseph 1	2	days	0	0	621.2049	0

After data process.. It was found that....
many 0 or low catches in first 12 years (1997-2008) : **unstable (bycatch)**
last 7 years (2009-2015) **target stable** : by 6 years are too short

行ラベル	平均 / CPUE(KAW)
1997	0
2000	3.672895887
2001	0
2002	0
2003	0
2004	0.796610169
2005	0
2006	3.100775194
2007	16.989721
2008	0.194174757
2009	4.531689864
2010	11.32827522
2011	11.73946142
2012	5.845590491
2013	10.26545181
2014	13.07477878
2015	5.104615368
総計	**6.254912907**



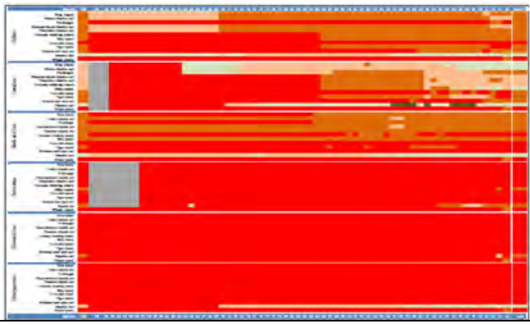
Another important point
After data collection
Data catalogue is important to know the situation

- From the catalogue we can learn

→What gear types of CPUE are available
→Sample size
→available years

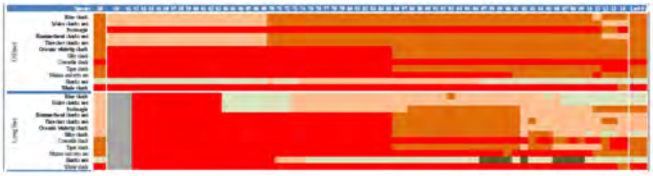
After data collection
Data catalogue is important to know the situation

Some crazy example   Guess what is this ????????



Some crazy example : AVAILABILITY OF CATCH DATA FOR SHARKS BY GEAR(IOTC) BLOOD TABLE

Key
- No catch data available at all
- Catch data available from less than 10% of the fleets for which nominal catches of IOTC species are available
- Catch data available from 10% to 30% of the fleets for which nominal catches of IOTC species are available
- Catch data available from 30% to 75% of the fleets for which nominal catches of IOTC species are available
- Catch data available from more than 75% of the fleets for which nominal catches of IOTC species are available



Data process TWO other Important issues

(1) Data massage or QC (Quality Control) (Massage)
Always Check errors, outliers etc.

(2) Effective managements (Message: where)
to NAME folders, files and Excel sheets
keep original file : don't use you will loose information (and cry)
Copy work file and use the work files

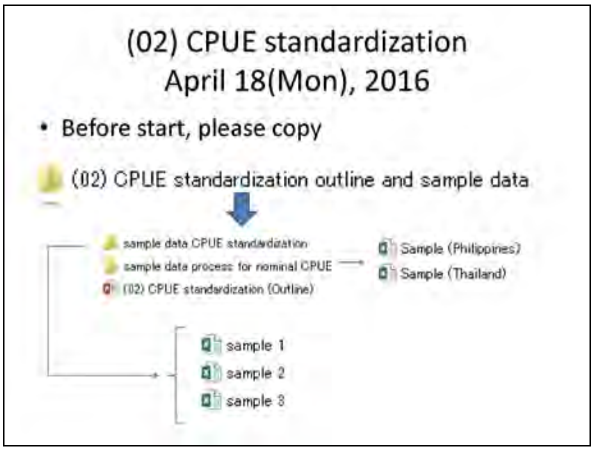
Summary

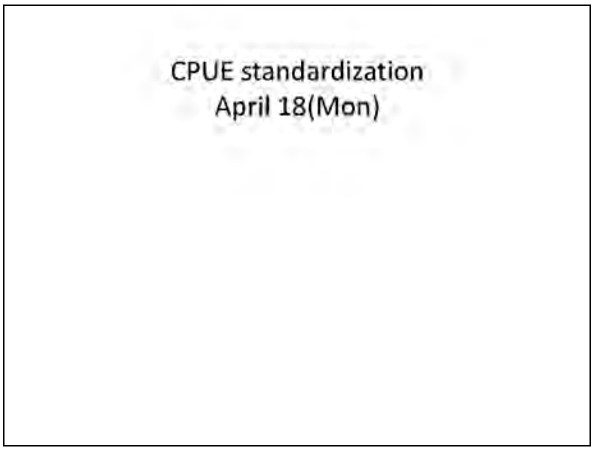
- Data collection (general and ASPIC)
- Progress of the data collection
- Data processing skills
- Data massage(QC)? And message (folders) management
- Sample size for analyses (example: CPUE standardization)
- Data catalogue (to see the global situation)

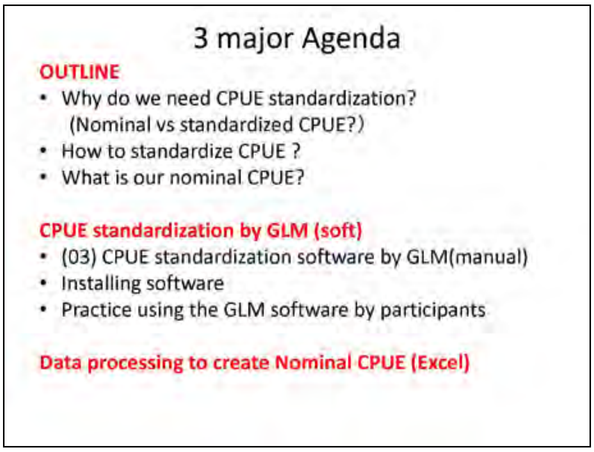
簡単な例題2件　練習用

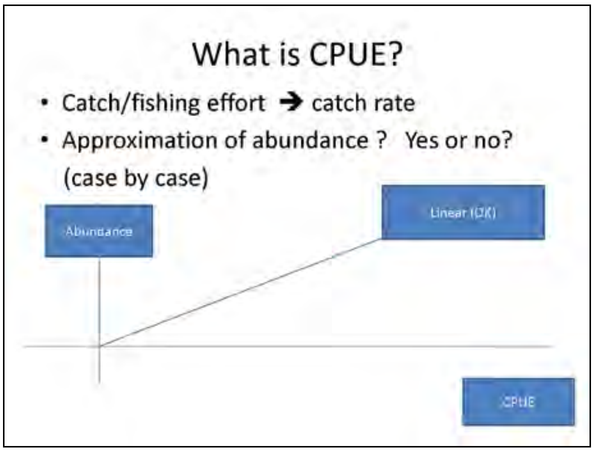
Summary

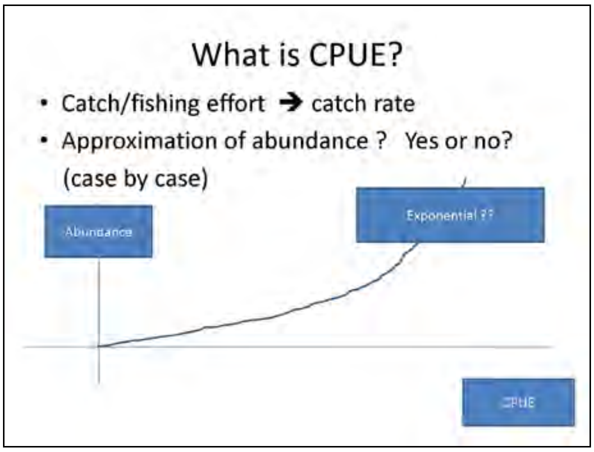
CPUE standardization

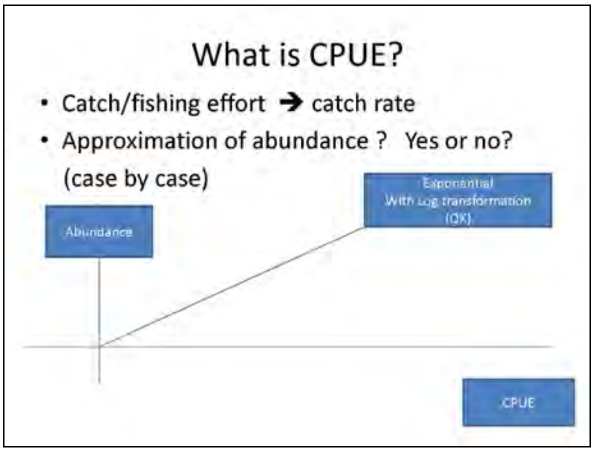










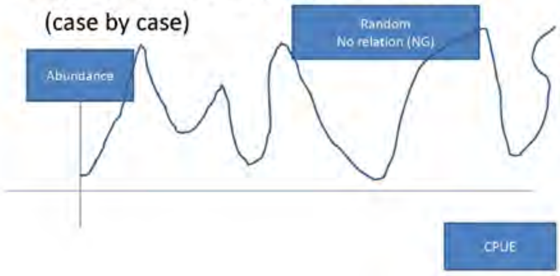


What is CPUE?

- Catch/fishing effort ➔ catch rate
- Approximation of abundance ? Yes or no?
  (case by case)

What is CPUE?

- Catch/fishing effort ➔ catch rate
- Approximation of abundance ? Yes or no?
  (case by case)



CPUE is proxy of the abundance

- Yes if CPUE can represents the linear relation to the abundance (with transformation)
- There are a number of transformation (equations)

Why do we need to standardize nominal CPUE?
2 reasons

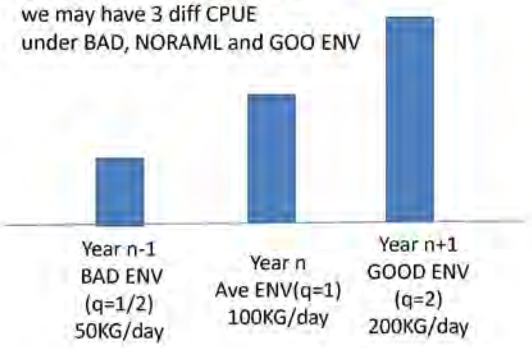
(1) To filter biases in N_CPUE

Nominal CPUE : raw data [Catch/Effort]

Many factors affect nominal CPUE
e.g., Year, season, area, ENV, evolution of gears..
Gear configuration (targeting)
➔ **Produce BIAS**

(2) To learn relation between CPUE vs. abundance

Simple example **RE: biases**
same area in 3 different years
we may have 3 diff CPUE
under BAD, NORAML and GOO ENV



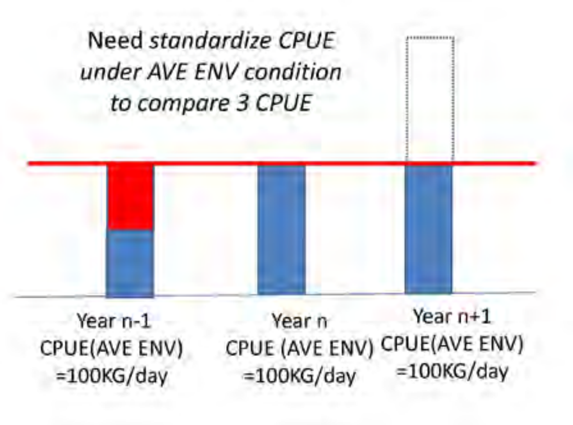
q

Catchability : efficiency of catch

Boat A q= 1 vs. Boat B q= 2

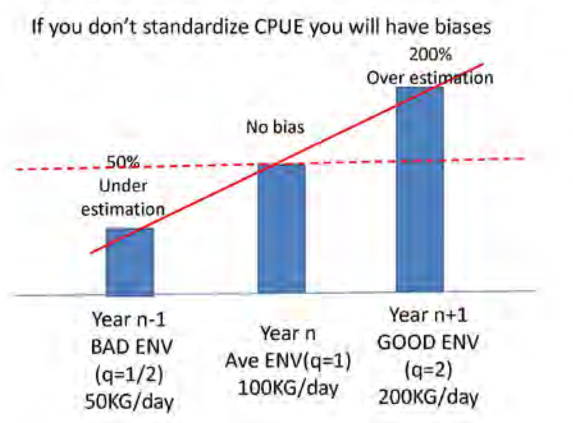
Boat B can make 2 times of catch
in the same fishing effort

Boat B 2 time efficiency



After standardizing CPUE

3 year of CPUE (n-1, n and n+1) are actually same level



But reality is very complicated many factors affect nominal CPUE

Major factors affecting nominal CPUE

Year, Season and Area

There are many other factors

ENV, Skipper ability, evolution of fishing gear etc..

But reality is very complicated many factors affect nominal CPUE

For this time we consider these 3 major factors
Year, Season and Area
as a first step….

Actually these 3 factors explain major biases based on many case studies

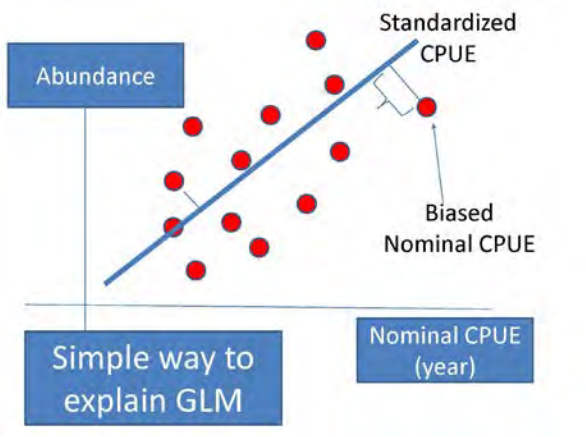
Even you add other factors their contribution are minor

How to proceed CPUE standardization

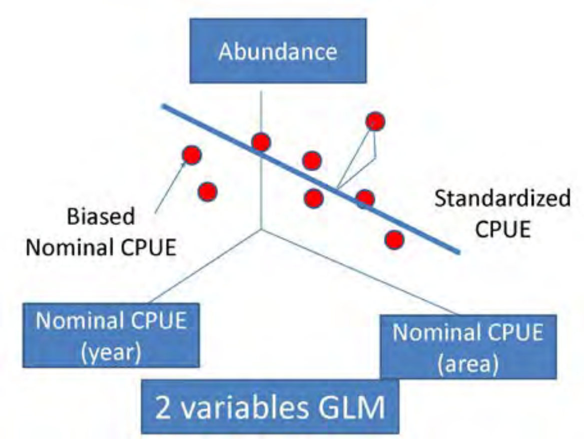
For this bias adjustment (i.e., CPUE standardization)
we use the statistical method

GLM: Generalized Linear Model
This is like simple regress

There are many other methods
for different data (error) structure..
(GAM, binominal model, regression tree..)
(future)(beyond our scope)
But the GLM is the standard approach



If you have more than 2 variables
(multivariate situation)
you have more complex way to
compute to standardize CPUE



What happen if 3 or more variables ?

- Can not draw images ...

- More complicated to compute
  So we need statistical package Software

statistical package Software
multivariate statistical analyses

- SAS $$(high)
- SPSS $$ (medium)
- BMDP $$ (medium)
- R free (Flexible)
- Statistica $$ (low)
- Excel $$ (low) difficult to do

Our GLM model

Log_(N_CPUE+ constant)
= (mean)+[yr]+[Season:Q]+ [Area] + error

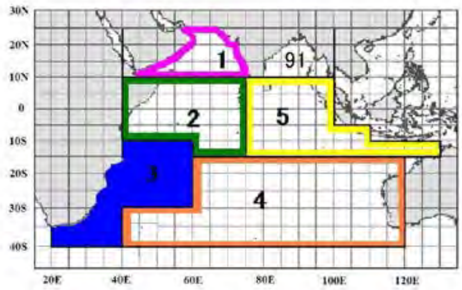
constant : 10% of N_CPUE
(Nishida & Campbell, 1998)
To avoid the log(0) problem without affecting the N_CPUE

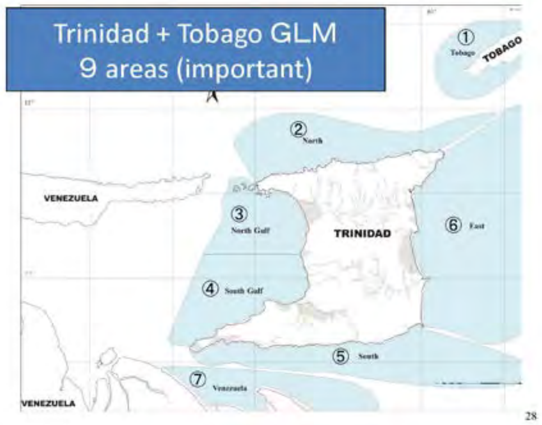
Area

Fishing area : artisanal fisheries
➔ statistical area (Polygon) (see example)

➔ Tuna longline
Grid 1x1 or 5x5 area (log book)

YFT (tuna LL)





Evaluation of STD_CPUE vs. global Catch

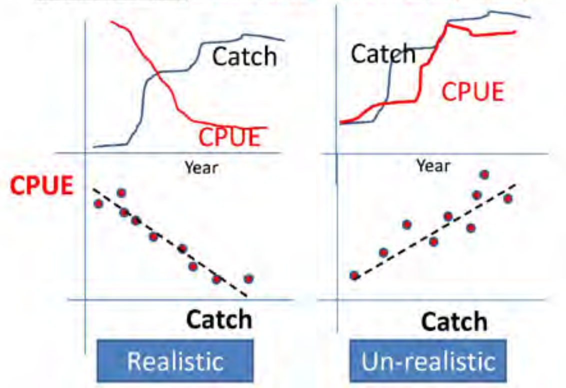
- Important to evaluated realistic CPUE

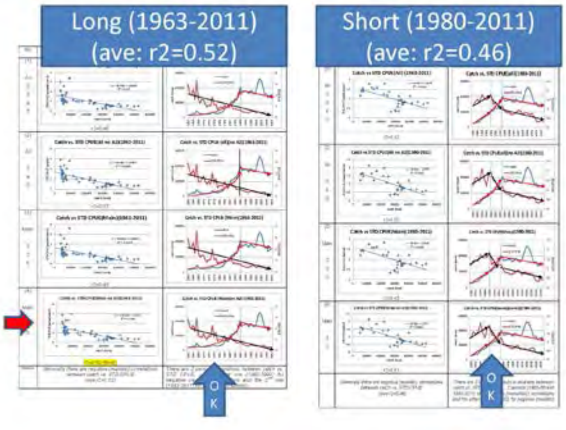
(1) Check Sample size

Gear , boat, area, month (season)

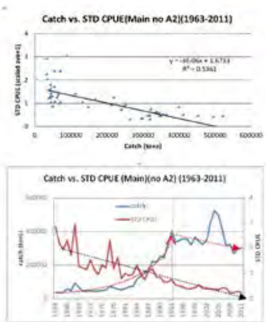
Select with large sample size

(2) Check relation Catch vs. CPUE => inverse CORR (realistic)





Selected STD CPUE (Main no area 2)



How to proceed the GLM

First we need to make nominal CPUE data set (we will practice later)

Simple example

year	Q	area	catch(kg)	effort (haul)	CPUE
1995	1	NC	45	9	5 (kg/haul)

Data set (simple sample)

YR	Q	area	KAW CPUE (KG/HAUL)
2006	1	6	26.88
2006	1	6	0.00
2006	1	6	0.00
2006	2	6	163.35
2006	2	6	314.64
2006	2	6	37.69
2006	3	6	237.87
2006	3	6	429.18
2006	3	6	18.69
2006	4	6	29.62
2007	1	6	0.00
2007	1	6	0.00

Some example...(more complicated) (Japan tuna LL: Swordfish N_CPUE)

yr	hpb	mo	day	lat	ns	long	ew	hook	swo_n	area	swo_w	eda	v	miki	a	DPI	IOI
1990	13	12	2	26	2	40	1	2520	0	89	0	2	KASUGA MARU NO.18	2	7	-0.38	-0.68
1990	13	12	3	26	2	40	1	2520	0	89	0	2	KASUGA MARU NO.18	2	7	-0.38	-0.68
1990	13	12	4	26	2	40	1	2520	0	89	0	2	KASUGA MARU NO.18	2	7	-0.38	-0.68
1990	7	12	4	27	2	39	1	2660	0	89	0	2	KASUGA MARU NO.88	2	7	-0.38	-0.68
1990	7	12	5	27	2	39	1	2660	0	89	0	2	KASUGA MARU NO.88	2	7	-0.38	-0.68
1990	7	12	9	27	2	39	1	2660	0	89	0	2	KASUGA MARU NO.88	2	7	-0.38	-0.68

STD CPUE smooth out N_CPUE

Installing the software

Please refer to

(3) Manual of CPUE standardization by GLM

SPECIFICATION 1

- This software was developed using "R computer language" to perform nominal CPUE (Catch-Per-Unit-of-Effort) standardization by GLM (Generalized Linear Model) from fisheries data.

SPECIFICATION 2

- Nominal CPUE means Catch/Fishing effort, where catch and fishing effort data in the original (raw) data.
- GLM is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution.

SPECIFICATION 3

- This software can conduct "GLM" and create relevant outputs using menus without making any programming.
- Main input (covariates) are "Year" effect, "season" effect, "area" effect. As for outputs, standard GLM outputs created by "R language" will be automatically produced for each GLM run.

SPECIFICATION 4

- Major outputs are (a) ANOVA table, (b) Coefficients of estimated parameters, (c) Estimated annual standardized CPUE, (d) residual plots and (e) Q-Q plots.

Important note

This soft was just made last week (1st version)

Covariates (year, season and area) by GLM

In the future

with interaction terms

+

Other models

(GAM, Negative binominal model, etc.)

Important note This soft was just made last week (1st version)

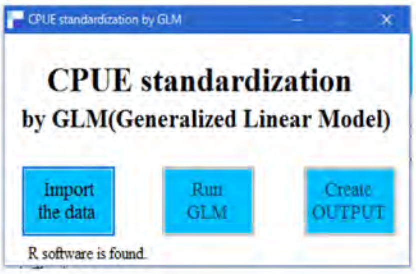
- We may need some improvements.
- We will note and later we will re-distribute the improved version after the training is completed.

How to set up Nominal CPUE data?

We need year, Season (Q or MO) and fishing area using Excel book file

	A	B	C	D
1	YR	Q	area	CPUE
2	2006	1	2	68.93996
3	2006	1	2	25.92267
4	2006	1	2	5.940594
5	2006	1	3	7.407407
6	2006	1	3	22.37979
7	2006	1	3	66.28212
8	2006	1	4	49.85229
9	2006	1	4	22.55489
10	2006	1	4	2.775675
11	2006	1	5	16.50444
12	2006	1	5	22.41932
13	2006	1	5	37.98127
14	2006	2	1	7.764953

Main menu



Try 3 sample data

How to interpret the outputs (most important)

- You will get 2 output files
- One Word file and One Excel file

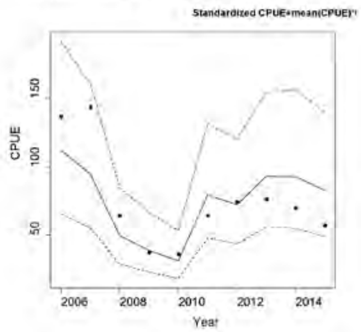
Word file: 4 types of output

[1] ANOVA table

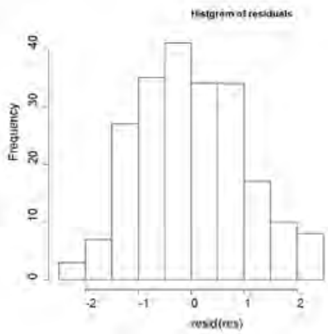
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	Adjusted R2
as. factor (Data$YR)	9	33. 758	3. 7509	3. 3986	7e-04	NA
as. factor (Data$Q)	3	48. 2649	16. 0883	14. 5775	0	NA
as. factor (Data$area)	1	0. 5977	0. 5977	0. 5415	0. 4626	NA
Residuals	202	222. 936	1. 1036	NA	NA	0. 2234

[2] Graph including 4 annual figures

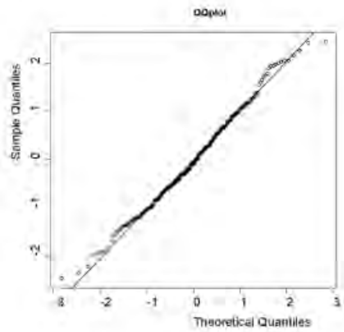
OBS (nominal) CPUE	Dot
EST (standardized) CPUE	Solid line
C: Lower limit of 95% CI	Dot line (Lower)
D: Upper limit of 95% CI.	Dot line (upper)



[2] Histogram of residuals



[3] QQ plot



How GLM is conducted by R?

```
#First, please set the working directory. This is the place of the file.
setwd("C:/")

#==========================================================#
#Loading data. Note that the order of column should be set as the name of the sample program.
#In other words, prepare these column by this order, "Year", "season", "area" and "CPUE", although
#the name of the column is not the matter.
#==========================================================#

Data <- read.delim("GOT KAW.txt", header=T)
colnames(Data) <- c("YR", "Q", "area", "CPUE")

#Model fitting by linear model.
#Here, we added the mean value of CPUE by 0.1 (i.e., mean(CPUE)*0.1) because there were a lot of zero values
res <- lm(log(Data$CPUE+mean(Data$CPUE*0.1)) ~ as.factor(Data$YR) + as.factor(Data$Q) + as.factor(Data$area))
summary(res)

###Calculating estimated CPUE+mean(CPUE)*0.1 and its 95% confidential interval###
Data$Estimated_CPUE <- exp(predict(res)+sd(summary(res)$residuals)^2/2)
Data$Estimated_CPUE975 <- exp(predict(res)+predict(res, se.fit=T)$se*1.96+sd(summary(res)$residuals)^2/2)
Data$Estimated_CPUE025 <- exp(predict(res)-predict(res, se.fit=T)$se*1.96+sd(summary(res)$residuals)^2/2)
```

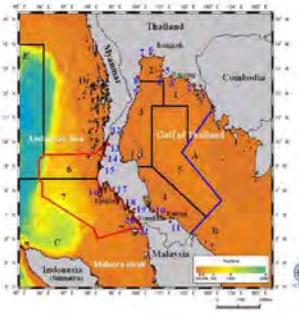
How GLM is conducted by R?

```
#If you want, you can check the estimated log(CPUE+mean(CPUE)*0.1) and its 95% confidential intervals
#plot(log(Data[, 4]+mean(Data[, 4])*0.1))
#points(predict(res), type="l")
#points(predict(res)+predict(res, se.fit=T)$se*1.96, type="l", lty=2)
#points(predict(res)-predict(res, se.fit=T)$se*1.96, type="l", lty=2)

#If you want, you can check the estimated CPUE+mean(CPUE)*0.1 and its 95% confidential intervals
#plot(Data[, 4]+mean(Data[, 4])*0.1, ylab="CPUE", cex.lab=1.5, cex.axis=1.5, pch=16)
#points(Data$Estimated_CPUE, type="l", lwd=1.2)
#points(Data$Estimated_CPUE025, type="l", lty=2, lwd=1.2)
#points(Data$Estimated_CPUE975, type="l", lty=2, lwd=1.2)

#Now, we estimated CPUE+mean(CPUE)*0.1 by year, area and season. However, we only need the CPUE by year.
#Therefore, the estimated CPUE was aggregated to yearly CPUE
Obs_CPUE <- aggregate(Data$CPUE+mean(Data$CPUE)*0.1~ Data$YR, FUN=mean, na.rm=T)
Est_CPUE <- aggregate(Data$Estimated_CPUE~ Data$YR, FUN=mean, na.rm=T)
Est_CPUE025 <- aggregate(Data$Estimated_CPUE025~ Data$YR, FUN=mean, na.rm=T)
Est_CPUE975 <- aggregate(Data$Estimated_CPUE975~ Data$YR, FUN=mean, na.rm=T)

#Estimated yearly CPUE+mean(CPUE)*0.1 and its 95% confidential interval.
#Bold line is estimated yearly CPUE+mean(CPUE)*0.1 and black points are observed yearly CPUE+mean(CPUE)*0.1.
#Break lines show the 95% confidential interval.
setwd("C:/") #the place of output file
pdf("Outputs GOT KAW.pdf") #output as PDF file
plot(Obs_CPUE[, 1], Obs_CPUE[, 2], ylim=c(min(Obs_CPUE, Est_CPUE025[, 2]), max(Obs_CPUE[, 2], Est_CPUE975[, 2])),
    xlab="Year", ylab="CPUE", cex.lab=1.5, cex.axis=1.5, pch=16, main="Standardized CPUE+mean(CPUE)*0.1")
points(Est_CPUE[, 1], Est_CPUE[, 2], type="l", lwd=1.5)
points(Est_CPUE025[, 1], Est_CPUE025[, 2], type="l", lty=2, lwd=1.5)
points(Est_CPUE975[, 1], Est_CPUE975[, 2], type="l", lty=2, lwd=1.5)
```

```
#Histgram of residuals (differences between estimated and observed CPUE)+mean(CPUE)*0.1)
hist(resid(res), cex.lab=1.5, cex.axis=1.5,main="Histgram of residuals")

#QQplot
qqnorm(resid(res),   cex.lab=1.5, cex.axis=1.5, main="QQplot")
qqline(resid(res))
dev.off()

#Anova table
resanova <- anova(res, test="F")

#R2
r2 <- summary(res)$adj.r.squared

M <- matrix(NA, nrow=nrow(resanova), ncol=(ncol(resanova)+1))
M[, 1] <- round(resanova[, 1], 4)
M[, 2] <- round(resanova[, 2], 4)
M[, 3] <- round(resanova[, 3], 4)
M[, 4] <- round(resanova[, 4], 4)
M[, 5] <- round(resanova[, 5], 4)
M[nrow(M), 6] <- round(r2, 4)
rownames(M) <- rownames(resanova)
colnames(M) <- c(colnames(resanova), "Adjusted R2")

#Anova table and adjusted R2 are output as CSV file
write.csv(M, "ANOVA and r2 GOT KAW.csv")

#The standardized and nominal CPUE
M2 <- matrix(NA, nrow=nrow(Obs_CPUE), ncol=4)
rownames(M2) <- Obs_CPUE[, 1]
M2[, 1] <- Obs_CPUE[, 2]
M2[, 2] <- Est_CPUE[, 2]
M2[, 3] <- Est_CPUE025[, 2]
M2[, 4] <- Est_CPUE975[, 2]
colnames(M2) <- c("Observed CPUE+0.1*mean(CPUE)", "Estimated CPUE+0.1*mean(CPUE)", "2.5%", "97.5%")
write.csv(M2, "Standardized CPUE0.1mean(CPUE) GOT KAW.csv")
```

Practice data process to create nominal CPUE

Thailand CPUE
Gulf of Thailand and Andaman Sea

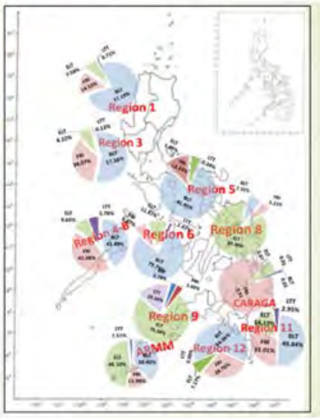


Philippines CPUE

Spp. Dominance:

- **longtail tuna** – Region 4B, 9, 11
- **eastern little tuna** – Regions 8, 9 and ARMM.

Data received Region1-6 and 11 (not major area for LOT and KAW)
➔ 0 catch



Philippines C+E data Received (Region 1-5+11)

Data are not from major fishing grounds
(LOT:4B+9+11)
(LOT: even major area ➔ very few catch)
(bycatch) (not possible to apply by GLM)

(KAW: 8+9+ARMM)
bycatch area Many 0 catches
(not possible to apply by GLM)

If you apply GLM for CE data with many 0 catches

We will have very unstable nominal CPUE
As well as standardized CPUE

Not realistic
Can not be used for ASPIC
and any other stock assessment models

There are some techniques for bycatch (many 0 catch) CPUE standardization (beyond this training course)

% of 0 (zero) catch	Model
less than 20%	GLM
20-60%	negative binominal
60% or more	0 inflated 2 set negative binominal

There are many other references (future considerations)

- Prof. Shono (Supopon's teacher)

Reference (2004) in Japanese

A Review of Some Statistical Approaches Used for CPUE Standardization

Hiroshi SHONO

Bull. Jpn. Soc. Fish. Oceanogr.

Anyway

- We practice Thai and Philippines catch and effort data

Annex 4

CPUE Standardization by GLM

(Menu-driven software) (1st version)
Manual

April, 2016

Developer: Dr. Kiyoshi ITOH
Environmental Simulation Laboratory (ELS)
2F, Noble Building, 2 -4 –1, Arajuku,
Kawagoe-City, Saitama, Japan 350-1124
Phone: 81(Japan)-49-242-9262, FAX: 81(Japan)-49-241-2442
E-mail: Itoh@esl.co.jp URL: http://www.esl.co.jp

Technical support: Dr Tom Nishida
Resources Person
SEAFDEC Neritic tuna Stock Assessment Project
National Research Institute of Far Seas Fisheries (NRIFSF)
Japan Fisheries and Education Agency
5-7-1, Orido, Shimizu-Ward, Shizuoka-City, Shizuoka, Japan 424-8633
E-mail: aco20320@par.odn.ne.jp Phone/FAX (direct):81(Japan)-54-336-5834
URL: http://fsf.fra.affrc.go.jp/

Specification

This software was developed using “R computer language” to perform nominal CPUE (Catch-Per-Unit-of-Effort) standardization by GLM (Generalized Linear Model) from fisheries data. Nominal CPUE means Catch/Fishing effort, where catch and fishing effort data area the original (raw) data. GLM is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution.

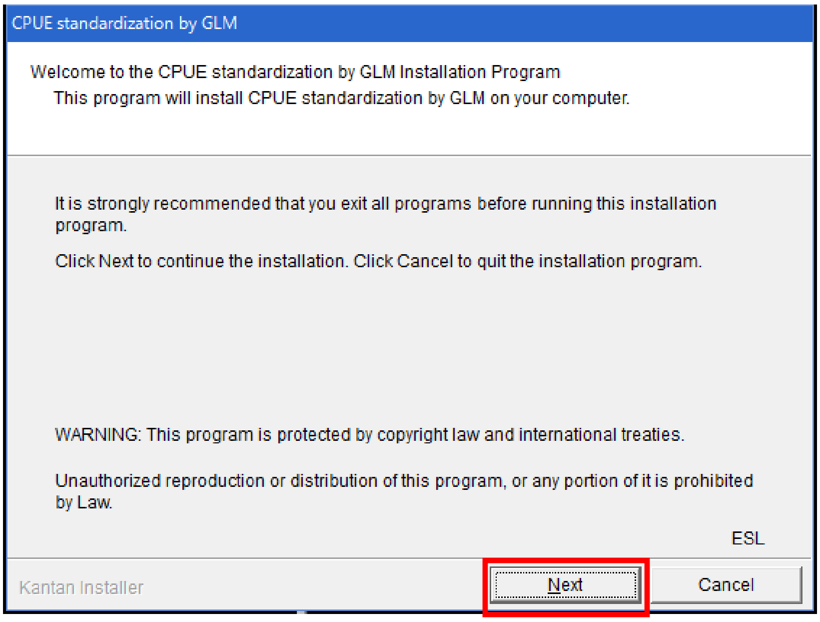
This software can conduct “GLM” and create relevant outputs using menus without making any programming. Main input (covariates) are “Year” effect, “season” effect, “area” effect. As for outputs, standard GLM outputs created by “R language” will be automatically produced for each GLM run. Major outputs are (a) ANOVA table, (b) Coefficients of estimated parameters, (c) Estimated annual standardized CPUE, (d) residual plots and (e) Q-Q plots.

1. Install

Down load the software from http://ocean-info.ddo.jp/kobeaspm/glm/cpueglm_setup.exe

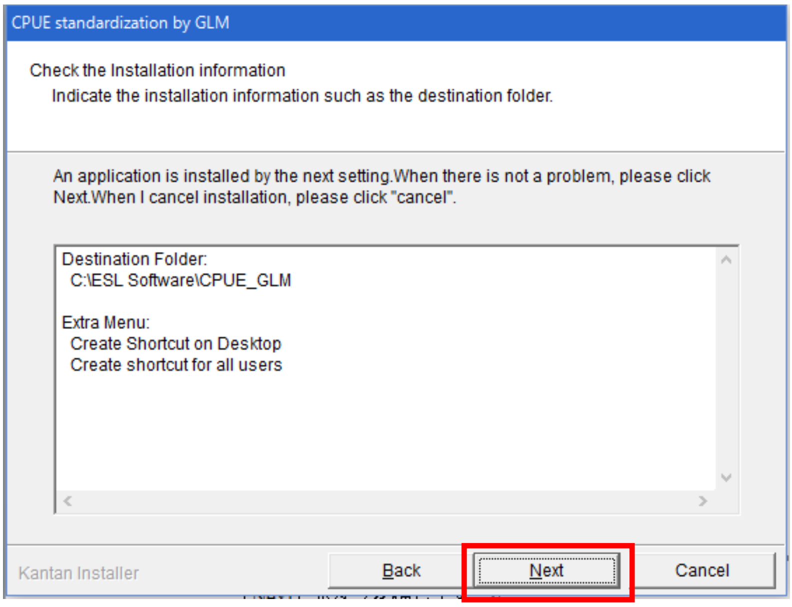
It will take about 5 minutes depending on performance to download the setup program (cpueglm_setup.exe) (49.9 MB) shown as below, then double click.

Then follow steps as below:



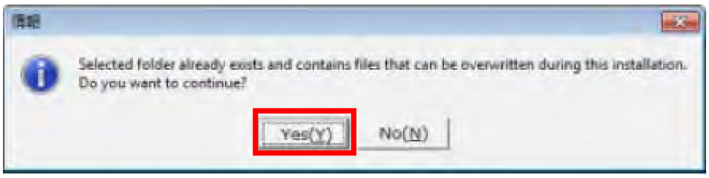
Click "Next"

Install folder

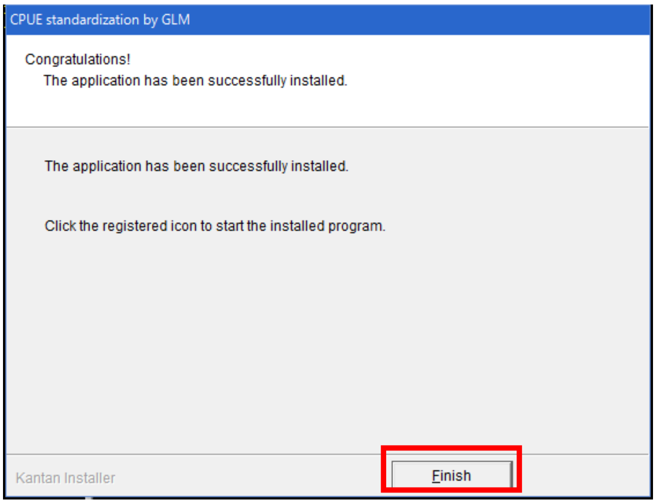


Click "Next"

Confirm the folder for installment

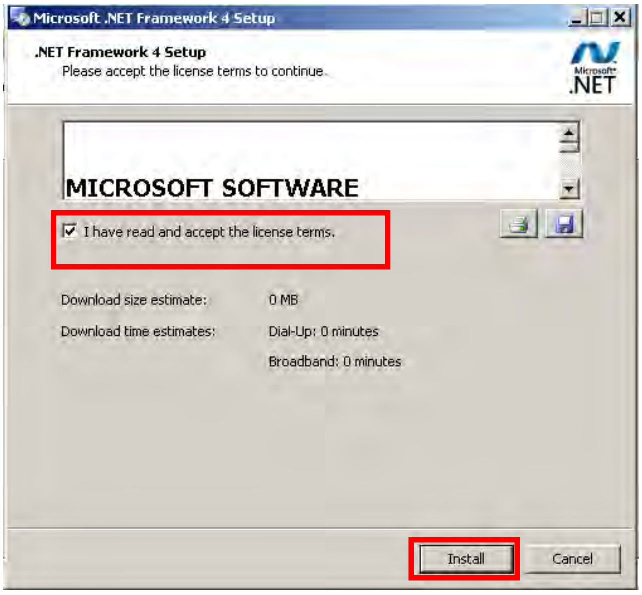


Completion of the installment



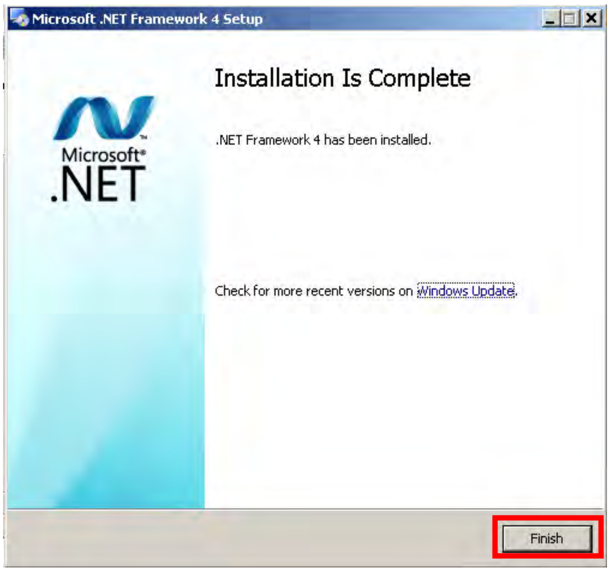
Click "Finish"

Install Microsoft .Net Framework 4



Check "I have read and accept the license terms" and click "Install".

Completion of installment of Microsoft .Net Framework 4



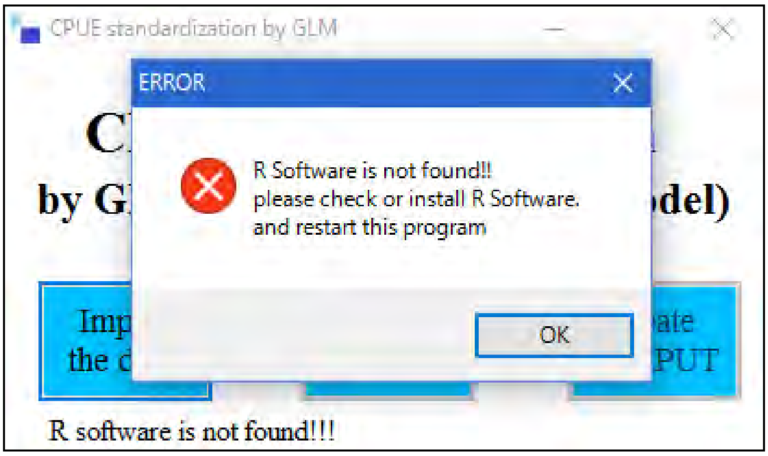
Click “Finish”

Make sure the icon “CPUE standardization by GLM” in the desktop

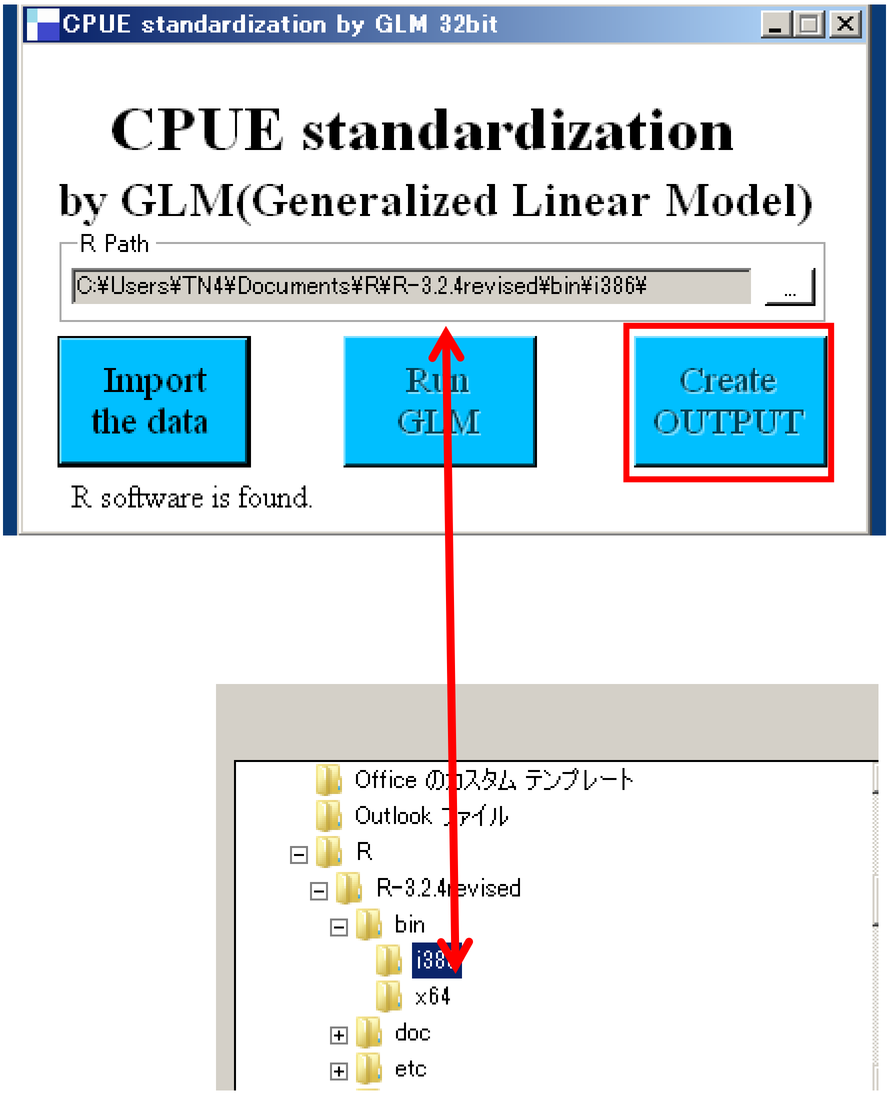
1. STARTING THE SOFTWARE

(1) Double click “CPUE standardization by GLM”

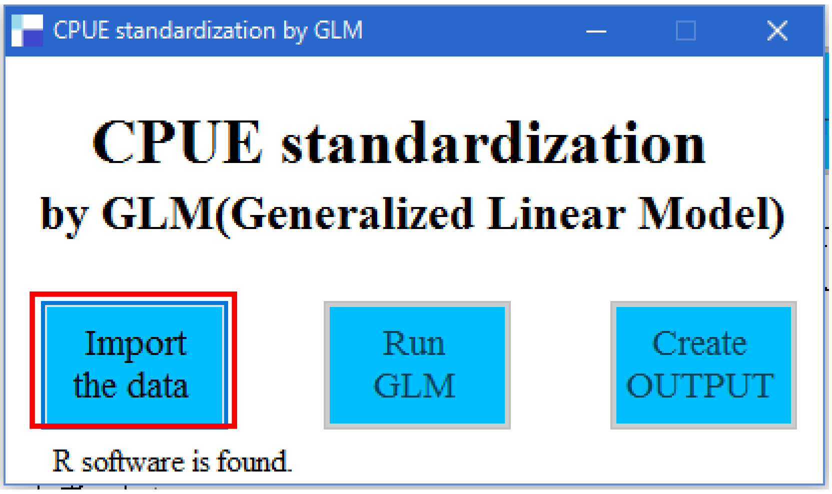
If the R program is not found, you will see the message (next page) then install “R” program and re-start.



(2) Locate R path by clicking the button



(3) Import the data.



Click “Import the data”.

(4) Select the nominal CPUE data set

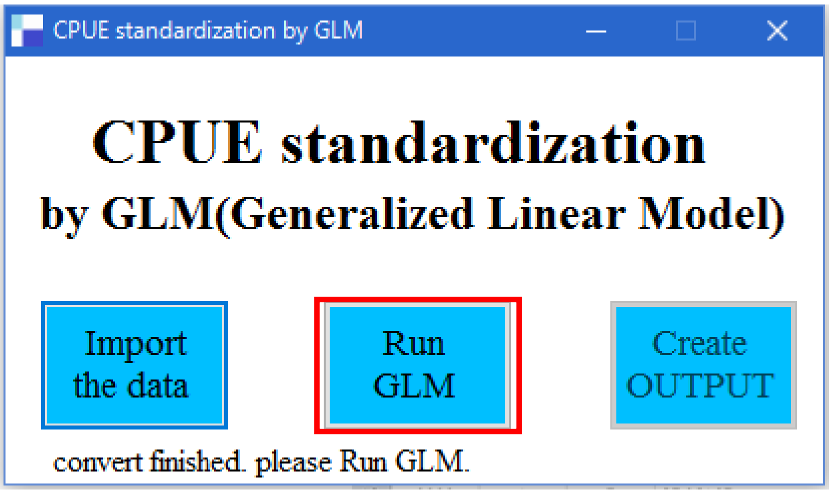
	A	B	C	D
1	YR	Q	area	CPUE
2	2006	1	2	68.93996
3	2006	1	2	25.92267
4	2006	1	2	5.940594
5	2006	1	3	7.407407
6	2006	1	3	22.37979
7	2006	1	3	66.28212
8	2006	1	4	49.85229
9	2006	1	4	22.55489
10	2006	1	4	2.775675
11	2006	1	5	16.50444
12	2006	1	5	22.41932
13	2006	1	5	37.98127
14	2006	2	1	7.764953

Select Excel file (.xlsx) like the above file (example).

Note: To create the nominal CPUE data set. As shown above, create the data set by the excel book file (.xlsx) including:

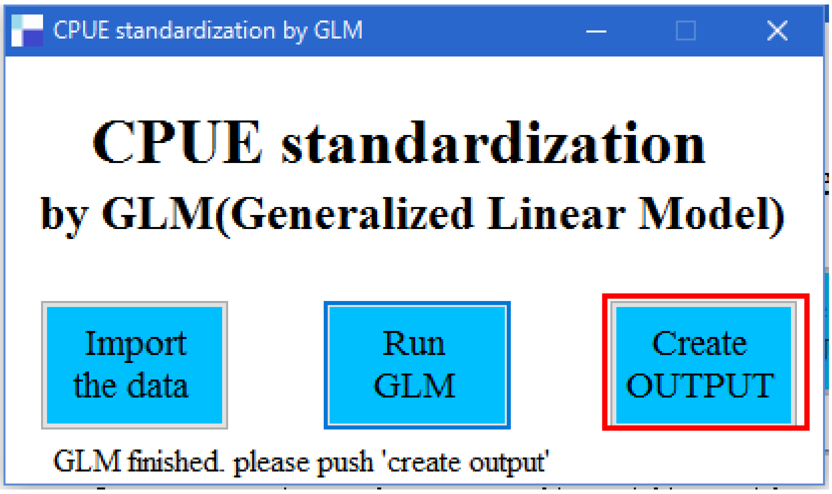
A year,
B season (month or quarter),
C area
D nominal CPUE

(5) Run GLM by R



Click “RUN GLM”, proceed running GLM

(6) Create output



Click “Create OUTPUT”, create reports.

(7) Report (OUTPUT) files

In the same folder of the input data, you will get two output files as below:

<u>Excel book file (GOT LOT_OBS+EST CPUE with 95% CI.xlsx) includes flowing annual figures:</u>

A: OBS (nominal) CPUE
B: EST (standardized) CPUE and its 95% CI (Confident Interval).
C: Lower limit of 95% CI.
D: Upper limit of 95% CI.

	A	B	C	D	E
1		Observed	Estimated	2.5%	97.5%
2	2006	136.9519	112.1606	65.66916	191.6172
3	2007	143.8965	94.39505	55.26758	161.2663
4	2008	64.28126	49.63898	29.06324	84.80416
5	2009	37.52347	38.91343	22.78351	66.48043
6	2010	35.97002	31.26225	18.30381	53.40902
7	2011	64.52363	79.36296	47.76027	131.8869
8	2012	74.67831	72.25503	43.48275	120.0748
9	2013	76.37469	93.04585	55.99457	154.6254
10	2014	70.05534	92.68391	54.86359	156.5838
11	2015	57.06242	82.79188	49.09276	139.6411

If you process this sheet, you will see the whole picture as shown next page. The graph of these 4 variable are provided in the output as shown in page 11.

	Observed CPUE+0.1*mean(CPUE)	Estimated CPUE+0.1*mean(CPUE)	2.5%	97.5%
2006	136.9519022	112.1605897	65.66916031	191.6172475
2007	143.8965225	94.39505442	55.26757642	161.2662751
2008	64.28125713	49.63897658	29.06323799	84.80415528
2009	37.52347108	38.91342957	22.78351292	66.48043031
2010	35.97001842	31.26225221	18.30380758	53.40901592
2011	64.52362761	79.36295919	47.76026559	131.8869098
2012	74.67831289	72.25503296	43.48274812	120.0748197
2013	76.37469376	93.04584941	55.99456629	154.625403
2014	70.05534459	92.68390515	54.86359411	156.583782
2015	57.06242023	82.7918825	49.09275571	139.6411448

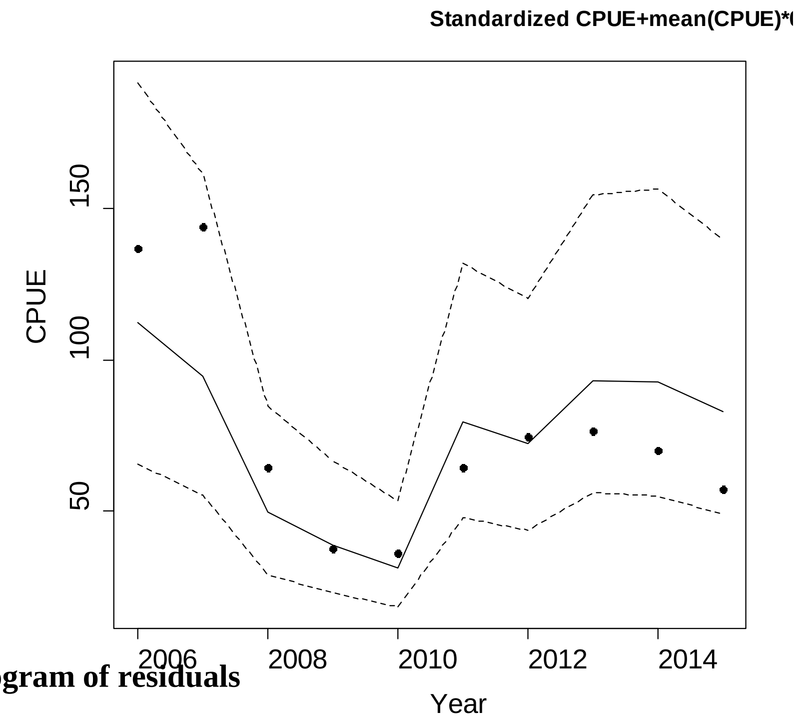
Word file (GOT LOT_OUTPUT.docx) includes flowing 4 reports:

[1] ANOVA table

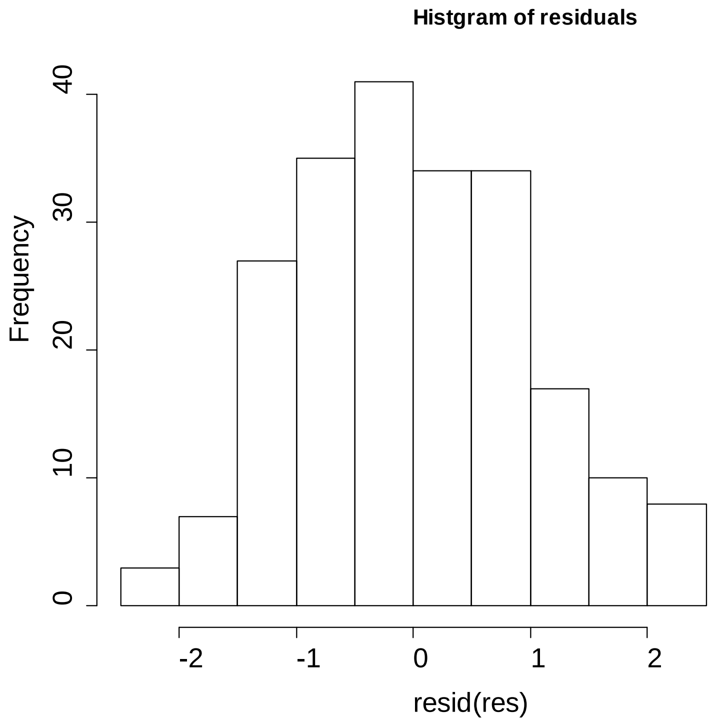
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	Adjusted R2
as.factor (Data$YR)	9	33.758	3.7509	3.3986	7e-04	NA
as.factor (Data$Q)	3	48.2649	16.0883	14.5775	0	NA
as.factor (Data$area)	1	0.5977	0.5977	0.5415	0.4626	NA
Residuals	202	222.936	1.1036	NA	NA	0.2234

[2] Graph including 4 annual figures

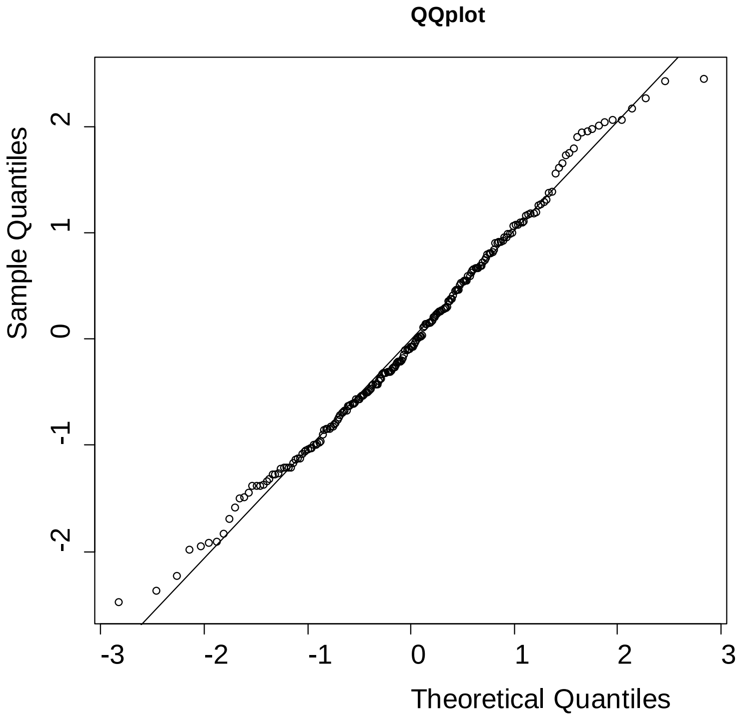
OBS (nominal) CPUE	Dot
EST (standardized) CPUE	Solid line
C: Lower limit of 95% CI	Dot line (Lower)
D: Upper limit of 95% CI.	Dot line (upper)



[2] Histogram of residuals



[3] QQ plot


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

Annex 5

ASPIC outline

April 19 (Tue), 2016 Day 3

- (04) ASPIC outline

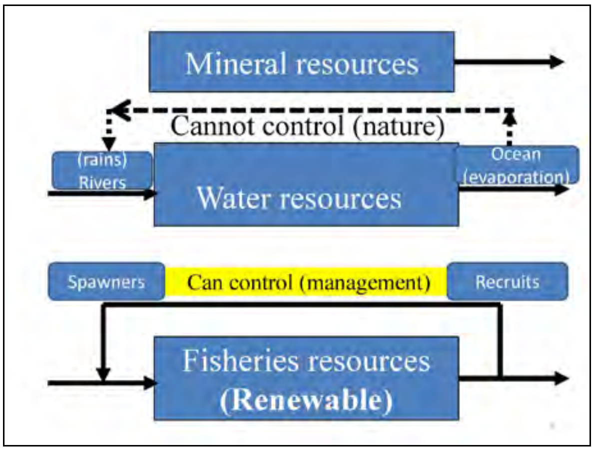
Stock assessments (SA) using ASPIC

Why we need stock assessments?

To understand **the status of the stock**
in order to manage the fisheries resources safely
for sustainable utilization

Fisheries resources is renewable
We need manage well

What is renewable ?



How do we use stock assessments results

Simple example
Catch (BET, Indian Ocean) in 2016
should not exceed
the MSY level (99,000 tons)

We need the reference point (MSY, Fmsy..)
by stock assessments for sustainable utilization

How many SA methods ? Many methods
(about 10 types and more than 50 approaches)

IOTC (2015)

Table

seems to be complicated and complex

But….

SA methods: 2 categories

[1] Qualitative (demography, PSA..) (parameters only)
[2] Quantitative (catch, CPUE, Biological parameters)
(2a) Snap shot (short term average situation)(FiSAT)
➔ **Partial reference point (no MSY)**
(2b) **Traditional (PM, Age based)**
(2c) Catch model (data poor)
(2d) Integrated approaches (SS3, Multifan-cl)
➔ **ALL reference points (MSY, Fmsy...)**

Summary of catch discussion

- Pacific ➔ we will use FAO
- Indian Ocean ➔ we will consider both FAO and IOTC

➔ need to investigate causes of big different 1996-98 (LOT)

➔ **If we can not find the causes, we might use averages**

We need SA methods with ALL reference points

(2b) Traditional
(Production , Age based models)
(2c) Catch model (data poor method)
(2d) Integrated approaches (SS3, Multifan-cl)

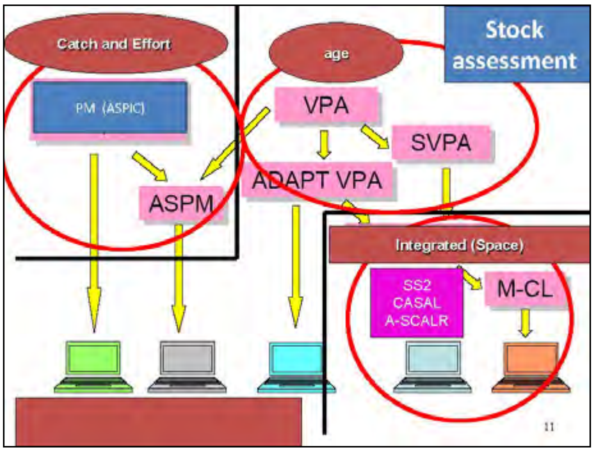
We consider (2b) as a first step..
If we have only catch we will consider (2c)
We will not consider (2d) : too complicated beyond our scope

Within (2a) Traditional SA: Two types

Catch and CPUE➔ PM (production model)

Catch, CPUE and Biological parameters
➔ Age/size based SA (VPA, SCAA, ASPM etc)

We attempt the simple PM first..



Why we choose ASPIC ?

Within PM: 2 types

Equilibrium (Pop increase=decrease)
PM: Schaefer, Fox, P-T models

Non equilibrium (Pop increase ≠ decrease)
ASPIC based Schaefer, Fox, P-T models
➔ **realistic and common among RFMOs**

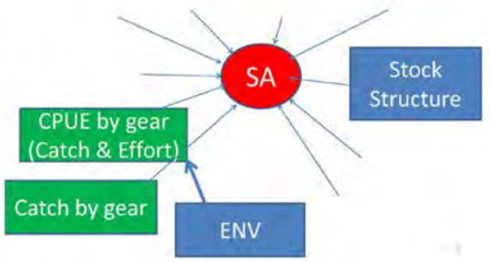
We will use ASPIC
A Stock Production Model Incorporating Covariates

Problems in Stock assessments

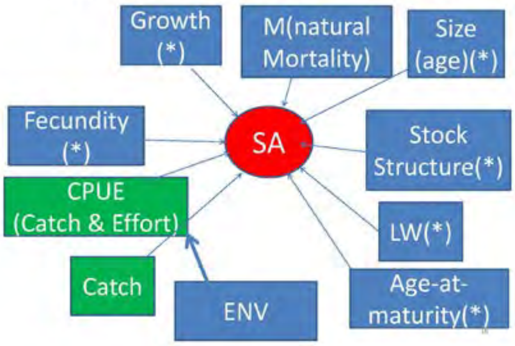
Not like fine scale (**exact**) sciences
Unlike physics, chemistry, engineering type

But more **fuzzy** sciences
Large Uncertainties (data + model)
⬇
Uncertain results(MSY, Fmsy..)
Precautionary approach
MSY=30,000 tons (95%CI: 10,000-40,000 tons)
We may choose **20,000 ton (2016 TAC)**

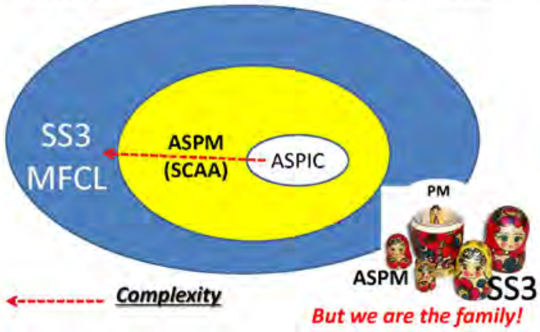
What do we need for SA(PM)



What do we need for SA(ASPM)



ASPM(SCAA) : Intermediate assessment model
not too simple(ASPIC)
not too complicated (MFCL, SS3, most complicate)



Later we will attempt

ASPM

using biological data

size, growth,

ASPIC

INPUT : Catch (global) and CPUE by gear

CPUE (1 or more OK)

OUTPUT

MSY, F, r (intrinsic Pop growth rate), K (Carrying capacity) and q (catchability)

⬇

Population size

(NO S-R relation ← critical points)

Introduction to 2 ASPIC software

- ASPIC **original software** (Prager, 2004)
  (06) ASPIC manual
- ASPIC **grid (parameter) search**
  (menu driven software)
  (05) manual

Where are your software ?

4 software (109MB)

What are the relation between 2 software ?

ASPIC original software (Prager, 2004)

This is the basic ASPIC program

=> We will input initial seeding values

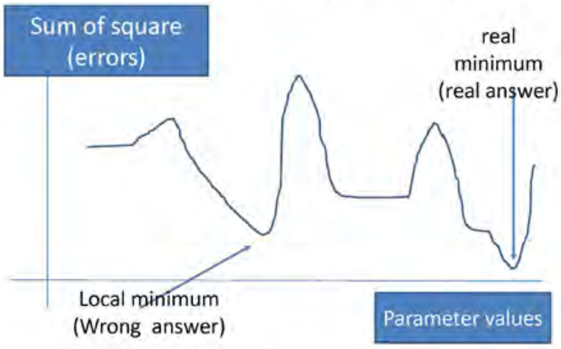
ASPIC grid (parameter) search (menu driven software)

The original program can run only one set of parameters at once.
This soft will search optimum parameters by grid search
using all combination of parameters

Original program
One run only at one time
You need to repeat until you find the optimum Parameters. **You may find the parameters at local minimum (Wrong answer)**

Grid search
This repeats runs for many combination of parameters at one time
Thus most optimum parameters can be found (**correct answer**)

What is the local minimum?



We now start the original program

Basic ASPIC program

- INPUT file test.inp (example)
- Program aspic
- Command prompt コマンド プロンプト

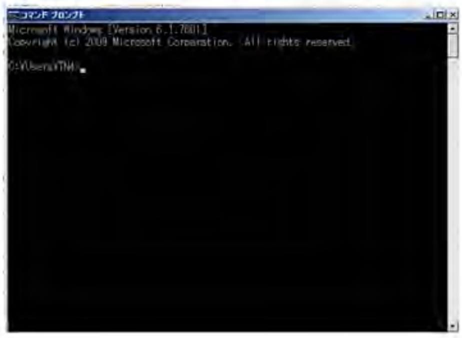
There are many steps to run ASPIC

- We will repeat a few times so that we can run ASPIC
- As explained, it take one year to get used to the program.. As for a few times of practice, it still difficult to learn.

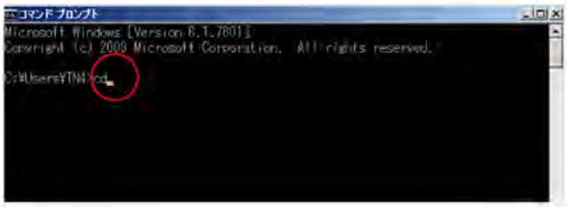
First you move to the command prompt mode in your folder

- How ?
- Double click コマンド プロンプト

Then you see the window like below

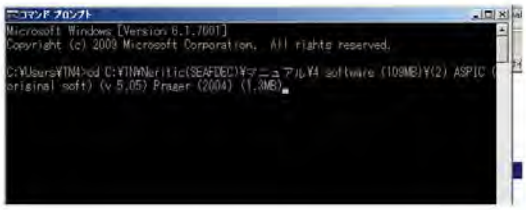


Change directory type cd and make one space

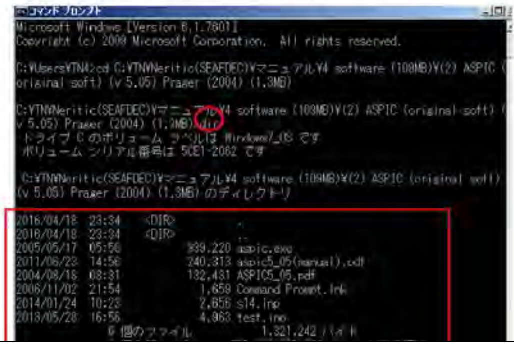


First copy the directory in the folder where you have you data file

Then paste



Then return then type dr then you see files in your folder

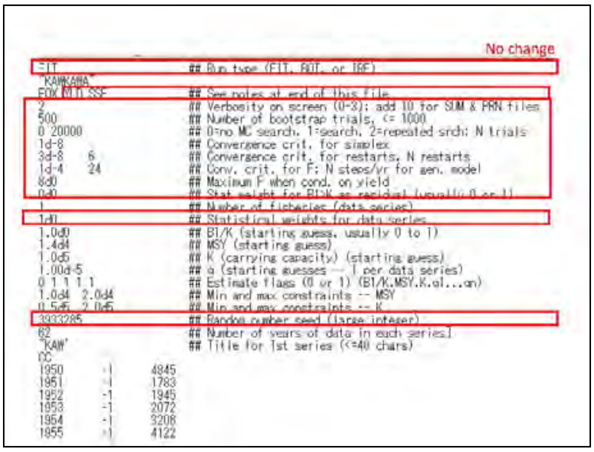


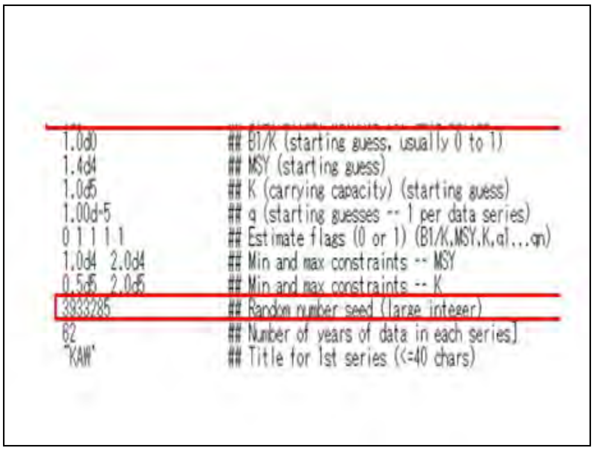
Now preparation of your input file

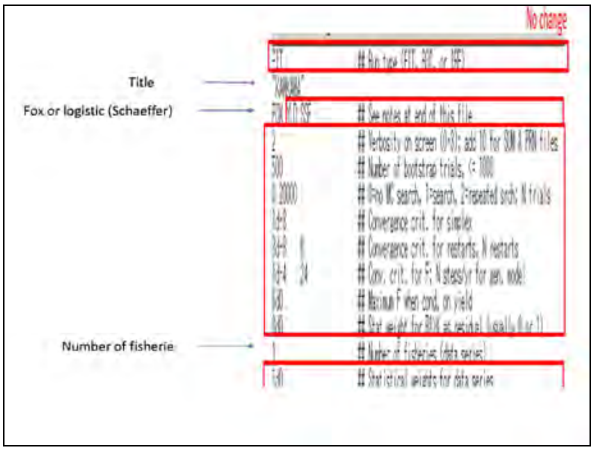
- You need the editor to edit your input file
- Use memo pad

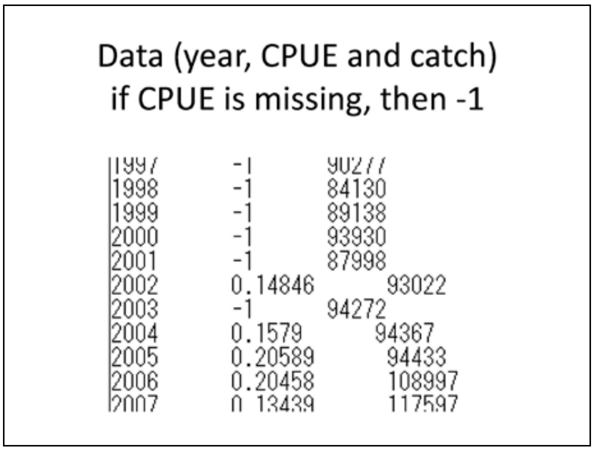
First look at test.inp

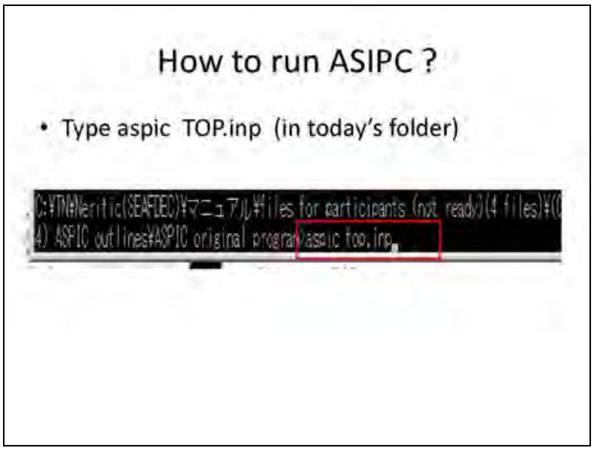
Then you will see the ASPIC input program as below

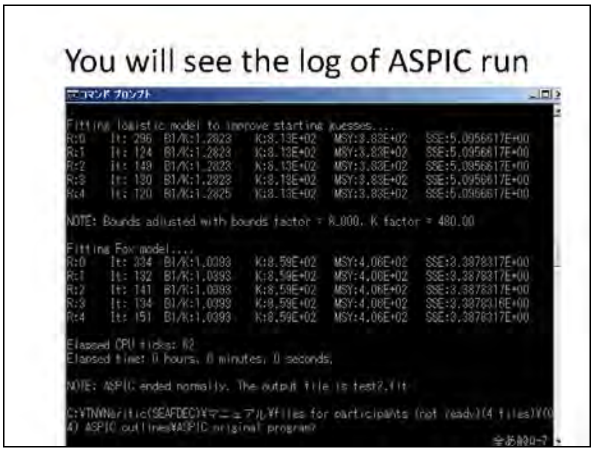

No change
FIT ## Run type (FIT, BOT, or IRF)
"KAWKAWA"
FOX MLD SSE ## See notes at end of this file
2 ## Verbosity on screen (0-3); add 10 for SUM & PRN files
500 ## Number of bootstrap trials, <= 1000
0 20000 ## 0=no MC search, 1=search, 2=repeated srch; N trials
1d-8 ## Convergence crit. for simplex
3d-8 6 ## Convergence crit. for restarts, N restarts
1d-4 24 ## Conv. crit. for F; N steps/yr for gen. model
8d0 ## Maximum F when cond. on yield
1 ## Number of fisheries (data series)
1d0 ## Statistical weights for data series
1.0d0 ## B1/K (starting guess, usually 0 to 1)
1.4d4 ## MSY (starting guess)
1.0d5 ## K (carrying capacity) (starting guess)
1.00d-5 ## q (starting guesses -- 1 per data series)
0 1 1 1 1 ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
1.0d4 2.0d4 ## Min and max constraints -- MSY
0.5d5 2.0d5 ## Min and max constraints -- K
3933285 ## Random number seed (large integer)
62 ## Number of years of data in each series
"KAW" ## Title for 1st series (<=40 chars)
CC
1950 -1 4845
1951 -1 1783
1952 -1 1945
1953 -1 2072
1954 -1 3208
1955 -1 4122


1.0d0 ## B1/K (starting guess, usually 0 to 1)
1.4d4 ## MSY (starting guess)
1.0d5 ## K (carrying capacity) (starting guess)
1.00d-5 ## q (starting guesses -- 1 per data series)
0 1 1 1 1 ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)
1.0d4 2.0d4 ## Min and max constraints -- MSY
0.5d5 2.0d5 ## Min and max constraints -- K
3933285 ## Random number seed (large integer)
62 ## Number of years of data in each series
"KAW" ## Title for 1st series (<=40 chars)

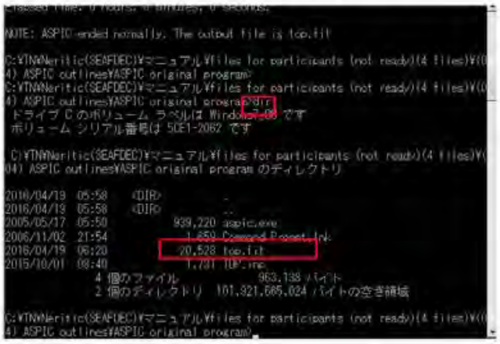

No change
Title
Fox or logistic (Schaeffer)
Number of fisherie
FIT ## Run type (FIT, BOT, or IRF)
"KAWKAWA"
FOX MLD SSE ## See notes at end of this file
1 ## Number of fisheries (data series)
1d0 ## Statistical weights for data series


Data (year, CPUE and catch)
if CPUE is missing, then -1
1997 -1 90277
1998 -1 84130
1999 -1 89138
2000 -1 93930
2001 -1 87998
2002 0.14846 93022
2003 -1 94272
2004 0.1579 94367
2005 0.20589 94433
2006 0.20458 108997
2007 0.13439 117597


How to run ASIPC ?
• Type aspic TOP.inp (in today's folder)
aspic top.inp


You will see the log of ASPIC run
Fitting logistic model to improve starting guesses....
NOTE: Bounds adjusted with bounds factor = 8.000, K factor = 480.00
Fitting Fox model....
NOTE: ASPIC ended normally. The output file is test2.fit

Results are in top.fit

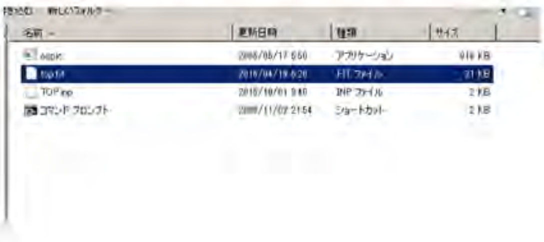


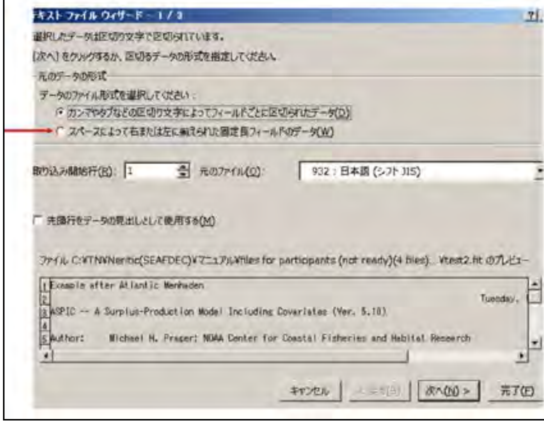
To see results

- Import to memo.pad

To see and use results for your paper

- Import test2.fit to excel





You have output in excel

Annex 6

ASPIC (ver. 5.05) Batch (Grid search) Job Software
(Menu-driven software) (1st version)
Manual

April, 2016

Developer: Yoshinobu Odaira
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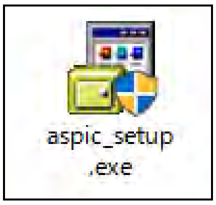
Technical support: Dr Tom Nishida
Associate Scientist
National Research Institute of Far Seas Fisheries (NRIFSF)
Japan Fisheries and Education Agency
5-7-1, Orido, Shimizu-Ward, Shizuoka-City, Shizuoka, Japan 424-8633
E-mail: aco20320@par.odn.ne.jp Phone/FAX (direct):81(Japan)-54-336-5834
URL: http://fsf.fra.affrc.go.jp/

1. INSTALL

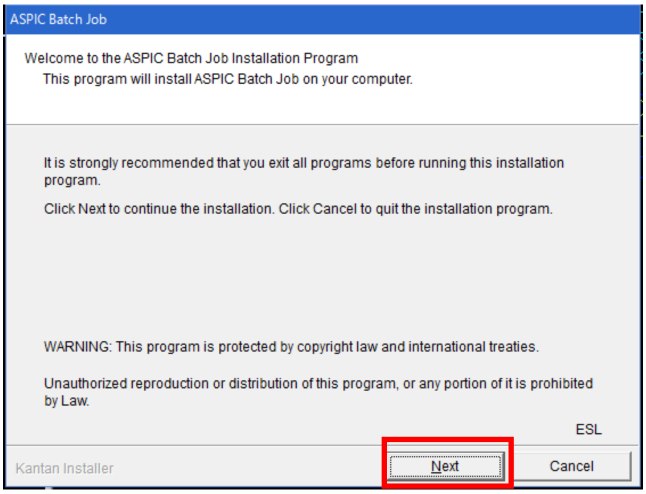
Down load the software from http://ocean-info.ddo.jp/kobeaspm/aspic/aspic_setup.exe

It will take about 5 minutes (depending on performance of PS) to download the setup program (aspic_setup.exe) (49 MB) as shown below, then double click.



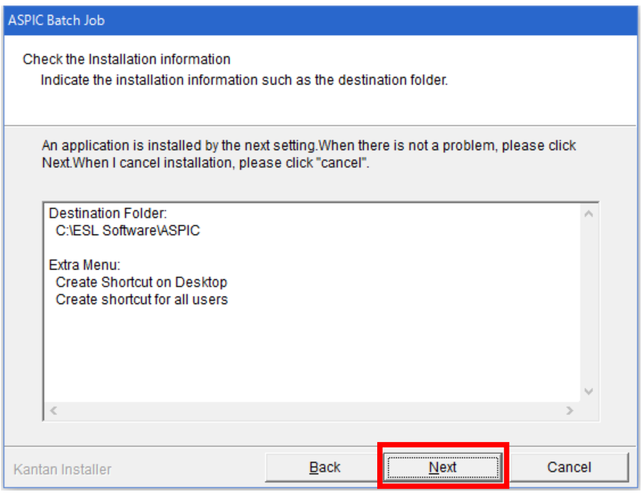
Click “aspic_setup.exe”

(1) Welcome



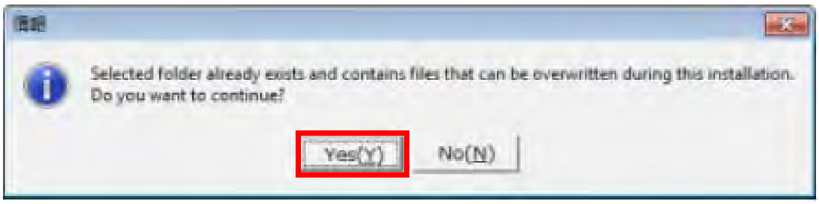
Click "Next" to continue.

(2) Check the installation information



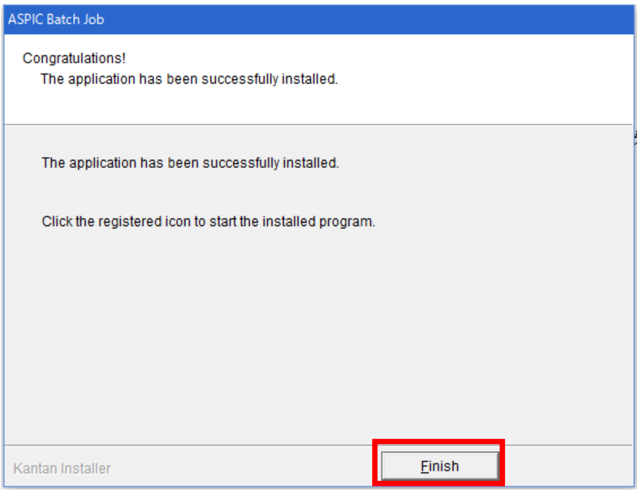
Click "Next" to continue.

(3) Check the installation folder.



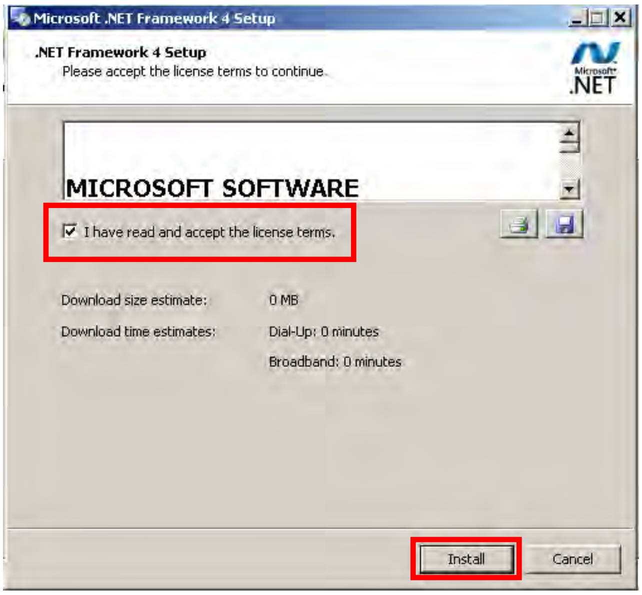
If there is no folder for installation, click "Yes" to continue.

(4) Installation completed.



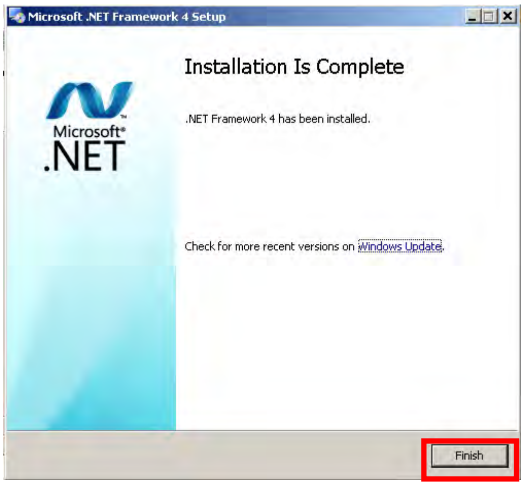
Click "Finish".

(5) Installing Microsoft .Net Framework 4



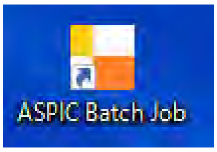
Select “I have read and accept the license terms“, Click "Install" to continue.

(6) Microsoft .Net Framework 4 installation is completed.



Click "Finish".

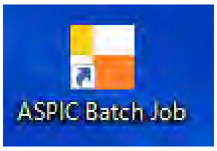
(7) Check Desktop icon



If you succeed installation, you will see “ASPIC Batch Job” icon on the desktop.

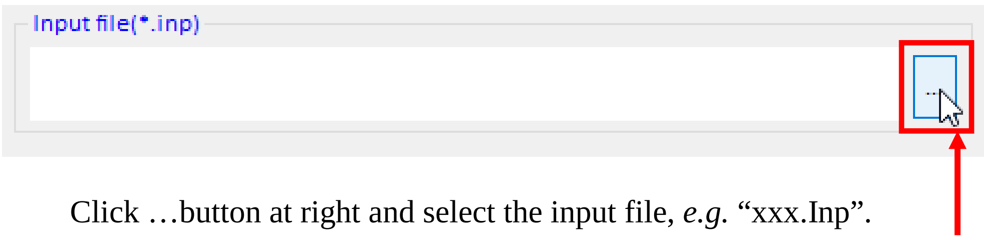
2. STARTING THE SOFTWARE

(1) To start ASPIC Batch Job



Double click “ASPIC Batch Job” icon on the desktop.

(2) To import the input file.



Click …button at right and select the input file, *e.g.* “xxx.Inp”.

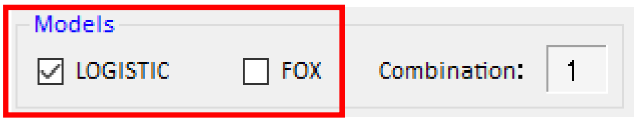
(Important Note)

You need to set up initial seeding values in the input file in advance. To set up initial seeding values, refer to the ASPIC manual (Ver. 5.05)

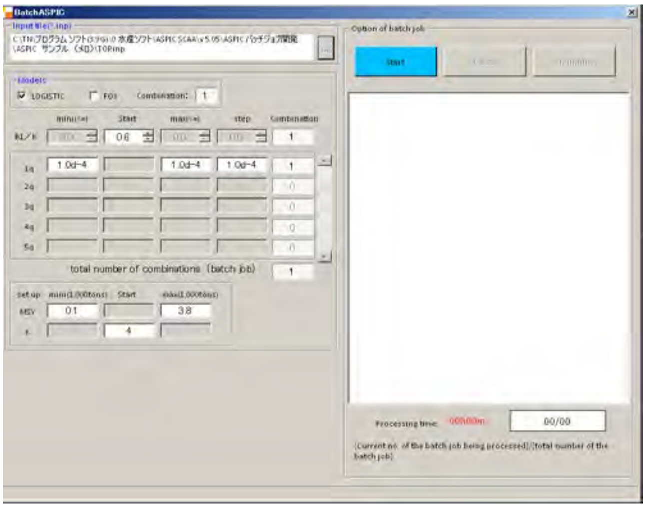
(3) Confirm the Input file and the initial set up window.

If you succeed loading your Input file, you can see initial seeding values shown as the screen above.

(4) Select type of production models.



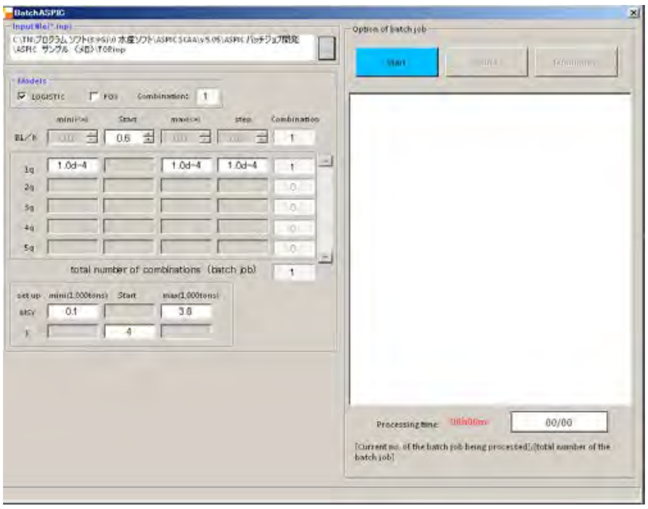
Select one or two types of '(Production) Models' for your batch job.



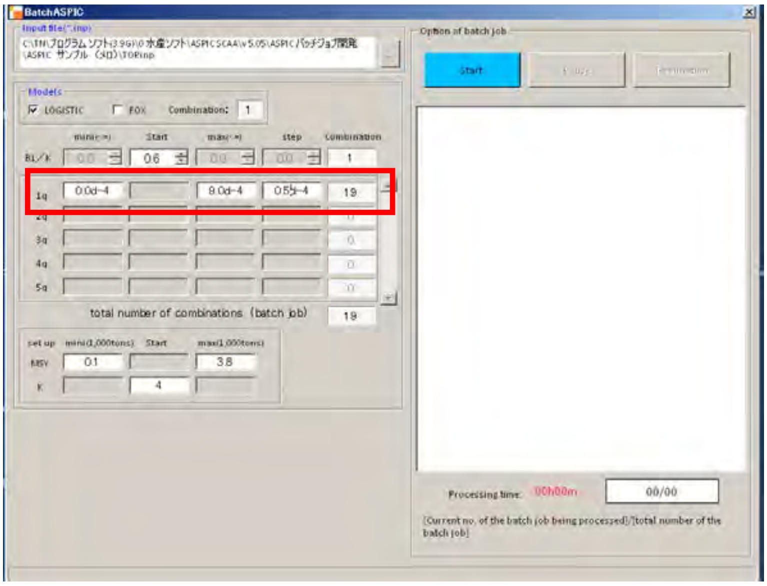
(5) Set up parameters

In each model, 3 parameters (MSY, K, B1/K and q) will be estimated in case of 1 fleet, where MSY: Maximum Sustainable Yield, K: Carrying Capacity, B1/K: depletion and q is catchability. If you have 2 fleets, you will estimate 4 parameters (MSY, K, B1/K, q1 and q2) and so on. You can fix some of these parameters.

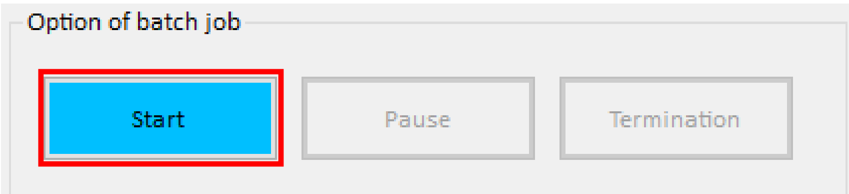
One example below is the case for B1/K and K fixed. You can change these values, but only one value can be used for the batch job. If you want to set up ranges, you need to change to values in the input file.



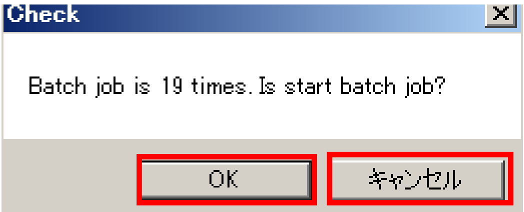
If you want to change ranges and steps of 1q (q1), just enter desired values shown as below. For this case, 19 batch jobs will run



(1) To start batch job.

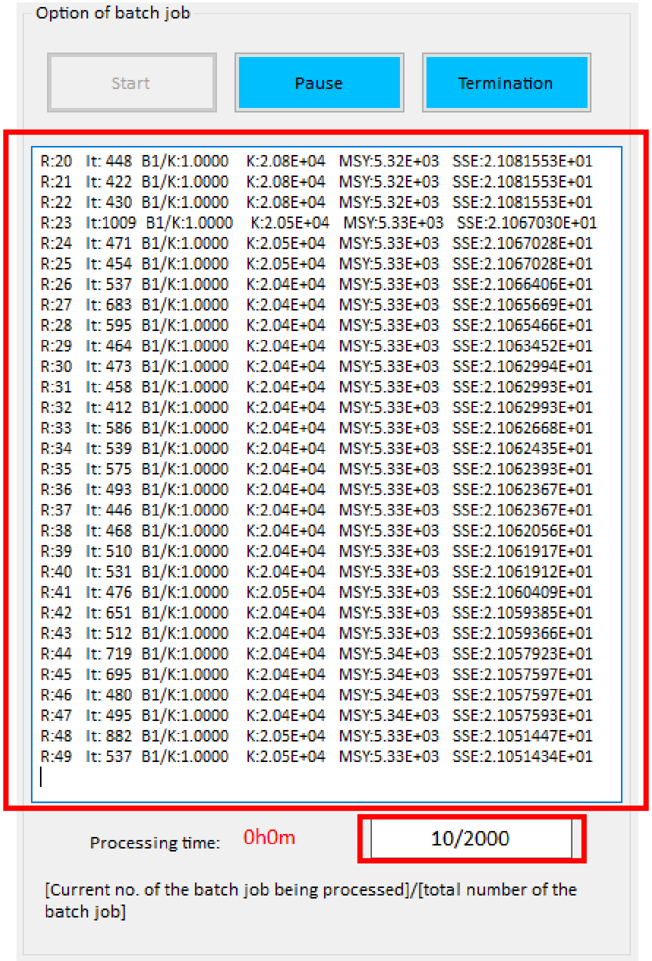


‘Click ‘Start’ for starting the batch job.



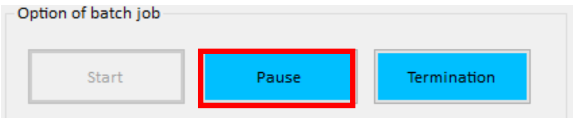
You can see the number of processing batch jobs. If you start processing, select “OK”. If you want to change parameters, select “Cancel (キャンセル)” and change parameters.

(2) Processing the batch job



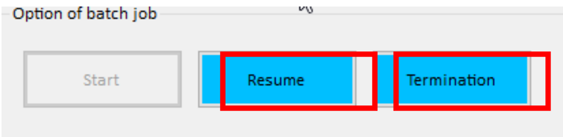
When batch job is being processed, you can see the current number of the batch job and logs shown as above. (Note: logs indicated above is the different example from the one in page 6).

(3) To pause batch job.



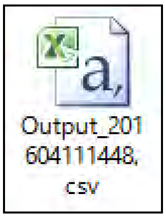
If you want to pause your batch job during processing of the batch job, click “Pause”

(4) Resume/terminate batch job.



You can restart the batch by clicking “Resume”. You can also terminate the batch job by clicking “Termination”.

(5) Report



After the batch job is completed, the report file will be created in the same folder of the Input file: “Output_YYYYMMDDHHMM.csv”, which indicates the starting time of the batch job using the following codes:

YYYY	:	Year
MM	:	Month
DD	:	Date
HH	:	Hour
MM	:	Minute

Example of the original report (.CSV file)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Time	0h6m	No of jobs	8	Average	0.771	Min/job	Sec/job	46.26									
2	Parameters	Model	B1/K	q(JPN1)	q(JPN2)	q(TWN)	MSY	K										
3	Range (ste	Fox and Lo	1	6.0d-5-9.0	1.0d-5-1.0	1.0d-5-1.0d-5 by 1.0d-5-1												
4	Flag (0: fixed / 1: estir		0	1	1	1	1	1										
5																		
6	No	Model	B1/K	q			MSY(1000 tons)			K(1000 tons)			R2			q		
7				JPN1	JPN2	TWN	mini	start	max	mini	start	max	JPN1	JPN2	TWN	JPN1	JPN2	TWN
8	1	logistic	1	6.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.048	0.332	0.411	7.56E-05	1.38E-04	1.28E-0
9	2	logistic	1	7.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.06	0.332	0.412	7.16E-05	1.29E-04	1.18E-0
10	3	logistic	1	8.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.056	0.32	0.423	6.76E-05	1.21E-04	1.14E-0
11	4	logistic	1	9.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.051	0.325	0.415	7.00E-05	1.26E-04	1.18E-0
12	5	fox	1	6.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	-0.084	-0.125	-0.107	1.50E-06	1.29E-06	1.47E-0
13	6	fox	1	7.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.126	0.307	0.525	6.19E-05	1.45E-04	1.24E-0
14	7	fox	1	8.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.124	0.308	0.525	6.17E-05	1.45E-04	1.24E-0
15	8	fox	1	9.0d-5	1.0d-5	1.0d-5	2	4	8	10	80	90	0.124	0.307	0.525	6.17E-05	1.45E-04	1.24E-0
16																		
17																		
18																		
19																		

	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1																		
2																		
3																		
4																		
5																		
6	RMS	r	K	MSY	Bmsy	Fmsy	B/Bmsy	F/Fmsy	TB	note								
7			(1000t)	(1000t)					(1000t)									
8	5.60E-01	1.437113	15.52	5.576	7.76E+03	7.18E-01	9.98E-01	7.98E-01	6.277	NOTE: ASPIC ended normally. The output file is test.fit								
9	5.61E-01	1.32524	16.64	5.513	8.32E+03	6.63E-01	9.30E-01	8.59E-01	6.4	NOTE: ASPIC ended normally. The output file is test.fit								
10	5.63E-01	1.252433	17.47	5.47	8.73E+03	6.26E-01	8.81E-01	9.08E-01	6.47	NOTE: ASPIC ended normally. The output file is test.fit								
11	5.62E-01	1.312277	16.78	5.505	8.39E+03	6.56E-01	9.27E-01	8.63E-01	6.448	NOTE: ASPIC ended normally. The output file is test.fit								
12	8.12E-01	0.22949	528.4	44.61	1.94E+05	2.30E-01	2.63E+00	3.46E-02	510.5	WARNING: At least one parameter estimate is at or near a constraint.						Solution may be trivial--		
13	5.35E-01	0.626512	22.67	5.225	8.34E+03	6.27E-01	7.66E-01	1.09E+00	5.455	NOTE: ASPIC ended normally. The output file is test.fit								
14	5.35E-01	0.62596	22.69	5.225	8.35E+03	6.26E-01	7.65E-01	1.09E+00	5.457	NOTE: ASPIC ended normally. The output file is test.fit								
15	5.35E-01	0.626236	22.68	5.225	8.34E+03	6.26E-01	7.65E-01	1.09E+00	5.453	NOTE: ASPIC ended normally. The output file is test.fit								
16																		

Processed output for easier look by Excel book file

	A	B	C	D	E	F	G	H	I
1	Time	0h6m	No of jobs	8	Average	0.771	Min/job	Sec/job	46.26
2									
3	Parameters	Model	B1/K	q(JPN1)	q(JPN2)	q(TWN)	MSY	K	
4	Range (step)	Fox and Logistic	1	6.0d-5-9.0d-5 by 1.0d-5-4	1.0d-5-1.0d-5 by 1.0d-5-1	1.0d-5-1.0d-5 by 1.0d-5-1			
5	Flag (0: fixed / 1: estimate)		0	1	1	1	1	1	
6									
7	No	Model	B1/K	q			MSY(1000 tons)		
8				JPN1	JPN2	TWN	mini	start	max
9	1	logistic	1	6.0d-5	1.0d-5	1.0d-5	2	4	8
10	2	logistic	1	7.0d-5	1.0d-5	1.0d-5	2	4	8
11	3	logistic	1	8.0d-5	1.0d-5	1.0d-5	2	4	8
12	4	logistic	1	9.0d-5	1.0d-5	1.0d-5	2	4	8
13	5	fox	1	6.0d-5	1.0d-5	1.0d-5	2	4	8
14	6	fox	1	7.0d-5	1.0d-5	1.0d-5	2	4	8
15	7	fox	1	8.0d-5	1.0d-5	1.0d-5	2	4	8
16	8	fox	1	9.0d-5	1.0d-5	1.0d-5	2	4	8
17									

	I	J	K	L	M	N	O	P	Q	R
1	46.26									
2										
3										
4										
5										
6										
7		K(1000 tons)			R2			q		
8	max	mini	start	max	JPN1	JPN2	TWN	JPN1	JPN2	TWN
9	8	10	80	90	0.048	0.332	0.411	7.56E-05	1.38E-04	1.28E-04
10	8	10	80	90	0.06	0.332	0.412	7.16E-05	1.29E-04	1.18E-04
11	8	10	80	90	0.056	0.32	0.423	6.76E-05	1.21E-04	1.14E-04
12	8	10	80	90	0.051	0.325	0.415	7.00E-05	1.26E-04	1.18E-04
13	8	10	80	90	-0.084	-0.125	-0.107	1.50E-06	1.29E-06	1.47E-06
14	8	10	80	90	0.126	0.307	0.525	6.19E-05	1.45E-04	1.24E-04
15	8	10	80	90	0.124	0.308	0.525	6.17E-05	1.45E-04	1.24E-04
16	8	10	80	90	0.124	0.307	0.525	6.17E-05	1.45E-04	1.24E-04

6										
7	RMS	r	K	MSY	Bmsy	Fmsy	B/Bmsy	F/Fmsy	TB	note
8			(1000t)	(1000t)					(1000t)	
9	5.60E-01	1.4371134	15.52	5.576	7.76E+03	7.18E-01	9.98E-01	7.98E-01	6.277	NOTE: ASPIC ended normally. The output file is test.fit
10	5.61E-01	1.3252404	16.64	5.513	8.32E+03	6.63E-01	9.30E-01	8.59E-01	6.4	NOTE: ASPIC ended normally. The output file is test.fit
11	5.63E-01	1.2524327	17.47	5.47	8.73E+03	6.26E-01	8.81E-01	9.08E-01	6.47	NOTE: ASPIC ended normally. The output file is test.fit
12	5.62E-01	1.3122765	16.78	5.505	8.39E+03	6.56E-01	9.27E-01	8.63E-01	6.448	NOTE: ASPIC ended normally. The output file is test.fit
13	8.12E-01	0.2294901	528.4	44.61	1.94E+05	2.30E-01	2.63E+00	3.46E-02	510.5	WARNING: At least one parameter estimate is at or near a constraint. Solution may be trivial--examine output file test.fit carefully.
14	5.35E-01	0.6265118	22.67	5.225	8.34E+03	6.27E-01	7.66E-01	1.09E+00	5.455	NOTE: ASPIC ended normally. The output file is test.fit
15	5.35E-01	0.6259596	22.69	5.225	8.35E+03	6.26E-01	7.65E-01	1.09E+00	5.457	NOTE: ASPIC ended normally. The output file is test.fit
16	5.35E-01	0.6262356	22.68	5.225	8.34E+03	6.26E-01	7.65E-01	1.09E+00	5.453	NOTE: ASPIC ended normally. The output file is test.fit

Annex 7

User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs

❀ ❀ ❀

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National Marine Fisheries Service
Beaufort Laboratory Document BL-2004-01
February, 2004
Last revised May 18, 2004

Preface

This user's manual describes Version 5.0 of ASPIC, a computer program to estimate parameters of a nonequilibrium surplus-production model from fisheries data. Several utility programs (ASPICP, FTEST, AGRAPH) are also described. Their purposes are making projections, comparing models, and quickly making graphs from ASPIC and ASPICP output files. The programs together are referred to here as the ASPIC Suite.

The major change from previous versions of ASPIC is the ability to fit the Pella-Tomlinson (generalized) production model, with the Fox exponential yield model included as a special case. The Schaefer (logistic) production model, the main component of earlier versions, is still part of ASPIC, and because many of its computations can be done analytically rather than numerically, it will be found quicker, and its solutions may be more stable.

The ASPIC Suite is not commercial software, and the programs are not warranted in any way, either by the author or by the U.S. government. The software was developed for use in the author's research, and it is used regularly. Distribution to fellow scientists in made in a cooperative spirit. *The software is intended as a set of research tools, and those who use them do so at their own risk.* ASPIC has been used on thousands of real and simulated data sets, and all supplied programs are believed to be substantially correct. The author appreciates receiving advice of suspected flaws, and he attempts to correct errors promptly.

By no means is ASPIC the final word in production modeling. It is intended as a reasonably flexible program that can serve as a basis for further innovation.

Formal description of the theory behind ASPIC is given in Prager (1994). Further references are given in the bibliography. The author requests that this manual and Prager (1994) be cited in any report or published article that uses ASPIC.

Those who have used version 3.x of ASPIC and who now are presented with version 5.x might ask what happened to version 4.x. The answer is simple: 4.x were test versions. It seemed more logical to release the new version as 5.0, rather than some number in the middle of the 4.x series.

Many colleagues have given valuable technical suggestions or assistance while ASPIC was being written and as it has been revised through the years. I thank S. Cadrin, R. Deriso, K. Hiramatsu, J. Hoenig, R. Methot, C. Porch, J. Powers, A. Punt, V. Restrepo, G. Scott, K. Shertzer, P. Tomlinson, D. Vaughan, E. Williams, and the many fishery scientists who have sent data sets to illustrate their applications and questions. Development of ASPIC and related research is supported by the Southeast Fisheries Science Center of the U.S. National Marine Fisheries Service.

Typographical conventions

In this manual, user commands, file names, and items in input files are displayed in a `monospaced font`. Some important sections are marked by a symbol in the margin, as here; ❖
attention to such material is especially important to obtaining good results from ASPIC. Material new in this version of the program is marked by a different marginal symbol, as here. ✳

Michael H. Prager
Beaufort, North Carolina
January, 2004

Contents

List of Tables

1 Introduction

This user's manual describes Version 5.0 of ASPIC, a computer program to estimate parameters of a nonequilibrium surplus-production model from fisheries data. Several utility programs (ASPICP, FTEST, AGRAPH) are also described. Their purposes include making projections, comparing models, and quickly making graphs from ASPIC and ASPICP output files. The programs together are referred to here as the ASPIC Suite.

The surplus-production model has a long history in fishery science and has repeatedly proven useful in management of fish stocks. The appeal of production models is in large part due to their conceptual and computational simplicity. Despite that simplicity, production models incorporate an implicit recruitment function, and thus can be used for studies of sustainability. Production models have also been found especially useful in stock assessments when the age-structure of the catch cannot be estimated.

Many early treatments of surplus-production models assumed that the yield taken each year could be considered the equilibrium yield (e. g., Fox 1975). However using that "equilibrium assumption" tends to overestimate MSY when used to assess a declining stock, and it has been found problematic by several studies (Mohn 1980; Williams and Prager 2002). The assumption was a computational convenience that is no longer needed, and ASPIC does not use it.

Earlier versions of ASPIC could fit only the logistic production model (Schaefer 1954, 1957; Pella 1967), in which the production curve (curve of surplus production vs. biomass) is symmetrical around MSY. Version 5.x also fits the generalized model of Pella and Tomlinson (1969) in the revised parameterization of Fletcher (1978).

ASPIC incorporates several extensions to classical stock-production models. One extension is that ASPIC can fit data from up to 10 data series. These may be catch–effort series (from different gears or different periods of time), catch–abundance-index series, biomass indices, or biomass estimates made independently of the production model. This feature is described in §4.4. A second major extension is the use of bootstrapping for bias correction and construction of approximate nonparametric confidence intervals. A third extension is that ASPIC can fit a model under the assumption that yield in each year is known more precisely than fishing effort or relative abundance; in other words, fitting can be statistically conditioned on yield, rather than on fishing effort or relative abundance.

The theory behind ASPIC and several worked examples were first presented in working documents of the International Commission for the Conservation of Atlantic Tunas (ICCAT) by Prager (1992a,b). Those reference have been superseded by the more formal and complete treatment of Prager (1994). The model and its extensions are also described in Quinn and Deriso (1999) and Haddon (2001). The basic theory of production models is of course also described in many other texts, including Hilborn and Walters (1992), and is the subject of a recent FAO publication (Punt and Hilborn 1996).

The ASPIC computer program as described here has been used by several assessment groups and in many studies, including Prager et al. (1996), Prager and Goodyear (2001), Prager (2002), Shertzer and Prager (2002), and Williams and Prager (2002). In the course of those studies, the program has been exercised on over 100,000 sets of simulated data. The resulting experience has been used to improve the program's reliability.

2 New in ASPIC 5.0

This section gives an overview of changes introduced between ASPIC 3.x and ASPIC 5.x. Although this section will be of most interest to users of previous versions, new users should also review it briefly for information on running ASPIC 5.0 productively.

2.1 Major changes

Generalized production model. Earlier versions of ASPIC could fit only the logistic form of the production model (Graham 1935; Schaefer 1954, 1957; Pella 1967; Prager 1994). As well as that form, ASPIC 5.0 can fit the generalized production model (Pella and Tomlinson 1969; Fletcher 1978) in one of three ways: by direct optimization, by a grid of fits on the model shape, or with fixed model shape to implement the Fox (1970) model or other predetermined shape.

Parameterization change. The generalized model requires parameterization in terms of MSY and carrying capacity K rather than MSY and intrinsic rate of increase r. This occurs because when the exponent n in the generalized model is in the region $n \leq 1$, then $r = \infty$. As a result, ASPIC 5.0 requires a starting guess for K, not for r.

Starting biomass parameterization. A parameter estimated by ASPIC is the biomass in the first year of the analysis. In previous versions, this was expressed (both in the input file and in ASPIC reports) as a ratio to the biomass providing MSY; i.e., as B_1/B_{MSY}. In version 5.0, it is expressed as a ratio to the carrying capacity, i.e., as B_1/K. This change is required because in the generalized model, B_{MSY} is no longer a fixed proportion of K. The change reduces correlation between estimates of the starting biomass ratio and of B_{MSY}.

Conditioning options. Option names for conditioning on yield or effort have been revised to indicate conditioning, rather than residuals. The new specifications are given in §6.3.

Fitting criteria. An additional objective function, least absolute values (LAV), is available. It is recommended that this robust objective function be used only in conjunction with a regular least squares fit, because the optimizer has a more difficult task in finding the best minimum of LAV fits. Nonetheless, LAV can be valuable where one or more data observations are markedly disjoint from the rest. For guidelines on appropriate use of LAV, please consult the statistical literature.

Bounds on catchability coefficient. To improve convergence, estimates of q (catchability) are now bounded to a geometric range around the user's starting guess. The bounds are determined internally by ASPIC and are not under the user's control. If the starting guess for q is severely wrong, the estimate may hit a bound, and the ASPIC report will indicate whether the starting guess was too low or too high. If that happens, the user should revise the starting guess of q accordingly and rerun the analysis.

Restarts during optimization. Previous versions of ASPIC required the optimizer to return to the same solution 3 times in a row to indicate convergence. That worked well on most data sets, but was not always sufficient. The number of identical returns is now specified in the input file. The recommended default is 6. This can improve stability of the fit on some poor data sets. This is specified on line 8 of the input file; see §6.3 on page 15.

Time steps. The generalized model is implemented by numerical integration that approximates a continuous-time solution. The number of time steps per year is specified on line 9 of the input file; see §6.3 on page 15.

Setting advanced options. A new `INI` file in the working directory can contain values for some advanced options, described in §7 on page 19.

Updated ASPICP. An updated version of the projection program ASPICP is compatible with analyses from ASPIC 5.0. It is also backwardly compatible with ASPIC 3.x and 4.x.

Windows installer. This release is distributed as a self-installing binary file for Windows. Versions for other operating systems may be available on request.

Drag-and-drop versions. ASPIC has always been a non-interactive program that reads from and writes to ASCII files. This release includes alternative versions that accept drag-and-drop of input files and that display their output in scrolling windows. The original command-line versions are also supplied.

2.2 Using new features

When using the new features of ASPIC 5.0, please consider the following—

2.2.1 Execution speed

Fitting the generalized model is done with a numerical solution of the catch equation and is thus slower than fitting the logistic model (which has an analytical solution). Execution will be especially slow in any the following cases:

1. Poor agreement between model and data
2. Analysis of more than one data series
3. Bootstrapping, especially in combination with #1 or #2
4. Extensive Monte Carlo trials in fitting

Program speed can be improved by reducing the number of time steps per year in the input file (see §6.3 on page 15). For the closest approximation to a continuous-time model, set this value to a large number; e.g., 80. For a fairly close approximation, use a number in the range 12–24 (recommended). For fastest operation set this to 2 steps per year.

❖ 2.2.2 DEVELOPMENTAL FEATURES

The following are believed to work correctly but have not been tested extensively:

- Generalized estimation (in all forms) with more than one data series.
- Objective functions other than SSE.
- Projections of generalized bootstraps with ASPICP.
- The values of the AIC (Akaike Information Criterion) printed when fitting the generalized model.
- The F-statistic printed for comparing the logistic and generalized models may be incorrect when more than one data series is analyzed. More importantly, simulations suggest that such tests are of little value (Prager 2002).

❖ It is wise to repeat estimation with several different random-number seeds. If results cannot be duplicated within a few percent (usually less), a fitting failure is indicated, and such results should not be considered valid estimates.

❖ The author will appreciate receiving reports of successful or unsuccessful use of the features itemized above. He will attempt to fix all bugs promptly.

3 Installation and Interaction

3.1 Compatibility

The ASPIC suite is compatible with personal computers running Microsoft Windows 9x (including Windows 95, 98 and Me) or Windows NT (including Windows NT 4.0, 2000, and XP).[1]

ASPIC is written in standard Fortran 95 and is portable to other operating systems. Please consult the author if you would like to use ASPIC under operating systems other than Windows.

[1]Use of tradenames does not imply endorsement by NMFS, NOAA, or the author.

3.2 Installation

This version of ASPIC is available as a self-installing executable file for Windows. The installer performs the following tasks:

- Installs binary files for ASPIC, ASPICP, FTEST and AGRAPH to a location specified by the user
- Installs this User's manual and a Quick Reference Card to the doc subdirectory of the installation location
- Installs sample input and output files to the `samples` subdirectory of the installation location
- Adds the installation location to the user's PATH specification so that ASPIC and related programs can be executed from a command window open to any directory
- Adds a `GINO` environment variable pointing to the installation location, as required by a graphics support library used in AGRAPH. If a `GINO` environment variable already exists on the system, it is not modified.
- Adds shortcuts to the Windows Start menu and Desktop, including a command window opening in a user-specified working directory
- Adds an uninstaller to the installation location and adds ASPIC to the system's "Remove Programs" list

The ASPIC uninstaller removes all of the above. However, any files added by the user are not removed.

This User's Manual is supplied with all distributions of ASPIC as an Adobe PDF file named `ASPICMAN.PDF`. It may be distributed freely.

3.3 Interface ❖

3.3.1 INTERFACE OF ASPIC AND ASPICP

The standard versions of ASPIC and ASPICP do not include graphical user interfaces. Instead, the programs are console-mode (character) programs that read all input from and write all output to ASCII (text) files. The screen is used only for status messages.

For added ease of use, the ASPIC 5.0 installation includes versions of ASPIC and ASPICP that support drag and drop. (The executable files of the command-line versions are `aspic.exe` and `aspicp.exe`; of the drag-and-drop versions, `aspicw.exe` and `aspicpw.exe`.

3.3.2 Interface of auxiliary programs

The auxiliary program FTEST has a text-mode user interface, is interactive, and does not require an input file. Output is written to the screen.

The graphics program AGRAPH incorporates a standard Windows GUI, with output available to any Windows printer or to a graphics file (WMF or EPS). It can be executed from the command line, by drag and drop, or by starting the program from its shortcut.

3.3.3 NMFS Toolbox

The US National Marine Fisheries Service (NMFS) has developed a "toolbox" of computer programs for stock assessment. The toolbox currently includes a graphical editor specifically for ASPIC input files and graphics that work with ASPIC output. It also includes many other stock-assessment and projection tools. For further information, contact Dr. Paul Rago at the NMFS laboratory in Woods Hole, Massachusetts.

4 Overview of ASPIC

4.1 Data requirements

Data needed by ASPIC are a series of observations on yield (catch in biomass) and one or more corresponding series of relative abundance. Data on fishing effort rate can be used instead of relative abundance, and when used are assumed to represent effective (standardized) effort. ASPIC assumes that the supplied abundance index is an unbiased index of the stock's abundance in biomass. If data on fishing effort are provided, ASPIC assumes that effort divided by yield forms an unbiased index of the stock's abundance.

In this User's Guide, the terms "catch" and "yield" are used interchangeably to mean total removals in biomass. Similarly, CPUE is used to mean relative abundance. The presumption is that the CPUE has been standardized before being used for modeling.

In addition to data, ASPIC requires starting guesses of its estimated parameters. Parameters directly estimated are K, the stock's maximum biomass or carrying capacity; MSY, the maximum sustainable yield; B_1/K, the ratio of the biomass at the beginning of the first year to K; and for each data series i, q_i, the catchability coefficient for that series. Description of the input file format, given in §6, includes suggestions for starting guesses.

4.2 Program limits

The array limits of ASPIC are as follows:

- Number of years of data: 90
- Number of data series: 10
- Number of bootstrap trials: 1,000

Any user with larger requirements is invited to contact the author.

4.3 Program modes

ASPIC has three modes of operation, here called "program modes."

- In FIT program mode, ASPIC fits the model and computes estimates of parameters and other quantities of management interest, including time trajectories of fishing intensity and stock biomass. Execution time is relatively short.
- In BOT program mode, ASPIC fits the model and computes bootstrapped confidence intervals on estimated quantities. Because computations are extensive, execution time in BOT mode is considerably longer than in FIT mode. For example, a bootstrap with 500 trials might take 200–500 times as long as a single fit.
- In IRF program mode, ASPIC conducts an iteratively reweighted fit when two or more data series are analyzed. Iterative reweighting of the data series (inverse-variance weighting) provides, under many circumstances, a maximum-likelihood solution.

The modes BOT and IRF cannot be combined. In other words, ASPIC cannot run a bootstrap on an iteratively reweighted fit.

A typical analysis might begin with FIT mode, including several runs to explore different model structures. If questions about series weighting are to be addressed, IRF mode might be used, instead, in the initial analysis. After model and data structure have been decided, BOT mode can be used to estimate the uncertainty in assessment results. ASPIC bootstrap runs do not incorporate iterative reweighting, and this will cause underestimation of variability when IRF mode has been used to develop a model structure.

IRF mode was developed in response to requests during assessment workshops, but it has not been much used by the author, and thus is less thoroughly tested than the other modes. Experience has shown that while series weights estimated in IRF mode may be statistically unbiased, they can be of high variance. (This is a characteristic of such weights generally, and is not specific to ASPIC.) For that reason, sensitivity to series weights should be examined whenever IRF program mode is used.

4.4 Fitting more than one data series

ASPIC can fit data on up to 10 simultaneous or serial fisheries (or biomass estimate series or biomass index series). Data series may be of several types (Table 1), but at least one series must be type CE (effort and yield) or type CC (CPUE and yield). When more than one series is analyzed, common estimates of B_1/K, MSY, and K are made, along with an estimate of q_i for each series. The interpretation of q_i depends on the type of data series to which it pertains.

A statistical weight w_i for each fishery is specified by the user in the input file. In summing the objective function, each squared residual from fishery i is multiplied by w_i. If the series have equal error variances, using weights of unity for each series provides a maximum-likelihood solution under the lognormal error structure assumed by ASPIC.

In FIT program mode, the program normalizes the user's w_i so that they sum to unity. In IRF mode, the program adjusts the weights interatively to provide nearly equal estimated variances. Weights are also adjusted so they sum to unity.

The computer time needed to obtain estimates generally increases as more data series are added. The increase is due both to addition of data and increased difficulty of optimization.

4.5 Objective function and penalty term

Parameters are estimated under the assumption that the errors in yield or effort are multiplicative with constant standard deviation. Thus the residuals are accumulated in logarithmic transform. The objective function Ω minimized, then, is

$$\Omega = \sum_{i=1}^{I} \sum_{j=1}^{N} w_i \left(\ln \frac{Y_{ij}}{\hat{Y}_{ij}} \right)^2 \qquad (1)$$

for residuals accumulated in yield (EFT optimization mode, §6.3), or a similar expression for residuals in effort (YLD optimization mode).

In equation (1), i indexes the data series, j the year, w is the series' statistical weight, Y_{ij} is the observed yield (or biomass index or estimates) from series i in year j, and $\hat{Y}_{ij}$ is the corresponding predicted value.

4.5.1 Penalty for initial biomass

A penalty term can be added to the objective function to discourage estimates in which the first year's biomass B_1 is greater than the carrying capacity K. This penalty can affect the estimates of other parameters, so when this term is used, the results should be compared to those obtained by setting the term to zero. The penalty term is described in more detail in Prager (1994), and its use is described in the section describing the input file format.

4.5.2 Conditioning on yield

ASPIC can consider yield known exactly and accumulate residuals in effort. Yield is usually observed more precisely than effort or the abundance index, and it is usually preferable on statistical grounds to compute residuals in the more imprecise quantity. Thus, conditioning on yield is recommended for most analyses. An additional advantage is that estimation of missing effort values is quite simple (and is included in this version of ASPIC). When conditioning on yield, an iterative solution of the catch equation is used, and computation is slower than when conditioning on effort.

4.6 Bootstrapped confidence intervals

In BOT mode, ASPIC uses bootstrapping to estimate bias-corrected confidence intervals on many quantities of interest. In doing this, estimated yields (if conditioning on effort; estimated efforts, if conditioning on yield) and residuals from the original fit are saved. The residuals are then increased by an adjustment factor (Stine 1990, p. 338), which is reported in the output file.

Bootstrapped data sets are then constructed by combining each saved predicted yield $\hat{Y}_{ij}$ with a randomly-chosen adjusted residual to arrive at a pseudo-yield value $\hat{Y}^*_{ij}$. (This procedure assumes

Table 1. Codes for the eight types of data series allowed in ASPIC.

Code	Data type	When measured
CE	Fishing effort rate, catch (weight)	Effort rate: annual average Catch: annual total
CC	CPUE (weight-based), catch (weight)	CPUE: annual average Catch: annual total
B0	Estimate of biomass	Start of year
B1	Estimate of biomass	Annual average
B2	Estimate of biomass	End of year
I0	Index of biomass	Start of year
I1	Index of biomass	Annual average
I2	Index of biomass	End of year

that the statistical series weights w_i are correct.) The model is then refit, using the pseudo-yields in place of the original observed yields. The process is repeated (always using the original predicted values) up to 1,000 times.

From the bootstrap results, bias-corrected (BC) confidence intervals can be computed by standard methods (Efron and Gong 1983). The statistical literature recommends 1,000 bootstrap trials when computing 95% confidence intervals. ASPIC computes 80% confidence intervals, and should require fewer trials. The author recommends using at least 500 trials for bootstrap runs.

4.7 Input and output files

As noted, all ASPIC input and output files (Table 2 on p. 11) are in plain ASCII format. Sample files are provided with the ASPIC distribution.

4.7.1 Input file

An ASPIC input file contains all data and settings required for a single ASPIC run. It is recommended that when series of runs is made, that each input file be given a distinct name. This will ensure that the resulting output file names also are distinct.

The input file format is described in detail in §6 on page 12. The simplest way to generate an ASPIC input file is to run the command

```
aspic -help
```

from the command line, to generate the file `sample.inp`. That file can then be renamed and edited to the user's specifications. It may be useful to save an extra copy of the resulting file for use as a template.

4.7.2 Editing input files

To create and edit ASPIC input files and ASPICP control files, a text editor is best used. Windows Notepad is a simple example of such a program. (Text editors are sometimes known as programmer's editors or ASCII editors.) Many high-quality text editors are available as freeware, shareware, or commercial software.

An especially useful feature in an editor used for ASPIC input files is the ability to cut and paste rectangular blocks of text. A relatively simple editor having that feature is ConTEXT, which as of January, 2004, was available without charge and could be located through Web search engines such as Google. Other well known editors, such as xemacs, are also suited to this task.

4.7.3 Output files

Output from ASPIC includes parameter estimates; measures of goodness of fit; and estimates of population benchmarks, biomass levels, and exploitation levels. Simple character plots are also provided. In addition, the output from bootstrap runs includes bias-corrected confidence intervals on parameters and on other quantities of management interest.

The name used by ASPIC for its main output file depends on the mode of operation (Table 2). Suppose the data (input) file is named `sword.inp`. Then in FIT and IRF modes, the main output would be written to a file named `sword.fit`. In BOT mode, the main output would be written to file `sword.bot`, and detailed intermediate results of the bootstrap would be written to `sword.det` and `sword.bio`. The special output file, if written (see next paragraph) would be written to `sword.prn`.

Table 2. Files read (R) or written (W) by ASPIC and related programs.

File type	Action	Used by	File contents and description
INP	R	ASPIC	Input file with data, starting guesses, and run settings.
INI	R	ASPIC	Optional file to set certain advanced options.
FIT	W	ASPIC	Output file with estimates and graphs; written in FIT and IRF program modes.
BOT	W	ASPIC	Output file with estimates and graphs; written in BOT program mode.
BIO	W, R	ASPIC, ASPICP	Stores estimated *B* and *F* trajectory for each bootstrap trial; used by ASPICP to generate confidence intervals.
DET	W	ASPIC	Stores estimates from each bootstrap trial.
SUM	W	ASPIC	Stores summary estimates from all runs made in a directory. Set verbosity to 10 or above in INP file to write to a SUM file.
PRN	W	ASPIC	Has estimated trajectories in ASCII format; easily read for graphing by S-Plus, R, SAS, or spreadsheet.
GEN	W	ASPIC	S-compatible ASCII file with summary results from GENGRID mode.
GRD	W	ASPIC	S-compatible ASCII file with summary results from LOGGRID mode.

Although the .FIT and .BOT files can be read into a spreadsheet or statistical package, they contain many headings that can be confusing. Thus, a special file designed to be compatible with computer programs including S-Plus and R, can be written if desired. This .PRN file contains input and estimated time series from an ASPIC BOT or FIT run. For information on enabling this file, see §6.3 on p 14 or §7 on p. 19.

To aid in simulation studies, a summary file (.SUM file) may also be written in the current directory. This is described in more detail in §6.3. The .SUM file can be written by S-Plus or R with S code like

```
read.table("aspic.sum",header=T)
```

The .BIO file is used by ASPICP (described below) for its computations after a bootstrap run. The .DET file provides information on the individual bootstrap trials. It is not used directly by any supplied program, but is provided in case needed for the user's convenience.

The main .FIT and .BOT output files, and all other ASPIC related files intended to be read by the user, and written with a maximum line length of 120 characters. The .BIO and .DET output files, which are intended to be read by computer programs, may have much longer lines.

4.8 Starting ASPIC

First prepare an input file in the correct format (described in §6 on page 12). It's easiest to copy one of the sample input files provided to use as a template.

Then start the program, giving the input file name on the command line.[2] For example, the command

```
aspic sword.inp
```

or just

```
aspic sword
```

will cause the program to read an input file named sword.inp and produce corresponding estimates and output files. If only the command

```
aspic
```

is given, the program looks for the default input file, ASPIC.INP.

If the .SUM file as been enabled, summary output from each run in the directory will be written to it. The default name is aspic.sum. To use a different name for the .SUM file, give the name on the command line. For example, the command

[2] Most operations are also possible by dragging and dropping icons. The ASPIC Quick Reference, available from the ASPIC shortcuts folder installed on the user's Windows Desktop, includes more information on such use.

```
aspic sword mysum
```

will read the file `sword.inp` and create (or write to) the summary file `mysum.sum`, along with the usual ASPIC output file(s).

Most errors detected while ASPIC is reading the input file will cause the program to print a descriptive message and stop. If the message is not clear, comparing the input file to the samples provided may reveal format errors.

5 Overview of Auxiliary Programs

5.1 Overview of ASPICP

The auxiliary program ASPICP can be used following an ASPIC bootstrap run. It provides estimated time trajectories of population biomass and fishing mortality rate with bias-corrected confidence intervals. ASPICP is also used for making population projections beyond the observed data set. When making projections, the user can specify future harvests or effort levels, and the program projects biomass and fishing-mortality trajectories for up to 15 years past the original data. Printer plots of the trajectories are also provided.

ASPICP reads information recorded in the `BIO` file of the corresponding bootstrap run. The user controls the program with a simple control file, default `ASPICP.CTL`. Thus, the first step in using ASPICP is to create a proper control file with a text editor. Details of the file contents are given in §8, and sample ASPICP input files are included in the ASPIC distribution.

When starting ASPICP, the control file name is given on the command line; for example the command,

```
aspicp sword
```

or equivalently

```
aspicp sword.ctl
```

starts ASPICP as described in control file `sword.ctl`. All output from ASPICP is written to a file whose name is supplied by the user within the `.CTL` file.

5.2 Overview of FTEST

A small program named FTEST is provided to perform significance tests when comparing different ASPIC models of a stock. The program is designed for comparing pairs of models that differ only in complexity (number of parameters). The TEST program has a text user interface. To run, type

```
ftest
```

at a Windows command prompt and answer the program's prompts.

5.3 Overview of AGRAPH

The Windows program AGRAPH is intended to provide quick, good-quality graphics of ASPIC and ASPICP results. Preformatted time-series plots of relative benchmarks and of observed and fitted abundance indices are provided. Plots can be viewed on the screen, sent to a Windows printer, or saved as graphics files in several formats.

The AGRAPH program was not meant to meet all graphics needs of ASPIC users. Instead, it allows one to examine results quickly and to have graphics suitable for assessment reports. Operation of AGRAPH is similar to that of any Windows program. It can also be started from the command line. For example, to make graphs from results in file `sword.fit`, use the command

```
agraph sword.fit
```

6 ASPIC Input File Specification

ASPIC reads its input from a single file containing control parameters and data. The format of that file is described here.

6.1 Generating a sample input file

A new feature of ASPIC 5.0 is that a sample input file can be generated with the command

```
aspic -help
```

The sample file is useful as a template for making new input files. It could also be helpful to have it available when reading this section.

6.2 General format guidelines

The representation of values in the input file must follow certain rules, which follow from the use of Fortran list-directed `read` statements to read the data.

- The exact position of values on a line is not important. However, if a line contains more than one value, they must be in the correct order.

- When a line contains more than one value, they must be separated by spaces (blanks). *Using* `tab` *characters to separate values is not recommended.*

The remaining rules depend upon the type of the data item (integer, real, or character).

- Each *real number* should contain a decimal point, an exponent (marked by the letter d or e), or a decimal point and an exponent. Examples: `1.0, 2e3, 1.3d6`. (Note that the notation `2e3` means 2×10^3.) An integer can be used in place of a whole real number.
- *Integers* must not contain decimal points or exponents. Examples: `0, 2, 94541`.
- *Character strings* may be delimited by matched apostrophes or quotation marks. However, this is necessary only if the string contains embedded blanks or other special characters. Examples (each on a separate line):
  `IRF`
  `'This is a valid string'`
  `"Another valid string"`
- Each line must have the specified number of values, separated by spaces. Values may not be otherwise arranged among lines.
- After the specified number of values have been read from a line, the program does not read it further. Thus, the rest of the line may be used to contain comments. Comments are included in the sample input files, preceded by pound signs, ##. The pound signs are used to make the comments stand out to the eye and do not themselves denote comments to ASPIC.
- After all data have been read from the file, as determined by the number of years of data and number of data series, any further contents of the file are ignored by ASPIC. Thus, additional comments may be appended to the file.

6.3 The ASPIC input file, line by line

Line 1: Program mode

This is a character string of length 3, with possible values `FIT` (fitting mode), `BOT` (bootstrap mode), or `IRF` (iteratively reweighted fit mode). Further explanation of program modes is found in §4.3.

Line 2: Title of analysis

This is a character string of length 110 characters or less. The title is written to the main output file to identify the particular analysis. The title will also appear on graphs made with AGRAPH and projections made with ASPICP.

Since the title almost always contains spaces, it should be surrounded by quotation marks.

If the first character in the title is an asterisk (*), the main output file will contain control codes to activate the "lineprinter" font on many laser printers. This provides a simple method of neatly printing ASPIC output files, which are 120 characters wide.

Example: `"*Run 4 for Redfin Tuna, 1994"`

However, printer control codes so generated can be a nuisance when the files are *not* being printed in this way.

Line 3: Model shape and optimization control

Note: In an effort to make ASPIC 5.0 as compatible as possible with earlier versions, the input file has the same general arrangement. However, additional control values are needed. Many of them appear on line 3, which make this section rather long. ✻

Line 3 has a varying number of items. ✥

☞ The *first value* on line 3 is a character string specifying the model shape (program shape mode).

Value	Meaning
`LOGISTIC`	Fit the logistic (Schaefer) model.
`GENGRID`	Fit the generalized model at grid of values *or at one specified value.*
`FOX`	Fit the Fox model (a special case of `GENFIT`, below).
`GENFIT`	Fit the generalized model and estimate its exponent directly.

☞ The *second value* on line 3 is a character string specifying the conditioning mode for the fit. For more information, see §4.5.2 on page 9.

Value	Meaning
`YLD`	Condition fitting on yield (recommended for most analyses).
`EFT`	Condition fitting on fishing-effort rate.

☞ The *third value* on line 3 is a character string specifying the objective function.

Value	Objective function
SSE	Sum of squared errors (recommended default).
LAV	Least absolute values (robust objective function).

Before setting values 4, 5, and 6 on line 3, define ϕ as the decimal fraction defining model shape, $\phi = B_{MSY}/K$ (thus $0 < \phi < 1$). Then define $\Phi = \text{nint}(100\phi)$, where "nint" is the nearest integer function, and thus $0 < \Phi < 100$).

For example, in the logistic model, $B_{MSY} = K/2$, so $\phi = 0.5$ and $\Phi = 50$. For the Fox model, $\phi = \exp(-1) \approx 0.3679$ and $\Phi = 37$.

☞ The *fourth value* on line 3 is an integer, the lowest Φ to consider in GENGRID and GENFIT shape modes. A reasonable default might be 25. If present, this value is ignored in LOGISTIC and FOX shape modes.

☞ The *fifth value* on line 3 is an integer, the highest Φ to consider in GENGRID and GENFIT shape modes. a reasonable default might be 75. If present, this value is ignored in LOGISTIC and FOX shape modes.

☞ The *sixth value* on line 3 is an integer whose interpretation depends on the shape mode chosen:

Shape mode	Meaning of fifth value
GENGRID	Step size for grid of shape parameters examined.
GENFIT	Starting value for shape parameter.
LOGISTIC	Ignored.
FOX	Ignored.

In GENFIT shape mode, a reasonable default is often to use the logistic, i.e., to use 50.

☞ The *seventh value* on line 3 is a real number that sets bounds to constrain the generalized fit near the logistic. For example, a value of 8.0 means that MSY for the generalized fit must lie between 1/8× and 8× the MSY estimated in the logistic fit. This ad hoc method is used to increase stability in fitting. In simulation studies, the value 8.0 has proven a reasonable default. The parameter K is also constrained, but on much wider bounds.

To use a specified model shape, use GENGRID *shape mode, set the fourth and fifth values equal to the specified shape, and set the sixth value (the step size) to zero.*

Examples of line 3

Example 1. Specify a grid-search for the shape parameter between $\Phi = 40$ and $\Phi = 60$ (a moderate range around the logistic, $\Phi = 50$). Use a step size in Φ of 5. Set bounds on MSY of 1/8× to 8× the logistic estimates. Use SSE (least squares) objective function (in log space), conditioned on (matching) the effort in the input file. Note that EFT here is the equivalent to the optimization mode CAT in ASPIC 3.x.

```
GENGRID EFT SSE 40 60 5 8.0
```

Example 2. Fit the generalized model conditioned on effort, with bounds of $\Phi = [40, 70]$ and starting value $\Phi = 50$. Constrain the generalized estimate closer to the logistic than in Example 1.

```
GENFIT EFT SSE 40 70 50 5.0
```

Example 3. Use a fitting procedure that could be accomplished with ASPIC 3.x. Fit the logistic model, conditioned on yield. When fitting the logistic model, only the first three values on line 3 are required.

```
LOGISTIC YLD SSE
```

Line 4: Verbosity & output file control

This is a single integer value that controls the amount of output printed to the screen during execution (the "verbosity") and whether the optional *.SUM and *.PRN files (§4.7) are generated. To generate those files, set this value in the range 10–14; to suppress the files, set the value in the range 0–4.

Note that the optional files can also be controlled by options in the .INI file (§7 on page 19). If the files are turned on *in either way*, they will be generated.

To control the amount of screen output, set the value within the ranges 0–4 or 10–14. In terms of screen output, 0 is equivalent to 10, 1 is equivalent to 11, and so on. A setting of 0 or 10 gives very little screen output; 4 or 14 are intended for debugging, and give too much for any practical purpose. The recommended value is 2 or 12 (moderate screen output).

Line 5: Number of bootstrap trials

An integer $0 \leq n \leq 1000$. A reasonable default is 500. Although this is used only in BOT program mode, in other program modes it still must be set to a valid integer, which will be ignored.

Line 6: Monte Carlo searching

This line contains two integers to control the optional Monte Carlo (MC) search during fitting.

☞ The *first value* on line 6 may be 0 to disable the Monte Carlo search during fitting; 1 to enable MC searching; or 2 for repeated searching. Turning MC on can help when a repeatable solution is otherwise difficult to find. Unfortunately, when strong local minima are present, the MC search can cause more problems than it solves. The author recommends leaving it off unless it is definitely needed.

☞ The *second value* on line 6 sets the initial number of Monte Carlo trials. when repeated searches are enabled, this number is reduced by the program in searches after the first. Even if the first number on this line is 0, the second number is needed as a placeholder.

As stated above, the recommended procedure is to leave searching off unless it is needed. If turned on, suggested parameters are: `1 50000`. Monte Carlo searching, and particularly repeated searching, increases execution time considerably.

Line 7: Convergence criterion for optimizer

This convergence criterion is a real number denoted ε_1. After each adjustment of the simplex, the objective function is computed for each vertex of the simplex. Convergence is defined to occur when the following condition is met:

$$\frac{2\,|L_1 - L_0|}{L_1 + L_0} < \varepsilon_1.$$

where L_1 is the highest objective-function value in the simplex and L_0 is the lowest.

The recommended value is $\varepsilon_1 = 1 \times 10^{-8}$, which is written as `1d-8` in the input file. Using a different value is not recommended.

Line 8: Restart control

Randomized restarts are used by the ASPIC optimizer to avoid local minima. The two values (real, integer) on line 8 control this mechanism.

☞ The *first value* on line 8 is the tolerance ε_2 for ending restarts. When objective function values from k restarts in a row agree to within this tolerance, the solution is accepted. The recommended value is $\varepsilon_2 = 3\times10^{-8}$, which is written as `3d-8` in the input file. Changing this value is not recommended.

☞ The *second value* on line 8 sets k, the minimum number of restarts required. The recommended default for this integer value is 6. Larger numbers can be used if needed to obtain a solution not overly sensitive to starting values. (The value used by ASPIC 3.x was $k = 3$, increased in version 3.89 to $k = 6$.) ✻

Line 9: Control of iterative computations

Iterative computations are used by ASPIC in several places. The two values (real, integer) on line 9 control two important sets of iterative computations.

☞ The *first value* on line 9 is the tolerance ε_3 for computing the annual fishing mortality rate (F). When conditioning on yield, an iterative method must be used to estimate F; it continues until successive estimates are within ε_3. The recommended value is $\varepsilon_3 = 1\times10^{-4}$, which is written as `1d-4` in the input file. Changing this value is not recommended.

In EFT optimization mode, ε_3 must be present in the input file, but it is ignored.

☞ The *second value* on line 9 is the number of time steps used per year for the generalized model, range 2–100. A reasonable default is between 12 and 24 steps. The choice affects execution speed (§2.2.1). ✻

When fitting the logistic (Schaefer) model, this number is not required. If present, it is ignored.

Line 10: Maximum estimated F

This line contains a real number specifying the maximum allowable estimate of F. This maximum (used when conditioning on yield) serves to aid the optimizer. The recommended default is `8d0`, which works well in most cases.

Line 11: Statistical weight for B_1 penalty in objective function

This line contains a real number that controls the influence of the penalty term on $B_1 > K$ (see §4.5.1). To omit the penalty term, set this to `0d0`. To use the penalty term, enter a positive real number (usually `1d0`). The penalty is useful in analyses showing a sharp decline in relative abundance in the initial years; such data sets can otherwise result in an extremely high estimate of B_1.

The recommended default is no penalty. If the resulting estimate of B_1/K is too high, the analyst can try either the penalty term or fixing B_1/K rather than estimating it. Either approach can affect estimates of management quantities; sensitivity analyses are useful to examine this. The penalty term is described in Prager (1994); fixing B_1, in Punt (1990).

Line 12: Number of data series

This line has a single integer from `1` to `10` that indicates how many data series are to be analyzed. The types of allowable data series are summarized in Table 1 on page 10.

Line 13: Series-specific statistical weights

The program reads as many real numbers from this line as series were specified on the preceding line. The statistical weight w_i for series i is multiplied by each squared residual for that series when the objective function is computed. When `IRF` program mode is used to analyze more than one data series, the w_i are adjusted to implement inverse-variance weighting. They can all be set to unity, best written `1d0` in the input file, unless there is reason to set them otherwise.

Line 14: Starting guess for B_1/K

This line contains a single real number between zero and one. Set this value based on your belief about the stock's condition at the start of the data set. In the absence of other information, a reasonable default is `0.5`.

Line 15: Starting guess for MSY

In the absence of other information, half the largest yield can be used as a starting guess. This should be entered as a real number.

Line 16: Starting guess for K

In the absence of other information, a reasonable guess is 2 to 20 times the largest recorded yield. This should be entered as a real number.

Line 17: Starting guess(es) for q

The program reads as many real numbers from this line as there are data series specified on line 12. The meaning of q depends on the data type that it refers to. When it refers to an effort-yield data series (code `CE` in Table 1), q is the catchability coefficient. When it refers to a biomass index data series (codes I0, I1, or I2, Table 1), q is the constant relating the index data to the internal ASPIC estimates of biomass; e.g., if $q = 2.0$, the index data are divided by 2.0 before being compared to the estimated biomass. When it refers to a biomass estimate series (codes B0, B1, or B2, Table 1, the user's value of q is ignored, but a number must be present as a placeholder.

❖ For technical reasons, optimization is more difficult when q is large. Thus, a successful result is most often obtained when the catch and index data are scaled so that all $q_i < 0.01$. This, of course, does not apply to Bn data series, for which by definition $q_i = 1$.

Line 18: Flags to estimate (or fix) individual parameters

If line 12 specifies I data series, the program reads $I + 3$ integer values ("flags") from this line. The flags refer, in order, to B_1/K, MSY, K, and $q_i, i = \{1, 2, \ldots, I\}$. Set the flag to `1` to estimate the corresponding parameter, or `0` to keep the parameter constant at the starting guess. No flag should be set to any value other than 0 or 1. Although q_i is not estimated for some series types, $I + 3$ flags are always required.

Line 19: Bounds on MSY

This line contains maximum and minimum bounds on the estimate of MSY. These two real numbers are used to limit the solution to reasonable values. The user defines what is reasonable by setting these values. If final estimates are at either constraint, an error message is printed on screen and in the output file. Bootstrap trials falling outside these bounds are discarded.

LINE 20: BOUNDS ON K

This line contains maximum and minimum bounds on the estimate of K. They are used in the same way as the bounds on MSY.

LINE 21: RANDOM NUMBER SEED

Use a large (7-digit) positive integer. Different numbers result in different random number sequences. Using the same seed allows duplication of a previous run.

Using a different seed should result in the same answer (within expected computation errors); if results are substantially different, at least one of the solutions was a local minimum. The user can attempt to remove sensitivity to random number seed by increasing the number of restarts required (second number on line 8).

LINE 22: NUMBER OF YEARS IN DATA SET

The total number y of years described by the input file, including any years with missing values. Within the file, each data series must be of length y and describe the same specific years. Nonoverlapping series can be accommodated by padding each series with missing values or zeroes as appropriate.

FOLLOWING LINES: INDIVIDUAL DATA SERIES

There must be one data block (group of lines) for each data series. Each block should include data for all y years; thus, thus each data block must be the same length y. The composition of each block is as follows —

(a) On the first line of the block, a series title (character string, length ≤ 40, in quotes). Example: `"Spring survey & total landings"`

(b) On the second line of the block, a character string of length 2 with the type code for the series. Type codes are listed in Table 1 (p. 10).

(c) Starting on the third line of the block, one data line for each year, with the following data on each line, separated by blanks —

(c1) *First number* — the year or other ID number. These are consecutive integers and must be identical from block (data series) to block. Numbers greater than 9999 will not print correctly.

(c2) *Second number* — a real number whose meaning depends on the series type. For type CE, it is the fishing-effort rate f for the year. For type CC, it is the average relative abundance (usually based on CPUE). For types B0, B1, or B2, it is a stock-biomass estimate. For types I0, I1, or I2, it is a relative abundance value.

(c3) *Third number* — a real number, required for CE or CC series only, giving the total yield (catch in biomass) from the fishery for that year. For other types of series (B*n* or I*n*), the third number is not needed and if present, it is ignored.

Although yield–effort data series are designated type CE, effort is entered before yield on these lines. Similarly, in series type CC, the relative abundance appears before the yield. ❖

As noted in §6.3, it is recommended (although not absolutely necessary) to scale the catch and index data so that all $q_i < 0.01$. This does not apply to Bn data series, for which by definition $q_i = 1$.

6.4 Common questions about data series

6.4.1 MISSING VALUES AND ZEROES

Missing or zero data values are allowed in an ASPIC input file in some cases, depending on the conditioning mode and type of data series. All possible cases are described in Table 3, along with the action taken by ASPIC. A data line with a missing value or with $f = 0$ does not contribute to the objective function; however, the information present on the line is used in the analysis and does influence the estimates.

Any negative data item in the input file is considered a missing value by ASPIC. Thus a value can be set missing by inserting a minus sign in front of it, and the value can be restored in a later analysis by removing the minus sign. When a missing value appears in the ASPIC input file, an estimate of the underlying value appears in the output file.

Missing values are always distinct from true zero values. Zero should never be used to indicate a missing value, and a negative number should never be used for an observed zero.

Zero values of the abundance measure (CPUE) are never permitted, because it is assumed that the resource is not extinct during the analysis period. If an abundance index calculated prior to using ASPIC is

Table 3. Actions taken by ASPIC when data series include data record(s) with missing value(s) or zero(es). Dash (—) indicates normal data (neither missing nor zero). M indicates a record with missing datum; Z, with zero datum. Series type Index *includes* I0, I1, I2, B0, B1, *and* B2 *series.*

Cond. mode	Series type	CPUE or effort	Yield	Action by ASPIC
YLD	CC	M	—	Fit; estimate missing CPUE.
YLD	CC	—	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CC	M	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CC	M	Z	Fit with $F = Y = 0$ (no fishing).
YLD	CC	Z	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CC	Z	—	Stop: zero CPUE never allowed.
YLD	CC	—	Z	Fit with $F = Y = 0$ (no fishing).
YLD	CC	Z	Z	Stop: zero CPUE never allowed.
YLD	CE	M	—	Fit; estimate missing CPUE.
YLD	CE	—	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CE	M	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CE	M	Z	Fit with $F = Y = 0$ (no fishing).
YLD	CE	Z	M	Stop: missing yield not allowed when conditioning on yield.
YLD	CE	Z	—	Stop for error: when $F = 0$, Y must be 0.
YLD	CE	—	Z	Stop: zero CPUE never allowed.
YLD	CE	Z	Z	Fit with $F = Y = 0$ (no fishing).
YLD	Index	M	—	Fit; estimate missing CPUE.
YLD	Index	Z	—	Stop: zero CPUE never allowed.
EFT	CC	M	—	Stop: missing CPUE not allowed when conditioning on effort.
EFT	CC	—	M	Stop: missing yield not estimable in this case.
EFT	CC	M	M	Stop: missing effort not allowed when conditioning on effort.
EFT	CC	M	Z	Stop: missing effort not allowed when conditioning on effort.
EFT	CC	Z	M	Stop: zero CPUE never allowed.
EFT	CC	Z	—	Stop: zero CPUE never allowed.
EFT	CC	—	Z	Fit with $F = Y = 0$ (no fishing).
EFT	CC	Z	Z	Stop: zero CPUE never allowed.
EFT	CE	M	—	Stop: missing effort not allowed when conditioning on effort.
EFT	CE	—	M	Fit; estimate missing catch
EFT	CE	M	M	Stop: missing effort not allowed when conditioning on effort.
EFT	CE	M	Z	Stop: missing effort not allowed when conditioning on effort.
EFT	CE	Z	M	Estimate with $F = Y = 0$ (no fishing).
EFT	CE	Z	—	Stop; if $F = 0$, Y must be 0.
EFT	CE	—	Z	Stop: zero CPUE never allowed.
EFT	CE	Z	Z	Estimate with $F = Y = 0$ (no fishing).
EFT	Index	M	—	Fit; estimate missing effort.
EFT	Index	Z	—	Stop: zero CPUE never allowed.

zero in a given year, one could try using a small number (e. g., 20% to 50% of the lowest nonzero value) in its place. Use of an *extremely* small number (e. g., 1% of the lowest nonzero value) will usually result in a large residual during the ASPIC analysis; such a residual can influence the results strongly. Thus, converting zeroes to very small numbers is not recommended.

6.4.2 ALLOCATION OF YIELD AMONG SERIES

When analyzing more than one data series, it is not always possible — or desirable — to associate a yield with each measure of fishing effort rate or relative abundance. A common example is having several abundance indices for a stock, but only the total annual yield. This section aims to describe how ASPIC assumes yield is allocated among data series.

Yield is entered in both CE and CC series. Because ASPIC derives an abundance index from each CE series, it is important that the yield in a CE series correspond to the fishing-effort rate in the same series.

In contrast, it is not necessary for the abundance index in a CC series to correspond to the yield in the same series. For example, a valid CC series might have an abundance index computed from one fishery on a stock, paired with the total catch from all fisheries on that stock.

Despite the above, it is important that yield, summed across series, represent a constant proportion (usually assumed 1.0) of total removals. Changes in that proportion, whether due to reporting changes or changes in discarding practices, violate a fundamental assumption of ASPIC (and of most other assessment models). The consequences of that violation will depend on its severity.

❖ 6.4.3 CAUTION ON ZEROS, MISSING VALUES

The author has attempted to ensure that results of computations including missing and zero values are correct under all combinations of data series type, conditioning mode, and model shape. To that end, a simple test has been done of every combination shown in Table 3. Still, some cases occur infrequently in real data and so have not been tested repeatedly. Users are urged to examine results critically when missing and zero values are used and to advise the author if any problems should arise.

7 Advanced Options for ASPIC

Several advanced options for ASPIC are available if the file ASPIC.INI is found in the directory where the program is run (usually the directory containing the data files). ASPIC.INI is a simple ASCII file. It should have on each line an option name, an = sign, and a value. Depending on the option, the value should be a number or a binary indicator. If binary, the values 1 or T turn the option on; values 0 or F turn it off. Comments may be included in ASPIC.INI as lines beginning with the hash character #.

The options are listed here with their meanings—

- `sfile`—If this is turned on, ASPIC writes an extra output file (extension .PRN) in an ASCII format readable by S-Plus or R with a command like

  `read.table("sword.prn",header=T)`

  The file can also be imported by spreadsheet programs, as it has fixed column widths delimited by spaces. After importing the file, it may be necessary to use search-and-replace to change the text 'NA' (the missing-value indicator in the .PRN file) to the spreadsheet's missing-value indicator.

  The .PRN file has the observed and estimated CPUE series and estimated series of F/F_{MSY} and B/B_{MSY}. It is intended mainly to facilitate making time-series plots.

- `sumfile`—If turned on, this option causes ASPIC to write in the current directory a summary file (file extension .SUM) with summary parameter estimates for each run made in that directory. The SUM file also can be read easily by S-language packages. It is intended mainly for use in simulation studies.

- `ci`—This option, if set to an integer n, $50 < n < 100$, adjusts the intervals calculated and printed in bootstrap mode. ASPIC prints two sets of confidence intervals. The defaults are 80% and 50% intervals. With this option the 50% intervals can be replaced by another value.

- `ljcode`—If turned on, this causes the main output file to be begun with an escape code that turns on the "lineprinter" font of most laser printers. This is a small font that allows ASPIC output files (which are 120 characters wide) to be printed without line breaks. (The same effect can be achieved by beginning the run title in the input file with an asterisk.)

Of the preceding options, only the option `ci` cannot be controlled by other means.

8 ASPICP Input File Specification

The control file for ASPICP is relatively short; it should have the file extension .CTL. For the correct way to represent different data types in the file, see §6.2. A sample file is provided with the ASPIC distribution.

8.1 Line by line

LINE 1: PROJECTION TITLE

This is a character string, length ≤ 70. The title usually contains blanks and should be delimited by quotation marks. The ASPICP output file will also include the title of the original ASPIC run.

LINE 2: NAME OF BIO FILE

A character string specifying the name of a BIO file from an ASPIC bootstrap run. Results from ASPICP will be based on the data in that file.

LINE 3: NAME OF OUTPUT FILE

A character string with the name of the ASPICP output file. If the file already exists, it will be overwritten. For compatibility with AGRAPH, use the file extension .PRJ.

LINE 4: ANY REAL NUMBER

A real number, not used at present, must be put here as a placeholder. It is best to use zero (represented 0d0), in case this option is implemented later.

LINE 5: NUMBER OF YEARS TO SKIP AT START OF PLOTS

An integer with recommended values 0 to 3. The first few years of biomass and mortality estimates are especially imprecise. Also, analysis of certain data sets can give in very high estimated biomasses in the first few years. Thus, omitting the first few years from the plots can be useful.

LINE 6: NUMBER OF YEARS OF PROJECTIONS

Integer between 0 and 15. The longer projections extend, the more speculative they are. For that reason, early versions of ASPICP limited projections to only 10 years, but some users found that overly restrictive. Projections are theoretical constructs and are most useful when comparing management strategies, rather than as forecasts of the future.

FOLLOWING LINES: MANAGEMENT REGIME TO PROJECT

Each following line has data for one projection year; the number of lines should equal the number of years specified on line 6. On each line, enter a real number followed by a single character. The real number represents the yield or relative fishing mortality rate to be applied that year, and the character tells which type of value the number is. For example, line 7 of the .CTL file might read

```
1.456d3  Y
```

to indicate that in the first projection year, a yield of 1,456 units will be taken. Thus, lines ending in Y are used for making projections conditioned on quota (TAC) management measures.

As another example, line 8 of the .CTL file might read

```
0.85d0  F
```

to indicate that in the second projection year, the fishing effort rate will be 85% of the rate in the final year of the original data. Thus, lines ending in F are used for making projections based on proportional reductions in fishing mortality rate. This use of relative values allows F-based projections to be made with reasonable confidence even when the estimated fishing mortality in absolute terms is quite imprecise.

F lines and Y lines can be mixed in the .CTL file. That might be done, e. g., when yield in the first projection year is already known, and management in subsequent years is to be by control of fishing effort.

8.2 Sample ASPICP input file

```
"Case with Y02=Y01; F03 to F07 = F(MSY)"
test.bio
test.prj
0d0
0
6
1200   Y
0.55   F
0.55   F
0.55   F
0.55   F
0.55   F
```

9 Interpretation of ASPIC Results

❖ This section explains some features of ASPIC estimates, and reviews considerations important when using ASPIC. Prager (1994) and Prager et al. (1996) contain additional discussion.

9.1 Precision of parameter estimates

Production models tend to estimate some quantities considerably more precisely than others. Among the quantities more precisely estimated are maximum sustainable yield (MSY), optimum effort (f_{MSY}), and relative levels of stock biomass and fishing mortality rate. Here, relative levels means the biomass level relative to the level at which MSY is attained or the level of fishing mortality relative to that at which MSY is attained.

To provide more precise estimates, then, it is often useful to divide the stock-size estimates provided by ASPIC by the corresponding estimate of stock size at MSY (B_{MSY}). Similarly, the estimates of fishing mortality rate F are divided by F_{MSY} to obtain relative estimates. In its output files, ASPIC provides such relative estimates. The relative estimates present a more precise picture of the condition of the stock, because in normalization, the estimate of q — which is usually imprecise — cancels out.

In contrast, absolute levels of stock biomass (and related quantities), which include uncertainty in the estimate of q, are usually estimated much less precisely. One cannot place nearly as much credence in the absolute estimates of stock size, F, or any quantities that depend upon them. Absolute estimates of B_t and F_t from ASPIC are provided for the modeler's information and are not intended for use as management guidelines.

When two or more data series are analyzed, estimated ratios of catchabilities are typically estimated more precise than estimates of each q. Also, K may be estimated imprecisely or inaccurately even when MSY and f_{MSY} are estimated well. Again, this reflects the difficulty of translating relative biomass changes to an absolute scale.

The starting biomass, estimated as B_1/K, may be considered a nuisance parameter, and its estimate is often imprecise. Punt (1990) recommended fixing $B_1/K = 1.0$ (rather than estimating it) for the Cape hake stock off southern Africa, but it is not clear that that approach is appropriate for every stock. A similar approach is taken in using the penalty term described in §4.5.1.

To stabilize estimates from a particular data set, it can be useful to fit the model with B_1/K fixed at a range of values. Although the resulting estimates of the biomass trajectory will of course diverge at the beginning, they may provide sufficiently consistent estimates of present stock status for management purposes.

9.2 Estimating several catchability coefficients

ASPIC can use more than one data series in estimation. The analyst should be aware that the underlying assumption is that each abundance measure reflects the entire stock, except for random error. Thus, using this feature is similar to deriving an abundance index from each series and averaging them together.

It is not recommended to use abundance indices that are uncorrelated or negatively correlated with one another, unless their overlap is short. When abundance indices present different pictures, CPUE might instead be standardized with a model to remove effects of vessel type, area, gear, season, etc., before fitting an assessment model. The resulting index of yearly abundance can then be used as a 'CC' series with the total catch. This provides quicker and more reliable estimation from ASPIC, but more importantly, it removes explainable variation from the data, which would otherwise become noise.

9.2.1 Catchability over time

The user can estimate separate catchability coefficients for different periods of time. This is accomplished in practice by putting the periods of time in separate data series, each padded with zeroes or missing values as appropriate. This procedure can be used to examine hypotheses about changing catchability with time, perhaps as a result of changing fishing gear or changing environmental conditions. In interpreting such models, there are several considerations.

One concern is estimating whether the improvement in fit obtained from a more complex model is statistically significant. An ASPIC model with time-varying catchability can be tested against the base model (i.e., the simpler model with constant catchability) with an F-ratio test. Here F is the F distribution of statistics, not fishing mortality rate. The test statistic is

$$F^* = \frac{(\mathrm{SSE}_s - \mathrm{SSE}_c)/\nu_1}{\mathrm{SSE}_c/\nu_2}, \qquad (2)$$

where SSE_s and SSE_c are is the error sums of squares of the simple and complex models, respectively; ν_1 is the difference in number of estimated parameters between the two models; and ν_2 is the number of data points less the total number of estimated parameters. The significance probability of F^* can be obtained from standard tables of the F-distribution with ν_1 and ν_2 degrees of freedom.

A small program called FTEST is supplied with ASPIC to facilitate making certain such tests. This program assumes that the same data are used for both models, but are divided into different periods with different estimates of q. The weighting for the penalty term (line 11 in the ASPIC input file) should be set to zero for this F-ratio test to be theoretically correct. The FTEST program is interactive, and takes all input from the screen.

Three often-repeated caveats apply when using the F-ratio test for this purpose. First, hypothesis tests are invalid when suggested by examination of the data. Instead, the test should be suggested by external information, such as changes in gear. Second, the significance of a series of tests is less than that of a single test. For information on this point, consult a reference on multiple comparisons (e. g., Klockars and Sax 1986). Third, hypothesis tests generally assume correct specification of the model. Thus, significance probabilities of tests on assessment models are always approximate. This caveat is especially important when there is evidence that the model does not fit well.

A nonparametric test of the null hypothesis $q_1 = q_2$ can be conducted from the fitting results. This test is constructed by examining the bootstrap estimates of the ratio of the two catchability coefficients. As an example, assume that the alternative hypothesis is that $q1 \neq q2$. Then the null would be rejected at $P < 0.05$ if a bias-corrected 95% confidence interval on q_1/q_2 did not include the value 1.0. Like the F test, this test is approximate because of the possibility of specification error. In addition, bootstrapping residuals may underestimate the true variability present in a time series (Freedman and Peters 1984). This has been addressed to some degree in the current version of ASPIC by the adjustment made to the residuals before bootstrapping is begun.

9.3 Estimation difficulties

The information in this section is central to obtaining correct results. Please read it thoroughly. ❖

The optimization method used in ASPIC (Nelder and Mead 1965) is quite robust, but in unmodified form frequently stops at local minima (these represent sub-optimal solutions). This has been addressed in ASPIC with a restarting algorithm that requires the same solution to be found several times in a row before it is accepted. In the author's experience, the resulting optimizer is reasonably effective at avoiding local minima.

Nonetheless, ASPIC, like other programs that attempt complex nonlinear optimization, occasionally finds local, rather than global, minima. Two features of the program—beyond the restarting algorithm already mentioned—are available to detect and remedy this problem. First, solutions obtained at local minima are often not reasonable, and this will often cause one of the parameters to be estimated at either its minimum or maximum bound. In such a case, a warning message is printed, both on screen and in the output file.

A second feature that can help avoid local minima is an optional Monte Carlo phase of estimation. When enabled, this tries to improve the initial fit by randomly searching for a better one in the neighborhood of the initial fit. If multiple searches are enabled, a shorter Monte Carlo search takes place periodically during fitting. Although such searches considerably increase the time required to find a solution, they can be helpful in avoiding local minima. If a solution is difficult to find, it can be helpful to enable the Monte Carlo searches.

When fitting difficult data sets, it can be useful to make several runs with different random number seeds. Agreement among a number of runs suggests that the solution is stable.

Occasionally ASPIC fails to converge to a minimum at all. This often indicates that the data do not fit the model very well, which can sometimes be verified by examining the results with AGRAPH. When there is no fit, the input file should be checked for errors (e. g., reversed catch and effort values). Rarely, changing the maximum value of F allowed (line 10 of the ASPIC input file) can improve convergence, if the problem occurs in EFF optimization mode. If the objective function appears (from the screen output) to have been near convergence, simply trying a second ASPIC run that uses the first run's results as starting guesses can sometimes provide a good solution. If the model includes several data sets (fisheries), it can be useful to eliminate one or more of them, at least temporarily, to see if convergence can be achieved.

If none of these suggestions is successful, estimates can often be made with the following strategy. Set one parameter (usually B_1/K) to a fixed value by setting the corresponding estimation flag (line 18 of the ASPIC input file) to zero. A solution might be possible conditional upon that value of B_1/K. If this technique leads to a solution, a range of fixed values of B_1/K can be tried and the solutions examined. Similar values of the objective function among solutions indicate that the solutions are nearly equivalent in terms of fit. Although the solutions will differ somewhat, they still may be useful, especially as confirmatory information or if little other information is available for management.

Although ASPIC has been tested on thousands of simulated and real data sets and is believed to operate correctly, errors can exist in any computer programs. Any user experiencing bugs or suspected bugs is asked to send the author copies of the input and output files by email: Mike.Prager@noaa.gov. The author attempts to correct all errors promptly.

10 Program change history

Changes in Version 3.33

Between version 2.8 and version 3.33, major changes were as follows:

- Addition of EFF mode (conditioning on yield) and estimation of missing effort
- Bias corrections of confidence intervals on parameters and population projections (using bootstrap)
- ASPIC-P program for computing bias corrected trajectories and projections with approximate nonparametric confidence intervals
- Character plots added to the program output
- The starting guess and estimate of B_1 specified as ratios to B_{MSY}
- Optional Monte Carlo phase to increase resistance to local minima
- Added iterative reweighting (IRF mode) when analyzing several series
- User-specified limits on MSY and K
- Management benchmarks $f_{0.1}$ and $Y_{0.1}$ computed
- User-specified random number seed
- Added detailed messages for errors in the input file

Changes in Version 3.55

Between version 3.33 and version 3.55, major changes were as follows:

- Added more statistics on stock status in final year
- Replaced K with MSY in parameterization
- Added CC series type to avoid manually converting CPUE to effort.
- Added CPUE plots to output
- Added correlation matrix among indices to output
- Revised IRF mode so that the sum of weights remains equal to the number of data points
- Added residual adjustment factor for bootstrapping
- Added "coverage" and "nearness" statistics
- Improved Monte Carlo search algorithm

Changes in Version 3.82

Between version 3.55 and version 3.82, major changes were as follows:

- Several improvements to Monte Carlo search routine
- Fixed bug in plotting index (I0, I1, I2) series and improved plot layouts
- Increased maximum number of years in data from 60 to 90
- Fixed a bug that didn't replace bad bootstrap trials
- Added LaserJet code option for output files
- Changed output for CE data series from observed and estimated effort to observed and estimated CPUE

- Fixed a crash when the number of bootstraps was set to 1
- Added printout of Monte Carlo setting to output file
- Allowed user to specify input file name on command line

Changes in Version 5.00

Version numbers in the 4.xx series were used for test releases of what is now designated version 5.00. Between version 3.82 and 5.00, the following additions and corrections were made:

- Added generalized model conditioned on effort and on catch.
- Added user-specified number of restarts for convergence.
- Renamed conditioning modes to `YLD` and `EFT` for conditioning on yield and effort, respectively.
- Added an optional basic, S-compatible output file (`.PRN` file).
- Added `.SUM` output file for simulation studies. File name can be passed as second command-line argument.
- Fixed a bug in which residuals $r > 4$ (in log space) weren't plotted.
- Made changes to the `.BIO` output file for compatibility of the generalized model with the new version of ASPICP.
- Changed negative correlation action from program stop to issuing a warning.
- Add FOX model shape as a special case of the generalized model.
- Revised format of the `.DET` output file for better compatibility with S-Plus and R.
- Made changes to unambiguously handle zero CPUE in a CC series as a missing value.
- Version 4.12: Added estimate of $Y.(F_{MSY})$ to output file at suggestion of A. D. MacCall.
- Corrected handling of the rare case of a year (1) conditioning on yield, (2) abundance index present, (3) yield is zero. A residual is now computed based on estimated and observed abundance indices.
- Added a penalty when MSY > K during fitting.
- Printed AIC on `GENFIT` and `GENGRID` output.
- Added internal constraints on q.
- A sample input file (`sample.inp`) can be generated by `aspic -help` on the command line.

11 Source Code

The Fortran source code for this software uses certain proprietary routines from the book *Numerical Recipes* by Press et al., and for that reason can not be freely distributed. Numerical Recipes Software has kindly granted their permission (ID number V95038) for the author to supply the source code to users upon specific request. However, any source code so supplied must not then be redistributed to others.

The author also wishes to be aware of all distribution of the source code, so that any useful modifications or error corrections can be made in the master copy of the software to benefit all users.

If you require a copy of the Fortran source code for this software, please request it from the author. In your letter or email, please include the following:

1. Your true name, institutional affiliation, physical address, and email address or telephone number
2. Your agreement that you will not redistribute the source code to others.
3. Your agreement that, if you modify the source code, you will not distribute any resulting program (or programs), nor the modified source code, beyond your immediate working group at your own location.
4. Your agreement that, if you modify the source code, you will ensure that your users do not redistribute either the modified source code or any resulting program or programs.
5. Your agreement that if you identify errors in the software, you will contact the author promptly so that the errors can be fixed for all users.

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Training materials (07)
Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

Kobe I (Kobe plot) +Kobe II (risk assessment) software

(New version 3, 2014)

User's manual

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Abstract and Notice (release of the software)

This is the users' manual describing how to use the 3rd version of Kobe I (stock status trajectory plots) +Kobe II (risk assessment diagram) software. Kobe I and II were recommended by the 5 tuna-RFMO meeting in 2007 (Kobe, Japan) and 2009 (Barcelona, Spain) respectively.

This software is free of charge available at http://ocean-info.ddo.jp/kobeaspm/kobeplot/KobePlot.zip (from Nov. 19, 2014). After users use this software and if users need improvements, please let us know. We will revise and will release more user's friendly software.

As for Kobe II, the risk assessment matrix format was recommended, but the table formats have been difficult to understand its meanings often, especially for mangers and industries as it uses mathematical and technical notations. To improve this situation, we developed the visualized presentation (diagram) of the matrix for anyone to be able to understand its meanings easily.

Please note that this software is suitable for those who have difficulties to make Kobe I plot and II quickly and effectively in a very short time, especially during the working meetings. Thus it may not be suitable for those who can make these plots and diagrams and/or create better ones by own using specific codes such as R. This is because this software can make fixed designed plots and diagrams. However, it has a lot of flexibilities to change colors, fonts, lines, symbols, legends and labels by graph setting functions (see the text for details).

This software development project has been funded by Fisheries Agency of Japan (2009-2014) for Tuna and Skipjack Resources Division, National Research Institute of Far Seas Fisheries (NRIFSF), Fisheries Research Agency of Japan (FRA). We sincerely acknowledge their continuous financial supports for this project.

Contents

Submitted to the IOTC WPTT16 (November 15-19, 2014), Bali, Indonesia.

ACRONYMS

B	Total biomass
BBDM	Bayesian Biomass Dynamics Model
Bmsy	Biomass which produces MSY
CI	Confidence interval
F	Fishing mortality; F2010 is the fishing mortality estimated in the year 2010
Fmsy	Fishing mortality at MSY
IOTC	Indian Ocean Tuna Commission
LRP	Limit Reference Point
MFCL	Multifan-CL
MSY	Maximum Sustainable Yield
SB	Spawning biomass (sometimes expressed as SSB)
SBmsy	Spawning stock biomass which produces MSY
TRP	Target Reference Point

1. Introduction

1.1 Overview

This Kobe I+II software consists of Kobe I (stock status trajectory plot) and Kobe II (risk assessment diagram). Kobe Plot I can make historical stock status trajectory plots for SB/SBmsy (or B/Bmsy) and F/Fmsy using results of stock assessments. Kobe II depicts color diagrams for results of risk assessments for SB/SBmsy and F/Fmsy, i.e., probabilities violating their MSY levels in the future by different catch level scenarios.

1.2 Operation Systems (OS)

This software can be used under MS windows OS operated by both 32 and 64-bit PCs.

1.3 History of the development

1st version (2011) (IOTC–2011–WPTT13–45)

- Release of the initial Kobe plot software containing basic functions for Kobe I plot and Kobe II diagram.

2nd version (2012) (IOTC-2012-WPM04-05)

- Graphic components were improved using TeeChart Pro.NET v2010 (Steema Software) according to requests by worldwide users.
- Release of two separate software for 32- and 64-bit OS PCs.

3rd version (2014) (IOTC-2014-WPTT16-53)

- Release of one united software for both 32- and 64-bit OS PCs for window OS.
- Designs and functions of Kobe plot I are further improved according to requests by worldwide users.
- Limit and target reference points can be depicted.
- One menu in Kobe I plot is added to show multiple comparisons among different stock assessment results.
- Pie chart option is added in Kobe Plot to show compositions of uncertainties in 4 phases.

2 Installation

1) Uninstall the old versions of Kobe I+II software if users have.

If users installed the previous versions, uninstall it first.

2) Download the package (Version 3, 2014) including software, manual and other references from http://ocean-info.ddo.jp/kobeaspm/kobeplot/KobePlot.zip.

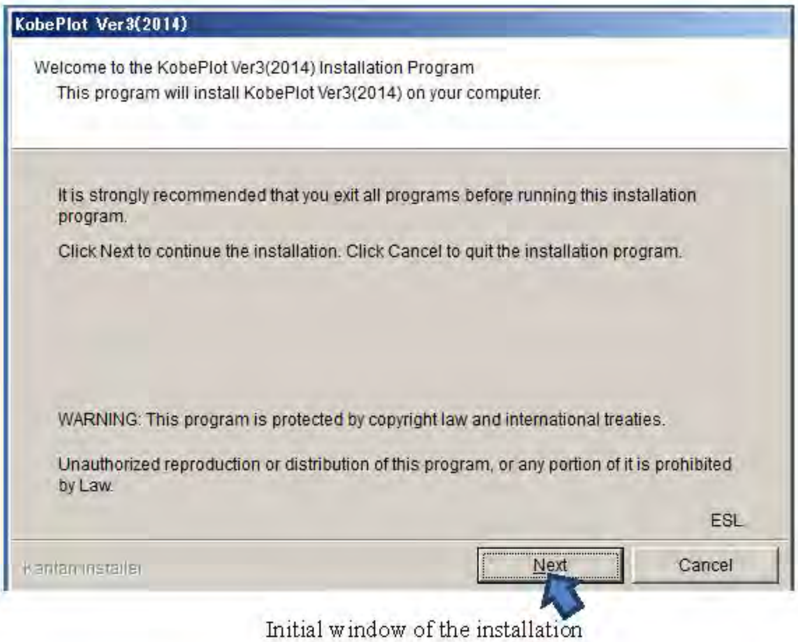
You will get KobePlot.zip

3) Unzip then you will get the installation file.

4) Setup and installation

Double click ➔

and follow the steps shown in page 5-6.

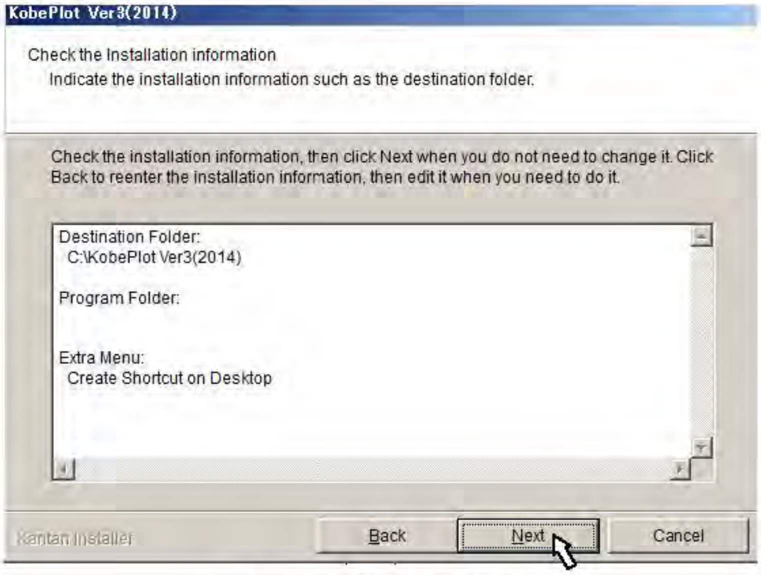


Initial window of the installation

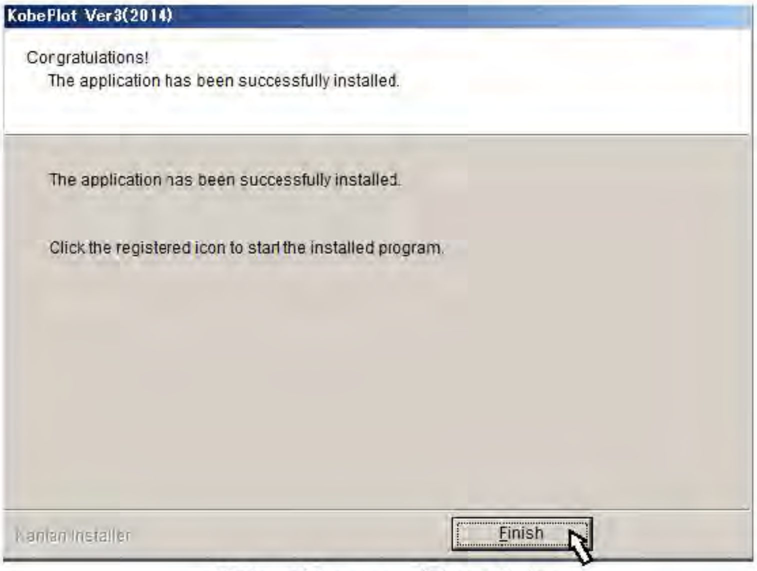
Install this software to the particular folder (C: for this case). If users want to install their favorite folder, select using Browse.

CAUTION: Users may not able to install Kobe plot software into their favorite folder due to users account control restriction under the OS.

5



Summary of the installation



Notice of the successful installation

Note: The Kobe plot software needs .NET Framework 4, which is normally available in Windows OS. But if users don't have it, install it by downloading from the web page.

6

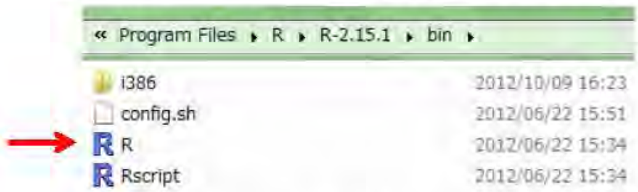
3. Starting the software

1) Click the **Kobe Plot (Ver.3, 2014)** icon located on user's desktop window

Important Note: Normally this icon will appear in the desktop after installation. But, in case users cannot get it in the desktop, please make a shortcut of KobePlotVer3 (2014).exe available in the Kobe plot folder then put it on the desktop.

2) Users will be asked to specify the path of the **R.exe** when launching **Kobe I+II software** for the first time. If users don't have R software, download and install to users PC. Then specify the path of the **R.exe**.

Generally R.exe exists in the following path after installing **R**.



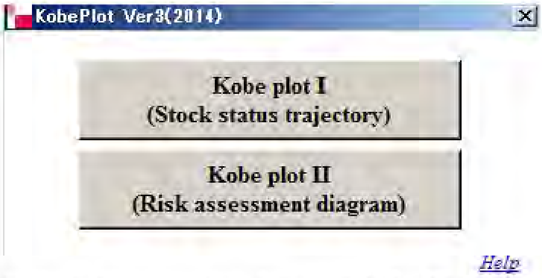
(Install Directory) / R / R-2.1x.x / bin / **R.exe**

Note: Recent version of R is R-3.12

7

3) Users can change the path of R.exe later from **File** > **Path of R.exe**.

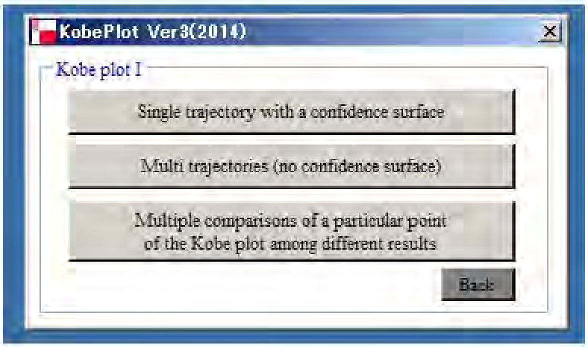
4) After the path of R is assigned, the first window will appear as below.



If users want to make stock status trajectory plots, click **Kobe Plot I**. If users want to make the risk assessment diagrams, click **Kobe Plot II**.

4. Kobe Plot I (stock status trajectory)

There are three sub-menus on Kobe plot I, i.e., 1st menu for one single plot with a confidence surface, 2nd for multi-plots without confidence surface and 3rd (the new option in the 3rd version) for multi-comparisons of a particular point of the Kobe plot (normally final year) among different stock assessment results (for example).



4.1 A single plot with a confidence surface

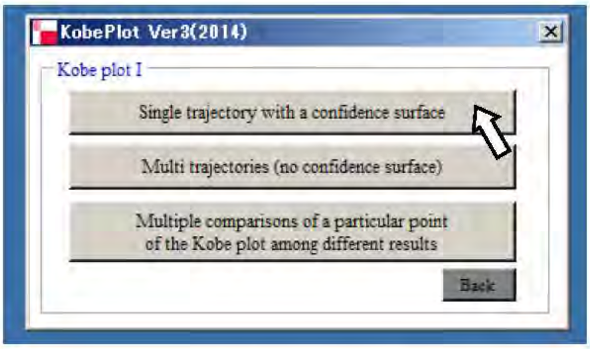
1) How to create the input data?

To create the input data, make a CSV file (see below), i.e., year (column 1), Spawning Stock Biomass (SB) or Total Biomass (B) ratio (SB/SBmsy or B/Bmsy) (column 2) and F ratio (F/Fmsy) (column 3). If users want to create the confidence surface, add 2 columns and put results from MCMC or bootstrap, i.e., SB ratio (SB/SBmsy) or B ratio (B/TBmsy) (column 4) and F ratio (F/Fmsy) (column 5).

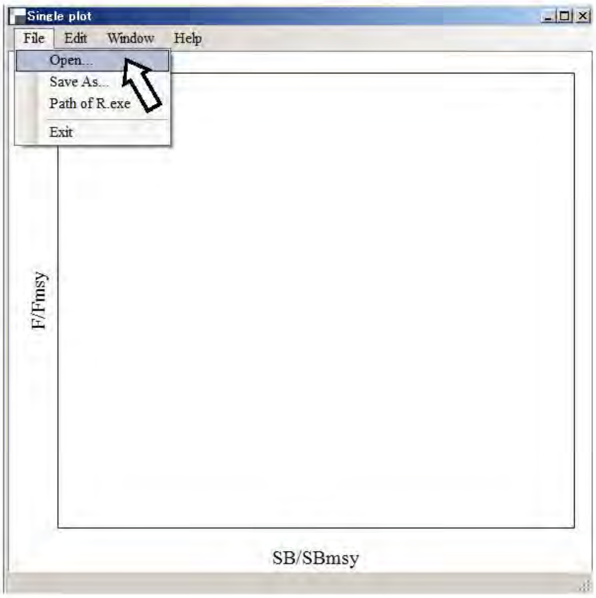
Columns 1-3 Input data a single plot (trajectory)			Columns 4-5 Input data confidence surface (MCMC, bootstrap etc.)	
Col_1	2	3	4	5
	X	Y	X	Y
year	B ratio	F ratio	B(ratio)	F(ratio)
1995	1.911	0.467	0.850	0.978
1996	1.740	0.576	0.632	1.289
1997	1.605	0.613	0.778	1.065
1998	1.485	0.720	0.749	1.101
1999	1.398	0.716	0.399	1.959
2000	1.352	0.737	0.814	1.021
2001	1.342	0.692	0.684	1.198
2002	1.345	0.709	0.918	0.912
2003	1.285	0.850	0.771	1.072
2004	1.193	0.918	0.606	1.338
2005	1.177	0.792	0.467	1.692
2006	1.235	0.711	0.834	0.997
2007	1.292	0.696	0.649	1.258
			0.809	1.024
			0.940	0.889
			0.989	0.848
			0.768	1.079

2) How to read the input data and initial plot?

Click the Single trajectory with the confidence surface sub-menu.

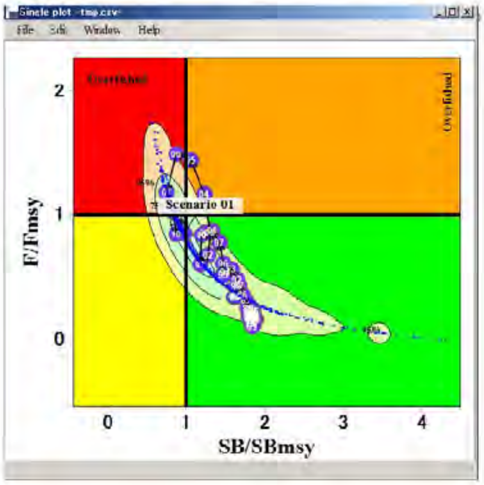


Then users will see the empty window (see below). Then click file, open, then go to the folder where the user's CVS file is located and import it to the software.

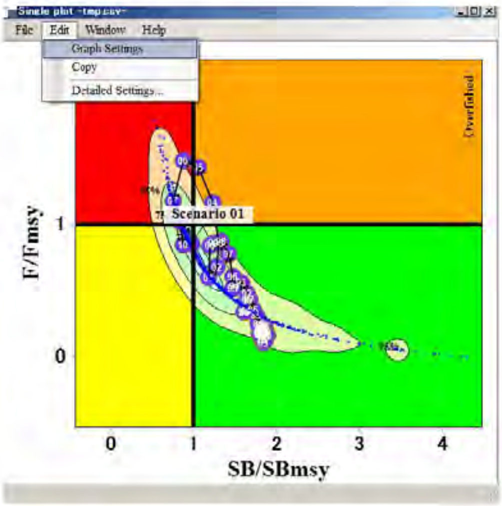


3) Initial default plot and graph settings

After users click Open, users will see the default plot as below. If users don't have confidence surface data, users will get only the trajectory.

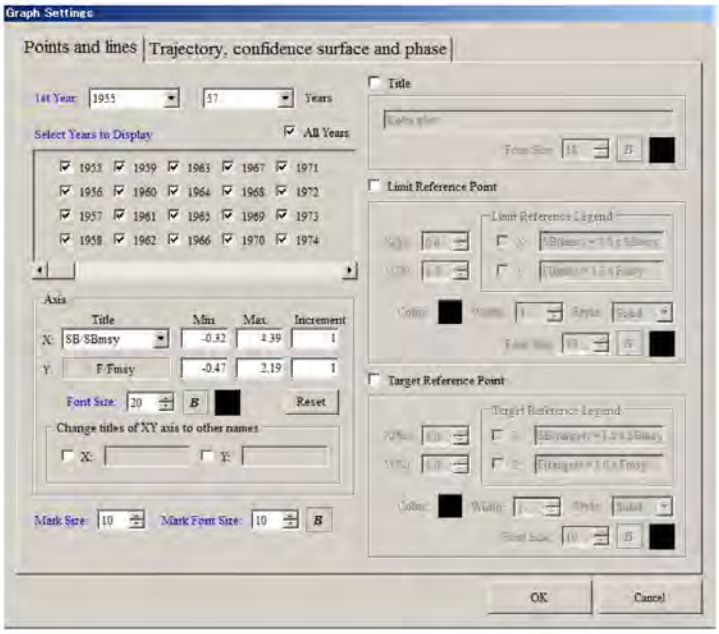


If users want to edit the initial graph, go to the graph setting menu as below:



4) Editing the initial plot (points and lines)

Then users will see the graph setting menu (two types). Users can adjust various parameters to create user's desirable plot. Below is the 1st type for points and lines.



Editing Points and Lines

Years
Set the number of years to display._

Select Years to Display
Choose each year individually to display/un-display._

X Axis (SB/SBmsy)
Choose SB/SBmsy, SSB/SSBmsy, Bmsy or TB/TBmsy using the pull down menu.
Set values of the minimum, the maximum and the increment of X axis._

Y Axis (F/Fmsy)
Set values of the minimum, the maximum and the increment of Y axis.

Font Size
Select the font size. Click ***B*** to make the font bold.

Title
Name the current Kobe plot (e.g. Indian Ocean Albacore)

Mark Size
Select the circle size of year marks (last 2 digits).

Mark Font Size
Select the font size of year (last 2 digits). Click ***B*** to make the font bold.

Limit and Target Reference Point
See next page

Creating Limit Reference Point

Click Limit Reference Point box, then, select % of SBmsy and Fmsy and click Limit Reference Legend as below. % levels are different by species. Table 1 is used in IOTC as an example.

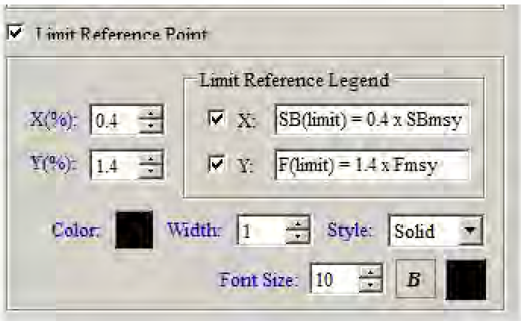
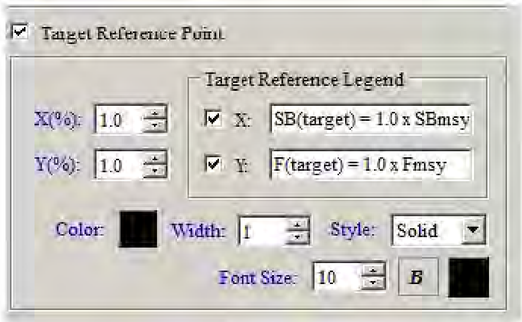


Table 1 Interim Limit Reference Point for Bmsy and Fmsy by species (IOTC)

Stock	Target Reference Point	Limit Reference Point
Albacore	SB_{MSY}; F_{MSY}	0.4*SB_{MSY}; 1.4*F_{MSY}
Bigeye tuna	SB_{MSY}; F_{MSY}	0.5*SB_{MSY}; 1.3*F_{MSY}
Skipjack tuna	SB_{MSY}; F_{MSY}	0.4*SB_{MSY};1.5*F_{MSY}
Yellowfin tuna	SB_{MSY}; F_{MSY}	0.4*SB_{MSY}; 1.4*F_{MSY}
Swordfish	SB_{MSY}; F_{MSY}	0.4*SB_{MSY}; 1.4*F_{MSY}

Creating Target Reference Point

Target Reference Point is also created in the same way as in Limit Reference Point. For example, IOTC, it is now SB/SBmsy=1 and F/Fmsy=1 for all species then set up is as below.

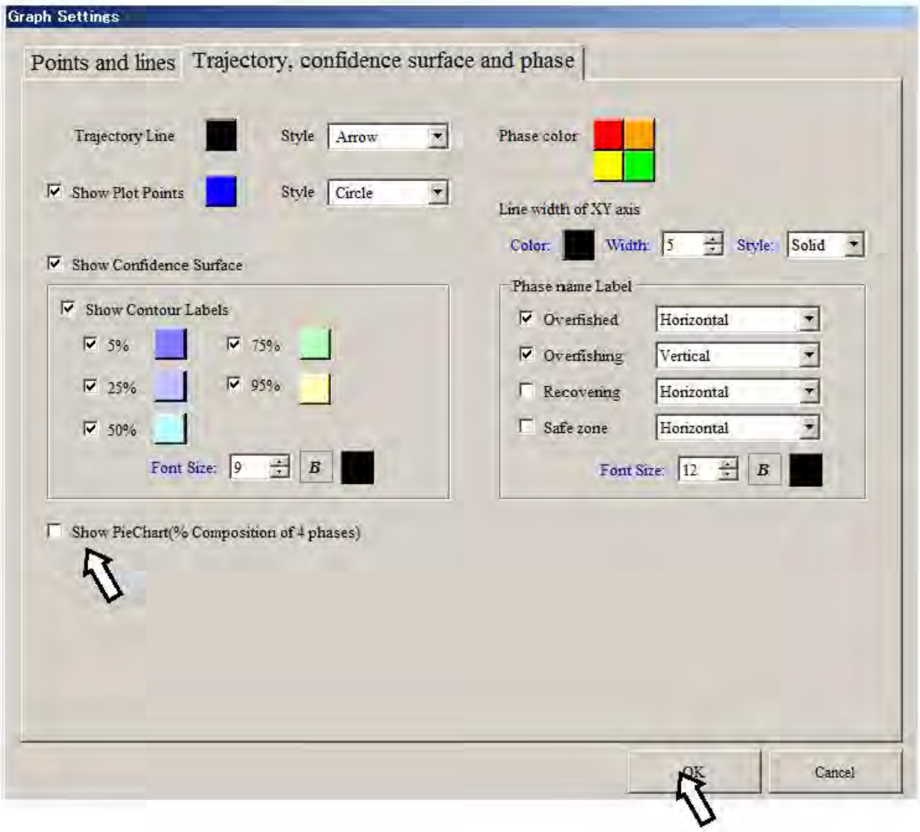


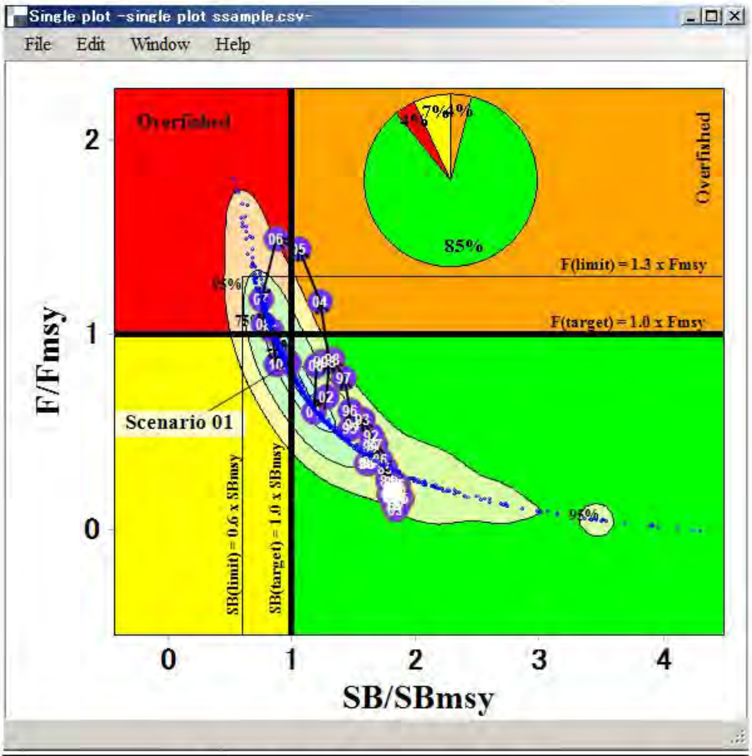
5) Editing the initial plot (trajectory, confidence surface, pie chart and phase)

In the 2nd sheet (below), users can edit trajectory, confidence surface, pie chart and phase using various editorial options and users can create desirable plots.

PieChart option: By checking the PieChart button (below), users can add the pie chart showing composition of 4 phases' areas in the confidence surface.

After users finish the initial graph setting, push OK button, then users will see the edited Kobe plot (next page).





Edited Kobe plot after graph settings

4.2 Multiple plots without confidence surface

This option will produce 2 or more Kobe plot 1 (stock status trajectories).

1) How to create the input data?

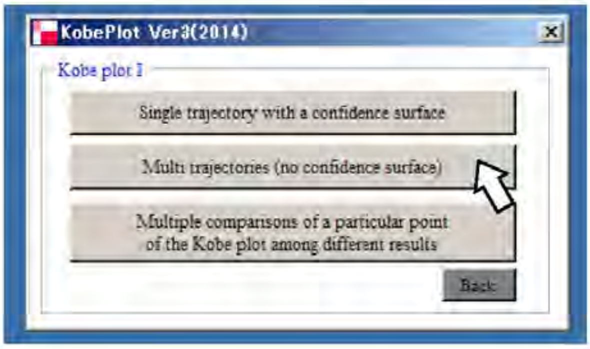
To create the input data, make one CSV file as shown next page, i.e., year (column 1), then the data for the first plot: Biomass: SB (B) ratio (column 2) and F ratio (column 3), then for the second plot: Biomass: SB (B) ratio (column 4) and F ratio (column 5) and so on.

Year	X	Y	X	Y	X	Y
year	TB(ratio)(1)	Fratio(1)	TB(ratio)(2)	Fratio(2)	TB(ratio)(3)	Fratio(3)
1970	3.74	0.00278	3.13	0.000521	5.31	0.00000690
1971	4.72	0.00169	3.12	0.000612	5.31	0.00002140
1972	6.12	0.00120	2.92	0.000715	5.37	0.00012900
1973	7.51	0.00122	2.83	0.000667	5.44	0.00017600
1974	7.81	0.00235	2.13	0.00109	5.41	0.00041800
1975	6.71	0.00352	1.86	0.00220	5.46	0.00030600
1976	5.29	0.00366	1.77	0.00300	5.41	0.00046100
1977	4.39	0.00333	1.99	0.00167	5.45	0.00054500
1978	4.09	0.00367	2.17	0.00122	5.39	0.00057100
1979	3.95	0.00511	2.19	0.00123	5.38	0.00069000
1980	3.85	0.00493	1.82	0.00191	5.36	0.00084300
1981	3.72	0.00498	1.96	0.00177	5.42	0.00083100

Data input (example) for Multiple Kobe plots

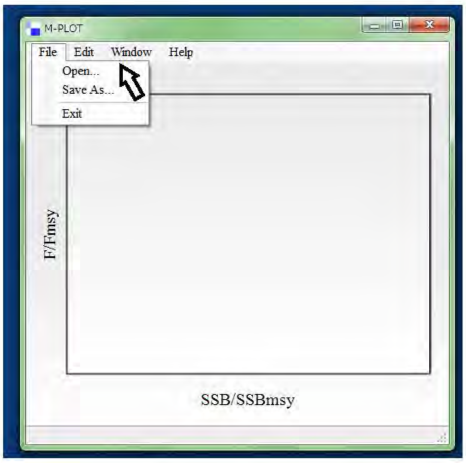
2) Getting started and importing the data

Click the Multi trajectory plot window.

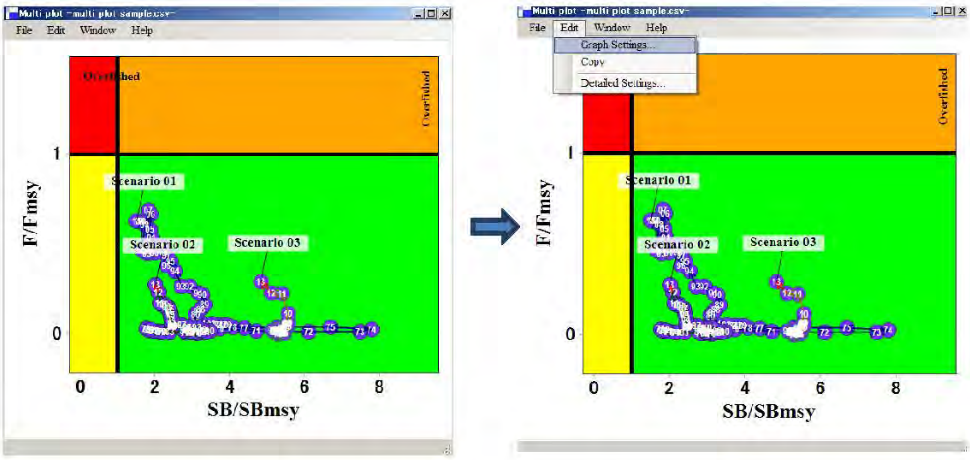


Then users will see the empty window (next page). Then click open file, open, then go to the folder where user's CVS file is located and import to the software.

16

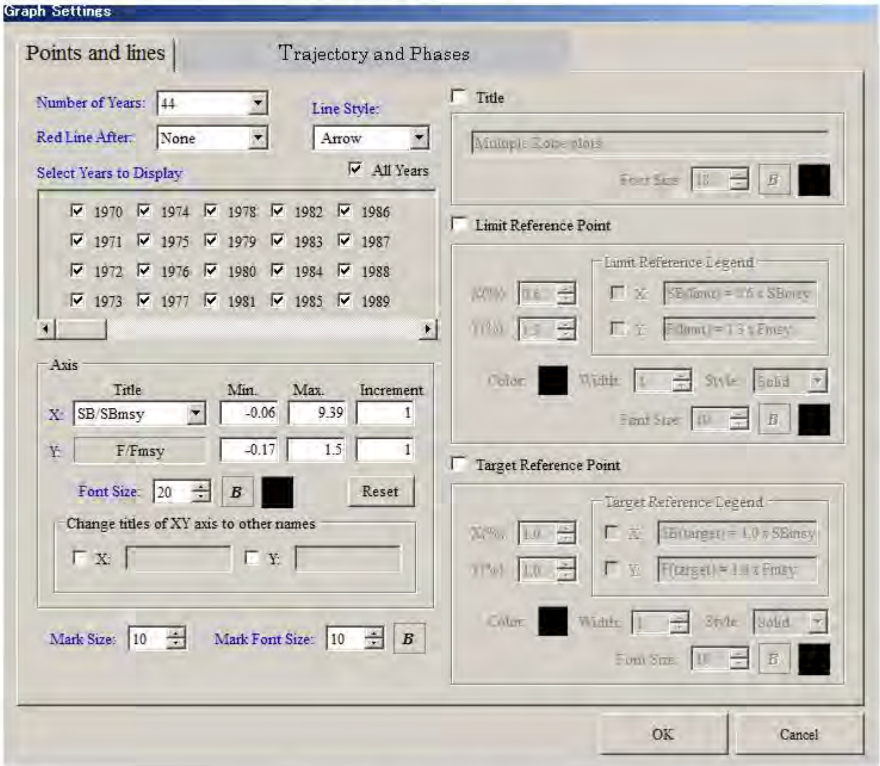


After users click Open, users will see the default plot as below (left). If users want to edit the initial graph, go to the graph setting menu as below (right).



3) Editing the initial plot (points and lines)

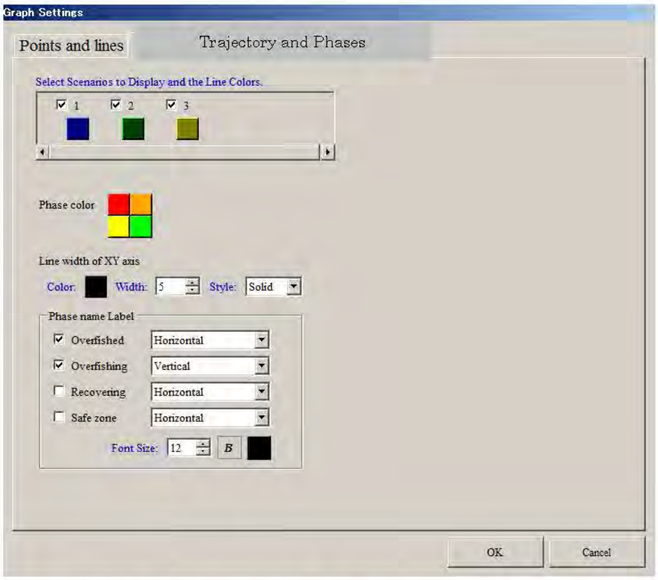
Then users will see the graph setting menu (two types). Users can adjust various parameters to create user's desirable plot. Below is the 1st type for points and lines. For details on this menu, refer to single plot (page 11-12) as the contents are same



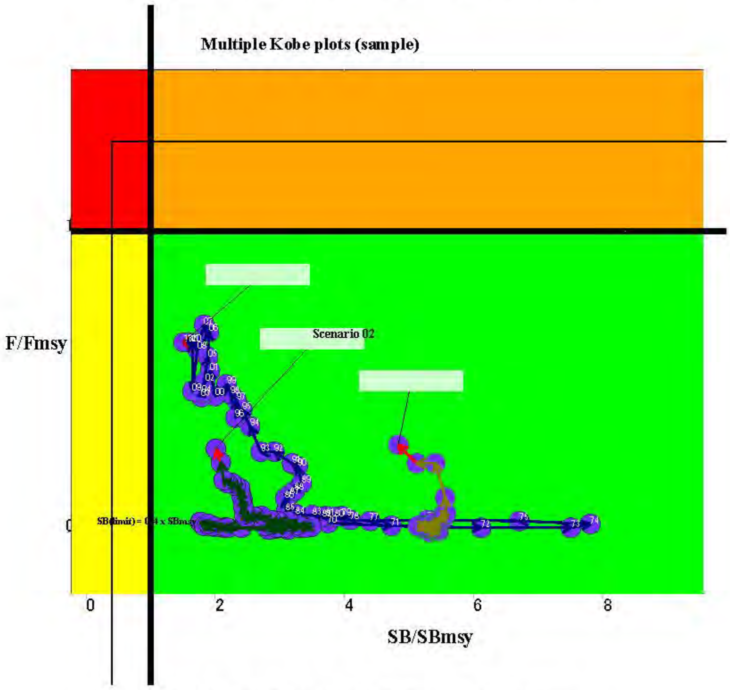
Graph setting menu for points and line

4) Editing trajectories and phases

In the 2nd sheet (next age), users can edit trajectories and phase using various editorial options and users can create desirable plots. After users finish the initial graph setting, push OK button, then users will see the edited Kobe plot (next page).



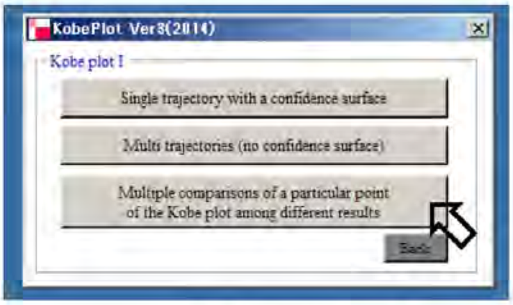
Graph setting menu for Trajectory and Phase



Edited multiple Kobe plots by graph settings

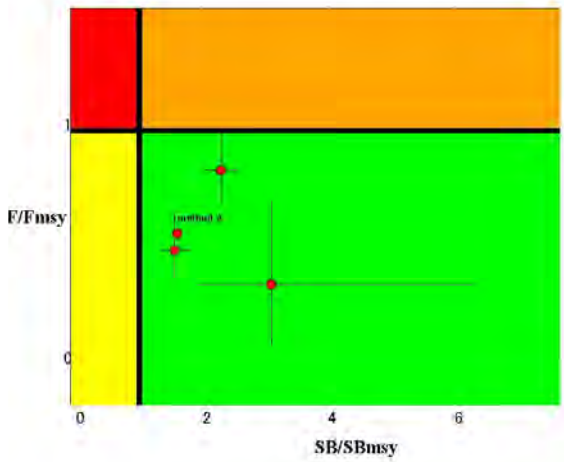
4.3 Multiple comparisons among different stock assessment results

In the similar way as previous options, multiple comparisons option can be conducted as below (only essential figures are provided):



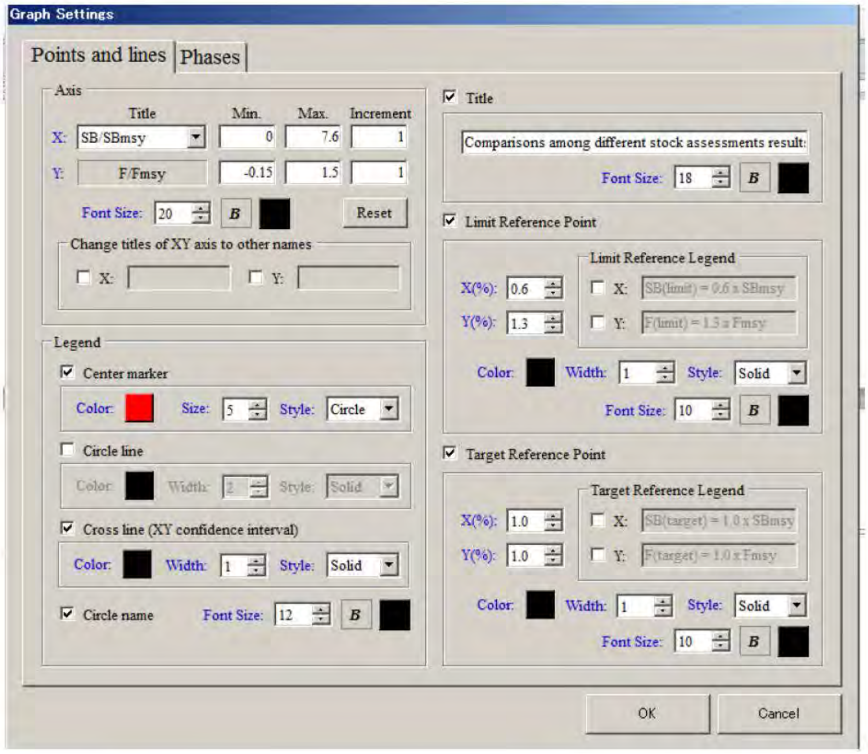
Data format (example)

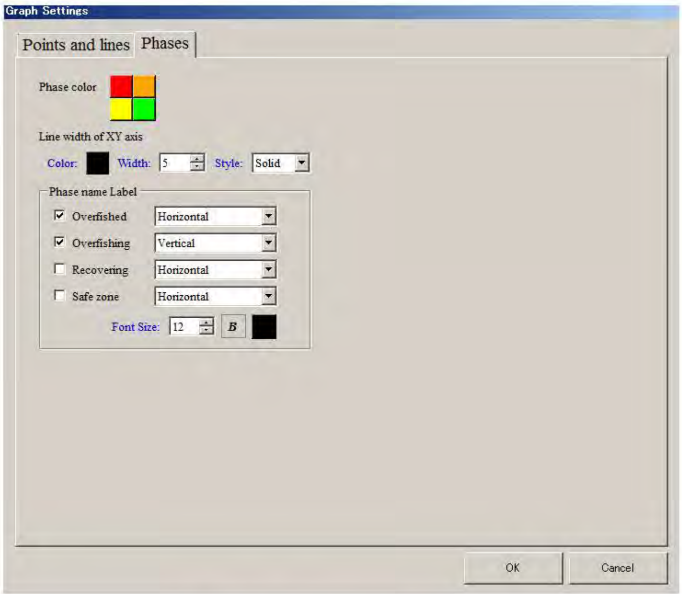
Methods	SB/Sbmsy (point)	SB/Sbmsy (lower)	SB/Sbmsy (upper)	F/Fmsy (point)	F/Fmsy (lower)	F/Fmsy (upper)
method A	1.61	1.58	1.68	0.56	0.52	0.59
method B	2.30	2.04	2.56	0.83	0.68	1.00
method C	1.57	1.36	1.82	0.49	0.35	0.66
method D	3.10	1.92	6.35	0.34	0.08	0.70



Initial plot

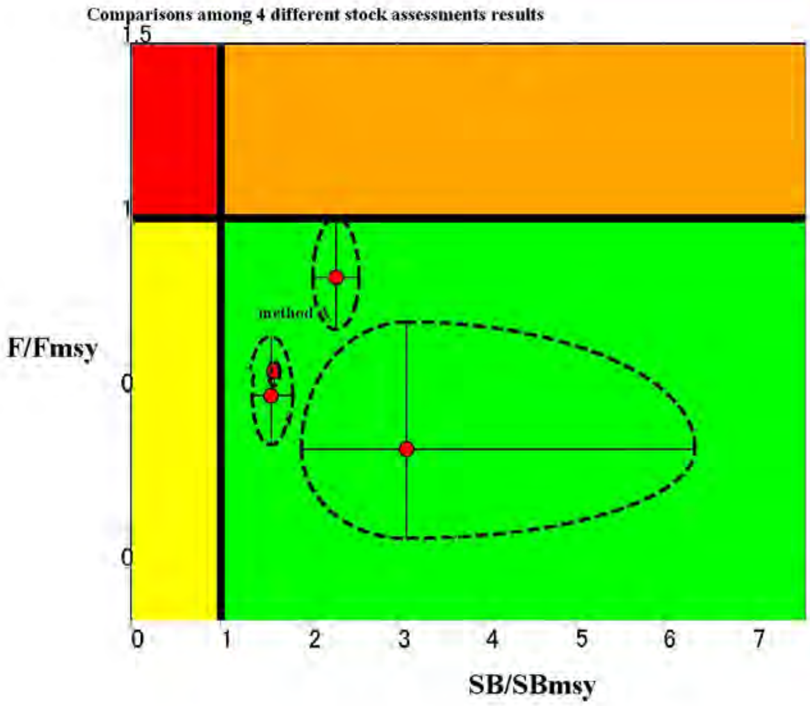
20





Graph settings (two windows)

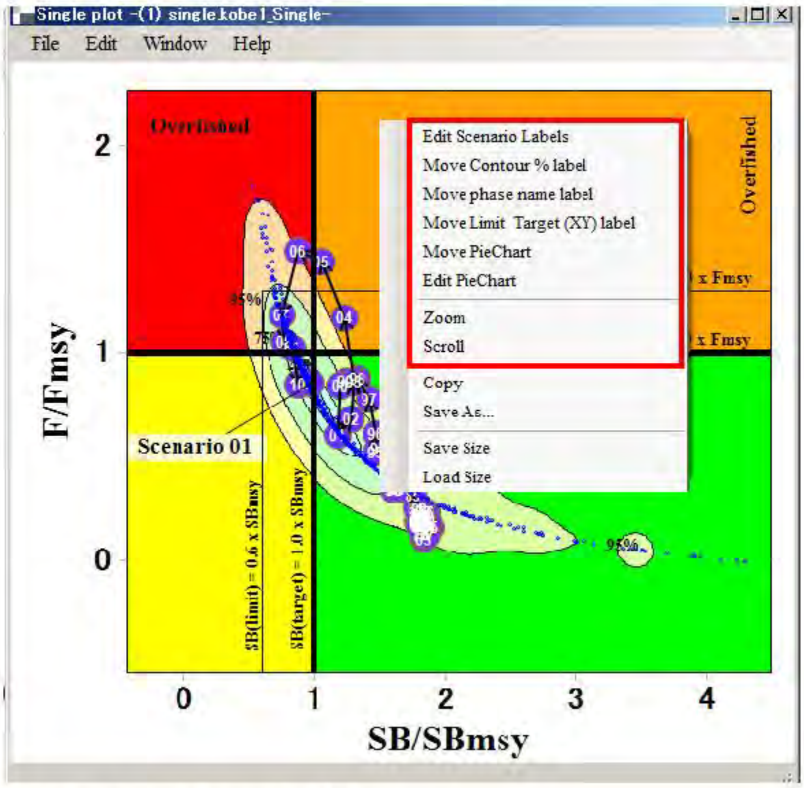
21



Edited multiple comparison Kobe plots after graph settings

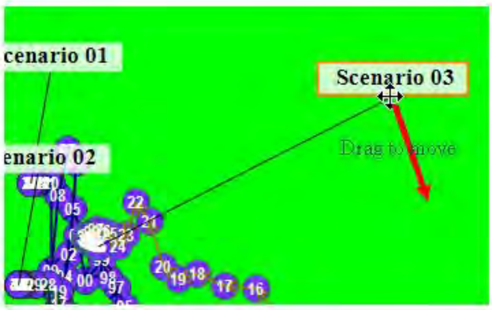
4.4 Common functions (editing and moving labels)

There are a number of labels in the Kobe plot 1. If users want to move and edit these labels, click the right button of the mouse (or equivalent operation), then users will see 5 types of menus to move and edit labels and 2 other functions in the red box as shown next page

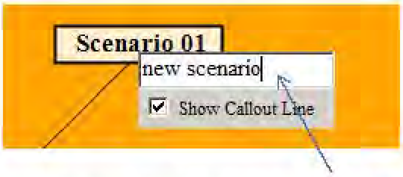


1) **Editing and moving scenario labels**

Click the right button of the mouse in the plot area then the context menu will appear. Select and tick "**Edit Scenario Labels**". Then click the label users want to move and drag it to where users desire to place.



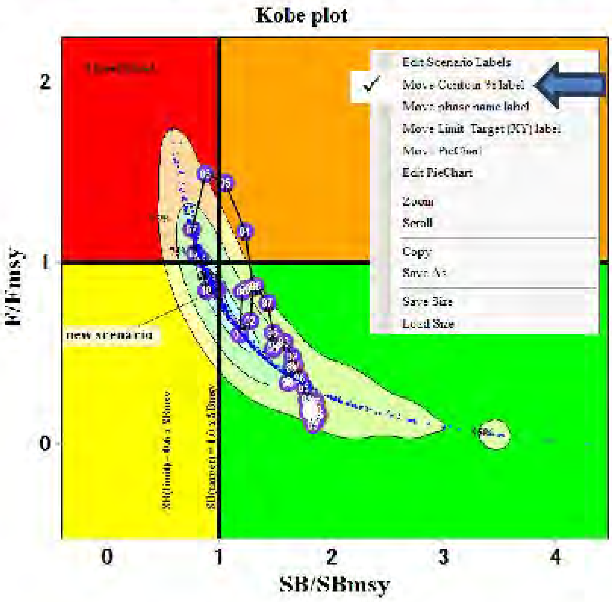
Callout line on and off



(Important) Press the Enter key to finish editing.

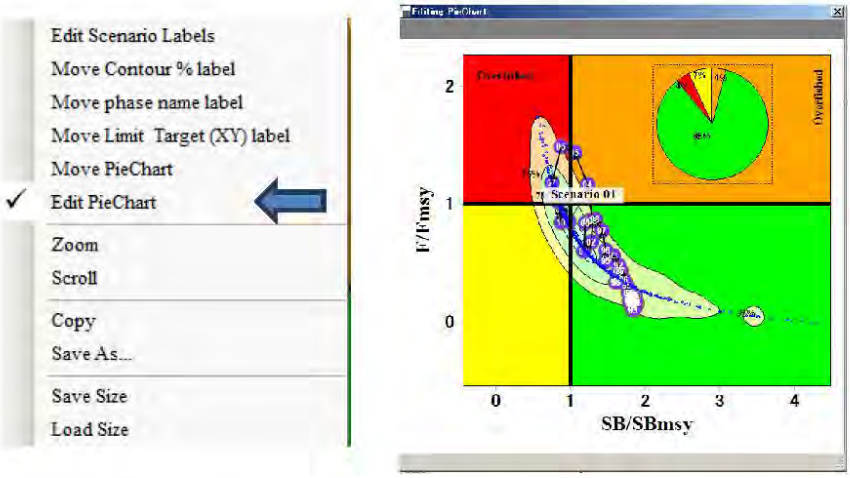
2) Moving contour percentage labels

Move the cursor to the percentage label of the plot and click the right button, then the context menu will appear as below. Select **Edit Contour Labels** then put the cursor on the percentage label (e.g. 95%) then move it to where users desire (see below).



3) Moving Pie Chart

4) **Edit Pie Chart** Users can edit location of % fonts



After users finish editions of the Pie Chart, please tick off, otherwise, the plot zone will remain as above and users cannot see and retrieve the main menu bar.

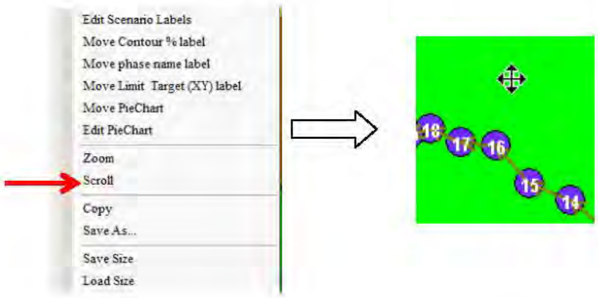
5) Moving phase names labels

6) Moving Limit Target Limit Reference Point

Users can apply these function in the similar way as in Moving contour percentage labels

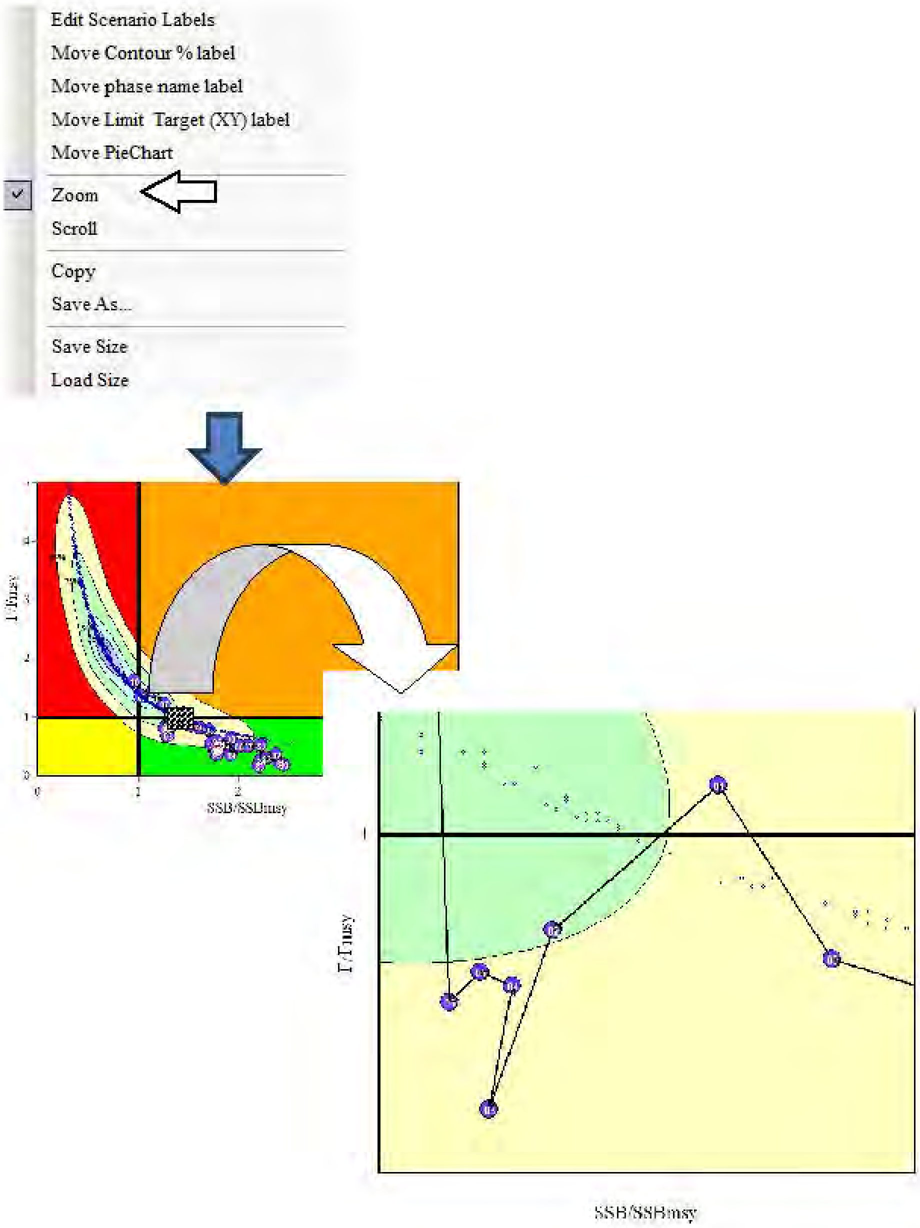
7) Scrolling

Click the right button of the mouse in the plot area then the context menu will appear. Select and tick **"Scroll"** then drag the cursor and scroll the plot area as you like.



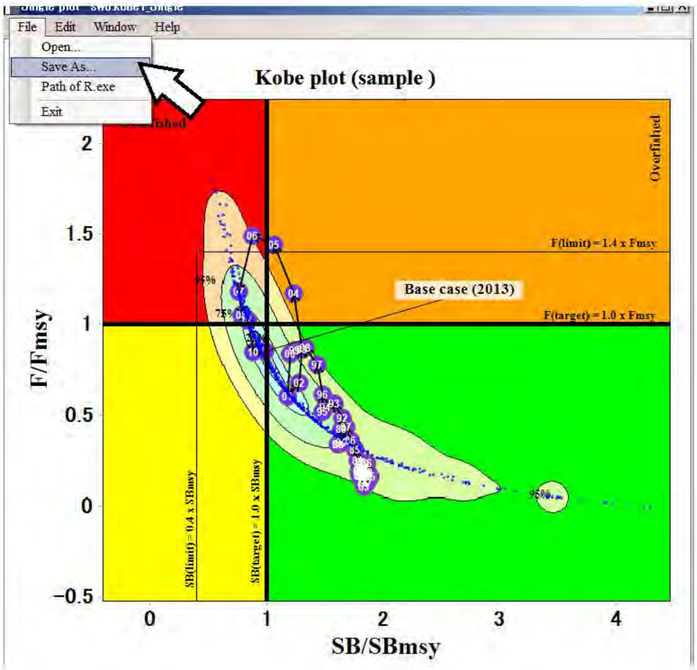
8) Zooming the plot area

Click the right button of the mouse in the plot area then the context menu will appear. Select and tick "**Zoom**". Then drag the cursor to the area users want to zoom then that area will be highlighted with slash lines (shades). To go back to the original plot, click the left button then drag towards the left-upper corner. Then users will get back the original plot.



9) Saving the plot

There are two ways to save the Kobe plot, i.e., only images or the whole Kobe plot which can retrieve the same image then users can edit further. In order to save, just click "**Save As**".



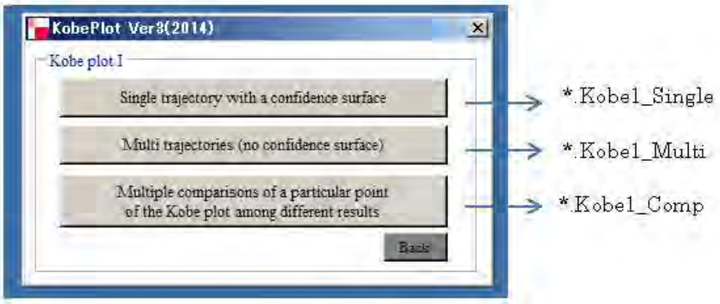
Image

There are 3 ways to save only images by 3 different types of external file, i.e., ".BMP", ".PNG" and ".EMF". It is recommended to use ".EMF" which provides the best quality of picture for users report in the word file for example.

While Kobe plot

If users want to retrieve the last plot and conduct further editions, there are 3 ways to save by menu as follows:

External file name



5. Kobe Plot II (Risk assessment matrix diagram)

Kobe II (Risk assessment matrix) was recommended to produce by 5 tuna RFMOs meeting (2010) in San Sebastian, Spain. The risk matrix here means the risk probabilities that SSB/TB ratio and F ratio will exceed their MSY levels in 3 and 10 years. But the matrix (table) has been quite difficult to understand its meanings especially for manger as the matrix is described by the mathematical notations (see below). To improve this situation, we developed the diagram to convert from the matrix (table) format, so that anyone can easily understand the meanings of the matrix. We applied spatial contour estimation techniques used in our marine GIS (Marine Explorer).

Reference point and projection timeframe	Alternative catch projections (relative to 2010) and probability (%) of violating MSY reference points							
	60%	80%	85%	90%	100%	110%	120%	140%
$B_{2013} < B_{MSY}$	45	48	50	53	57	62	67	81
$F_{2013} > F_{MSY}$	11	47	54	58	66	71	76	82
$B_{2020} < B_{MSY}$	18	51	59	66	74	82	87	91
$F_{2020} > F_{MSY}$	<1	49	61	70	82	89	91	96

1) How to create the input data?

To create the input data, make one CSV file based on the risk matrix for 10 years as below, i.e., Colum 1: percentage increase or decrease from the current catch (status quo). Columns 2-11 projected years and corresponding risk probabilities by percentage (Y axis). This format is the diagrams for both SSB (or TB) ratio and F ratio. Please note that colors are not needed. Here colors are used only for the illustration purpose to understand the risk probability levels.

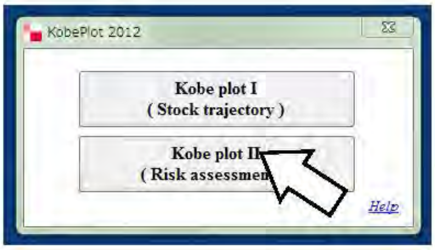
Example from Indian Ocean albacore stock and risk assessment.

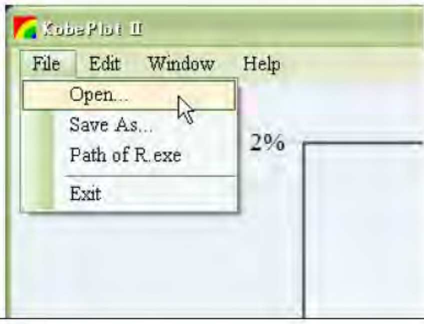
	column 1	*column 2*	*column 3*	*column 4*	*column 5*	*column 6*	*column 7*	*column 8*	*column 9*	*column 10*	*column 11*
row 1		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
row 2	-40%	0.101	0.008	0.002	0.001	0	0	0	0	0	0
row 3	-30%	0.101	0.05	0.042	0.044	0.05	0.048	0.054	0.056	0.058	0.063
row 4	-20%	0.101	0.091	0.081	0.087	0.099	0.096	0.107	0.111	0.115	0.127
row 5	-10%	0.101	0.194	0.239	0.291	0.342	0.37	0.409	0.437	0.459	0.489
row 6	0%	0.101	0.296	0.396	0.495	0.584	0.644	0.71	0.762	0.808	0.871
row 7	10%	0.101	0.434	0.572	0.677	0.757	0.811	0.853	0.881	0.902	0.923
row 8	20%	0.101	0.572	0.748	0.859	0.929	0.978	0.996	1	1	1
row 9	30%	0.101	0.683	0.847	0.925	0.935	0.989	0.998	1	1	1
row 10	40%	0.101	0.794	0.945	0.992	1	1	1	1	1	1

2) How to get the input data into the software?

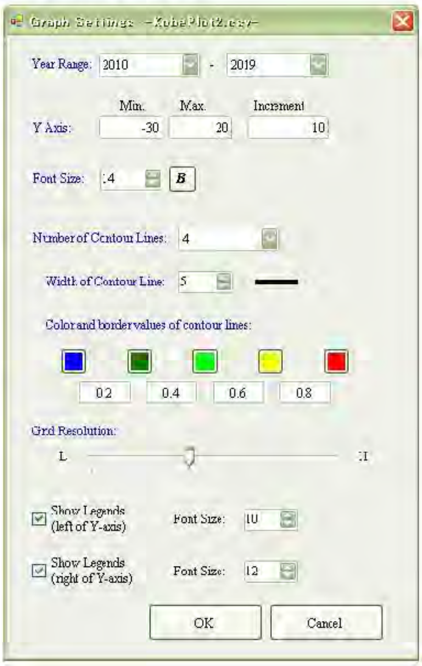
Click Kobe Plot II.

Then users will see the empty window (see right below). Then click file, open, then go to the folder where user's CVS file is located and import to the software. Then users will see the graph setting menus as described below, which are self-explanatory. Users can adjust various parameters to create user's desirable output (diagram).





3) Graph Settings



Year Range

Set the year range to display.

Y Axis

Set values of the minimum, the maximum percentage and the interval (increment).

Font Size Select the font size. Click on the ***B*** button to make the font bold.

Number of Contour Lines

Select the number of contour lines from 2 to 4.

Width of Contour Lines

Select the width of contour lines from 0 to 10.

Colors and border values

Set colors and border values of the contour lines

Grid Resolution

Move the grid resolution bar for the optimum resolution of the diagram (default position is recommended).

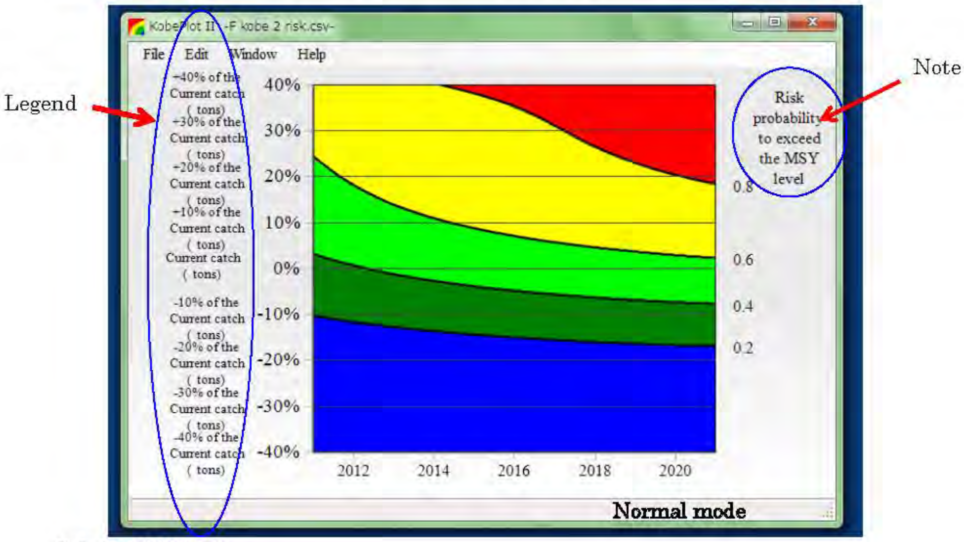
Legends/Note and Font size

Tick the box to show Legend (left of Y-axis) or Note (right) (refer to the sample, next page) and select Font size.

30

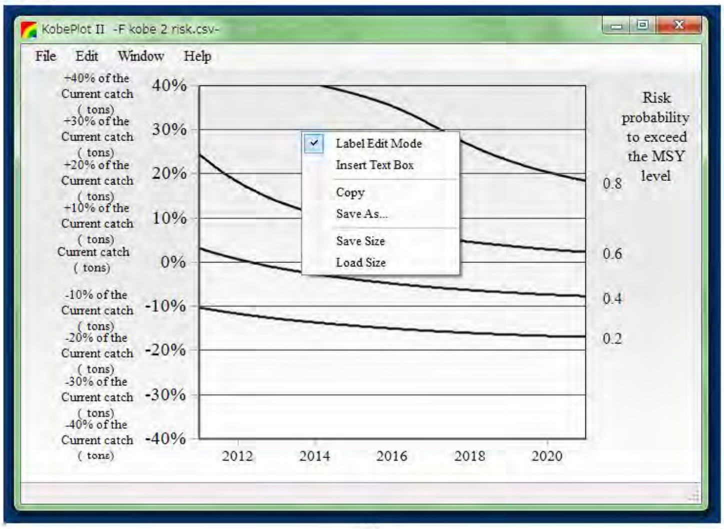
4) Displaying the Kobe plot II diagram (SSB/TB ratio or F ratio)

After users set up the graph setting, click OK button (see previous page), then users will get the Kobe plot II (risk assessment matrix) diagram with "Legend" and "Note" as below. *[Note] <u>Users can change ranges, for example, (-40%) – (40%) by 10% interval by graph settings.</u>*



5) Label Edit Mode

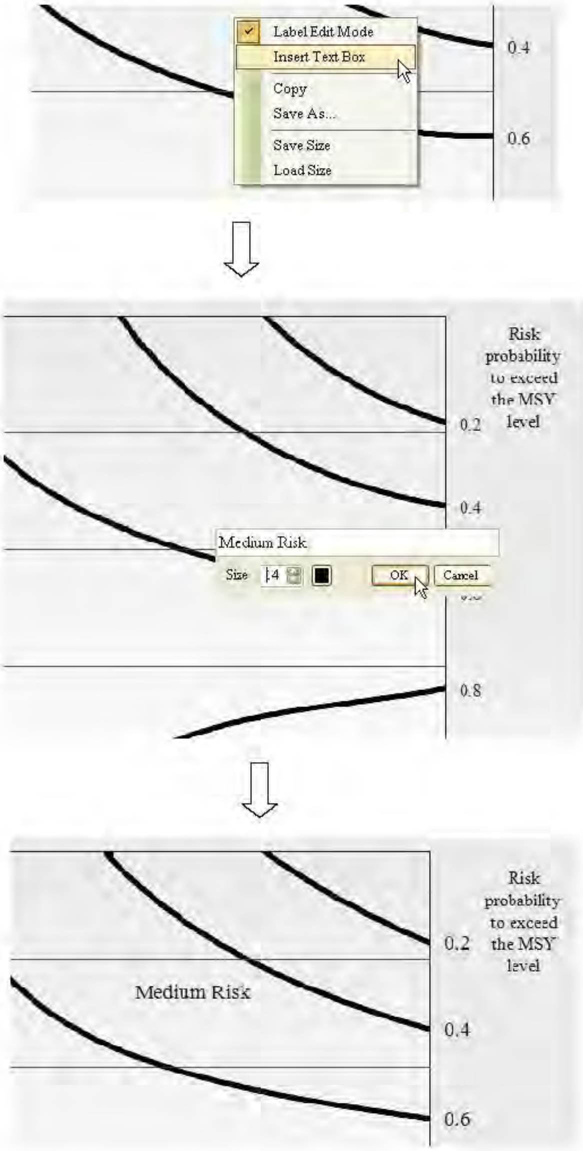
To edit the "Legend", "Note" and "To insert some text", Change from Normal Mode (above) to Label Edit Mode (below). To get the menu, click the right button of user's mouse (or other ways if users don't use the mouse).



31

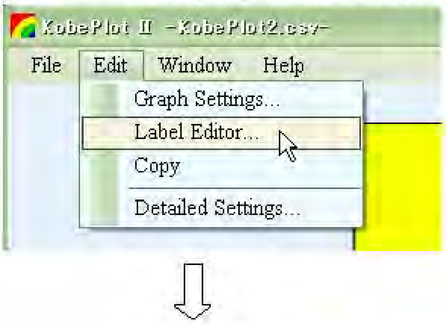
6) Insert and Edit the text in the diagram

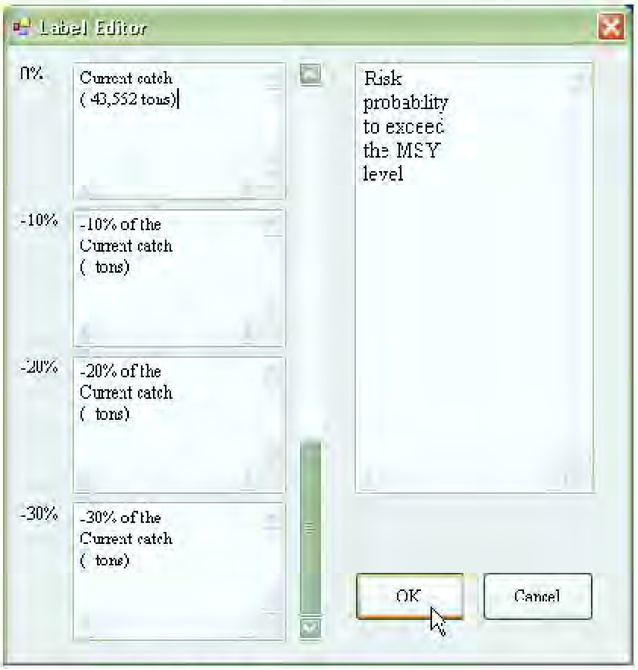
Users can add the text anywhere in the diagram. First, move the cursor to the location where users want to make text box then click the right button of user's mouse. Users will see the context menu as below. Click **Insert Text Box** then make the text. Users can drag the text box by the cursor to move the location that users want to place.



7) Editing Legends (X-axis left) and Note (X axis right)

To edit Legends (X-axis left) and Note (X axis right), get "Label Editor" (below) then edit.





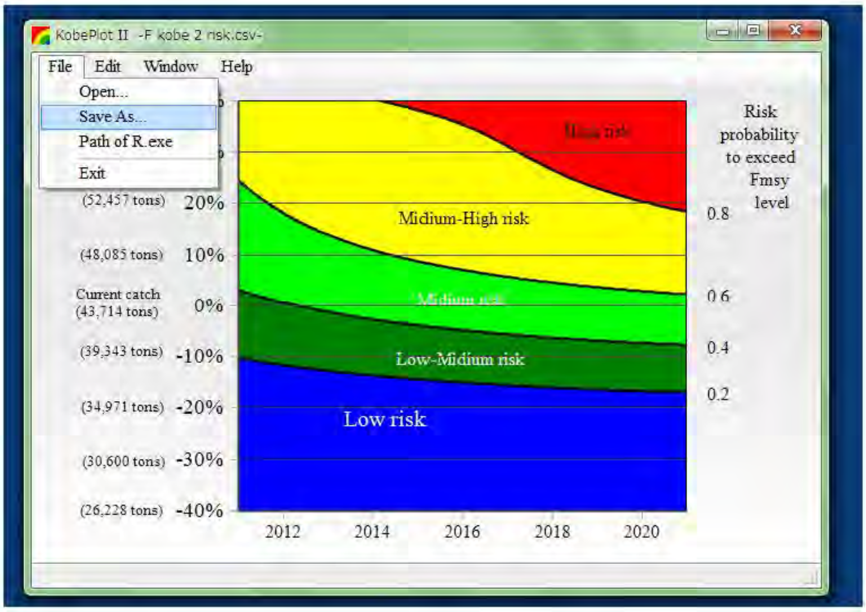
7) Moving Legends (X-axis left) and Note (X axis right)

In the "Label Edit Mode" (see above), users can adjust positions of Legend (X-axis left) and Note (X-axis right) by dragging with mouse.

33

8) Saving the diagram

After users finalize the plots, save the plots by click "**Save As**". There are 4 ways to save to the external file, i.e., .Kobe2, .BMP, .PNG, and .EMF. If users save ".Kobe2" file, then users can retrieve the last diagram that users save then users can do further editions. To save only mages, users ca use BMP, .PNG, or .EMF. But, ".EMF" is recommended to use for user's paper/document file as it will provide the best quality of picture, although it is a bit heavy file.



ACKNOWLEDGEMENTS

We sincerely thank to Fisheries Agency of Japan (2009-2014) to provide the fund to "Tuna and Skipjack Resources Division" in National Research Institute of Far Seas Fisheries (NRIFSF), Fisheries Research Agency of Japan (FRA) for this Kobe software development project. In addition we appreciate world-wise users who made comments and suggestions to improve this software.

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APPENDIX A: SPECIFICATION OF KOBE I AND II SOFTWARE

General

- Operation Systems (OS) : MS windows OS (both 32 and 64-bit PCs)
- Microsoft Visual Studio 2010 (general programming)
- TeeChart Pro .NET v2010 (graphical components)
  Copyright © 2010 by Steema Software SL

Confidence surface in Kobe plot I and contour estimations in Kobe plot (diagram) II

Following functions in "R" are applied

Confidence surface

- 'kde2d' function : Kernel estimation

Kobe plots 2 (Contour estimation of the diagram)

- 'surf.gls' function :to assign contour surface by least square means
- 'prmat' function: to assign the contour line by kriging

35

Training materials (08)
Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

Kobe Plot I and II software

(ver. 3, 2014)

Revised (Jan. 15, 2015)

"R" needs to be pre-installed to your PC

- Otherwise you cannot attend the training course as "R" is the main engine of the software to be used for the training course.
- Please note that you will not need to learn "R". We need "R" in your PC to run the menu driven software that you need to learn.
- You don't need to know any computer languages if you use software to be provided in the training course.

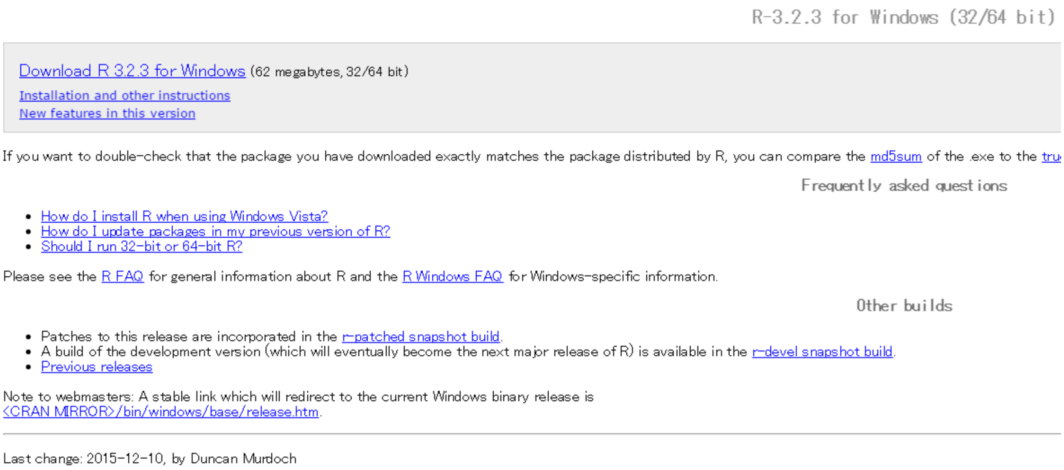
Minimum requirement of your PC

- Lap top PC: windows 7 or higher (64 bits).
- No MAC/Apple PC nor Tablets because of software compatibility problems

Now how to install "R"

(1) Go to https://cran.r-project.org/bin/windows/base/

(2) Then you will see window as below:


R-3.2.3 for Windows (32/64 bit)

Download R 3.2.3 for Windows (62 megabytes, 32/64 bit)
Installation and other instructions
New features in this version

If you want to double-check that the package you have downloaded exactly matches the package distributed by R, you can compare the md5sum of the .exe to the tru

Frequently asked questions

- How do I install R when using Windows Vista?
- How do I update packages in my previous version of R?
- Should I run 32-bit or 64-bit R?

Please see the R FAQ for general information about R and the R Windows FAQ for Windows-specific information.

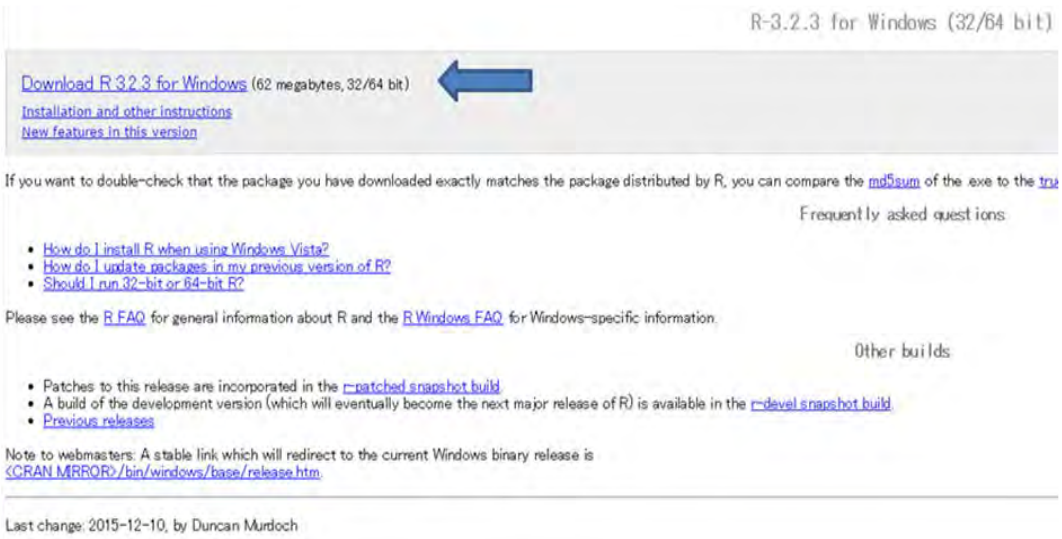
Other builds

- Patches to this release are incorporated in the r-patched snapshot build.
- A build of the development version (which will eventually become the next major release of R) is available in the r-devel snapshot build.
- Previous releases

Note to webmasters: A stable link which will redirect to the current Windows binary release is
<CRAN MIRROR>/bin/windows/base/release.htm.

Last change: 2015-12-10, by Duncan Murdoch

(3) Then click


R-3.2.3 for Windows (32/64 bit)

Download R 3.2.3 for Windows (62 megabytes, 32/64 bit)
Installation and other instructions
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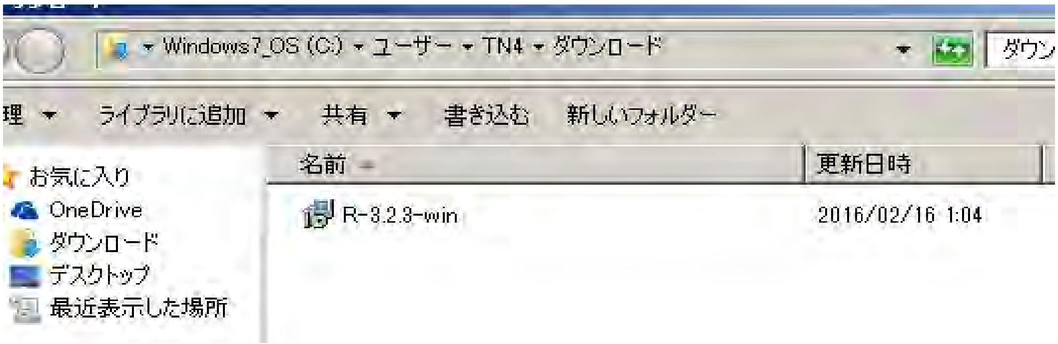
<CRAN MIRROR>/bin/windows/base/release.htm.

Last change: 2015-12-10, by Duncan Murdoch

(4) Then R will be downloaded to your download folder of your PC as below (don't worry about Japanese).

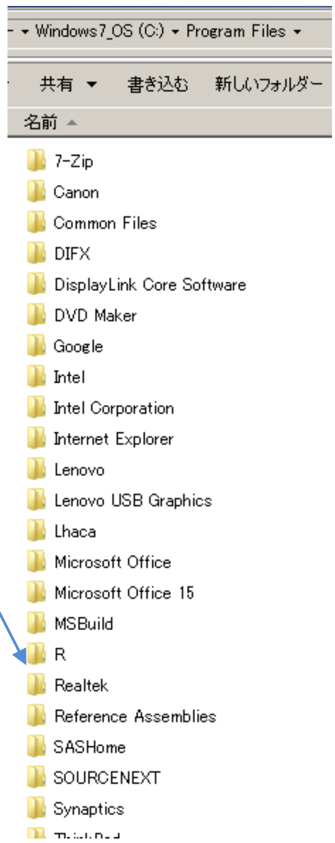


(5) Then double click the icon (above)

(6) Then follow the instruction and choose default for all options.

(7) It will take some time to finish.

(8) After you will finish your installation,
Your R is stored in C: drive



Training materials (09)

Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

Longtail tuna (*Thunnus tonggol*) stock assessment in the Indian Ocean by ASPIC (A Stock–Production model Incorporating Covariates) using available CPUE information

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2/ Environmental Simulation Laboratory (ESL), Kawagoe, Saitama, Japan

May, 2015

Abstract

We attempted the stock assessment for longtail tuna in the Indian Ocean by ASPIC using nominal catch and four available CPUE (1950-2013). We assume that longtail tuna in the Indian Ocean is a single stock. Results of the ASPIC analysis suggested that longtail tuna stock status (2013) is in the overfishing phase (orange zone in the Kobe plot) (F/Fmsy=1.43 and TB/TBmsy=1.01), i.e., high F (high fishing pressure, 43% above the Fmsy level), while the TB is about in the TBmsy level. Uncertainty around the 2013 point estimate in the Kobe plot is covered by 54% in the red zone, 25% in orange and 21% in green. In addition, the direction of the stock status trajectory vector is toward the red zone. These facts suggest that the 2013 stock status has the high probability in the red (overfished) zone. The risk assessment (Kobe II) suggests that if the current catch continues (159,313 t), there are high risks (100%) for both TB and F to violate their MSY levels. If the current catch level is reduced by 30%, then risk probabilities for both TB and F will be reduced by 50% in three years later (2016).

Contents

1. Introduction

We attempted the stock assessment of longtail tuna (*Thunnus tonggol*) in the Indian Ocean by ASPIC (A Stock–Production model Incorporating Covariates) (ver. 5) (Prager, 2004) using available nominal catch and CPUE data. As the WPNT has been suggesting the single stock hypothesis until the stock structure is elucidated, we also apply this hypothesis.

2. Data

2.1 Global catch data

Fig. 1 shows the longtail tuna nominal catch for 64 years (1950-2013) in the whole Indian Ocean by gear type based on the IOTC database (as of April, 2015). Catch has been increasing steadily since 1950 until 2012 (170,000 tons) and slightly decreased in 2013 (169,000 tons) as the first time. There are very sharp increases in recent years (2008-2012), which is caused by the intensified piracy activities from 2008. This is because that gillnets fisheries especially in the NW Indian Ocean moved into their EEZ and target more neritic tuna (Nishida et al, 2014)

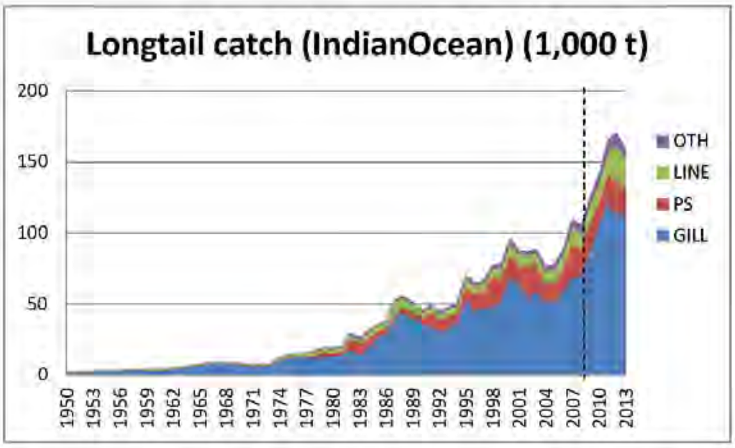


Fig. 1 Nominal longtail catch (1950-2013) by gear type (IOTC database) (April, 2015)

(Note) Others include longline, bait boat and all other gear types. The broken vertical line shows 2008.

2.2 **Available CPUE**

We use four available CPUE series in the IOTC database and previous WPNT documents. We search the CPUE data series minimum 10 years to conduct reliable stock assessment.

(1) - (2) Nominal PS and GILL CPUE in the Andaman Sea, Thailand (1998-2010) (IOTC–2013–WPNT03–33 Rev_2).

Two nominal CPUE series are available in "Analyses of catch, fishing efforts and nominal CPUE of neritic tuna and king mackerel exploited by purse seine and king mackerel drift gillnet fisheries in the Andaman Sea (Sa-nga-ngam et al, 2013) (IOTC–2013–WPNT03–33 Rev_2). Fig. 2 shows these nominal CPUE series including landing places and fishing grounds in the Andaman Sea and the Gulf of Thailand. These two CPUE series are from the statistical areas 6 and 7.

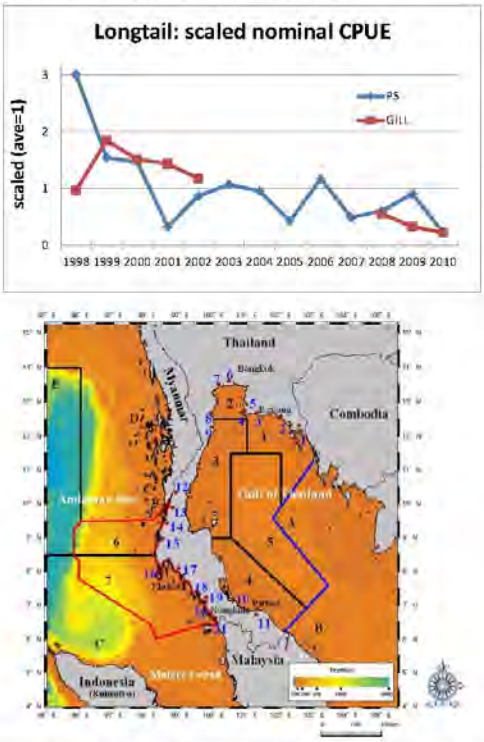
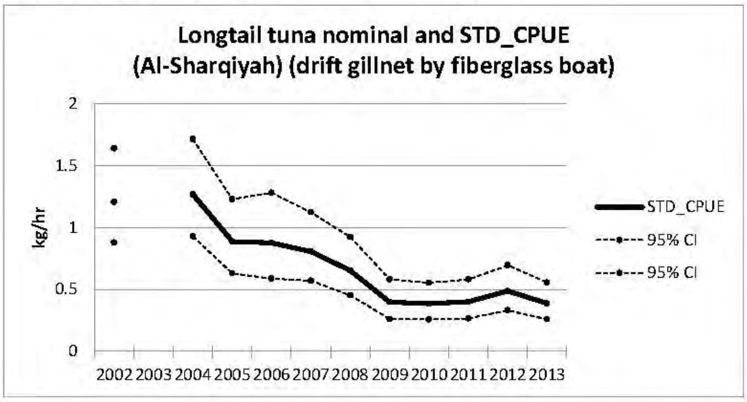


Fig. 2 (*above*) Nominal CPUE of GILL and PS fisheries from fishing areas 6 and 7 (Sa-nga-ngam et al, 2013) (IOTC–2013–WPNT03–33 Rev_2)
(*below*) Locations of fishing grounds (1-7 and A-E) and landing places (1-21) in the Andaman Sea and the Gulf of Thailand

(3) Standardized CPUE of drift-gillnet in Oman (2002-2013) (IOTC-2014-WPNT04-28)

The standardized CPUE of drift-gillnet fisheries in Oman (2002-2013) by Al-Kiyumi et al (2014) are available in IOTC-2014-WPNT04-28 (Fig. 3).



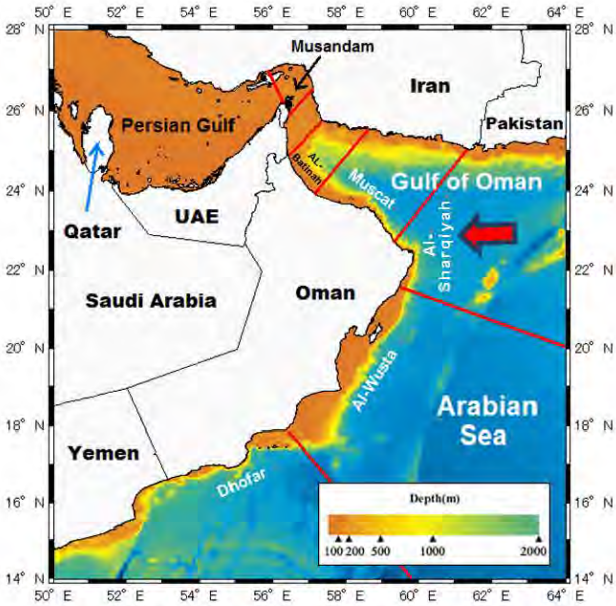
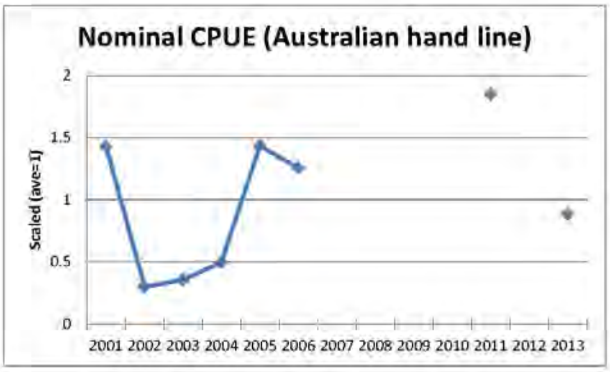


Fig. 3 *(above)* STD_CPUE and its 95% confidence intervals with nominal longtail tuna CPUE of drift gillnet fisheries by fiberglass boat in Al-Sharqiyah (one of six fishing grounds) (below) Six fishing areas in Oman

(4) Nominal CPUE of Australian handline fisheries (2001-2013) (IOTC database)

In the IOTC catch-effort dataset (as of April, 2015), there is one nominal CPUE dataset containing a longer time series, i.e., Australian handline catch and effort data set. Fig. 4 shows the trend of the nominal CPUE.



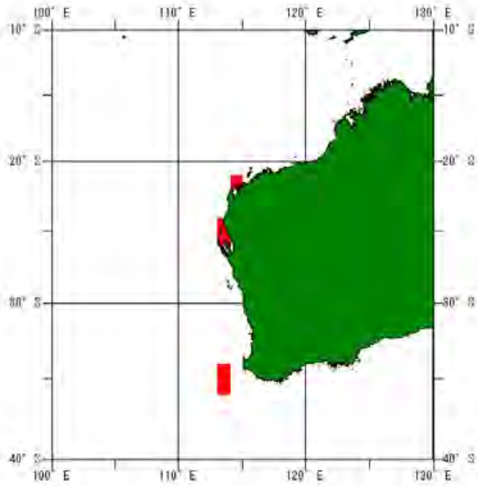


Fig. 4 (*above*) Australian nominal CPUE data set by handline
(*below*) Locations of fishing grounds of the CPUE data

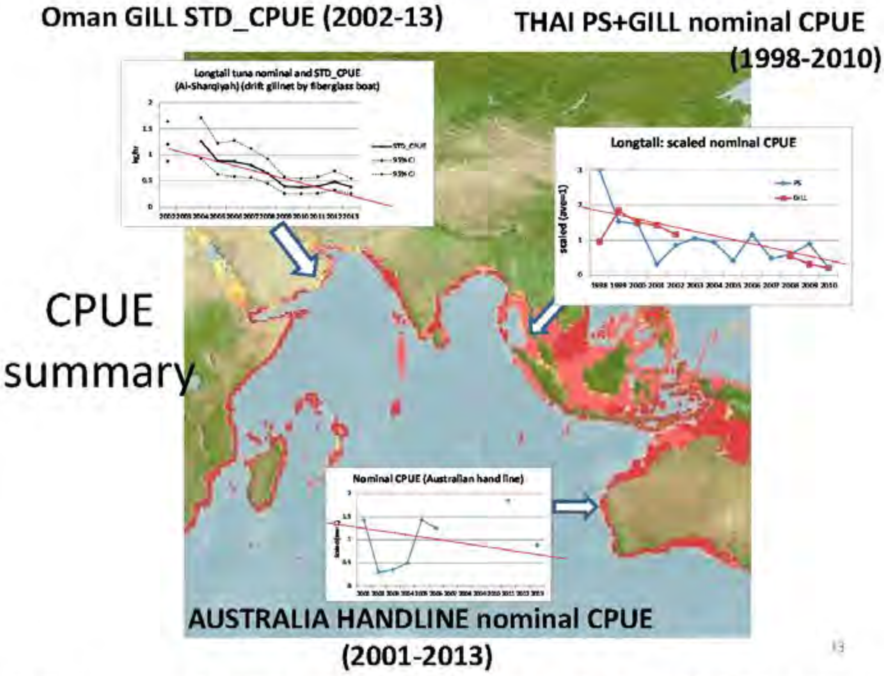
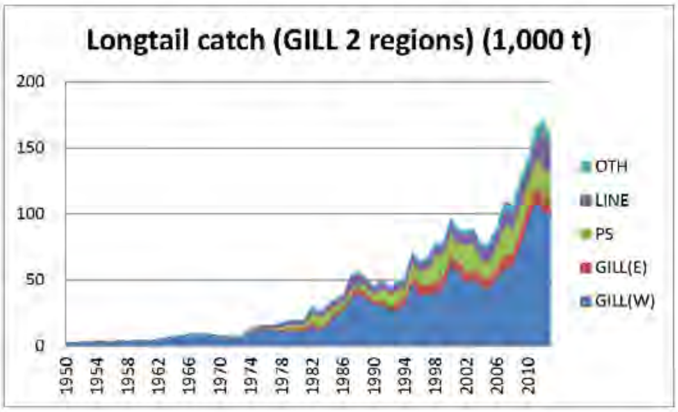


Fig. 5 Distribution of longtail tuna in the Indian Ocean and four available CPUEs in three regions. All CPUE show the declining trends.

3. ASPIC

3.1 Gear types

Using four available CPUE series, we conduct stock assessment by ASPIC. In ASPIC, we use 5 gear types, (a) GILL (W), (b) GILL (E), (c) PS, (d) (HAND) LINE and (e) OTHERS. The reason that we have GLL by 2 regions (W: Western IO for F51 and E: Eastern IO for F57) is as follow: we have 2 CPUE from Oman (West) and Thailand (West) and we assume that CPUE in the western region reflect to catch in the same region and vice versa. Fig. 6 shows the restructured nominal catch corresponding to 5 fleet types used in ASPIC assessment.



Nominal catch by gear		Corresponding CPUE	Average composition of catch (%) of CPUE fleet
GILL (W)	Gillnet (Western IO)	Standardized CPUE (Oman)	16.9
GILL (E)	Gillnet (Eastern IO)	Nominal CPUE (Thailand)	5.8
PS	Purse seine	Nominal CPUE (Thailand)	34.0
LINE	Line type gears	Nominal Handline (Australia)	0.2
OTH	Other gears	Not available	

Fig.6 (*above*) Nominal catch corresponding to 5 gear types used in the ASPIC assessment

(*below*) List of nominal catch and corresponding CPUE used in the ASPIC stock assessment

3.2 ASPIC runs

In ASPIC for our dataset, we need to estimate 8 parameters (K: carrying capacity, B0/K where B0 is the total biomass in 1950, q: catchability for 5 gear types and MSY). We assume that B0=K and attempt to estimate 7 parameters (K, MSY and 5 q's).

(1) Initial ASPIC runs

Using 64 years data and assuming K=B0, we attempted the initial ASPIC runs using the Fox model. However we could not get any convergences nor plausible estimates in the initial run.

(2) Final ASPIC runs

Then, we fixed K and attempted to explore seven K values within plausible ranges, i.e., 300, 400, 500, 600, 700, 800, 900,000 tons. Table 1 shows the ASPIC results by K values. Fig. 7 shows locations of seven TB/TBmsy and F/Fmsy in the Kobe plot, which indicate ranges of uncertainties among K values.

We considered that TBmsy=110,000 and 147,000 tons (when K=300,000 and K=400,000 tons respectively) are too low comparing MSY. In addition, MSY=107,000 tons and 100,000 tons are also too low considering the current catch levels (142,000 tons in 5 years average). Thus, we selected the median case (K=600,000 tons) (among K=500, 600 and 700,000 tons) as the representative ASPIC result.

Table 1 Summary of ASPIC runs within seven plausible K values

Optimum K=600,000 tons (median)

K	MSY	TBmsy	TB2013	Fmsy	TB2013/TBmsy	F2013/Fmsy	B2013/B1950 (depression)
(1,000 tons)							
300	152	110 (too low)	128	1.38	1.16	0.94	0.43
400	142	147 (too low)	165	0.97	1.12	1.07	0.41
500	132	184	196	0.72	1.07	1.23	0.39
600	122	221	223	0.55	1.01	1.43	0.41
700	114	258	243	0.44	0.96	1.63	0.39
800	107 (too low)	294	274	0.36	0.93	1.80	0.34
900	100 (too low)	331	296	0.30	0.89	2.02 Too high	0.33

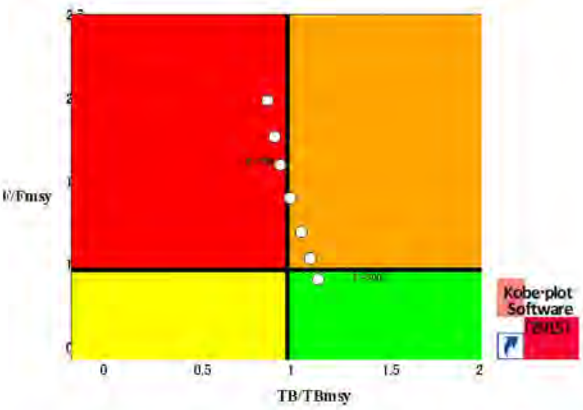


Fig. 7 Locations of the 2013 stock status points by K value (1,000 tons), which also shows uncertainties among seven plausible K values

(3) Results

Table 2 shows the summary of the ASPIC stock assessments. Box 1 shows results including graphs for catch vs. MSY, TB (total biomass) vs. TBmsy, F vs. Fmsy, observed vs. predicted CPUE for GILL (W), Gill (E), PS, LINE and OTHER and estimated q (catchability) by gear type.

Table 2 Longtail tuna stock status summary in the Indian Ocean based on ASPIC

Management Quantity	Whole Indian Ocean
Most recent catch estimate (1,000 t)(2013)	159
Mean catch over last 5 years (1,000 t) (2009-2013)	142
MSY (1,000 t)	122 (106-173)
Current Data Period (catch)	1950-2013
CPUE	GILL (Andaman Sea, Thailand) (1998-2010) GILL (Oman) (2001-2012) (2002-2013) PS (Andaman Sea, Thailand) (1998-2010) HANDLINE (Australia) (2001-2013)
Fmsy (80%CI)	0.55 (0.48-0.78)
TBmsy (1,000 t) (80%CI)	221 (189-323)
F(2013)/F(MSY) (80% CI)	1.43 (0.58-3.12)
TB(2013)/TB(MSY) (80% CI)	1.01 (0.53-1.71)
TB(2013)/TB(1950) (80%CI)	0.41(n.a.)
K (tons) (fixed)	600,000
r	0.81

Box 1 Results of ASPIC (longtail tuna in the Indian Ocean)

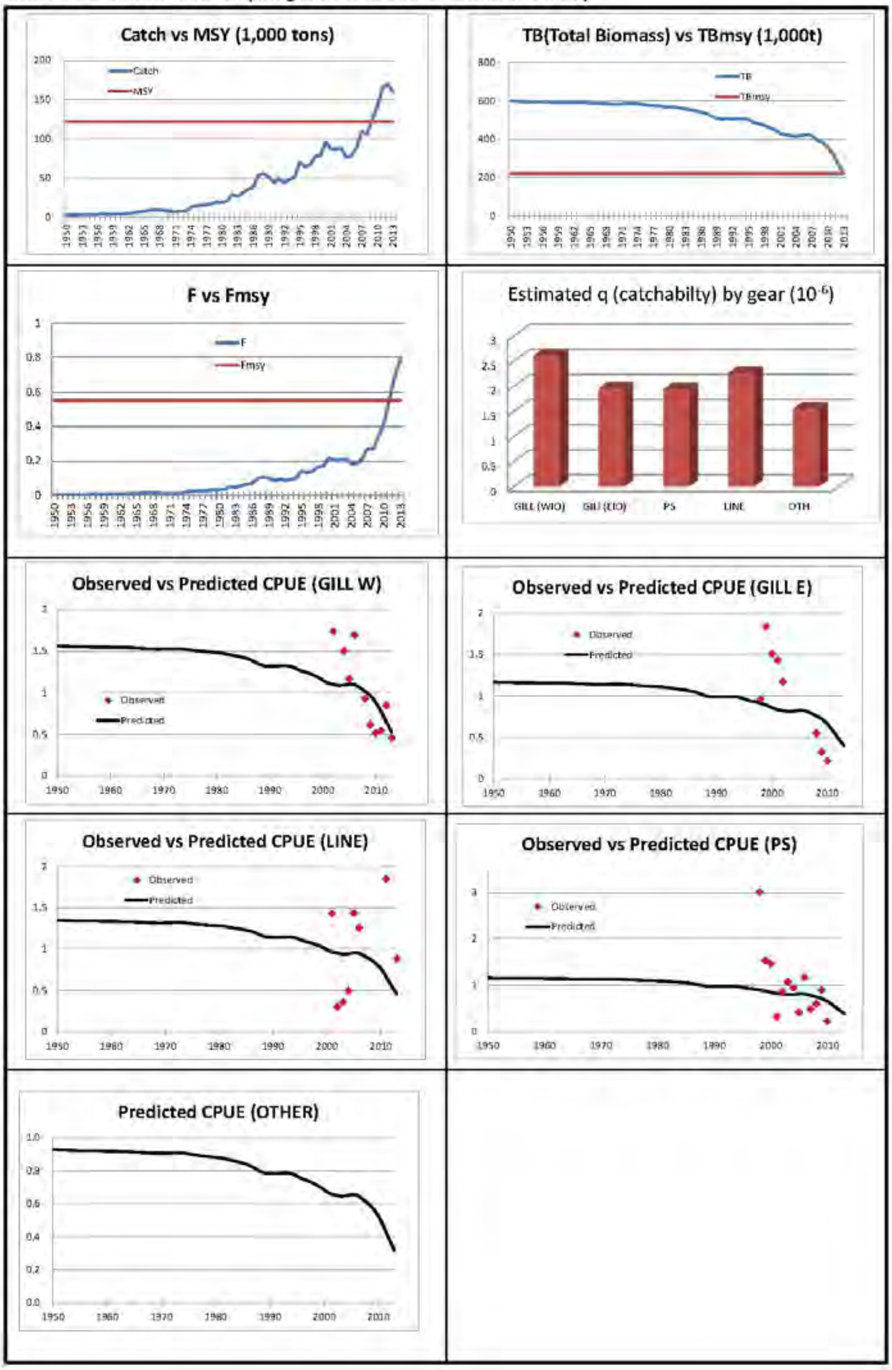


Fig. 8 shows the Kobe plot suggesting that the current stock status is in the overfishing (orange) zone (F/Fmsy=1.44 and TB/TBmsy=1.01), i.e., high F (high fishing pressure, 44% above the Fmsy level), while the TB is about in the TBmsy level.

The Confidence surface around the 2013 point in the Kobe plot (Fig. 8) was estimated by 500 times of the bootstrap using the Kobe plot software (Nishida, et al, 2015). Uncertainty around the 2013 point estimate is covered by 54% in the red zone, 25% in orange and 21% in green. In addition, the direction of the stock status trajectory vector is toward the red zone. These facts suggest that the 2013 stock status has the high probability in the red (overfished) zone.

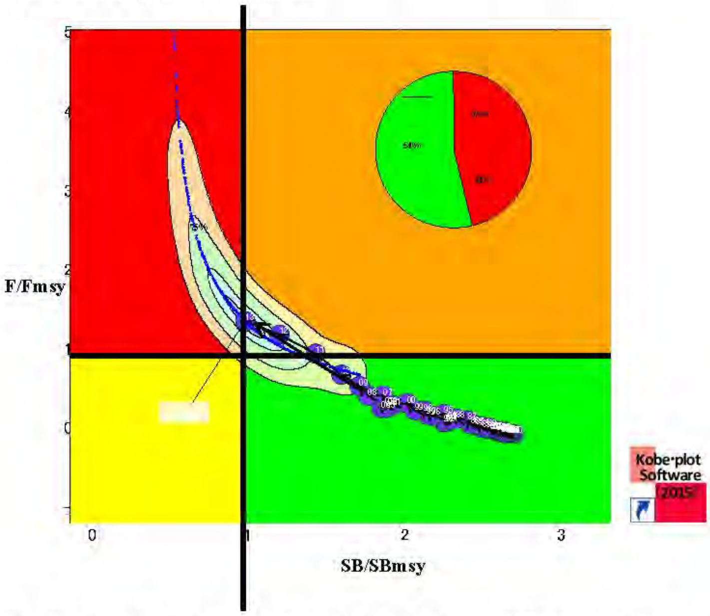


Fig. 8 Kobe plot of the longtain tuna in the Indian Ocena (1950-2013) with uncertinty around the 2013 point and compostions of uncertainties in terms of 4 phases (colors) of the Kobe plots (pie chart)

3.3 Risk assessment (Kobe II)

The risk assessment (Kobe II) was conducted using the bootstrap results (Table 3), which suggests that if the current catch continues (159,313 t), there are high risks (100%) for both TB and F to violate their MSY levels. If the current catch level is reduced by 30%, then risk probabilities for both TB and F will be reduced by 50% in three years later (2016).

Table 3 Longtail tuna ASPIC aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target for nine constant catch projections (2013 catch = 159,313 t, ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to the current catch level in 2013) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$) MSY=122,000 t								
% of status quo	60%	70%	80%	90%	100%	110%	120%	130%	140%
tons	95,588	111,519	127,450	143,382	159,313	175,244	191,176	207,107	223,038
3 years later									
$TB_{2016} < TB_{MSY}$	48	56	66	100	100	100	100	100	100
$F_{2016} > F_{MSY}$	13	53	71	87	100	100	100	100	100
10 yers later									
$TB_{2023} < TB_{MSY}$	52	76	100	100	100	100	100	100	100
$F_{2023} > F_{MSY}$	65	82	89	96	100	100	100	100	100

4. Discussion

Piracy effects

To interpret the ASPIC results, the piracy effect is very important factor to understand the situation. Thus, firstly, we will discuss this issue then will discuss the ASPIC results incorporating the piracy effect.

The piracy activities started in the middle of 2000's off Somalia and became intensified in 2008 afterwards. Areas of their activities have been expanding to the entire north and central western Indian Ocean by 2013 (Fig. 9). Numbers of active tuna longliners and purse seiners have been decreasing after 2008. Some industrial tuna longline vessels moved to Pacific or Atlantic Ocean. However, from the later 2013, the piracy activities have been weakened and then longline vessels have been back to the Indian Ocean. Now more purse seine and longline vessels operate off Somali with armed security staff.

Small scale fishing operating in the high seas, especially drift gillnet fisheries in the NW Indian Ocean, have been exploiting yellowfin tuna in the waters beyond their EEZs. But after 2008 when the piracy activities were intensified and some fishing vessels have attacked by pirates, they go back to their EEZs and they are now exploiting more neritic tuna. This situation resulted sharp increase in the neritic tuna catch (Figs. 1 and 10).

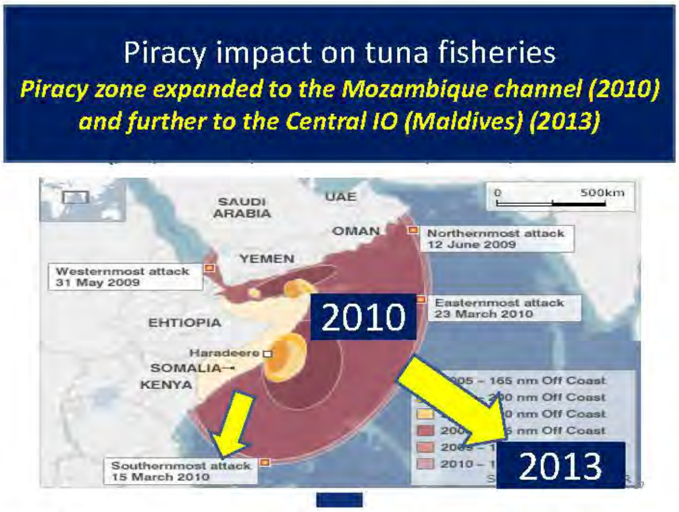
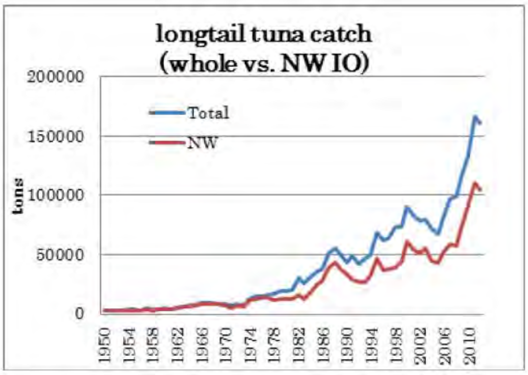


Fig. 9 Expansion of the piracy activities in the western Indian Ocean



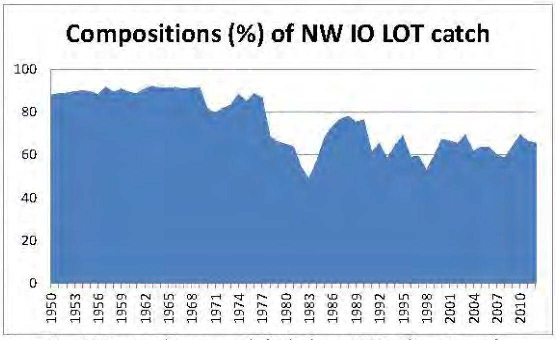


Fig. 10 Longtail tuna catch (Whole vs NW Indian Ocean)
(above) Nominal catch (t) and (below) Compositions (%)

Stock assessments

ASPIC stock assessments suggests that the current stock status of the Indian Ocean is overfishing stage (TB/TBmsy=1.01 and F/Fmsy=1.43). This is due to the sharp increase of the catch in the NE region by the piracy effects as discussed. The risk assessment suggests that if the current catch level continues, then there is 100% of chance violating MSY levels for both TB and F. If the catch is reduced by 30%, then risk probabilities for both TB and F will be reduced by 50% in three years later (2016).

In the stock assessments, nominal CPUE are used for Thailand PS and Australian handline as the original data are not available. However, the trends of 4 CPUE are similar (decreasing trend). It is suggested that these nominal CPUE need to be standardized in the future.

In addition, the catch compositions of 4 CPUEs are 17% for GILL in WIO (Oman CPUE), 6% GILL (Thailand) for EIO, 34% PS (Thailand) and 0.2% LINE (Australia). As coverages by GILL for EIO (6%) and LINE (0.2%) are low, the results should be interpreted carefully. However, the catch compositions of these two fleets are low (11% and 8% respectively) (Fig. 11), hence it is considered that effects of low coverages of these two fleets may be not too serious.

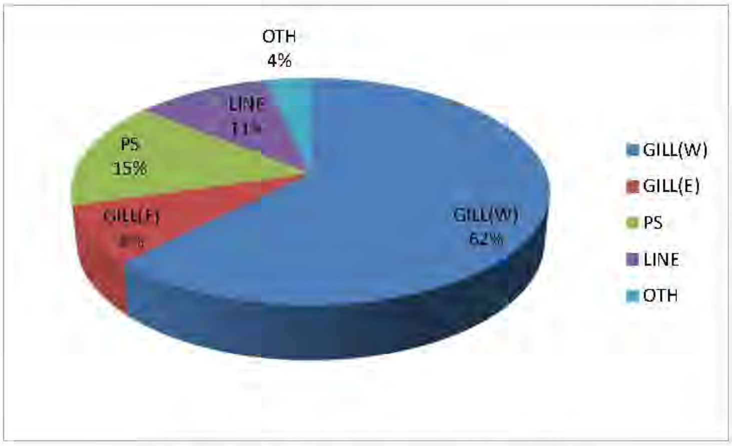


Fig. 11 Average catch compositions of 5 fleets

Longtail stock assessments in the whole Indian Ocean (IOTC, 2015) and this study (Nishida and Iwasaki, 2015) shows very similar and consistent results suggesting the stock is the overfishing status (Orange zone in the Kobe plot) (Fig. 12).

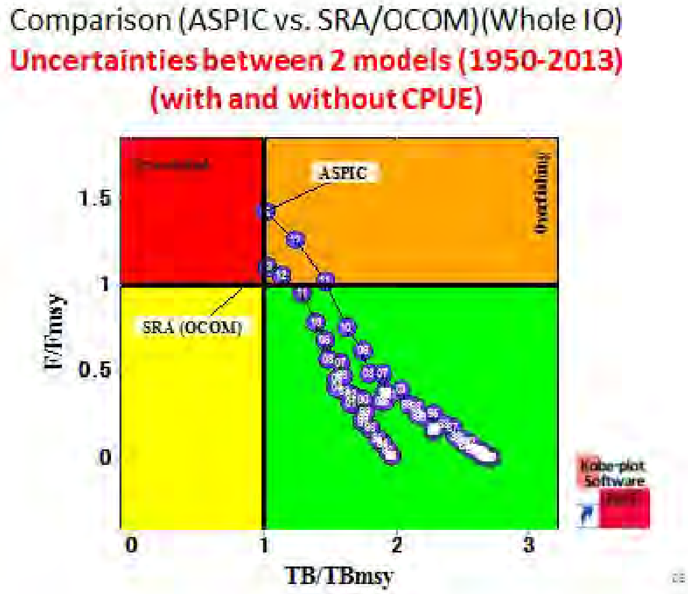


Fig. 12 Comparisons of longtail tuna stock assessments results between ASPIC and SRA (OCOM)

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Annex 11

Training materials (10)

Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia

SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

Preliminary kawakawa (*Euthynnus affinis*) stock assessment by ASPIC using standardized CPUE of drift gillnet fisheries in Sultanate of Oman

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1/ Marine Science and Fisheries Centre, Ministry of Agriculture & Fisheries, Sultanate of Oman

2/ National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Japan

June, 2013

Abstract

We preliminary attempted the stock assessment of kawakawa by ASPIC using the standardized CPUE of Omani drift gillnet fisheries (2001-2011) and the nominal catch (1950-2011). With an assumption of one stock structure in the Indian Ocean, we could not get the convergence in the first ASPIC run. With the alternate assumption of 4 stocks structure hypothesis (NW, NE, SW and SE), we re-attempted ASPIC run for the NW (Gulf and Oman Sea) hypothetical stock. Then we could get the conversion. The preliminary result suggested that the Gulf and Oman Sea hypothetical stock is at the orange zone in the Kobe plot with high Fratio (F2011/Fmsy) =1.57 and the safe level of the total biomass (TB) ratio (TB2011/TBmsy) =0.74. We also discussed about the piracy effect on the stock status and stock structure hypothesis.

Contents

1. Introduction

Neritic tuna stock assessments in the Indian Ocean has been difficult to conduct due to data/information poor situation on (a) stock structure, (b) nominal catch, (c) CPUE and (d) biological parameters. We reduce these difficulties to some extent by setting the hypothetical stock structures, using available (best) nominal catch in IOTC secretariat and newly available standardized CPUE (STD_CPUE). Then we attempt the simple stock assessment without biological information for kawakawa (*Euthynnus affinis*) by A Stock Production Model Incorporating Covariates (ASPIC) (ver. 5) (Prager, 2004). This is a preliminary work before the IOTC/WPNT03 (July 2-5, Bali, Indonesia) using newly available STD_CPUE of Omani drift gillnet fisheries (IOTC-WPNT03-31). During the meeting, we may attempt further to explore ASPIC runs by incorporating other possibly available STD_CPUEs.

2. Stock structure

IOTC WPNT02 (2012) suggests considering the stock structure of kawakawa as one stock. We conduct the ASPIC stock assessment by following this hypothesis.

3. Input data

Global catch data

We extract the nominal kawakawa catch (1950-2011) from the IOTC nominal catch data set. Fig. 1 shows the trends of the catch by fleet.

STD_CPUE

We used estimated kawakawa STD_CPUE of gillnet fisheries by launch boat (see IOTC-2013-WPNT03-31). Fig. 2 shows the annual trend of STD_CPUE.

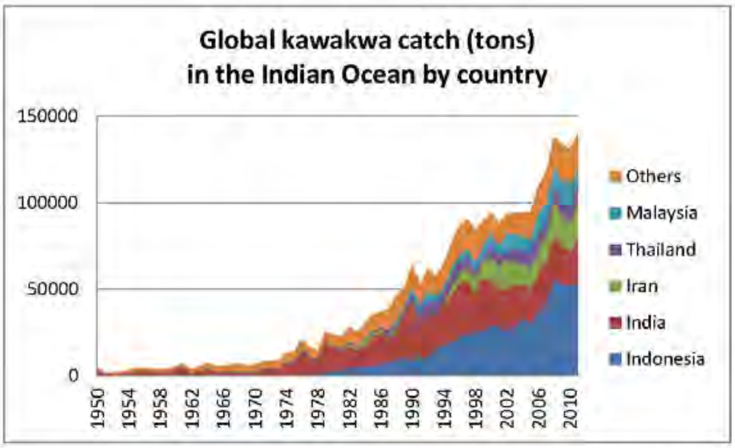


Fig. 1 Trends of global kawakawa catch (tons) by fleet in the whole Indian Ocean (1950-2011) (Source: IOTC).

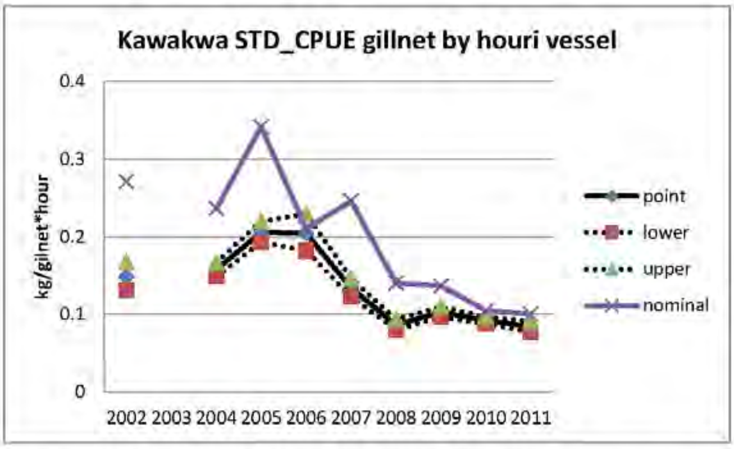


Fig. 2 STD_CPUE and its 95% confidence intervals with nominal CPUE of drift gillnet fisheries (houri type boat) in Oman (IOTC-2013-WPNT03-31)

4. ASPIC

4.1 Base (initial) run

As the base (initial) run, we attempted to run ASPIC using the global catch in the whole Indian Ocean and Omani STD_CPUE by assuming B0 (1950) =K. But ASPIC run could not get convergence.

4.2 Alternative (second) run

Alternative stock structure hypothesis

We consider that one stock structure hypothesis may not be realistic because of long geographical distances among countries, for example, between Oman and Indonesia, i.e., kawakawa probably cannot move from Oman to Indonesia as an extreme example (Box 1). However, kawakawa can migrate for shorter distances among countries, for example, between Indonesia and Australia. Thus, STD_CPUE may not able to reflect well to the global catch in the whole Indian Ocean, which might cause the convergence problem in the initial ASPIC run.

Then we set up the alternative hypothesis of the stock structure. The first IOTC-WPNT01 (2011) report considered some stock structure hypotheses for neritic tuna. For kawakawa, it indicated 4 stock structures (Box 1). Assuming the 4 stocks hypothesis, we re-attempted the ASPIC alternate run. As the STD_CPUE (Oman) belong to the NW region, we apply ASPIC for the Gulf and Oman Sea (hypothetical) stock. We again assume B0 (1950) =K.

Global catch in the Gulf and Oman Sea region

We again extracted the kawakawa nominal catch in the northwest region (1950-2012) from the IOTC catch data set, i.e., Oman, Iran, UAE, Pakistan, Somalia, Saudi Arabia and Yemen. Fig. 3 shows the trends of the nominal catch by fleet.

Results

For this time we could get the convergence and could get the reasonable results. Figs. 4-9 and Table 1 shows the results.

Box 1 Hypothesis of 4 kawakawa stocks structure in the Indian Ocean

IOTC-2011-WPN01-report (p.18)

IOTC–2011–WPNT01–R[E]

Table 1. Neritic tunas (and tuna-like species) under the IOTC mandate with potential sub-regions/stock identified.

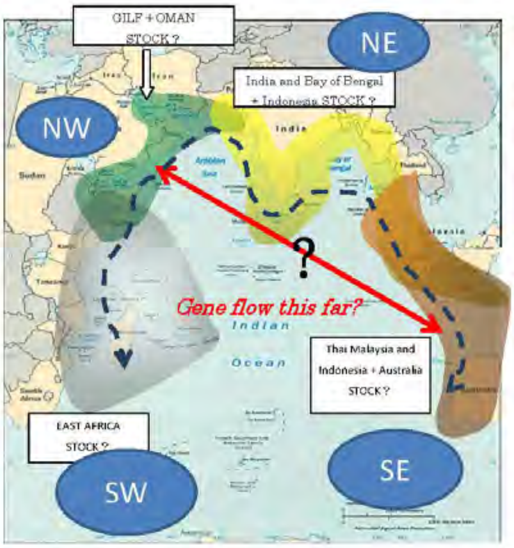
Species	Possible sub-regions and countries				
	East Africa (Kenya, Tanzania, Mozambique, Madagascar, Seychelles, Mauritius, La Réunion, Comoros, Somalia)	**Gulf, Oman Sea** (I.R. Iran, Oman, Pakistan, U.A.E., Yemen, Somalia, Qatar)	**West India** (India, Pakistan, Sri Lanka, Maldives)	**East India/Bay of Bengal** (India, Sri Lanka, Malaysia, Indonesia, Thailand, Myanmar, Bangladesh)	**Indonesia and Australia** (Australia, Indonesia, Thailand)
Longtail tuna (*Thunnus tonggol*)	━━━	━━━	━━━	━━━	━━━
Narrow-barred Spanish mackerel (*Scomberomorus commersoni*)	━━━	━━━	━━━	━━━	━━━
Bullet tuna (*Auxis rochei*)	–	–	━━━	━━━	━━━
Frigate tuna (*Auxis thazard*)	━━━	━━━	━━━	━━━	━━━
Kawakawa (*Euthynnus affinis*)	━━━	━━━	━━━	━━━	━━━
Indo-Pacific king mackerel (*Scomberomorus guttatus*)	━━━	━━━	━━━	━━━	━━━

Black bars refer to potential management units for further examination/research, by species. Countries in red text are not yet Members of the IOTC, however collaborative research is encouraged.

Kawakawa

4 stocks hypothesis based on the Table 1 above.

Northwestern Stock
[Oman+Gulf]
Oman, Iran, Pakistan, UAE, Yemen, Somalia, Qatar



Schematic diagram of 4 stocks structure hypothesis

Red line with? Implies if kawakawa moves such a long distance to support the one stock hypothesis as the direct gene flows between these 2 regions unlikely occurs.

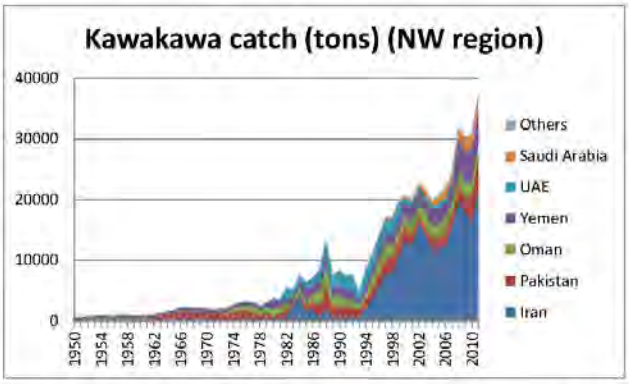


Fig. 3 Trends of kawakawa catch (tons) by fleet in the Gulf-Oman Sea (NW) region of the Indian Ocean (1950-2011) (Source: IOTC).

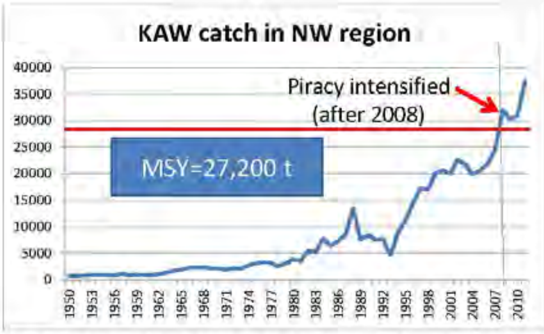


Fig. 4 Result of the alternative ASPIC run (1): Catch vs. MSY

(After the piracy intensified in 2008, catch increased. For details see the discussion)

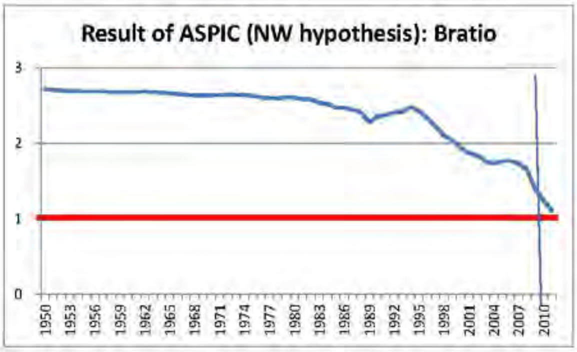


Fig. 5 Result of the alternative ASPIC run (2): TB (total biomass) ratio (TB/TBmsy)

(After the piracy intensified in 2008, TB (ratio) decreased. For details see Discussion).

Red line: MSY level (TB ratio=1)

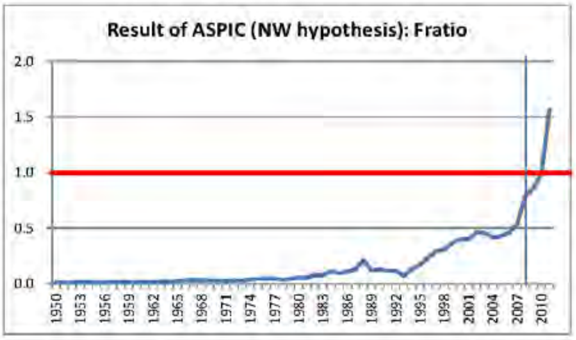


Fig. 6 Result of the alternative ASPIC run (3): Fratio (F/Fmsy)

(After the piracy intensified in 2008, F (ratio) increased sharply. For details see the discussion)

Red line: MSY level (TB ratio=1)

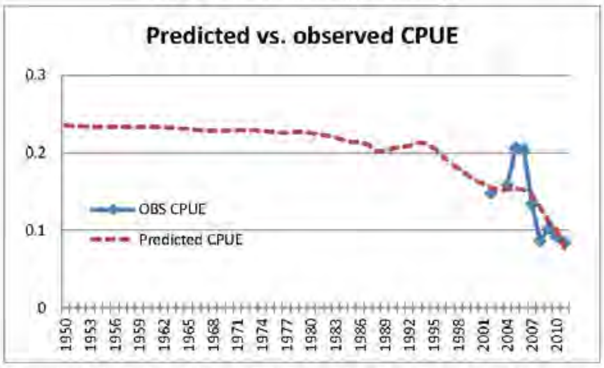


Fig. 7 Result of the alternative ASPIC run (4): Predicted vs. observed CPUE

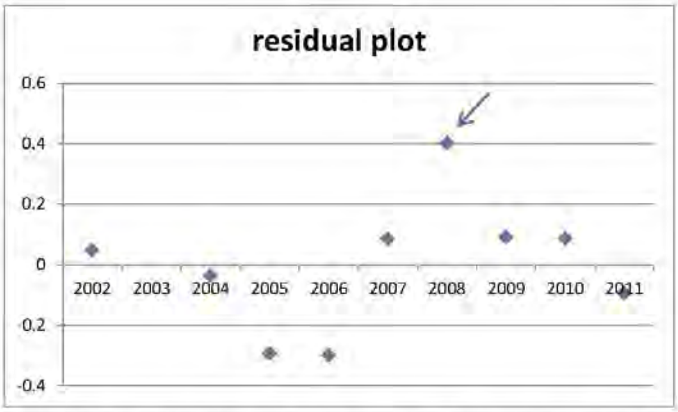


Fig. 8 Result of the alternative ASPIC run (5): Residual plot of CPUE

(Residual levels are small except the 2008 point,)

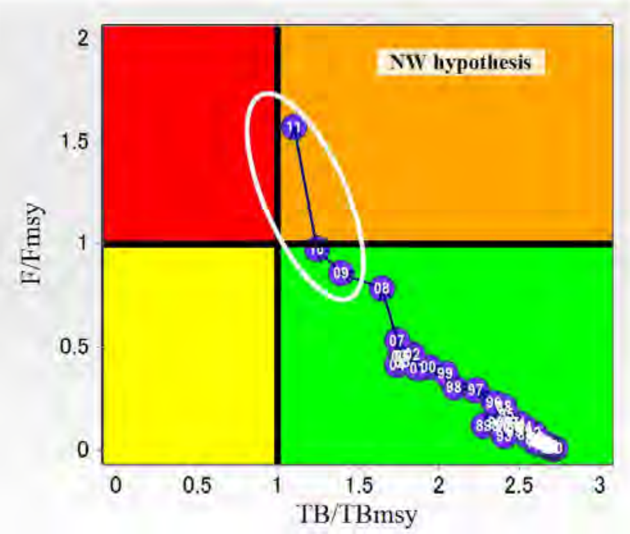


Fig. 9 Result of the alternative ASPIC run (6): Kobe plot (stock trajectory)

(After 2008, fishing pressure sharply increased due to intensified piracy activities. For details see Discussion)

Table 1 Indian Ocean kawakawa stock status preliminary summary
for the NW (Gulf and Oman Sea) stock under the 4 stocks structure hypothesis.

Management Quantity	**ASPIC (Al-Kiyumi et al, 2013)**
Most recent catch estimate (t) (2011)	37,497
Mean catch over last 5 years (t) (2007-2011)	31,016
MSY	27,180
Current Data Period (catch)	1950-2011
CPUE	Omani drift gillnet fisheries (annual) (2001-2011)
F(2011)/F(MSY)	1.57
TB(2010)/TB(MSY)	0.74
TB(2010)/TB(1950)	0.27

5. Discussion

For this time, we did preliminary attempt of the kawakawa stock assessment by ASPIC using the Omani drift-gillnet STD_CPUE. As mentioned in Introduction, we may need to explore ASPIC runs further during the IOTC-2013-WPNT03 meeting using possibly additional available STD_CPUE.

Piracy effects

To interpret the ASPIC results, the piracy effect is very important factor to understand the situation. Thus, firstly, we will discuss this issue then will discuss the ASPIC results incorporating the piracy effect.

The piracy activities started in the middle of 2000's off Somalia and became intensified in 2008 afterwards. Areas of their activities have been expanding to the entire north and central western Indian Ocean by 2013 (Fig. 10). Numbers of active tuna longliners and purse seiners have been decreasing after 2008 (Figs. 11-12). Some vessels moved to Pacific or Atlantic Ocean.

Thus, fishing intensities for tropical tuna (yellowfin, bigeye tuna and skipjack) and also swordfish had greatly reduced after 2008. Consequently their catch sharply decreased (Fig. 13). However, a number of tuna longliners remained in the Indian Ocean moved to the southern ocean where there are albacore fishing grounds and they have been targeting albacore. Hence, only albacore catch has been increased (Fig. 13). This situation is well reflected in the Kobe plots for 5 commercially important species in IOTC, i.e., the stock status of yellowfin, bigeye, skipjack and swordfish have been recovering after 2008, while for albacore, it has been worsening after 2008 (Fig. 14).

As for the small scale fishing operating in the high seas, especially drift gillnet fisheries in the NW Indian Ocean, they have been exploiting yellowfin tuna in the waters beyond their EEZs. But after 2008 when the piracy activities were intensified and some fishing vessels have attacked by pirates, they go back to their EEZs and they are now exploiting more neritic tuna. This situation resulted sharp increase in the neritic tuna catch (for example, kawakawa in Fig 3). This situation is very similar to the one in albacore.

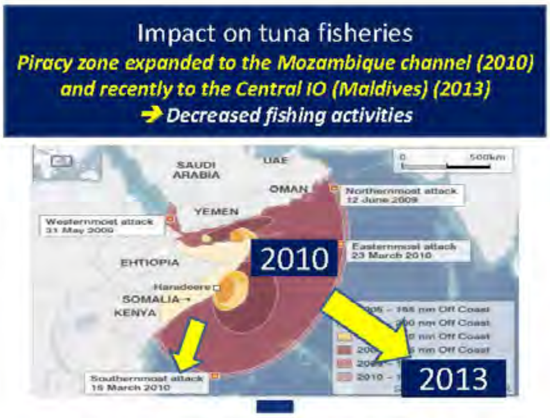


Fig. 10 Affected waters by piracy activities

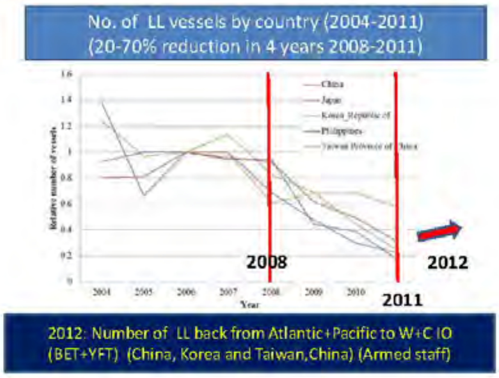


Fig. 11 Change of number of Asian industrial tuna longliners in the Indian Ocean

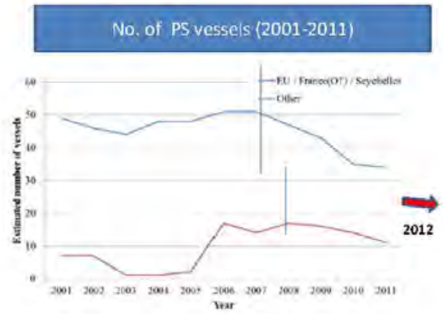


Fig. 12 Change of number of purse seiners in the Indian Ocean

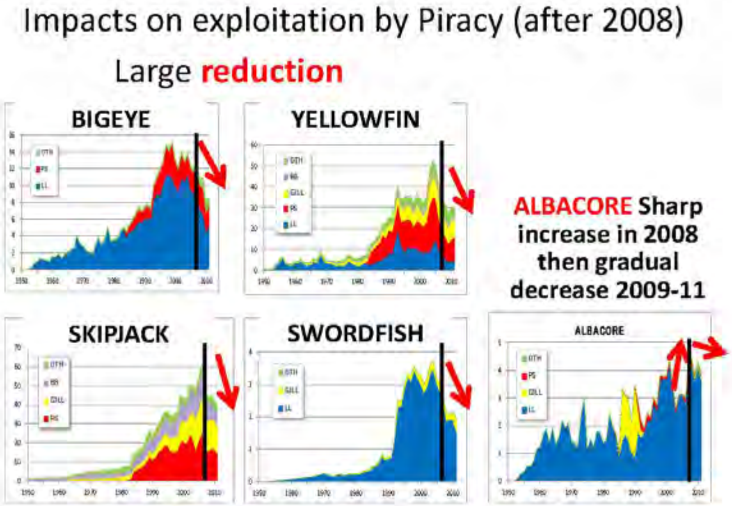


Fig. 13 Catch trends of 5 commercially important species in the IOTC. Catch except albacore sharply decreased after 2008.

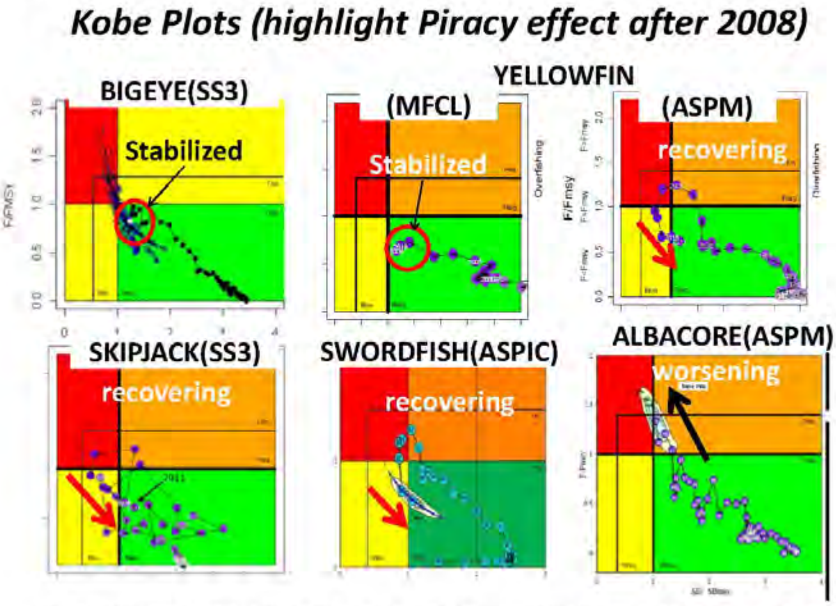


Fig. 14 Status of the stock (Kobe plots) of 5 commercially important species. All species except albacore have been recovering after 2008 when piracy activities intensified. This situation is very similar to kawakawa in the NW (Gulf-Oman Sea) region.

Stock structure

There may be some possibilities of gene flows (exchanges) in the entire Indian Ocean region and one stock hypothesis may be true (Box 1). But we could not get the convergence in the first ASPIC run when we assumed one stock, while we could get the convergence in the alternative ASPIC run using the NW (Gulf and Oman Sea) hypothetical stock structure under the 4 stocks scenario.

We wonder if gene flows are possibly occurred and genes can be mixed well in the entre Indian Ocean region as there are large geographical distances among some countries (e.g. between Kenya and Australia). Although convergence does not imply that 4 stock hypothesis is true, it might imply its possibility to some extent.

Exploring other STD CPUEs

During the WPNT03 meeting, we may need to compare available kawakawa STD_CPUE (or even with nominal CPUE: N_CPUE) from different fleet operating different waters, so that we may be able to learning geographically homogenous groups that have similar CPUE trends. Then we may be able to learn the possible stock structure, although similar CPUE trends do not necessarily imply any stock structure, but it is worth to compare and discuss.

Stock status

Assuming that there is the NW (Gulf and Oman Sea) stock in the Indian Ocean, we now discuss the kawakawa stock status. Based on the Kobe plot (Fig. 9), we understand that the kawakawa stock in the NE Indian Ocean region is now about entering to the overfished status due to high fishing pressure after 2008 when piracy activities intensified.

As discussed previously, major drift gillnet fisheries in this region moved back to their EEZ waters and targeted more neritic tunas after 2008 when piracy activities intensified. That is the major reason why catch (F) has been sharply increased in recent years after 2008 (Figs. 4, 6 and 9). This caused the sharp decrease in its biomass (population) size and the status of the stock has been worsening (Figs. 5 and 9). This situation is very similar to the one in albacore, i.e., more Asian industrial tuna longline fisheries started targeting albacore after 2008 in the piracy-free zone in the southern Indian Ocean, which worsen its stock status.

Acknowledgements

We are grateful to H.E. Dr. Hamed Al-Oufi, the Undersecretary, Ministry of Agriculture and Fisheries Wealth, Dr. Saoud Al-Habsi, the Director General of Fisheries Research in in Sultanate of Oman for their encouragement. We also thank to the Agriculture & Fisheries Development, the funding agency of our on-going project, *"Management of the exploited coastal tuna fisheries resources of the Sultanate of Oman"*. Also we would like to extend our appreciation to our colleagues in the Marine Biology Section of Marine Science and Fisheries Center, for their kind supports to our work. Finally, we appreciate Mr. Miguel Herrera (IOTC data manager) to prepare kawakawa nominal catch. Without this important data, we cannot attempt the ASPIC runs.

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IOTC (2012). Report of the Second Working Party on Neritic Tuna meeting (Penang, Malaysia) (IOTC-2012-WPNT02-R[E]).

Training materials (11)

Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

STOCK STATUS OF LONGTAIL TUNA, KAWAKAWA FRIGATE TUNA AND STRIPED BONITO IN THE NW INDIAN OCEAN

THIS WORK WAS CONDUCTED AS A PART OF THE NERITIC TUNA PROJECT,
"MANAGEMENT OF THE EXPLOITED COASTAL TUNA FISHERIES RESOURCES OF THE SULTANATE OF OMAN"

FINAL REPORT
(January, 2014)

Tom Nishida (Tuna scientist and Consultant)
PhD (Tokyo University), MS+BS (University of Washington) and BS (Hokkaido University)
IOTC Scientific Committee Chair (2012-2015)

Project scientists in Oman
Dr Lubna Al-kharusi and Dr Fatma Rashid Al-Kiyumi
Marine Science and Fisheries Centre
Ministry of Agriculture & Fisheries, Sultanate of Oman

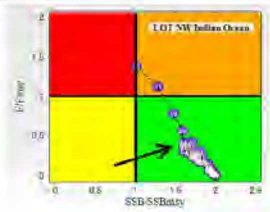
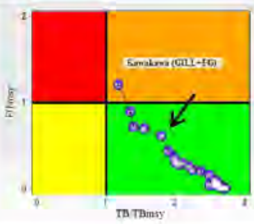
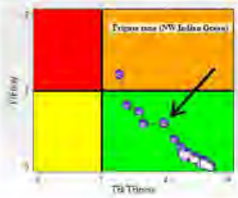
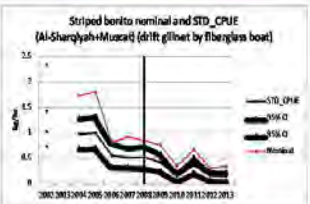
Contents

Contributions to the project (Separate documents)

Appendix A: First report (First visit)(May, 2012)
Appendix B: Lecture notes (Second visit)(May, 2013)
Appendix C: Tutorials (Data process, nominal & STD_CPUE, ASPIC and Kobe plot) (Third visit) (Jan., 2014)
Appendix D: Kawakawa CPUE standardization (IOTC neritic tuna working paper)(July 2013)
Appendix E: Kawakawa ASPIC (IOTC neritic tuna working paper) (July 2013)

EXECUTIVE SUMMARY
STATUS OF STOCK OF FOUR NERITIC SPECIES IN THE NW INDIAN OCEAN

Stock status of longtail tuna, kawakawa and frigate tuna (2012) are at the orange zone of the Kobe plot (stock trajectory), i.e., fishing pressure is much higher than their MSY levels, while total biomasses are in the safe levels (at the MSY level or higher). Stock status of striped bonito is unknown due to incomplete catch statistics. After 2008 when piracy activities are intensified, more fleets started operating within their EEZs and targeting more neritic tuna. Thus both fishing pressure and catch became very high levels (*positions of 2008 are indicated in Figures below*).

LONGTAIL TUNA	
	In 2012, F (fishing mortality rate) is beyond Fmsy (38% higher than the MSY level), i.e., high fishing pressure, while the total biomass is about in the MSY level. It is clear if current F level continues, longtail tuna stock will be entering the overfishing stage from 2013.
KAWAKAWA	
	In 2012, F (fishing mortality rate) is beyond the Fmsy level (21% higher than the MSY level), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (safe level). It is clear if the current F level continues, kawakawa stock will be entering the overfishing stage in the near future.
FRIGATE TUNA	
	In 2012 F (fishing mortality rate) is beyond Fmsy (22% higher than the MSY level), i.e., high fishing pressure, while the total biomass is still in the safe zone, i.e., beyond the MSY level (27% higher). However, it is clear if current F level continues, frigate tuna will be entering the overfishing stage in the near future.
STRIPED BONITO	
	**STOCK STATUS IS UNKNOWN.** It is not possible to conduct stock assessment with the current catch information because it is incomplete. It is strongly recommended to make complete catch statistics through IOTC. Although the stock status is not known, there is a concern as standardized CPUE shows continuous and consistent decreasing trend as shown in the graph (left).

1. INTRODUCTION

Marine Science and Fisheries Centre and Ministry of Agriculture & Fisheries, Sultanate of Oman initiated the project "Management of the exploited coastal tuna fisheries resources of the Sultanate of Oman" in 2011. Details on the project are described in the project proposal (Anon., 2011). In this project, four coastal neritic tuna species are focused i.e., (by the order of commercially value and the catch level) Longtail (*Thunnus tonggol*), Kawakawa (*Euthynnus affinis*), Frigate tuna (*Auxis thazard*) and Striped-bonito (*Sarda orientalis*) (Figs. 1-2). These four species are commercially important and major incomes for some fishers in Oman, thus effective management strategy is essential to conserve these resources.

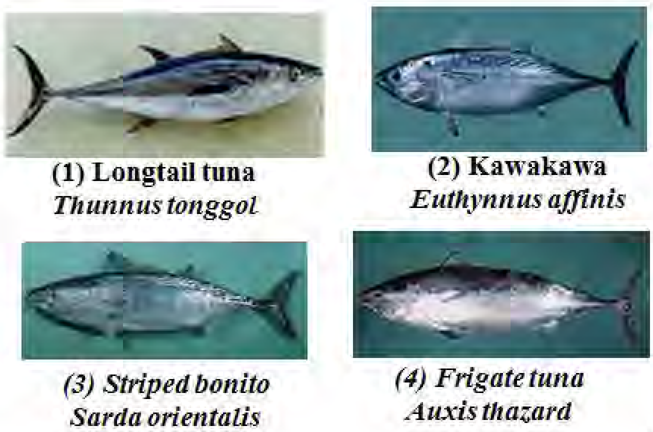


Fig. 1 Pictures of four neritic tuna species focused by this project

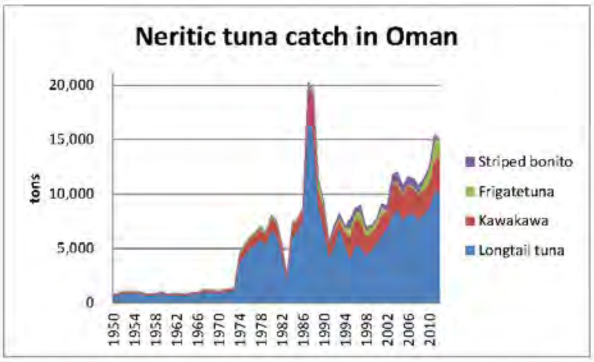


Fig. 2 Trends of four neritic tuna catch exploited in Oman (IOTC and FAO)

Stock structures of neritic tuna in the Indian Ocean are unknown. Based on the geographical features and ranges of possible gene flows, the hypothesis of four stock structures for neritic tuna is assumed in the Indian Ocean (Fig. 3) (Nishida, 2013). In this paper, we focus on the NW Indian Ocean hypothetical stock mainly in the Gulf region, Oman and Arabian Sea.

Fig. 3 Four hypothetical neritic tuna stock structure in the Indian Ocean (Nishida, 2013)

4

Fig. 4 shows catch trends of longtail tuna, kawakawa and frigate tuna (1950-2012) in the NW Indian Ocean, based on IOTC database (September, 2013) and striped bonito (1989-2011) based on the FAO FISHSTAT (2013). Catches of longtail tuna, kawakawa and frigate tuna show the simultaneous sharp increase in recent years especially after 2008, while striped bonito, the unstable trend.

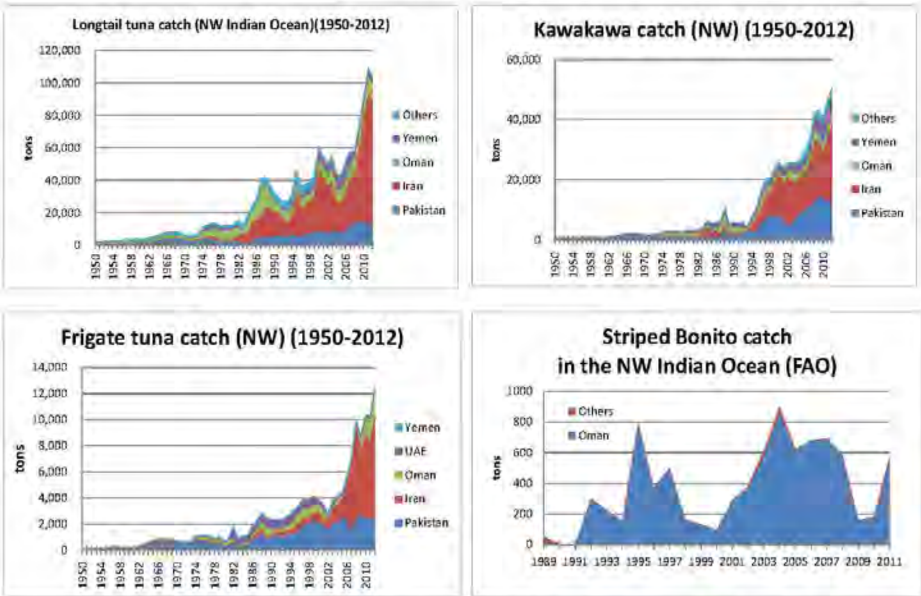


Fig. 4 Four neritic tuna catch by fleet in the NW Indian Ocean (1950-2012)

Such sharp increases are caused by piracy activities off Somalia which were intensified after 2008. Before 2008, more fleets operated outside of their EEZs. But after 2008, fleets tend to go back to their EEZs to avoid pirate attacks, which made sudden increases of four three tuna catch simultaneously. We very much concern such sharp increases, thus it is the urgent task to elucidate stock status for these three species, in order to conserve these stocks, in addition to striped bonito.

To implement this important task, the project timely hires the consultant (Dr Tom Nishida, Japan). He visited Marine Science and Fisheries Centre in Oman three times (May 2012, May, 2013 and January 2014). During three visits, he worked with several Omani scientists and carried out this task. During visits, capacity buildings on the data process, CPUE standardization and stock assessment were also conducted. Products (documents) made during three visits are provided in Appendix A-E (separate documents).

This paper is the final report describing these activities, especially stock assessment results and stock status of these four species. This report contains five Sections and five Appendices (separate documents). After the current Section 1 (Introduction), Section 2 describes data and data processes, Section 3 for Methods including nominal CPUE, CPUE standardization, stock assessments and Kobe plot, Section 4 for Results, then lastly, Section 5 provides summary, conclusion and recommendations. In addition, references and pictures on our activities are provided at the end of this report.

Five Appendices (A-E) are provided in the separate documents. Appendix A is the first report made in the first visit (May, 2012). Appendix B is the lecture notes made in the second visit (May, 2013), Appendix C for tutorials developed in the third visit (January, 2014) and finally Appendix D and E are two working papers on kawakawa STD_CPUE and stock assessment submitted to the IOTC neritic tuna meeting in July, 2013 (Bali, Indonesia).

2. DATA AND DATA PROCESS

We use three types of the data for our works, i.e., (a) catch statistics for longtail tuna, kawakawa and frigate tuna (1950-2012) from the IOTC database (as of September, 2013), (b) catch statistics for striped bonito (1989-2011) from FAO FISHSTAT database (as of 2013) and (c) catch and effort database (2000, 2002-2013) from Fisheries Statistical Section, Ministry of Agriculture & Fisheries, Sultanate of Oman for four species. Please note that striped bonito is not included in the IOTC species, thus its catch data are not available in the IOTC database and we get the catch data from FAO FISHSTAT. Please also note 2003 catch and effort data from Fisheries Statistical Section in Oman are missing because the data were accidentally deleted during the data processing according to that section.

When we process the catch and effort database from Fisheries Statistical Section, we noticed various matters need to be clarified as described as below, which is hoped to be cleared in the future:

- Boat type: "Launch (net)" (2011-2012) should be categorized as "Launch" as used in 2000, 2002-2010 and 2013. We modified such data in our works.
- Boat type: "Fiberglass (net) (2011-2012) should be categorized as "Fiberglass' as used in 2000, 2002-2010 and 2013. We modified such data for our works.
- Within the same operation, there are 0 catch in number, while catch in weight are available, i.e., catch in number are often missing in the data set. Thus we use catch in weight (kg) to evaluate nominal CPUE and Standardized CPUE (STD_CPUE).

- We use fishing hours for effort. But there are often the data with 0 fishing hours or with no data (blanks). As such data cannot be used to calculate CPUE, we deleted these data.
- Definition of fishing days is not clear. Thus we did not use this information.
- It is not clear the meaning of Yes or No in NO_CATCH field. Thus we did not use this information.

We found one potential error in the IOTC frigate tuna catch data, i.e., Iranian catch in 1995 is 4,438 tons, which seems to be too high comparing the catch data in 647 ton in 1994 and 776 tons in 1996. Thus we used average catch 458 tons between 1994 and 1996. We will report this to the IOTC secretariat.

3. METHODS

3.1 Nominal CPUE

As the first step for stock assessments, we need to compute nominal CPUE to estimate standardized CPUE (STD_CPUE), which will be used for stock assessment by ASPIC.

(1) Parameters

In evaluating nominal CPUE and STD_CPUE, we need define various parameters such as gear (fisheries) and boat types, area, season and CPUE unit. We now discuss these parameters one by one.

Gears and boat types

Based on the catch and effort database from Fisheries Statistical Section, Ministry of Agriculture & Fisheries, there are different types of gears and boats. As for gears, there are ten different types, i.e., (by alphabetical order) beach seine net, cast net, drift gillnet, fish trap, hand line, linear fixed gill, lobster trap, longline, pen-type fixed gill, surrounding gill net and troll line.

As for boats, there are twelve different types, i.e., Aluminum, FG (FT), FG (HL+TL), FG (net), FG-lobster, fiberglass, beach seine, hori, launch-net, launch, launch-FT and launch-line+TL. As explained in the previous Section, FG (net) needs to be categorized as fiberglass and launch-net for launch. Thus there are ten boat types.

Within these gear and boat types, three particular gear-boat types target neritic tuna, i.e., (a) drift gillnet by fiberglass boat, (b) drift gillnet by launch boat and (c) hand line by fiberglass boat. Details will be explained in Section 4 (results and discussions) by species.

Fishing areas

In the catch and effort database from Fisheries Statistical Section, Ministry of Agriculture & Fisheries, there are spatial information regarding landing locations such as region, wilaya (district) and landing sites. In our previous paper on CPUE standardization for kawakawa (Al-Kiyumi et al, 2013a), we noticed that "region" is the optimum spatial unit by considering sample sizes (number of operations). This means that if we use wilaya or landing site, we will have problems on lack of sample sizes.

Thus we use region as the spatial unit (fishing ground). There are six regions as shown in Fig 5, i.e., (from north to south) Musandam, Al-Batinah, Muscat, Al-Sharqiyah, Al-Wusta and Dhofar.

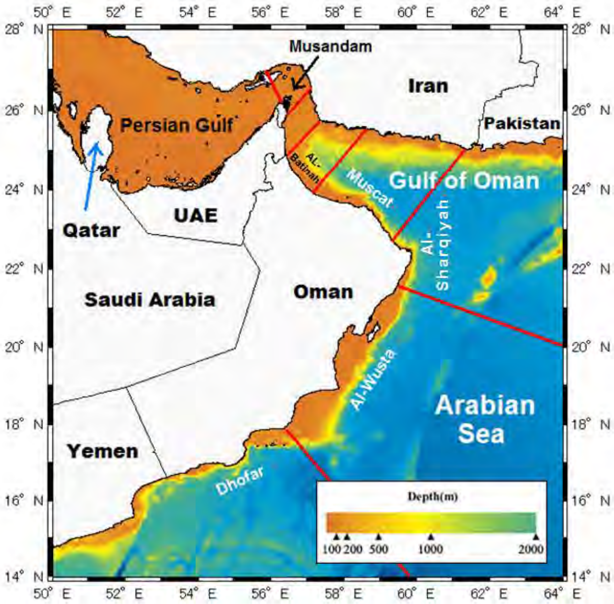


Fig. 5 Six regions used for nominal CPUE and CPUE standardization

(from north to south) Musandam, Al-Batinah, Muscat, Al-Sharqiyah, Al-Wusta and Dhofar

Fishing season

Based on also our previous paper on CPUE standardization for kawakawa (Al-Kiyumi *et al*, 2013a), the optimum temporal unit is quarter (four 3 months in one year). This is because if we use month as the time unit, we will have serious problems on lack of sample sizes.

CPUE unit

As explained in the previous Section, within the same operation, there are 0 catch in number, while weight data are available in many cases. Thus we consider that catch in number may include many missing values in the dataset, hence we use weight data (kg) for the catch in CPUE. As for fishing effort unit, they are different by gear and boat type, hence CPUE unit is defined according to the fishing units as follow:

Gillnet: The gear expert, Captain Al-Harthy, Marine Science and Fisheries Center in Oman suggested to use the number of gillnet units as shown in Table 1.

Table 1 Number of gillnet unit by boat type and period suggested by Captain Al-Harthy

Type of boats	suggested number of gillnet units
Fiber glass	unit=7.5
Launch	unit=33 before 2007 and unit=50 after 2008

As we have also the fishing hours in the data set, we define the nominal CPUE unit as below:

Nominal CPUE = [Kg]/[(number of gillnet unit)(fishing hours)]*

Hand line: We use fishing hours for the effort and CPUE is defined as below.

Nominal CPUE = [Kg]/[fishing hours]

Crew size for boat size

We don't have boat size information in the catch and effort database from Fisheries Statistical Section, Ministry of Agriculture & Fisheries. But there are number of crew information, hence we use this information as the proxy of the boat size. We use this in GLM as the boat size factor (refer to the next Section).

(2) Evaluation of nominal CPUE

We will compute a number of nominal CPUEs by gear-boat type and region in each species. Then we will select the best plausible nominal CPUE. In evaluating the best one, we examine relations between catch and nominal CPUE, which should be negatively correlated.

3.2 CPUE standardization

As nominal CPUE includes biases caused by effects of year, season, area and boat (crew) size, we need to standardize nominal CPUE to reduce such biases. There are various multivariate statistical methods in CPUE standardization such as GLM, GAM, negative binominal model, regression tree, Tweedie model etc. (Shono, 2004). Among them, we use GLM which has been used as the standard approach. We will evaluate if GLM is the appropriate model in each CPUE standardization process. If GLM is not suitable, we will use other statistically valid methods. In general, we use the following the GLM model. But the terms depend on the situation of missing data:

$$\log(CPUE+c) = (mean) + [Y] + [Q] + [R] + [INT] + [crew] + (error)$$

where, c: 10% of average overall nominal CPUE
Y : effect of year
Q : effect of quarter(season)
A : effect of region (see Fig. 2)
INT: interaction terms by combination among Y, Q and R.
Crew: boat size effect (number of crew is used as proxy)

3.3 Stock assessment by ASPIC

There are three types of stock assessment models as described in Fig. 6 (left), i.e., simple production model (e.g. ASPIC), intermediate model (ASPM) and integrated and complex model (SS3) as described in Fig. 6.

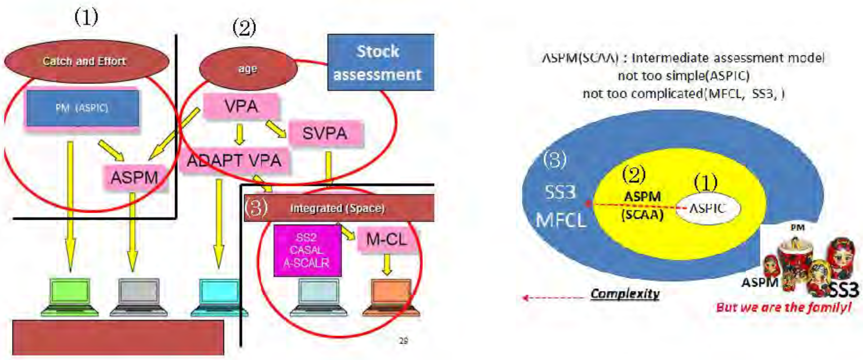


Fig. 6 (*left*) Outline of the stock assessment models and (*right*) Relations among simple production model (ASPIC), intermediate model (ASPM) and complex model (SS3). ASPIC use only global catch and catch/effort data, while ASPM and SS3 use additional biological information.

In our work for this time, we use A Stock Production Model Incorporating Covariates (ASPIC) (ver. 5) (Prager, 2004). This is the simplest model using the global catch and STD_CPUE because such information is available for our works. But, it is strongly recommended that stock assessment methods incorporating biological information (size, L-W relation, S-R relation, age, growth maturity etc.) should be conducted in the future. For example, Age Structured Production Model (ASPM) (Fig. 7, right) is one of the methods.

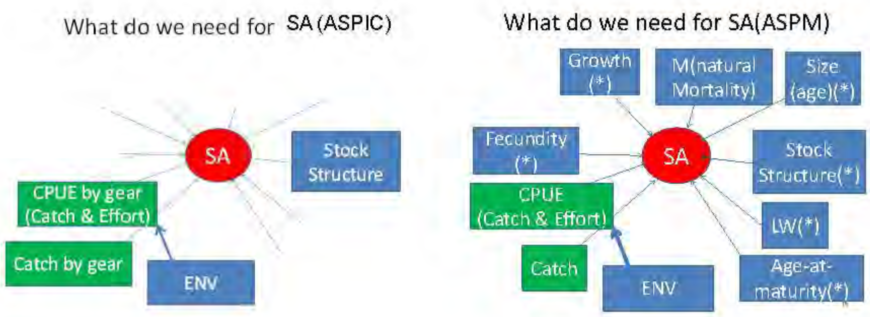


Fig. 7 Information needed to conduct simple production model such as ASPIC (left) and also for the intermediate model such as ASPM (right)

This is because of following two reasons, i.e., (a) this project has been collecting large numbers of biological data and (b) it is important to cross checks results of stock assessments through a few different models to evaluate and confirm results as production model using only catch and CPUE may produce biased results because no biological information and S-R relation are used.

14

However ASPIC is useful in the data limited situation to learn the quick and rough stock status. Thus ASPIC has been applied for many different species world-widely. So in our case, it will be no problem as a first step of the stock assessment using ASPIC.

In ASPIC, there are a few options for the basic production model to be applied. In our work, we attempted to use Fox and Schaefer model. In the Schaefer model, we need to estimate 4 parameters (K: carrying capacity, B0/K where B0 is the total biomass at the start of fisheries, q: catchability and MSY). In the Fox model, we need to estimate one extra (shape) parameter (total five parameters). In theory, Fox model produce less biased results but there are often some difficulties to get conversions (solutions) due to more parameters need to be estimated than in the Schaefer model.

In conducting ASPIC, we assume that B0 =K as it is quite often difficult to get conversions when we have a longer timer series of catch and much less for CPUE series, which is our case. In such case, B0 =K assumption will be effective to get more realistic results. If we cannot get any convergences, we will fix K and explore ASPIC by varying plausible K values (scenarios). Then we will decide the best result using R2 and MSE (mean squared errors), i.e., we will select the scenario with highest R2 and lowest MSE.

3.4 KOBE PLOTS (STOCK TRAJECTORY)

In five tuna RFMOs, it has been the routine procedure to depict results of stock assessments using Kobe plot (stock trajectories). Kobe plot is recommended by 5 tuna RFMOs joint meeting held in Kobe, Japan in 2007. Kobe plots can provide the stock status from the past to the present very effectively using F ratio (=F current/Fmsy) and B (biomass) ratio (=B current/Bmsy). Through Kobe plot anyone can understand the stock status very easily. Fig. 8 shows the outline of the Kobe plot.

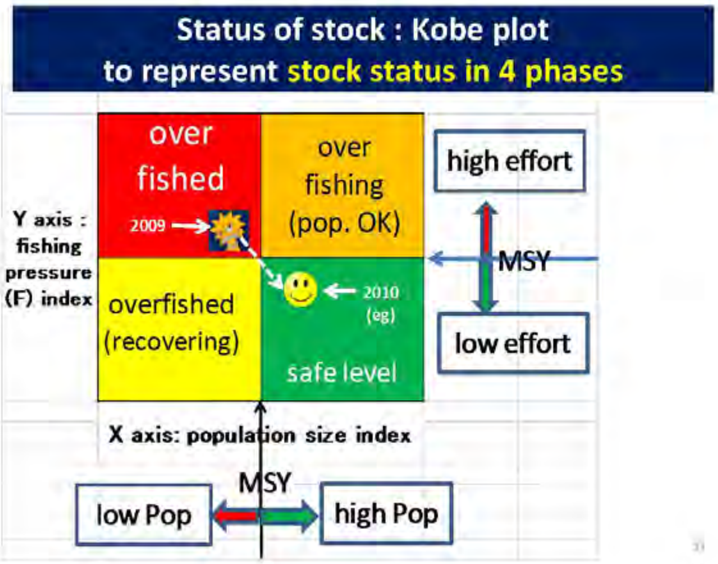


Fig. 8 Outline of the Kobe plot (stock trajectory)

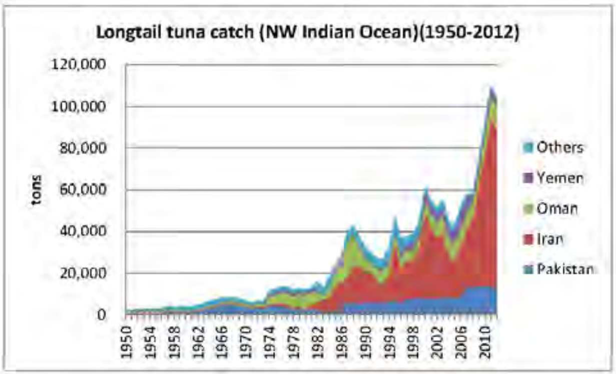
16

4. Results and discussions

4.1 Longtail tuna

(1) Nominal catch

Fig. 9 shows longtail tuna nominal catch in the whole period (1950-2012) and in the recent years (2000-2012) in the NW Indian Ocean based on IOTC database (September, 2013). Catch has been increasing since 1950 and there are sharp increases in recent years (2008-2012).



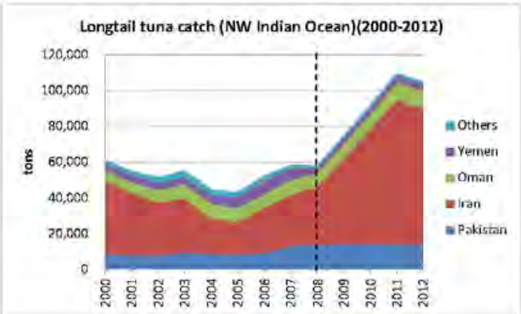


Fig. 9 Longtail catch in NW Indian Ocean

(Above) Entire period (1950-2012) and (Below) Recent years (2000-2012)

(2) Nominal CPUE

Using the catch and effort database (Fisheries Statistical Section, Ministry of Agriculture & Fisheries, Sultanate of Oman); we initially investigated sample size (number of operations) by gear and boat type (Table 2). From Table 2, we selected drift gillnet fisheries by fiberglass boat, drift gillnet fisheries by launch boat and hand line fisheries by fiberglass boat to evaluate nominal CPUE as these three fisheries have large number of sample sizes comparing to other types.

Table 2 Sample size (number of operations) by gear and boat type (2002-2013)

	ALU-MINUM	FG(FT)	FG (HL+TL)	FG-lobster	FIBER-GLASS	BEACH SEINE	HORI	LAUNCH	Launch -FT	Launch line+TL
BEACH SEINE NET					545	501		35		
CAST NET					6			1		
DRIFT GIL NET		2	10		13,328		4	3,921		6
FISH TRAP		6	3		67			7		
HAND LINE		3	2,607		8,093			22	1	12
LINEAR FIXED GILL			4		487			189		2
LOBSTER TRAP					1			1		
Long Line			46		3					
PEN-TYPE FIXED GILL				1	770			131		
SURROUNDING GILL NET			1		88			1		
TROLL LINE	1		211		1,114			5		

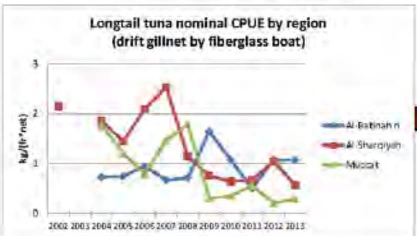
Drift Gillnet by fiberglass boat

We investigated sample sizes (number of operations) by region, year and quarter (Table 3). Table 3 suggests that three regions (Al-Batinah, Al-Sharqiyah and Muscat) have large sample sizes by year and quarter in general. Hence we selected catch and effort data for these three regions and evaluate nominal CPUE. Fig. 10 (left) shows nominal CPUE by region. Nominal CPUE trend in Al-Batinah shows the upward trend which is not plausible as catch increase sharply in recent years, while trends of other two nominal CPUEs (Muscat and Al-Sharqiyah) show the decreasing trends which are more realistic. However nominal CPUE in Muscat include a number of missing years, thus we did not select as the representative nominal CPUE. The last nominal CPUE in Al-Sharqiyah shows the plausible trend. As a result, we selected nominal CPUE in Al-Sharqiyah as the representative one in drift gillnets fisheries by fiberglass boat.

Table 3 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah n				Al-Sharqiyah				Al-Wusta			Dhofar				Musandam				Muscat			
Q	1	2	3	4	1	2	3	4	1	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2002					14	205	143	53															
2004	241	227	485	159	56	136	63	65												81	191	67	144
2005	23	229	174	58	27	112	37	35									5			74	137	138	23
2006			102	56		5	12	54							1				1	11	46	26	6
2007	97	196	120	89	58	117	42	21				1							1	3	18	4	1
2008	96	308	302	123	15	134	30	22								2	15	2		3	16		
2009	89	774	463	270	30	114	22	12									29		1		11	3	29
2010	575	892	687	405	119	165	33	39		1		1	1			1	2	2	3	141	77	36	106
2011	45	255	147	52	17	171	12	32			1		3		2	2	15		2	26	72	36	14
2012	44	171	135	108	38	111	41	38	2				1	3		1			5	32	61	40	28
2013	44	182	145	92	82	118	43	23				2				1	3	3	2	34	61	1	42



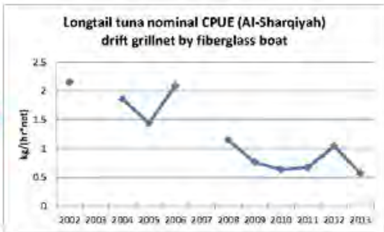


Fig. 10 (left) Trends of longtail tuna nominal CPUE for three region (drift gillnet by fiberglass boat) and (right) the selected nominal CPUE (Al-Sharqiyah).

Hand line by fiberglass boat

We attempted same investigation for the nominal CPUE for hand line fisheries by fiberglass boat. Table 4 shows sample size (n) (number of operations) by region, year and quarter. Al-Wusta and Muscat don't have enough sample sizes; hence we did not use the data from these two regions and use the data from four other regions.

Fig.11 (left) shows nominal CPUE for four regions. Behaviors of almost all nominal CPUE trends in four regions include a lot of noises (mixed up and downward trends) except the one in Al-Batinah. These noises are not plausible considering the sharp and consistent increase catch trend in recent years. Thus we selected the nominal CPUE in Al-Batinah as the representative one for hand line fisheries by fiberglass boat. However we exclude two data points in 2011 and 2013 as these two years have only a few sample sizes (operations) (n=1 or n=3) as shown in Table 4. Fig. 11 (right) shows selected nominal CPUE.

Table 4 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah				Al-Sharqiyah				Al-Wusta		Dhofar				Musandam				Muscat			
Q	1	2	3	4	1	2	3	4	2	3	1	2	3	4	1	2	3	4	1	2	3	4
2002					3	50	40	11														
2004	29	197	28	12	47	101	8	8			259	119		89	8	2	10	12	5	37	6	18
2005		92	20	1	20	11	1	3			287	227	4	33	9	41	1		6	7	3	
2006			9	2				2		2				117			9	18		9	4	
2007	4	298	3	16	43	45	1	1			267	199	2	46	9	49	39	27		5	3	2
2008	26	138	20	33		76	16				146	128		199	10	116	14	4	5	1		
2009	1	461	72	108	2	108	10	121	8		78	236	15	62	14	252	51	20		9	8	58
2010	106	639	133	45	98	65	4	14	6		107	187		212	84	225	51	87	23	119	37	30
2011			1								1	1				1	2			1		
2012																	1					
2013		1		2		21					2	48		14	1	1	1					

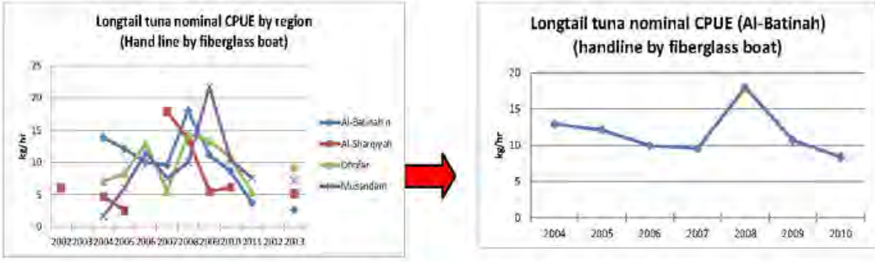


Fig. 11 (left) Trends of nominal CPUE for four regions (hand line fisheries by fiberglass boat) and (right) Selected nominal CPUE (Al-Batinah) (2011 and 2013 data are not included as their sample sizes are too few, i.e., n=1 and n=3 respectively.

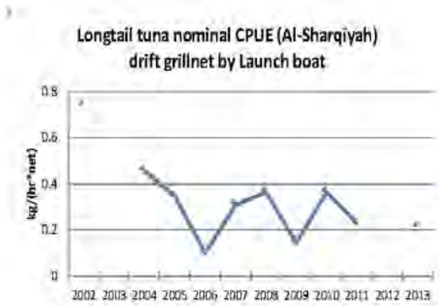
Drift gillnet fisheries by launch boat

By following previous cases, we attempted same investigations for nominal CPUE for hand line fisheries by launch boat. Table 5 shows sample size (n) (number of operations) by region, year and quarter. Only Al-Sharqiyah region has satisfactory sample sizes. Thus we evaluate the nominal CPUE only for this region. Fig 12 shows the resultant nominal CPUE. However we decided not to select as the representative nominal CPUE for drift gillnet fisheries by fiberglass boat because its up and down trend is not reflected to the sharp and consistent increase catch trend.

Table 5 Sample size (n) (number of operations) by region, year and quarter.
(10<=n are highlighted by yellow marker)

	Al-Batinah	Al-Sharqiyah				Al-Wusta				Dhofar			Musandam			Muscat
	3	1	2	3	4	1	2	3	4	1	2	3	4	2	3	2
2000		2														
2002		79	336	310	60											
2004		151	237	143	115						1	3				
2005		51	185	165	50					2		4				
2006	1			29	63								1			1
2007		91	150	105	27					5		16	4			
2008		16	227	119	16					4	2		1			
2009		13	95	36	11					7	5	16	8			
2010		19	46	73	5		42	111	94	6	13	2	10			
2011		6	55	10	6	15	5		2	2	13	10	1	1		
2012		10	47	32	21	4				4	17	24	8	4	1	
2013		24	86	65	13					1	19	22	7	1	1	

21



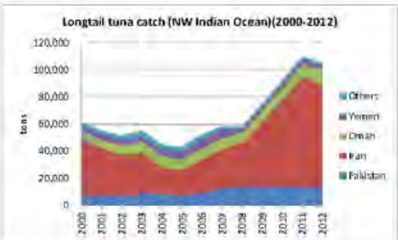
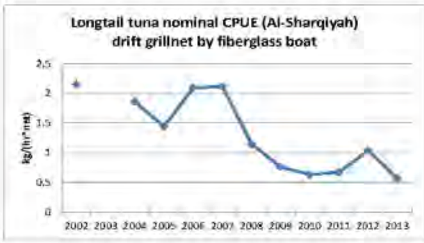
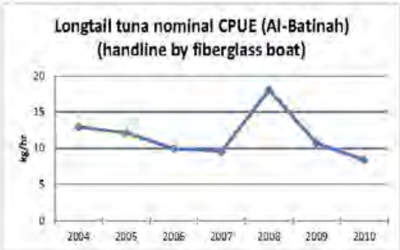
Nominal CPUE for drift gillnet fisheries by fiberglass boat was not selected as the representative one as its trend was not plausible.

Fig.12 Trend of nominal longtail tuna CPUE for Al-Sharqiyah (hand line fisheries by launch boat), which does not represent realistic signals, thus no nominal CPUE was selected for drift gillnet fisheries by fiberglass boat.

Summary of nominal CPUE

We now compare selected nominal CPUEs, in order to choose the most plausible one to be used for STD_CPUE and ASPIC afterwards. Box 1 shows the recent catch trend with two nominal CPUEs for two different gear-boat types. As the nominal CPUE in hand line fisheries by fiberglass boat has much shorter time series than the one in drift gillnet fisheries by fiberglass boat, we did not select that nominal CPUE. As a result, we select the representative nominal CPUE as drift gillnet fisheries by fiberglass boat, to be used for STD_CPUE and the stock assessment by ASPIC.

Box 1 Comparisons and evaluation of nominal CPUE

	
Recent longtail tuna catch in the Oman and Gulf region.	Nominal longtail tuna CPUE (drift gillnet by fiberglass boat). Selected as the representative nominal CPUE for STD_CPUE.
	No plausible nominal CPUE was found
Nominal CPUE (hand line fisheries by fiberglass boat). Not selected as the data points are not enough comparing to the one of drift gillnet by fiber glass boat.	Nominal longtail tuna CPUE (drift gillnet by launch boat)

(3) CPUE standardization

We standardize longtail tuna nominal CPUE of drift gillnet fisheries by fiberglass boat (Al-Sharqiyah) using GLM. Our model is described as follows:

Log (CPUE+c) = (mean) + (Y) + (Q) +(Crew) + (error)

*where, CPUE : kg/(gillnet unit*fishing hours) (refer to Table 1, page 11)*

c: 10% of average overall nominal CPUE

Y : effect of year

Q : effect of quarter(season)

Crew: crew (boat size) effect

Box 2 (top) shows results of GLM procedures. Based on ANOVA table, Year and quarter (season) affect nominal CPUE significantly. Box 2 (middle) shows resultant STD_CPUE with 95% confidence intervals made smooth noises in nominal CPUE and show the consistent declining trend, which is a good reflection to the recent sharp decreasing catch trend. Box 2 (bottom) shows frequency distribution of residuals and QQ plot suggest that GLM is the appropriate method for CPUE standardization.

(4) Stock assessment by ASPIC and the stock status

Using the standardized CPUE, we conducted stock assessment by ASPIC. In ASPIC we need to estimate 4 parameters (K: carrying capacity, B0/K where B0 is the total biomass in 1950, start of fisheries in our case, q: catchability and MSY). We assume that B0 =K and attempt to estimate 3 parameters (K, MSY and q). But we could not get any conversions for both Schaefer and Fox production model.

Box 2 Results of GLM for longtail tuna STD_CPUE (Al-Sharqiyah) in drift gillnet fisheries by fiberglass boat. *(top: ANOVA, middle: STD_CPUE and bottom: residuals)*

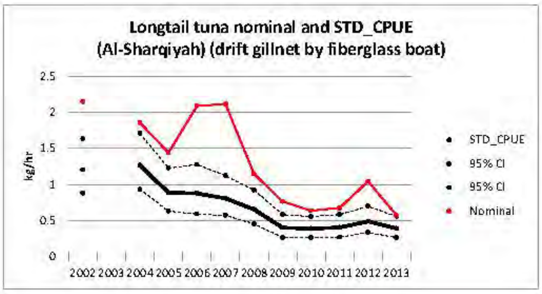
The GLM Procedure

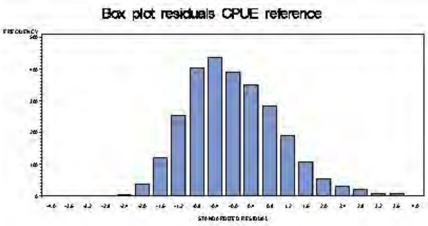
ependent Variable: L_CPUE

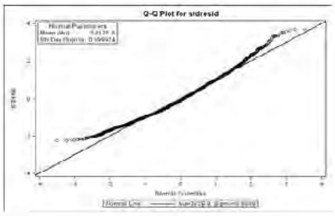
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	561.998414	25.545382	33.29	<.0001
Error	2688	2062.589716	0.767332		
Corrected Total	2710	2624.588130			

R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.214128	-436.0233	0.875975	-0.200901

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	10	396.3105287	39.6310529	51.65	<.0001
q	3	127.8215908	42.6071969	55.53	<.0001
crew	9	52.3305018	5.8145002	7.58	<.0001







Then we fixed K and attempted to explore various K values within plausible ranges, i.e., 100, 170, 180, 190 and 200 thousand tons. With the constraint (MSY < Bmsy), we found that K=180,000 tons with Schaefer model produced the best fit to the ASPIC model based on R2 and MSE (Mean Square Errors) (Table 6). Thus we selected this scenario as the representative of ASPIC result.

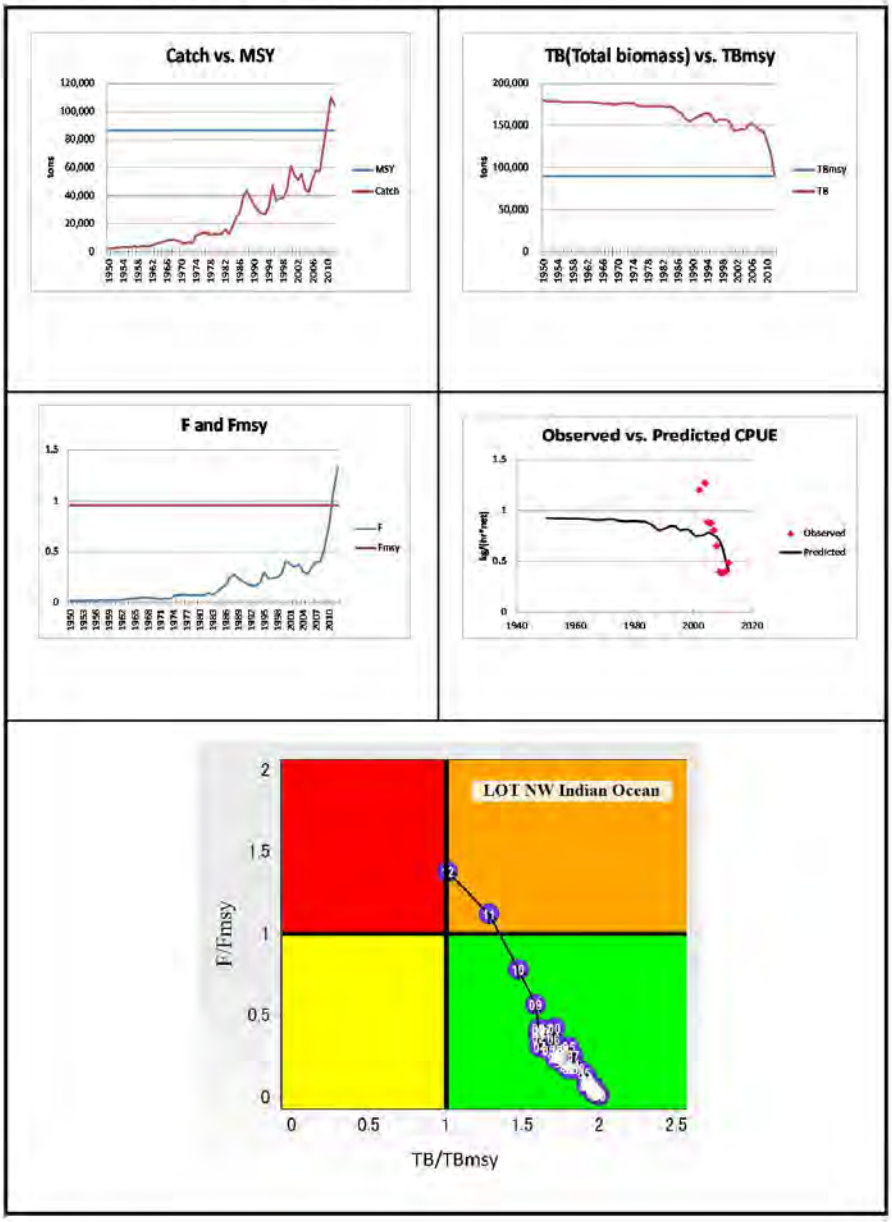
Table 6 ASPIC results based on various scenarios of K values.

model	Schaefer					FOX
K (1000 tons)	R2	MSE	TB ratio	Fratio	MSY	NC
100	NC					NC
170	NC					NC
180 (best fit)	0.321	0.1483	0.789	1.379	86,490	NC
190	0.319	0.1488	0.780	1.409	85,160	NC
200	0.318	0.1493	0.770	1.440	83,770	NC

NC: Neither converged nor plausible parameters were estimated

Box 3 shows results including graphs for catch vs. MSY, TB (total biomass) vs TBmsy, F vs. Fmsy, observed vs. predicted CPUE and Kobe plot (stock trajectory). Based on this ASPIC results, the stock status of longtail tuna (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond Fmsy (38% higher than the MSY level), i.e., high fishing pressure, while the total biomass is about in the MSY level. It is clear if current F level continues, longtail tuna will be entering the overfishing stage in 2013 afterwards.

Box 3 Results of ASPIC (longtail tuna)



4.2 KAWAKAWA

(1) Nominal catch

Fig. 13 shows kawakawa nominal catch for the whole period (1950-2012) and for the recent year (2000-2012) in the NW Indian Ocean based on IOTC database (September, 2013). Catch has been increasing since 1950 and there is a sharp increase in recent years (2008-2012).

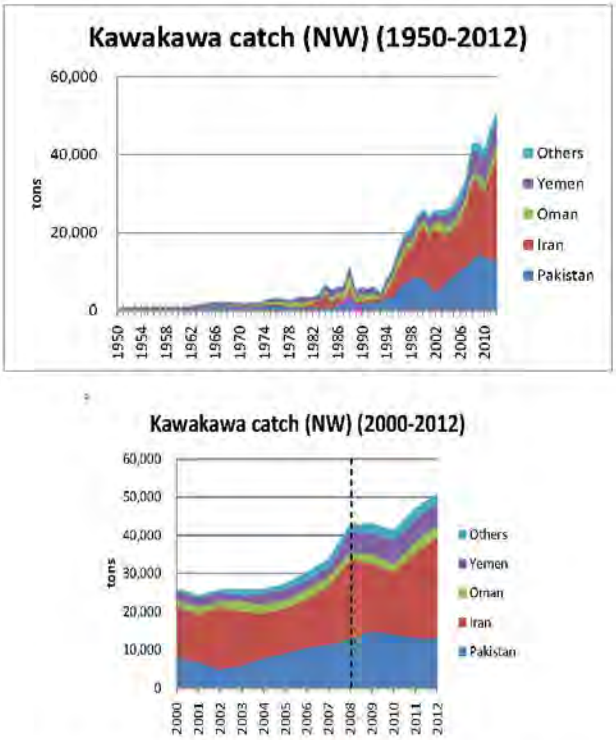


Fig. 13 Kawakawa catch in the NW Indian Ocean

(Above) entire period (1950-2012) and (Below) recent years (2000-2012)

(2) Nominal CPUE

Using the catch and effort database (Fisheries Statistical Section, Ministry of Agriculture & Fisheries, Sultanate of Oman); we initially investigated sample sizes (number of operations) by gear and boat type (Table 7). From Table 7, we selected drift gillnet fisheries by fiberglass boat, drift gillnet fisheries by launch boat and hand line fisheries by fiberglass boat to evaluate nominal CPUE as these types of fisheries have large sample size comparing to other types.

Table 7 Sample size (number of operations) by gear and boat type (2002-2013)

	FG(FT)	FG (HL+TL)	FIBER-GLASS	BEACH SEINE	HORI	LAUNCH	Launch-line+TL
BEACH SEINE NET			412	208		14	
CAST NET			4				
DRIFT GIL NET		6	6839		2	2006	3
FISH TRAP			43			2	
HAND LINE	1	1012	3771			2	3
LINEAR FIXED GILL	1		558			108	
LOBSTER TRAP	1		1				
Long Line		9	8				
PEN-TYPE FIXED GILL		1	338			44	
SURROUNDING GILL NET			100	1			
TROLL LINE		131	452			2	

Drift Gillnet fisheries by fiberglass boat

We investigated sample sizes (n) (number of operations) by region, year and quarter (Table 8). Table 8 suggests that three regions (Al-Batinah, Al-Sharqiyah and Muscat) have large sample sizes by year and quarter in general. Hence we selected catch and effort data for these three regions and evaluate nominal CPUE. Fig. 14 (left) shows the nominal CPUE by region. Almost all nominal CPUE except the one Al-Sharqiyah after

2005, shows the upwards and/or flat trends, which are not plausible as catch increase sharply and consistently in recent years. Thus we chose nominal CPUE in Al-Sharqiyah (2005-2013) as the representative one in the drift gillnet fisheries by fiberglass boat (Fig. 14, right).

Table 8 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah n				Al-Sharqiyah				Dhofar				Musandam			Muscat			
	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	1	2	3	4
2002					16	61	72	48											
2004	118	125	251	71	81	83	52	36								30	73	57	34
2005	3	114	85	34	61	66	75	48			1		1			23	81	103	11
2006			36	44		1	5	71				1				7	36	22	4
2007	25	29	40	44	42	97	58	18	1		2	1				2	7	8	
2008	27	81	112	106	21	77	53	17		1			2			8	3		
2009	73	250	116	124	9	45	41	36					1				5	11	41
2010	378	250	144	196	65	106	64	47	1					1		42	80	39	55
2011	47	92	94	43	33	55	16	30	1	4		1	2		2	33	45	45	15
2012	44	69	81	102	43	35	21	20							1	16	42	39	44
2013	93	75	82	57	45	21	20	9					2		1	40	37		19

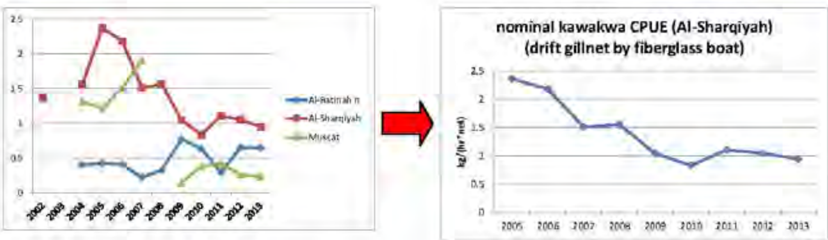


Fig. 14 Trends of nominal CPUE for three regions (drift gillnet fisheries by fiberglass boat) (left) and selected nominal CPUE (Al-Sharqiyah) (2005-2013).

Hand line by fiberglass boat

As in the previous case we attempted same investigation for nominal CPUE for hand line fisheries by fiberglass boat. Table 9 shows sample size (n) (number of operations) by region, year and quarter. Not all regions have enough sample size by year and quarter except Dhofar. Thus we combined two neighboring regions in order to increase sample sizes, i.e., Muscat and Al-Batinah (MUS+ALB) as one, while Musandam and Al-Sharqiyah (MUD+ALS) as another one. Hence we have three regions for nominal CPUE, i.e., Dhofar, MUS+ALB and MUD+ALS. Fig. 15 (left) shows trends of nominal CPUEs for three regions. Its behavior in Dhofar is not plausible considering the sharp increase catch trend. Thus we did not select this nominal CPUE. Fig 15 (right) shows selected nominal CPUEs in MUS+ALB and MUD+ALS.

Table 9 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah n				Al-Sharqiyah				Al-Wusta		Dhofar				Musandam				Muscat			
	1	2	3	4	1	2	3	4	1	2	1	2	3	4	1	2	3	4	1	2	3	4
2002					5	15	9	7														
2004	10	69	10	5	17	21	4	1			96	119		72	8	12	6	10	2	18	8	5
2005		40	5		12	22	2	4			173	153	1	14	9	16		1	2	1		
2006				1				7					2	52	10	3	10	15		6	2	1
2007		25	3	4	16	19	2	13			30	282	13	31	36	12	3	20		2	3	1
2008	10	15	5	21	2	48	16	2			108	380	1	30		13	6					
2009	1	60	10	21		35	3	53		1	132	225	8	42		29	10	5		5	9	16
2010	30	90	31	11	44	16	22	1	9	5	55	215		33	4	11	7	7	9	148	73	14
2011	1	1														1				2		1

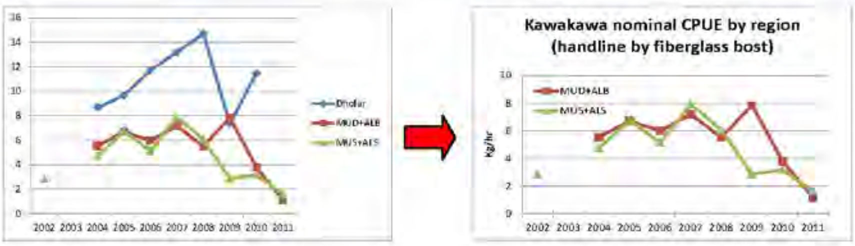


Fig.15 (left) Trends of nominal CPUE for three region (hand line fisheries by fiberglass boat) and (right) selected nominal CPUE (two regions).

Drift gillnet fisheries by launch boat

By following previous cases, we attempted same investigations for nominal CPUE in drift gillnet fisheries by launch boat. Table 10 shows sample size (n) (number of operations) by region, year and quarter. Only the Al-Sharqiyah region has satisfactory sample sizes. Thus we evaluate nominal CPUE only for this region. Fig 16 shows the resultant nominal CPUE.

Table 10 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Sharqiyah				Al-Wusta				Dhofar				Musandam		Muscat
	1	2	3	4	1	2	3	4	1	2	3	4	2	3	2
2002	30	74	124	20											
2004	79	82	76	49							2				
2005	46	88	132	71					1		1				
2006			5	54								1			1
2007	46	62	62	8					5	10	56	3			
2008	15	105	138	2					7	40	5	2			
2009	5	26	26	8					6	8	13	7			
2010	7	18	88	15		12	15	3	5	19	5	2			
2011	3	28	5	7	2	2	2		2	11					
2012	8	26	30	8						9	4	7		1	
2013	7	16	24	3						9			1	1	

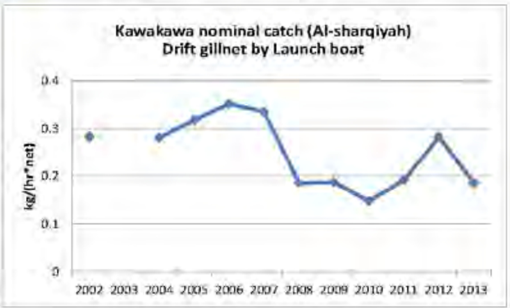


Fig.16 Trends of nominal kawakawa CPUE for Al-Sharqiyah (drift gillnet fisheries by launch boat)

Summary of nominal CPUE

We now compare and evaluate selected nominal CPUE for 3 types of fisheries in order to choose the most plausible one to be used for STD_CPUE and ASPIC. Box 4 shows recent catch trend with three nominal CPUE for three different gears. In Box 4, we made circles onto the trends which are not plausible considering the increasing catch trend. As a result, nominal CPUE by drift gillnet fisheries by fiberglass boat indicates the most realistic trend comparing to others. Thus we select it as the representative nominal CPUE to be used for STD_CPUE and the stock assessment by ASPIC.

Box 4 Comparisons and evaluation of the most plausible nominal CPUE

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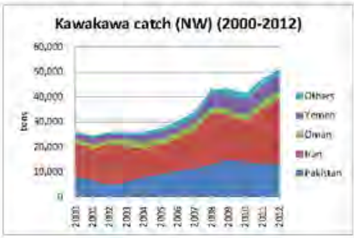
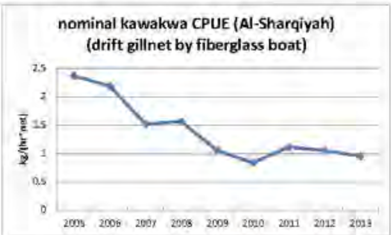
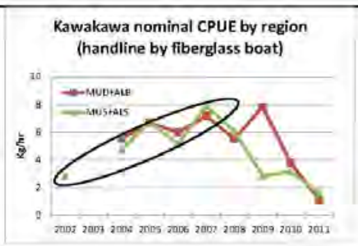
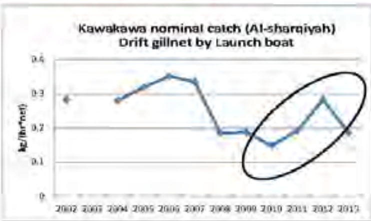
<tr><td>
</td><td>
</td></tr>
<tr><td>Recent kawakawa catch in the Oman and Gulf region.</td><td>Nominal kawakawa CPUE (drift gillnet fisheries by fiberglass boat). Selected as the representative nominal CPUE for STD_CPUE.</td></tr>
<tr><td>
</td><td>
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<tr><td>Nominal kawakawa CPUE (hand line by fiberglass boat) (trend for 2002-2007 is not plausible).</td><td>Nominal kawakawa CPUE (drift gillnet fisheries by launch boat) (trend 2010-2012 is not plausible).</td></tr>
</table>

33

(3) Standardization of nominal kawakawa CPUE

We standardized kawakawa nominal CPUE of drift gillnet fisheries by fiberglass boat (Al-Sharqiyah) using GLM. Our model is described as below:

Log (CPUE+c) = (mean) + [Y] + [Q] + [Crew] + (error)

*where, CPUE : kg/(gillnet unit*fishing hours) (refer to Table 1, page 11)*

c: 10% of average overall nominal CPUE

Y : effect of year

Q : effect of quarter(season)

Crew: crew (boat size) effect

Box 5 shows results of GLM procedures. Box 5 (top) indicates that year and crew affect nominal CPUE significantly. Box 5 (middle) shows the resultant STD_CPUE with 95% confidence interval, which shows the declining trend. Box 5 (bottom) shows the frequency distribution of residuals and QQ plot which suggests GLM is the appropriate method for standardization.

(4) Stock assessment by ASPIC and stock status

Using the standardized CPUE, we conducted stock assessment of kawakawa in the NW Indian Ocean by ASPIC. In ASPIC we need to estimate 4 parameters (K: carrying capacity, B0/K where B0 is the total biomass in 1950, start of fisheries in our case, q: catchability and MSY). We assume that B0 =K and attempt to estimate 3 parameters (K, MSY and q). Using the Fox model, we could get conversion and estimate 3 parameters (K, MSY and q). Box 6 shows results including graphs for catch vs. MSY, TB (total biomass) vs TBmsy, F vs. Fmsy, observed vs. predicted CPUE and Kobe plot (stock trajectory).

Box 5 Results of GLM for kawakawa STD_CPUE (Al-Sharqiyah) in drift gillnet fisheries by fiberglass boat. *(top: ANOVA, middle: STD_CPUE and bottom: residuals)*

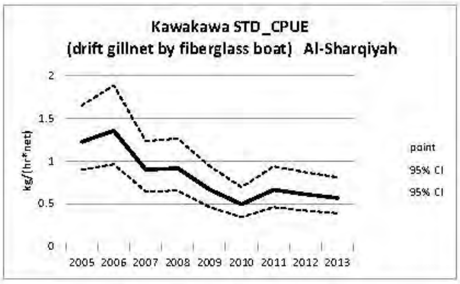
The GLM Procedure

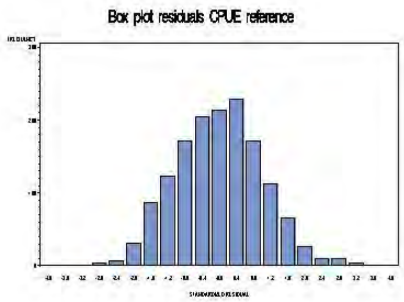
Dependent Variable: L_CPUE

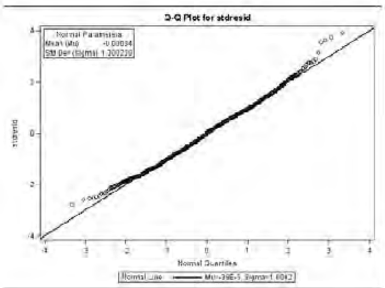
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	219.513958	11.553366	18.75	<.0001
Error	1450	893.431919	0.616160		
Corrected Total	1469	1112.945877			

R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.197237	1580.033	0.784959	0.049680

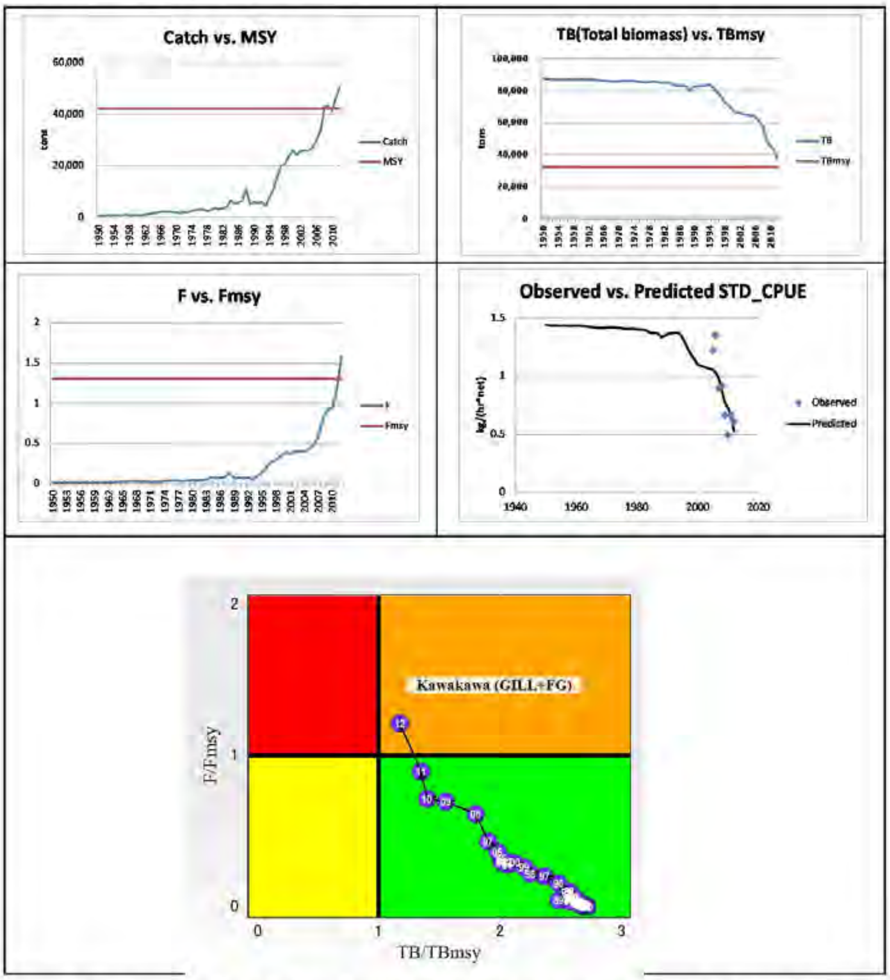
Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	8	106.6636605	13.3329576	21.64	<.0001
q	3	8.4290905	2.8096968	4.56	0.0035
crew	8	63.4458568	7.9307321	12.87	<.0001







Box 6 Results of ASPIC (Kawakawa)

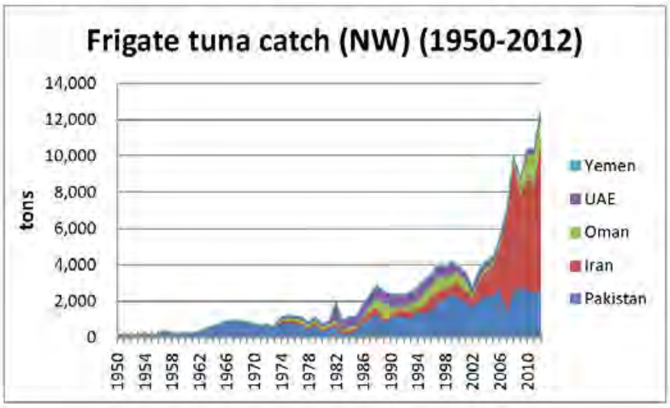


Based on the ASPIC results, the stock status of kawakawa (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond the Fmsy level (21% higher), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (still in the safe level). It is clear if the current F level continues, kawakawa stock will be entering the overfishing stage in the near future.

4.3 FRIGATE TUNA

(1) Nominal catch

Fig. 17 shows frigate tuna nominal catch in the whole period (1950-2012) and in the recent years (2000-2012) based on IOTC database (September, 2013). Catch has been increasing since 1950 and there is a sharp increase in recent years (2008-2012).



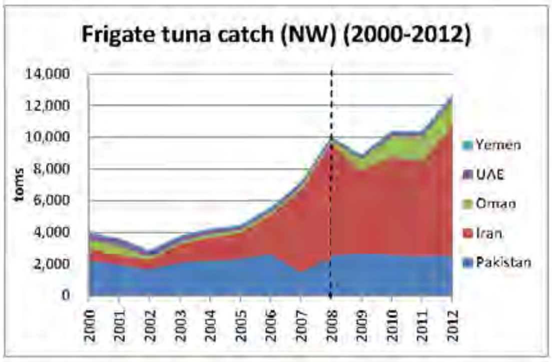


Fig. 17 Frigate tuna catch in the NW Indian Ocean

Above: entire period (1950-2012) and Below: recent years (2000-2012)

(2) Nominal CPUE

Using the catch and effort database (Fisheries Statistical Section, Ministry of Agriculture & Fisheries, Sultanate of Oman); we initially investigated sample sizes (number of operations) by gear and boat type (Table 11). From Table 11, we selected drift gillnet fisheries by fiberglass boat, drift gillnet fisheries by launch boat and hand line fisheries by fiberglass boat to evaluate nominal CPUE as these three types of fisheries have larger sample sizes comparing to other types.

Table 11 Sample size (number of operations) by gear and boat type (2002-2013)

	FG(HL+TL)	FIBERGLASS	BEACH SEINE	LAUNCH
BEACH SEINE NET		28	60	
CAST NET		2		1
DRIFT GIL NET		2,077		865
FISH TRAP		15		2
HAND LINE	189	1,649		5
LINEAR FIXED GILL		94		1
Long Line	1			
PEN-TYPE FIXED GILL		64		12
SURROUNDING GILL NET		24		
TROLL LINE	3	34		2

Drift Gillnet fisheries by fiberglass boat

We investigated sample sizes (number of operations) by region, year and quarter (Table 12). Table 12 suggests that only Al-Sharqiyah includes enough sample size by year and quarter in general. Al-Batinah and Muscat include partially large sample sizes, thus we combined these two regions as one area (ALB+MUS). Hence we will evaluate two nominal CPUE (Al-Sharqiyah and ALB+MUS). Fig. 18 (left) shows the nominal CPUE for these two regions.

Nominal CPUE for both regions show upwards and downward trends, which are not plausible as frigate tuna catch increase sharply and consistently in recent years. However, both nominal CPUEs in the later period from 2008 (ALB+MUS) and 2009 (Al-Sharqiyah) show the decreasing trends which are reasonable reflection to the catch. Thus we chose nominal CPUE in Al-Sharqiyah after 2008 as the representative one in drift gillnet fisheries by fiberglass boat because it has one year longer time series (2008-2013) (Fig. 18) (right).

Table 12 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah n				Al-Sharqiyah				Dhofar			Musandam		Muscat			
Q	1	2	3	4	1	2	3	4	1	2	3	1	2	1	2	3	4
2002					3	42	21	1									
2004	6	14	4	2	16	18	28	19						4	18	3	
2005	2	5			14	29	16	3			5			5	30	6	3
2006			5	7		1	1	1							31	14	1
2007	4	8	4	4	8	7	18		1		2						1
2008	7	16	13	21	6	53	24	5							1		
2009	26	41	4	9	18	71	29	27							6		14
2010	55	46	20	19	105	99	50	49	1			1		54	71	71	39
2011	7	24	11	8	24	54	3	4		1		1	1	32	39	45	14
2012	5	8	2	4	13	18	8	20						15	32	33	34
2013		1	9	7	14	18	8	5						6	24	2	17

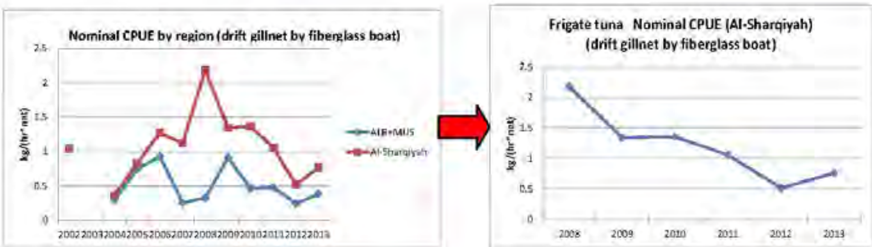


Fig.18 (left) Trends of frigate tuna nominal CPUEs in two region (ALB+MUS and Al-Sharqiyah) (drift gillnet by fisheries fiberglass boat) and (right) selected nominal CPUE (Al-Sharqiyah) as the representative ones. ALB: Al-Batinah and MUS: Muscat

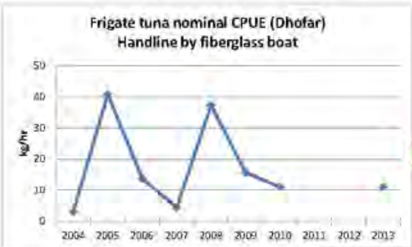
Hand line fisheries by fiberglass boat

As in the previous case we attempted same investigation for nominal CPUE for hand line fisheries by fiberglass boat. Table 13 shows sample size (n) (number of operations) by region, year and quarter. Not all regions have enough sample size by year and quarter except Dhofar. Thus we evaluate only nominal CPUE in Dhofar. Fig. 19 (left) shows its nominal CPUE. The behavior of its trend in Dhofar is not plausible considering the sharp increase catch trend. Thus we did not choose any nominal CPUE in hand line fisheries by fiberglass boat.

Table 13 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Batinah n		Sharqiyah			Al-Wusta			Dhofar				Muscat			
Q	2	4	1	2	3	4	2	3	1	2	3	4	1	2	3	4
2002			2		2											
2004			2	1	2	2				18				1	1	
2005			2	4							49	114		1		
2006											43	60		1		
2007		1							10	4	47	91				
2008				2	2				88	118	1	212				
2009	2	2		4	1				146	246	54	22		1		1
2010			9	6			2	1	14	129	1	96	2	12	10	4
2011				1											1	
2013										1						



Nominal CPUE in Dhofar is not considered to show the plausible trend. Hence we consider that there are no representative nominal CPUE in Dhofar.

Fig. 20 (left) Trend of nominal CPUE in Dhofar (hand line fisheries by fiberglass boat) and (right) conclusion of the evaluation,

40

Drift gillnet by launch boat

By following previous cases, we attempted same investigations for nominal CPUE in hand line fisheries by launch boat. Table 14 shows sample size (n) (number of operations) by region, year and quarter. Only Al-Sharqiyah region has satisfactory sample sizes. Thus we evaluate nominal CPUE only for this region. Fig. 20 (left) shows the resultant nominal CPUE. We consider that 2000 and 2006 data are based on very low sample sizes (n=1) and the data in 2013 is the outlier, thus we exclude these three points (Fig. 20, right)

Table 14 Sample size (n) (number of operations) by region, year and quarter.
(10<=n are highlighted by yellow marker)

	Al-Sharqiyah				Al-Wusta			Dhofar			
Q	1	2	3	4	2	3	4	1	2	3	4
2000	1										
2002	13	33	36								
2004	27	16	34	19							
2005	8	47	51	2						5	
2006				1						1	2
2007	14	14	3					1	2	32	3
2008	5	52	20	5				2	31	5	1
2009	3	37	23	7				7	4	9	2
2010	17	9	62	12	3	4	1	3	16	2	2
2011	3	34	8	3				1	7		
2012	3	10	7	3				3	13	1	2
2013	9	9	18	1					7	9	5

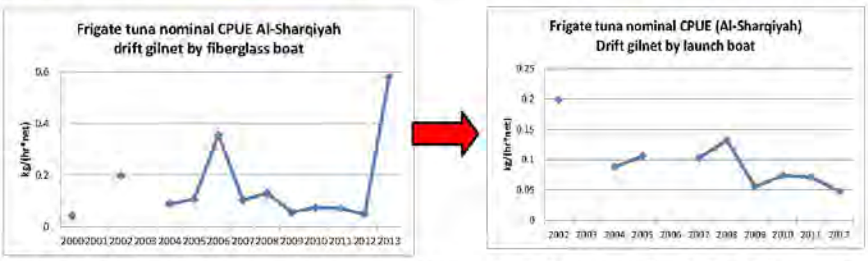
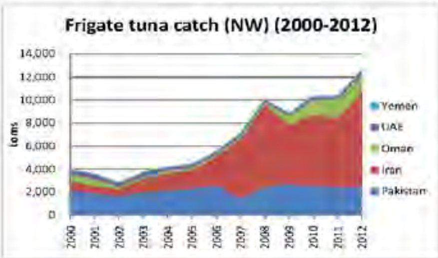


Fig.20 (left) Trends of nominal frigate tuna CPUE in Al-Sharqiyah (hand line fisheries by launch boat) and (right) selected nominal CPUE without 2000, 2006 and 2013 data points as the representative one.

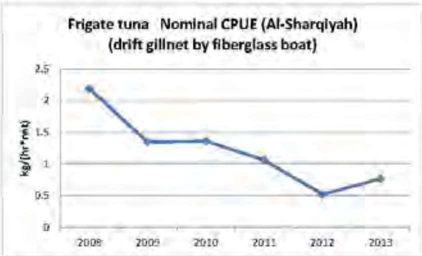
Summary of nominal CPUE

We now compare and evaluate selected nominal CPUEs in order to choose the most plausible one to be used for STD_CPUE and ASPIC. Box 7 shows recent catch trend and two types nominal CPUEs showing similar declining trends well reflecting the increasing catch trends. As nominal CPUE in drift gillnet fisheries by fiberglass boat has less time series than the one in Drift gillnet fisheries by launch boat, we selected the latter nominal CPUE be used for STD_CPUE and the stock assessment by ASPIC.

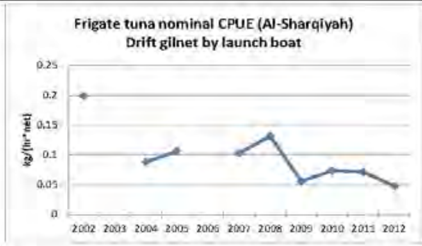
Box 7 Comparisons and evaluation of nominal CPUE and



Recent kawakawa catch in the Oman and Gulf region.



Nominal frigate tuna CPUE (drift gillnet fisheries by fiberglass boat). Not selected as the data points are not enough comparing to the one of drift gillnet fisheries by launch boat (below).



Nominal CPUE (hand line fisheries by fiberglass boat). Not selected as the trends are not realistic.

Nominal frigate tuna CPUE (drift gillnet fisheries by launch boat) Selected as the representative nominal CPUE as this includes longer time series than the one in drift gillnet fisheries by fiberglass boat (above).

(3) Standardization of nominal kawakawa CPUE

We standardized frigate tuna nominal CPUE of drift gillnet fisheries by launch boat (Al-Sharqiyah) using GLM. Our model is described as below:

Log (CPUE+c) = (mean) + (Y) + (Q) +(Crew) + (error)

*where, CPUE : kg/(gillnet unit*fishing hours) (refer to Table 1, page 11)*

c: 10% of average overall nominal CPUE

Y : effect of year

Q : effect of quarter (season)

Crew: crew (boat size) effect

Box 8 (top) shows results of GLM procedures. Year affects nominal CPUE most significantly. Box 8 (middle) shows the resultant STD_CPUE with 95% confidence interval. Box 8 (bottom) shows the frequency distribution of residuals and QQ plot which suggests GLM is the appropriate method for standardization.

(4) Stock assessment by ASPIC and stock status

Using the standardized CPUE, we conducted stock assessment of frigate tuna by ASPIC. In ASPIC we need to estimate 4 parameters (K: carrying capacity, B0/K where B0 is the total biomass in 1950, start of fisheries in our case, q: catchability and MSY). We used both Fox and Schaefer models.

Box 8 Results of GLM for frigate tuna STD_CPUE (Al-Sharqiyah) (hand line fisheries by fiber glass boat) *(top: ANOVA, middle: graphs and bottom: residuals)*

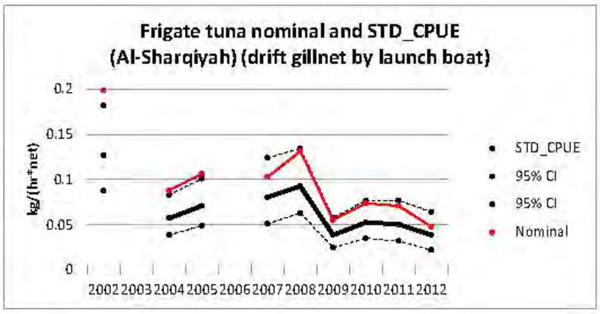
The GLM Procedure

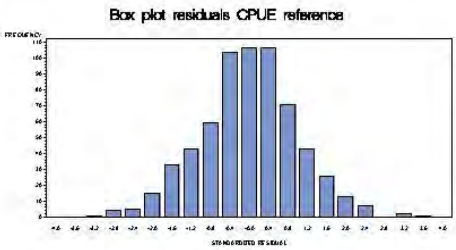
Dependent Variable: L_CPUE

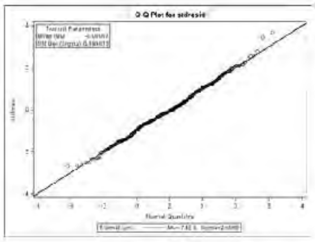
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	77.8165975	4.3231443	7.71	<.0001
Error	621	348.3639012	0.5609725		
Corrected Total	639	426.1804987			

R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.182591	-29.68830	0.748981	-2.522815

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	8	58.62856031	7.32857004	13.06	<.0001
q	3	2.64609221	0.88203074	1.57	0.1949
crew	7	6.27513044	0.89644721	1.60	0.1330







We assume that B0 =K and attempt to estimate three parameters (K, MSY and q). But we could not get any conversions for both Schaefer and Fox production model. Then we fixed K and attempted to explore various K values within plausible ranges, i.e., 10, 17, 18, 19 and 20 thousand tons. With the constraint (MSY < Bmsy), we found that K=18,000 tons with the Schaefer model produced the best fit to the ASPIC model based on R2 and RMSE (root mean square errors) (Table 15), while we could not get any conversions when we applied Fox model. Thus we selected this scenario (K=18,000 by Schaefer model) as the representative of ASPIC result.

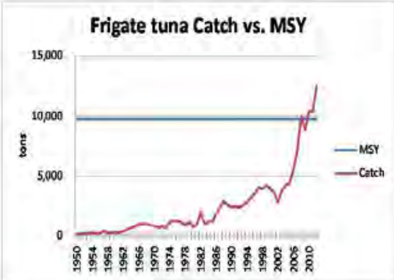
Table 15 ASPIC results based on various scenarios of K values.

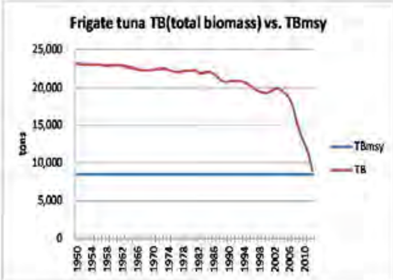
model	Schaeffer					FOX
K (1,000 tons)	R2	MSE	TB ratio	Fratio	MSY	NC
10	NC					NC
17	NC					NC
18 (best fit)	0.321	0.1483	0.789	1.379	86,490	NC
19	0.319	0.1488	0.780	1.409	85,160	NC
20	0.318	0.1493	0.770	1.440	83,770	NC

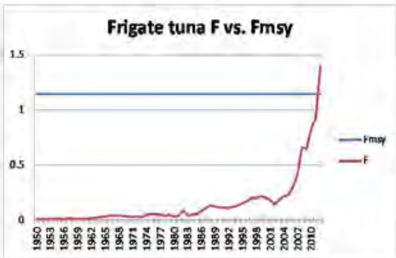
NC: Neither converged nor plausible parameters estimated

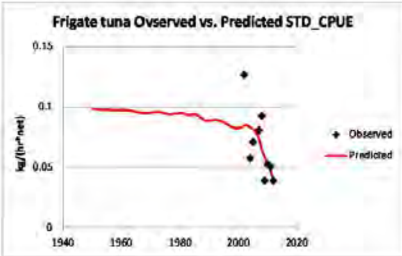
Box 9 shows results including graphs for catch vs. MSY, TB (total biomass) vs TBmsy, F vs. Fmsy, observed vs. predicted CPUE and Kobe plot (stock trajectory). Based on this ASPIC results, the stock status of frigate tuna (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond Fmsy (22% higher than the MSY level), i.e., high fishing pressure, while the total biomass is still in the safe zone, i.e., beyond the MSY level (27% higher). However, it is clear if current F level continues, frigate tuna will be entering the overfishing stage in the near future.

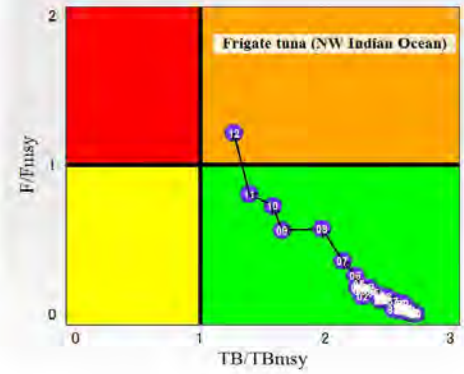
Box 9 Results of ASPIC (frigate tuna)







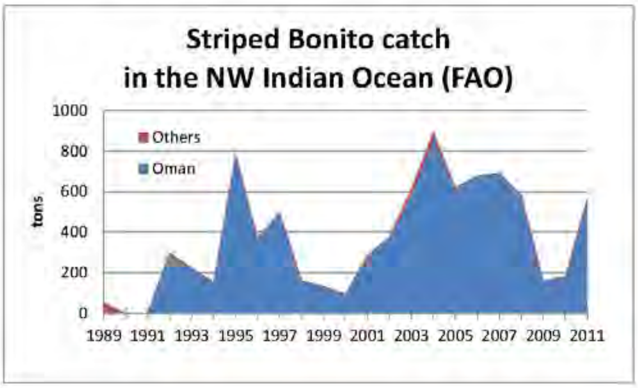




4.4 STRIPED BONITO

(1) Nominal catch

Fig. 21 shows available striped bonito nominal catch (1989-2011) and in the recent year (2000-2012) based on the FAO FISHSTA database. Please note that striped bonito is not included in the IOTC species, thus its catch data are not available in the IOTC database. Catch has been not stable showing up and down trend. We consider that striped bonito catch in the NW Indian Ocean is incomplete as it is unstable and very low level (less than 1,000 tons).



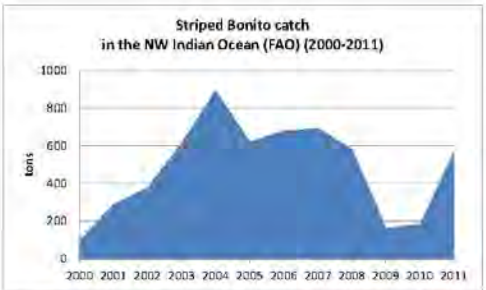


Fig. 21 Striped bonito catch in NW Indian Ocean
Above 1989-2011 Below: 2000-2011

Thus we don't think that we can conduct any stock assessments with this catch information. Even if we conduct, we will get unrealistic results which will mislead management strategies. We strongly recommend making complete catch statistics through IOTC. This means that we need to request IOTC to include striped bonito as one of IOTC species. Hence, as for striped bonito in the report, we will evaluate only nominal and standardized CPUE to see the trend of the abundance

(2) Nominal striped bonito CPUE

Using the catch and effort database (Fisheries Statistical Section, Ministry of Agriculture & Fisheries, Sultanate of Oman); we initially investigated sample sizes (number of operations) by gear and boat type (Table 16). From Table 16, we selected drift gillnet fisheries by fiberglass boat, drift gillnet fisheries by launch boat and hand line fisheries by fiberglass boat to evaluate nominal CPUE as these three fisheries have more sample sizes comparing to other types.

Table 16 Sample size (number of operations) by gear and boat type (2002-2013)

	FG(FT)	FG(HL+TL)	FIBERGLASS	LAUNCH
DRIFT GIL NET		1	1,747	662
FISH TRAP	1		12	
HAND LINE		47	348	
LINEAR FIXED GILL			63	6
PEN-TYPE FIXED GILL			52	1
SURROUNDING GILL NET			8	
TROLL LINE		1	11	

Drift Gillnet fisheries by fiberglass boat

We investigated sample sizes (n) (number of operations) by region, year and quarter (Table 17). Table 17 suggests that only Al-Sharqiyah have good numbers of sample sizes by year and quarter. But it has some low sample sizes in some quarters. Hence we added the data from Muscat as these two regions are neighboring regions. Fig. 22 shows its nominal CPUE.

Table 17 Sample size (n) (number of operations) by region, year and quarter.
(10<=n are highlighted by yellow marker)

	Al-Batinah n				Al-Sharqiyah				Al-Wusta	Muscat			
Q	1	2	3	4	1	2	3	4	4	1	2	3	4
2002						45	4	48					
2004	21	1	5	5	113	80	41	60		2	1		39
2005	3	4	1	5	64	90	1	47		46	13	20	13
2006			2	9				32					8
2007	14	1		12	27	46	18	13		7	7		
2008	6	7	2	5	1	14	10	28			1		
2009	7	25	5	8	18	19	20	12			2		12
2010	27	14	1	2	24	65	3	8	1	35	5		15
2011	2	4	2	7	12	21	4	43		2	3		28
2012	1	9	2	5	18	37	8	7		6	54	6	10
2013	13	2			21	10	2	1		19	16		2

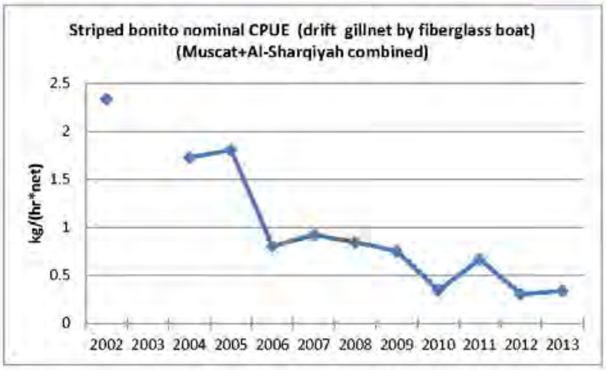


Fig.22 Trend of Striped bonito nominal CPUE in drift gillnet fisheries by fiberglass boat (Al-Sharqiyah and Muscat combined)

Drift gillnet fisheries by launch boat

We investigated sample size (number of operations) by region, year and quarter (Table 18). Table 18 suggests that only Al-Sharqiyah have good numbers of sample sizes by year and quarter. But it has some low sample sizes in some quarters. Hence we added the data from Al-Wusta as these two regions are neighboring regions. Fig. 23 shows its nominal CPUE.

Table 18 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

	Al-Sharqiyah				Al-Wusta				Dhofar		
Q	1	2	3	4	1	2	3	4	1	2	3
2002		29	2	19							
2004	25	63	48	44							
2005	26	82	1	38							
2006				22							
2007	23	18		1							
2008	3	9	12	8							
2009	2	13	5	2							
2010	10	5		2		10	27	43			
2011		8		4	2	7	3			2	
2012	5	14	8	3					1		
2013		2	2							7	2

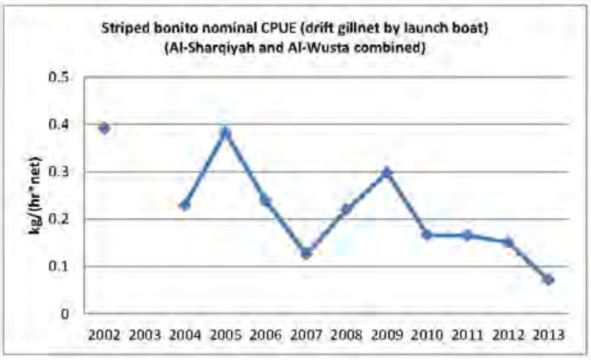


Fig.23 Trend of nominal CPUE (drift gillnet by launch boat)
(Al-Sharqiyah and Al-Wusta combined)

Hand line fisheries by fiberglass boat

By following previous cases, we attempted same investigations for nominal CPUE for hand line by launch boat. Table 19 shows sample size (n) (number of operations) by region, year and quarter. No regions have enough sample sizes, thus we did not produce any nominal CPUE.

Table 19 Sample size (n) (number of operations) by region, year and quarter.

(10<=n are highlighted by yellow marker)

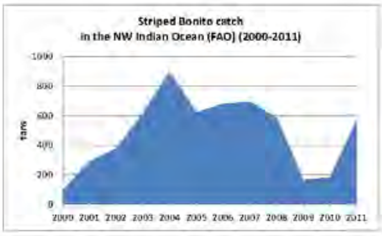
	Al-Batinah n			Al-Sharqiyah				Al-Wusta			Dhofar				Musandam	Muscat		
Q	1	2	4	1	2	3	4	1	2	3	1	2	3	4	3	1	2	4
2002				6	21	6	10											
2004				39	15	9	2				23	27	2	36				3
2005				30	16		9				19	7	1	2				
2006														2				
2007				8	5	1					3	2	1	2				
2008					1						4							
2009	1	2	1	2	2	1			3									1
2010	3	1			3			5		1		1			1	4	2	
2011																		1
2013												1						

Not enough sample size to evaluate nominal CPUE

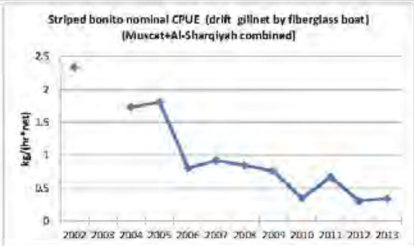
Summary of nominal CPUE

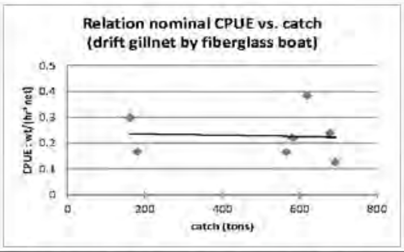
We now compare and evaluate selected nominal CPUE for 2 gear-boat types in order to choose the most plausible one to be used for STD_CPUE. Box 11 shows recent catch trend with three nominal CPUE for two different gear-boat types. As the catch trend of striped bonito is incomplete and unstable, which are much different from those of other three species showing continuous increasing trends Thus we don't know what types of nominal CPUE is reflection of the catch. To understand the relation between catch and nominal CPUE, we made scatterplots (Box 10). As a conclusion, we cannot accept nominal CPUE in hand line fisheries by fiberglass boat as the relation shows the positive correlation. The one in drift gillnet fisheries by fiberglass boat, show the slight negative correlation. Thus we selected its nominal CPUE.

Box 10 Comparisons and evaluation of nominal CPUE

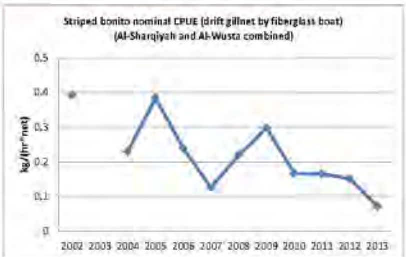


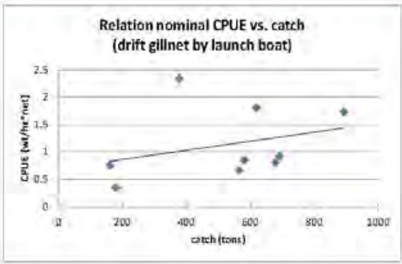
Recent striped bonito catch in NW Indian Ocean (Oman)





(left) Nominal Striped bonito CPUE (drift gillnet by fiberglass boat) and (right) relation between nominal CPUE vs. Catch. Selected as the representative nominal CPUE as the relation is better than the one in drift gillnet by launch boat.





Nominal CPUE (drift gillnet by fiberglass boat). Not selected as the representative nominal CPUE as the relation between nominal CPUE vs. catch is positively correlated.

(3) Standardization of nominal striped bonito CPUE

We standardized striped bonito nominal CPUE of drift gillnet by fiberglass boat (Al-Sharqiyah) using GLM. Our model is described as below:

Log (CPUE+c) = (mean) + [Y] + [Q] +[Crew] + (error)

*where, CPUE : kg/(gillnet unit*fishing hours) (refer to Table 1, page 11)*
c: 10% of average overall nominal CPUE
Y : effect of year
Q : effect of quarter (season)
Crew: crew (boat size) effect

Box 11 (top) shows results of GLM procedures. Year affects nominal CPUE significantly. Box 11 (middle) shows the resultant STD_CPUE with 95% confidence interval, which shows the declining trend. Box 11 (bottom) shows the frequency distribution of residuals and QQ plot which suggests GLM is the appropriate method for standardization.

(4) Stock assessment by ASPIC and stock status

As discussed, we don't think that we can conduct any stock assessments with the current catch information. Even if we conduct, we will get unrealistic results which will mislead management strategies. We strongly recommend making complete catch statistics through IOTC, so that we can attempt stock assessment. This means that we need to request IOTC to include striped bonito as one of IOTC species. Although we don't know the stock status, we concern the current situation as standardized CPUE shows continuous and consistent decreasing trend.

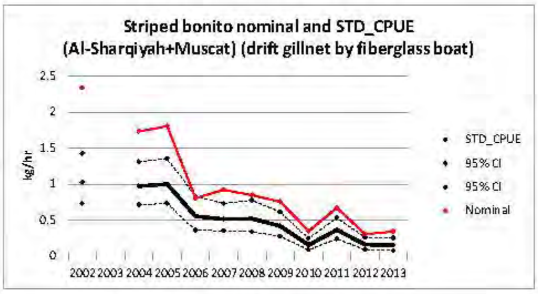
Box 11 Results of GLM for Striped bonito STD_CPUE (Al-Sharqiyah + Muscat combined)
(hand line by fiber glass boat)
(top: ANOVA, middle: graphs and bottom: residuals)

Dependent Variable: L_CPUE

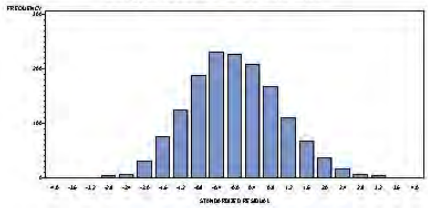
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	633.480501	31.674025	50.21	<.0001
Error	1485	936.818747	0.630854		
Corrected Total	1505	1570.299248			

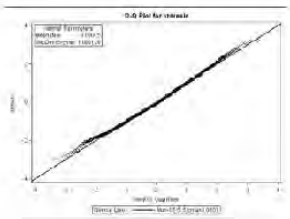
R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.403414	-319.1212	0.794263	-0.248891

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yr	10	474.2625994	47.4262599	75.18	<.0001
q	3	9.6339256	3.2113085	5.09	0.0017
crew	7	77.4954569	11.0707796	17.55	<.0001



Box plot residuals CPUE reference





5. SUMMARY AND CONCLUSIONS

Box 12-15 show summary of catch, nominal CPUE, CPUE standardization, ASPIC, Kobe plot and also conclusion on the stock status for four neritic species.

6. RECOMMENDATIONS

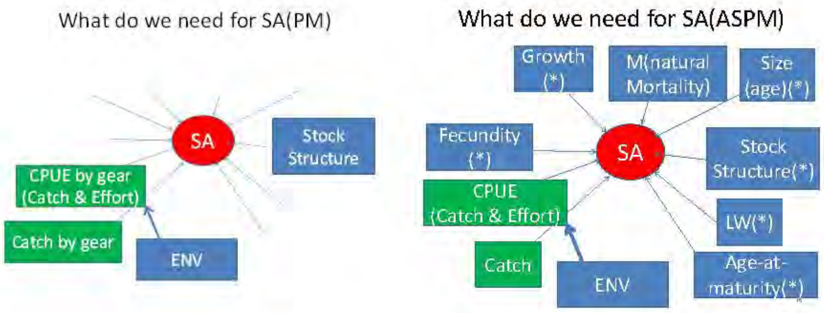
Based on our works, we put a list on number of recommendations as below, which are collected from the text:

Data and CPUE

- We could get good quality of catch and effort data from Al-Sharqiyah. Other regions also produce good quality of catch and effort data only for some limited cases. It is recommended to improve the data collection in five regions (Musandam, Muscat, Al-Wusta and Dhofar) as in Al-Sharqiyah.
- Boat type: "Launch (net)" (2011-2012) should be categorized as "Launch" as used in 2000, 2002-2010 and 2013.
- Boat type: "Fiberglass (net) (2011-2012) should be categorized as "Fiberglass' as used in 2000, 2002-2010 and 2013.
- Within the same operation, there are 0 catch in number, while catch in weight are available, i.e., catch in number are often missing in the data set. Thus we use catch in weight (kg) to evaluate nominal CPUE and Standardized CPUE (STD_CPUE).
- We use fishing hours for effort. But there are often the data with 0 fishing hours or with no data (blanks). As such data cannot be used to calculate CPUE, we deleted these data.
- Definition of fishing days is not clear. Thus we did not use this information.
- It is not clear the meaning of Yes or No in NO_CATCH field. Thus we did not use this information.
- We strongly recommend making complete catch statistics of Striped bonito through IOTC, so that we can attempt stock assessment. This means that we need to request IOTC to include striped bonito as one of IOTC species.
- In CPUE standardization, it is recommended to incorporate environmental factors.

Stock assessment

It is strongly recommended that stock assessment methods incorporating biological information (size, L-W relation, S-R relation, age, growth maturity etc.) should be conducted in the future. For example, Age Structured Production Model (ASPM) is one of the methods.

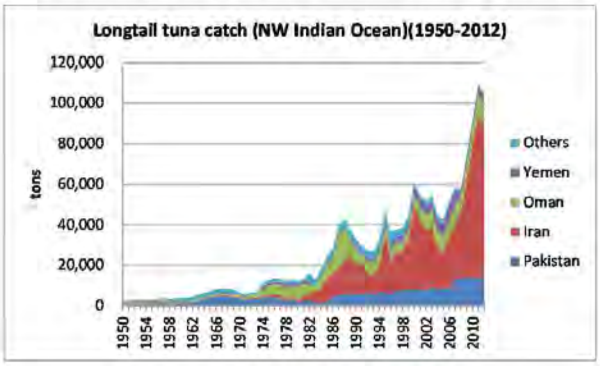


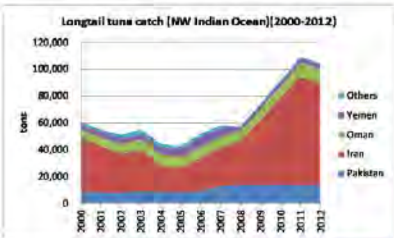
ASPIC ASPM

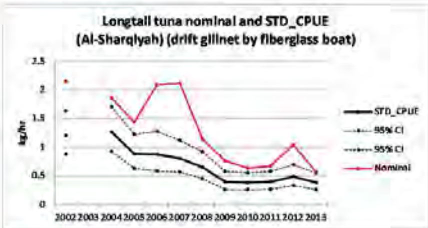
This is because of following two reasons, i.e., (a) this project has been collecting large numbers of biological data and (b) it is important to cross checks results of stock assessments by a few different models to evaluate and confirm results as production model using only catch and CPUE may produce biased results because no biological (realistic) information and S-R relation are used.

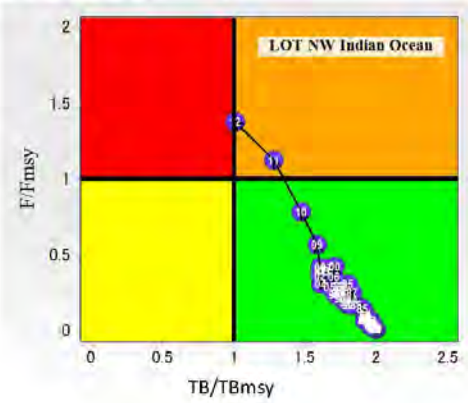
However, ASPIC is useful in the data limited situation to learn the quick and rough stock status. Thus ASPIC has been recommended for many different species world-widely. So in our case, it will be no problem as a first step of the stock assessment using ASPIC.

Box 12 Summary of longtail stock assessment and status of stock



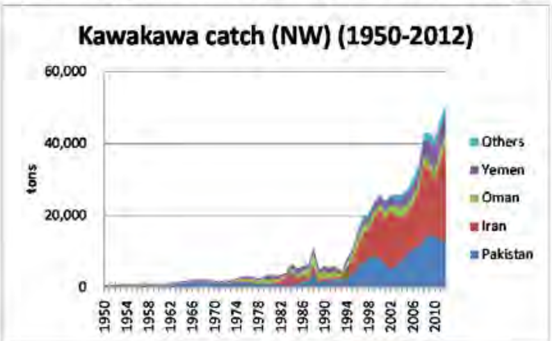


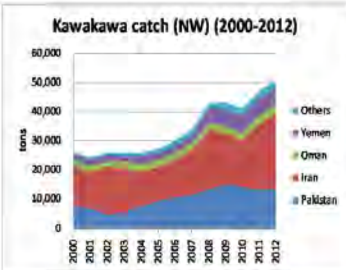


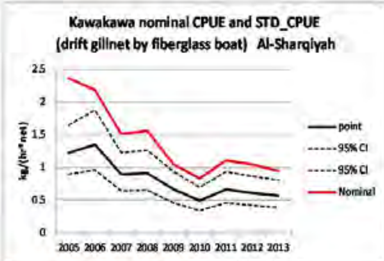


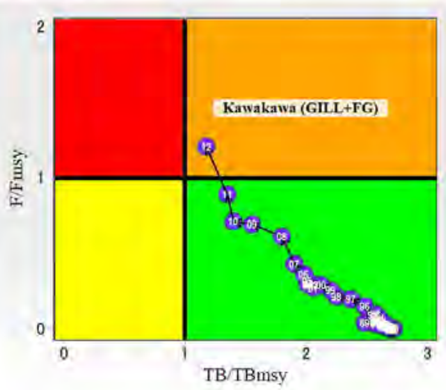
In 2012, F (fishing mortality rate) is beyond Fmsy (38% higher than the MSY level), i.e., high fishing pressure, while the total biomass is about in the MSY level. It is clear if current F level continues, longtail tuna stock will be entering the overfishing stage from 2013.

Box 13 Summary of kawakawa stock assessment and status of stock



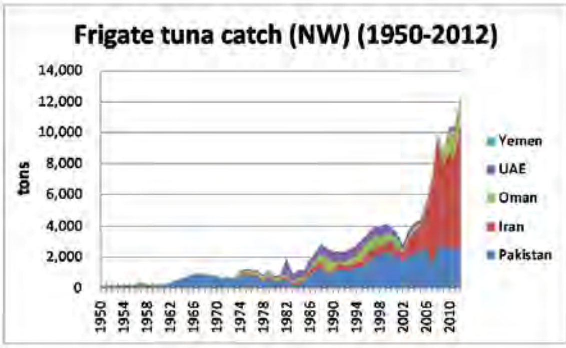


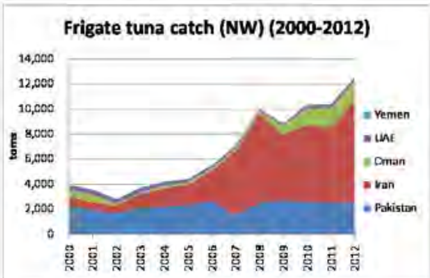


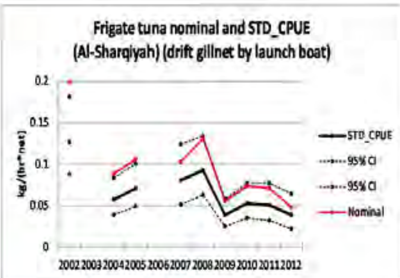


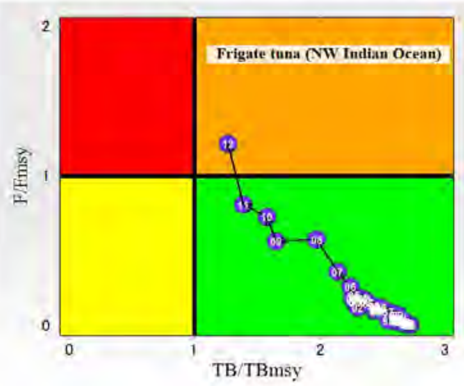
In 2012, F (fishing mortality rate) is beyond the Fmsy level (21% higher than the MSY level), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (still in the safe level). It is clear if the current F level continues, kawakawa stock will be entering the overfishing stage in the near future.

BOX 14 SUMMARY OF FRIGATE TUNA STOCK ASSESSMENT AND STATUS OF THE STOCK



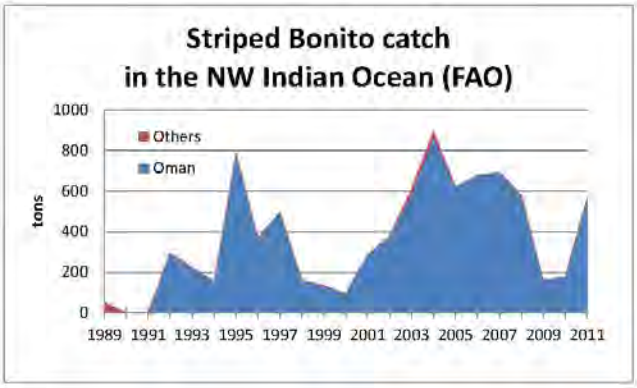


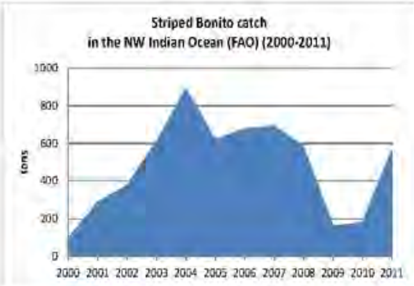


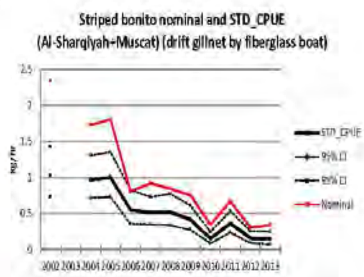


In 2012 F (fishing mortality rate) is beyond Fmsy (22% higher than the MSY level), i.e., high fishing pressure, while the total biomass is still in the safe zone, i.e., beyond the MSY level (27% higher). However, it is clear if current F level continues, frigate tuna will be entering the overfishing stage in the near future.

Box 15 Summary of striped bonito stock assessment and status of the stock







STOCK STATUS IS UNKNOWN. It is not possible to conduct any stock assessment with the current catch information. Even if it were conducted, unrealistic results will be obtained, which will mislead management strategies. It is strongly recommended to make complete catch statistics through IOTC, so that stock assessment can be attempted. Although the stock status is not known, there is concern as standardized CPUE shows continuous and consistent decreasing trend.

ACKNOWLEDGEMENTS

The consultant (Nishida) very much appreciate dedicated scientists in Marine Science and Fisheries Centre, Ministry of Agriculture & Fisheries, Sultanate of Oman, who worked this paper together, i.e., Dr Lubna Al-kharusi (Director), Dr Fatma Rashid Al-Kiyumi (Chief scientist), Ms Badriya Al-Siyabi, Ms Iman Sulieman, Ms Nabeela Al-Bulushi, Mr Ibrahim Al-Anboori and Mr Haritham Al-Busaidi. Through our works, not only we learned a lot and enjoyed the works, but also we became good friends, which is more than any treasures in my life.

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PICTURES


64

Training materials (12)
Training course on stock assessments of Longtail tuna and Kawakawa in the SE Asia
SEAFDEC/MFRDMD, Kuala Terengganu, Malaysia (April 17-25, 2016)

Preparation for SEAFDEC
Neritic stock assessments training course

How to install “R” computer language?

Tom Nishida (PhD), Resources Person, National Research Institute of Far Seas Fisheries (Japan),

Email: aco20320@par.odn.ne.jp

“R” needs to be pre-installed to your PC

- Otherwise you cannot attend the training course as “R” is the main engine of the software to be used for the training course.
- Please note that you will not need to learn “R”. We need “R” in your PC to run the menu driven software that you need to learn.
- You don’t need to know any computer languages if you use software to be provided in the training course.

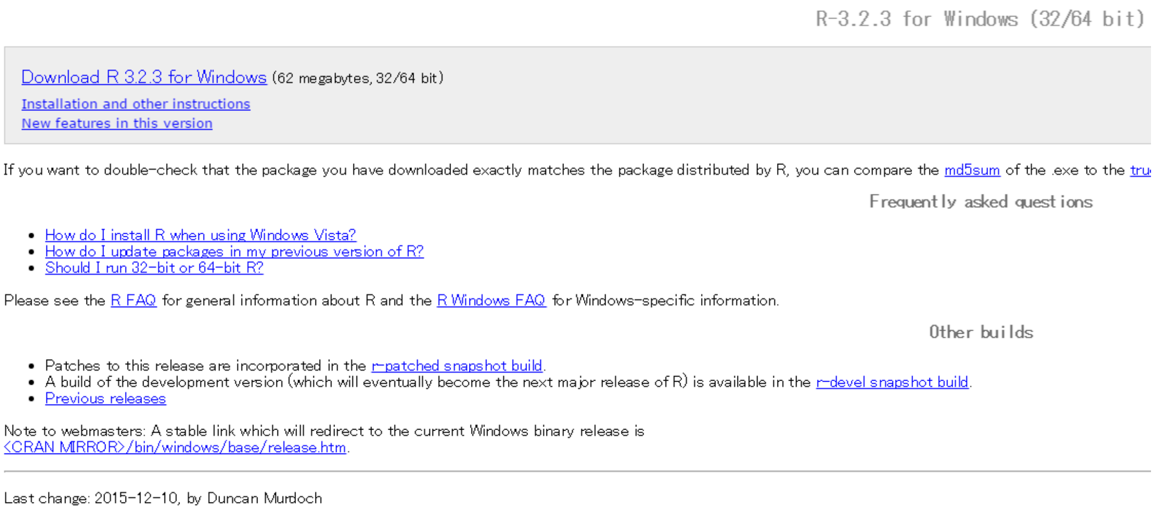
Minimum requirement of your PC

- Lap top PC: windows 7 or higher (64 bits).
- No MAC/Apple PC nor Tablets because of software compatibility problems

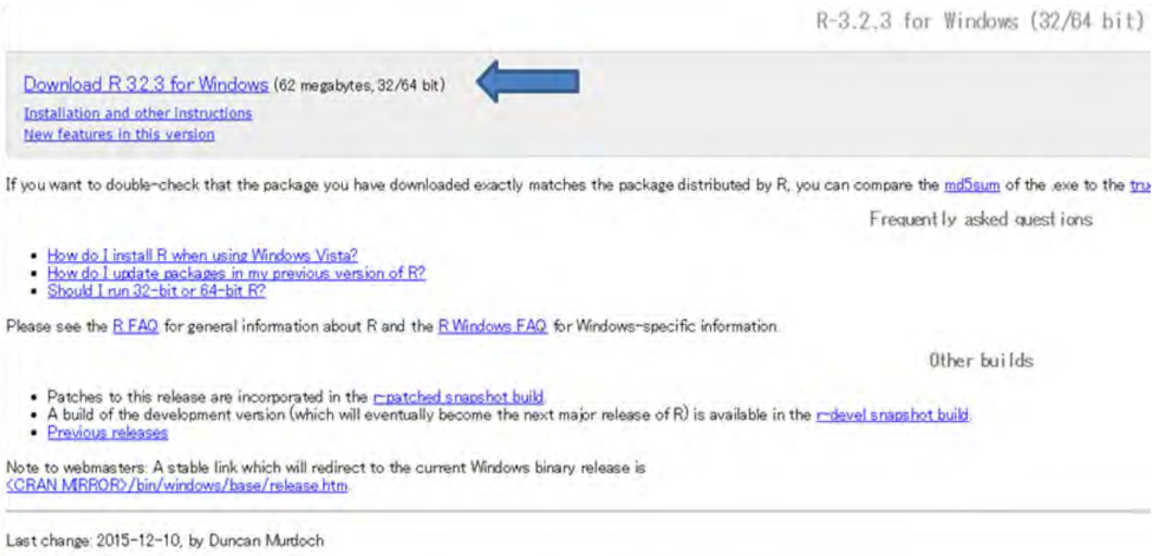
Now how to install “R”

(1) Go to https://cran.r-project.org/bin/windows/base/

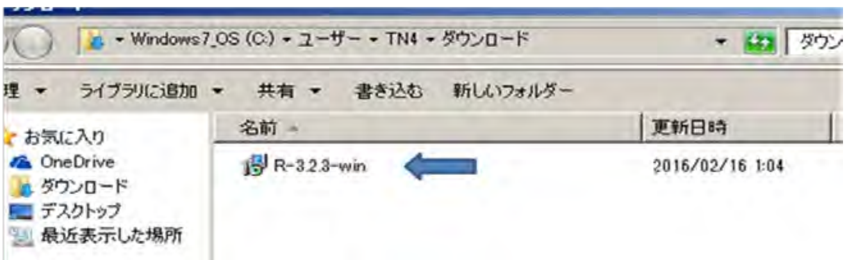
(2) Then you will see window as below:



(3) Then click



(4) Then R will be downloaded to your download folder of your PC as below (don’t worry about Japanese).



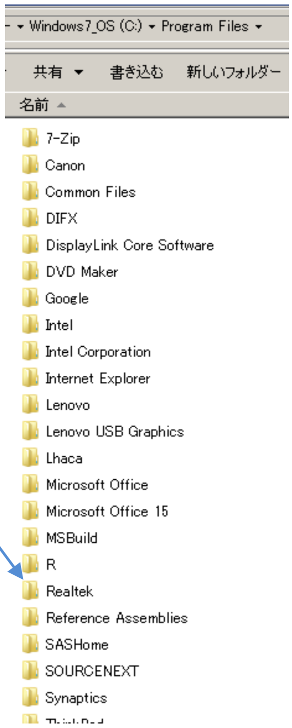
(5) Then double click the icon (above)

(6) Then follow the instruction and choose default for all options.

(7) It will take some time to finish.

(8) After you will finish your installation,

Your R is stored in C: drive



(9) You will not touch nor use “R” folder.

(10) Only software will use “R” behind you!

(11) If you have any problems, please contact

Tom Nishida (PhD),
Resources Person,
National Research Institute of Far Seas Fisheries (Japan)
Email: aco20320@par.odn.ne.jp