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
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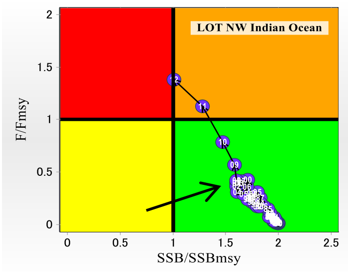
Executive Summary
Status of Stock of Four Neritic Species in the NW Indian Ocean

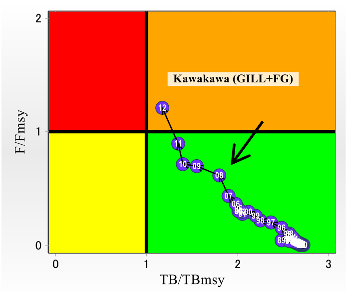
Stock status of longtail tuna, kawakawa and frigate tuna (2012) are at the orange zone of the Kobe plot (stock trajectory), i.e., fishing pressure is much higher than their MSY levels, while total biomasses are in the safe levels (at the MSY level or higher). Stock status of striped bonito is unknown 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



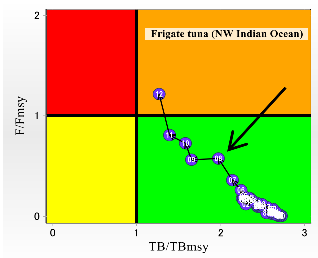
In 2012, F (fishing mortality rate) is beyond Fmsy (38% higher than the MSY level), i.e., high fishing pressure, while the total biomass is about in the MSY level. It is clear if current F level continues, longtail tuna stock will be entering the overfishing stage from 2013.

Kawakawa



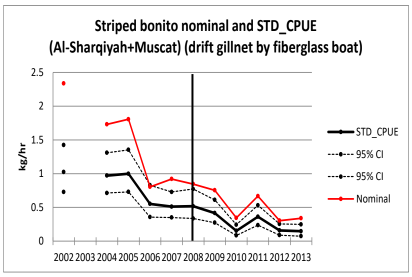
In 2012, F (fishing mortality rate) is beyond the Fmsy level (21% higher than the MSY level), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (safe level). It is clear if the current F level continues, kawakawa stock will be entering the overfishing stage in the near 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.

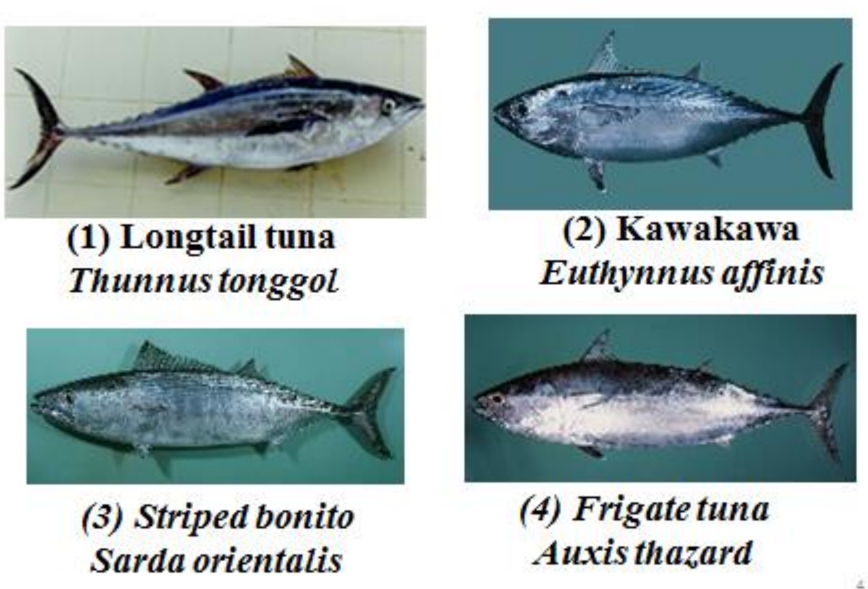


Fig. 1 Pictures of four neritic tuna species focused by this project

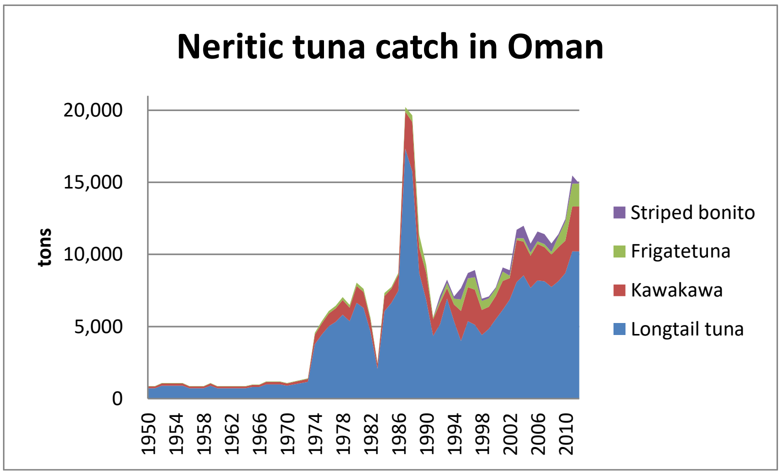


Fig. 2 Trends of four neritic tuna catch exploited in Oman (IOTC and FAO)

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.

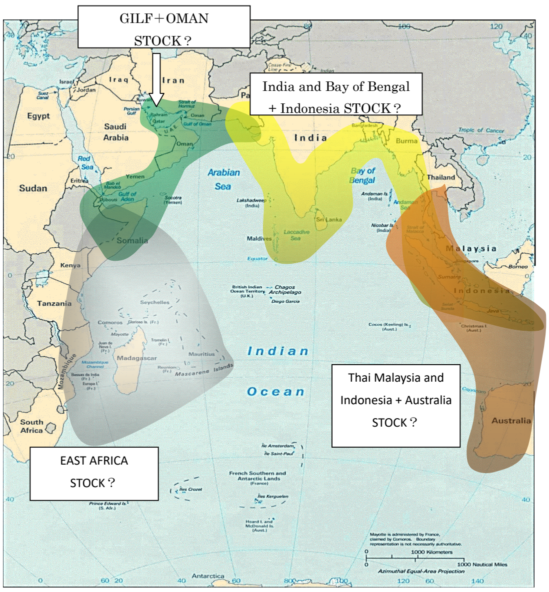


Fig. 3 Four hypothetical neritic tuna stock structure in the Indian Ocean (Nishida, 2013)

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.

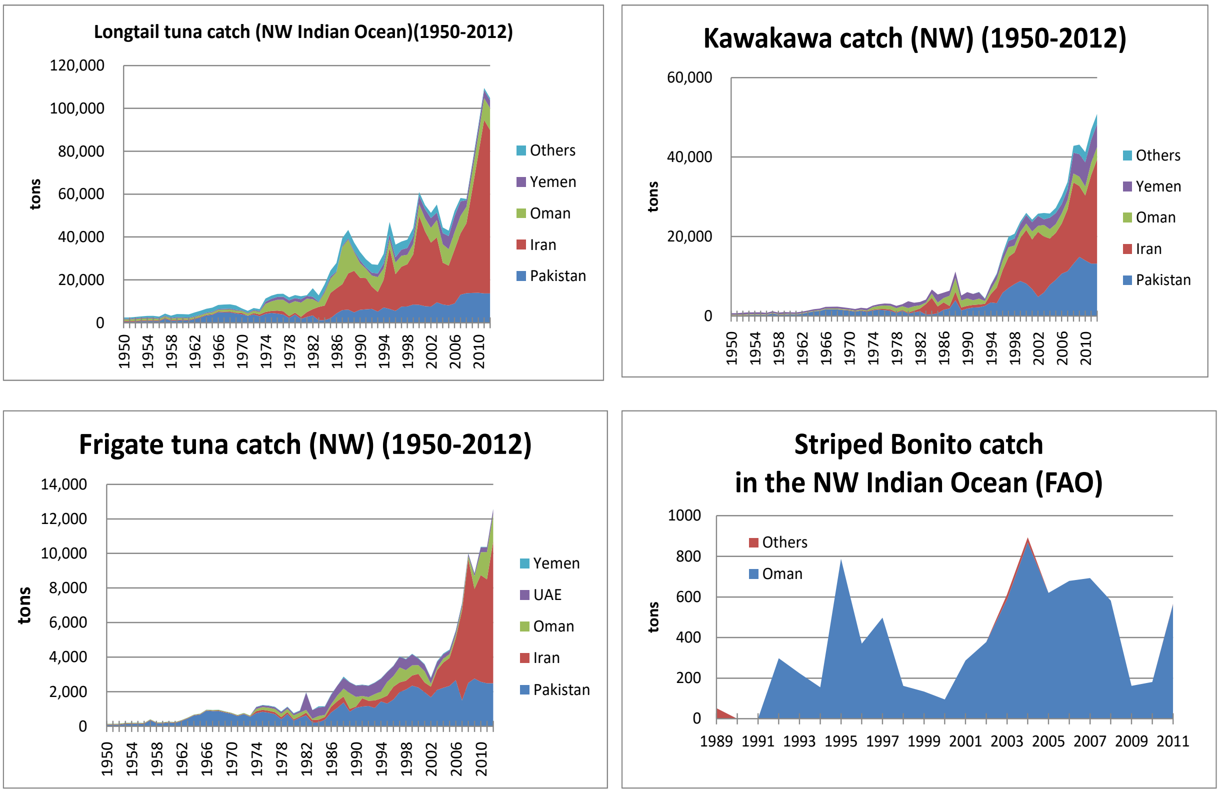


Fig. 4 Four neritic tuna catch by fleet in the NW Indian Ocean (1950-2012)

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.

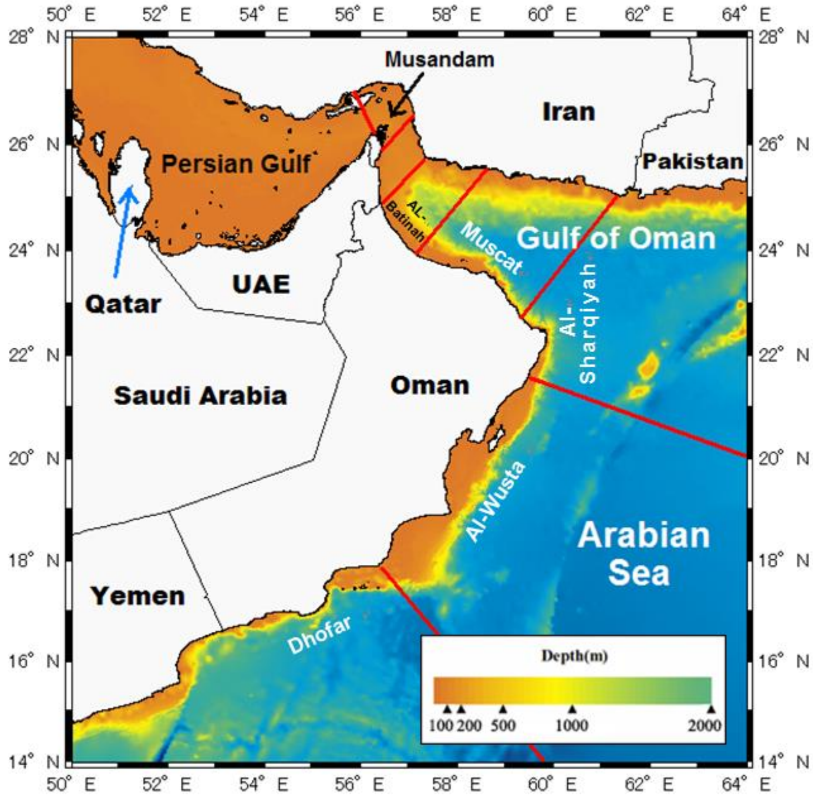


Fig. 5 Six regions used for nominal CPUE and CPUE standardization

(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.

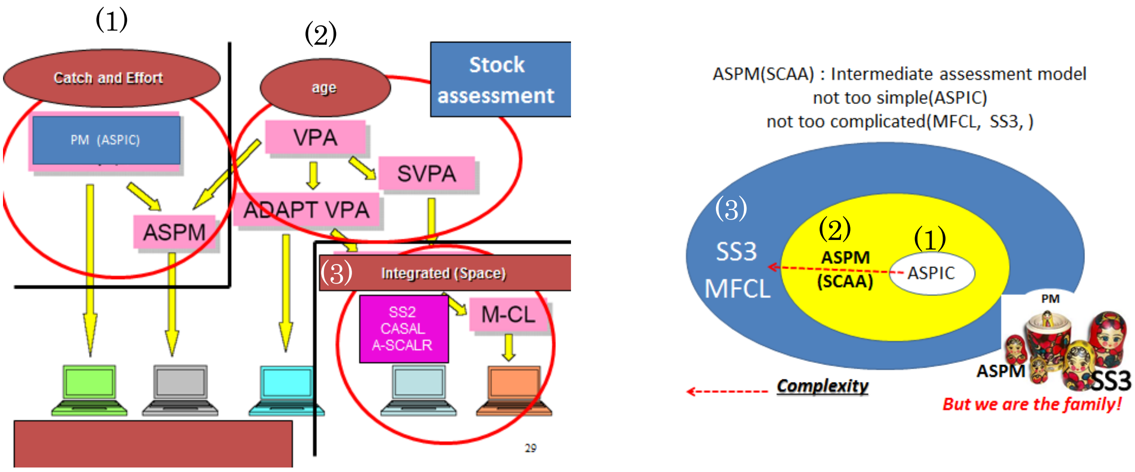


Fig. 6 (*left*) Outline of the stock assessment models and (*right*) Relations among simple production model (ASPIC), intermediate model (ASPM) and complex model (SS3). ASPIC use only global catch and catch/effort data, while ASPM and SS3 use additional biological information.

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.

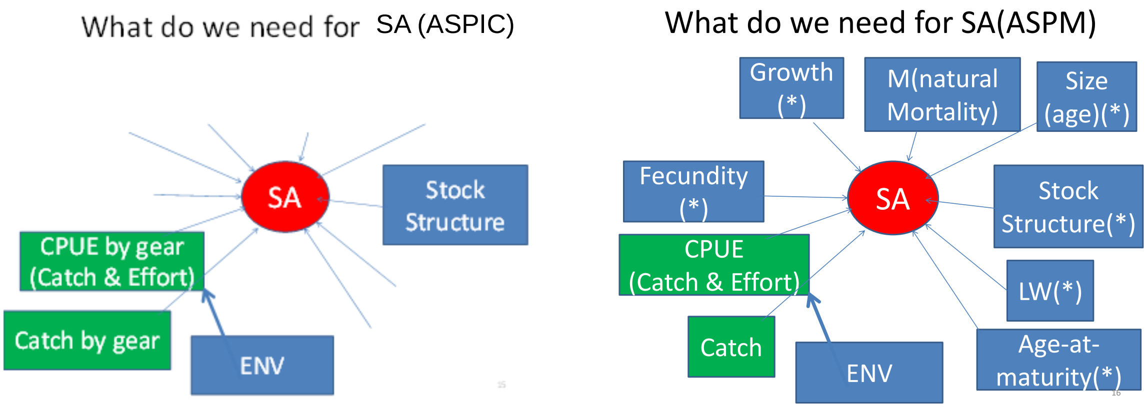


Fig. 7 Information needed to conduct simple production model such as ASPIC (left) and also for the intermediate model such as ASPM (right)

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.

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.

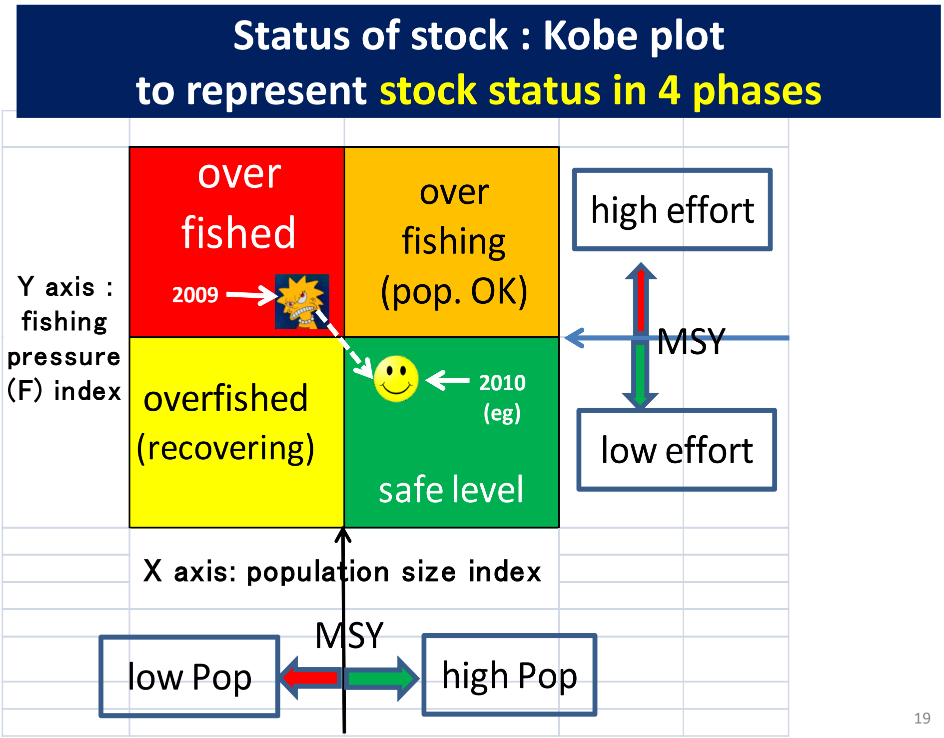


Fig. 8 Outline of the Kobe plot (stock trajectory)

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).

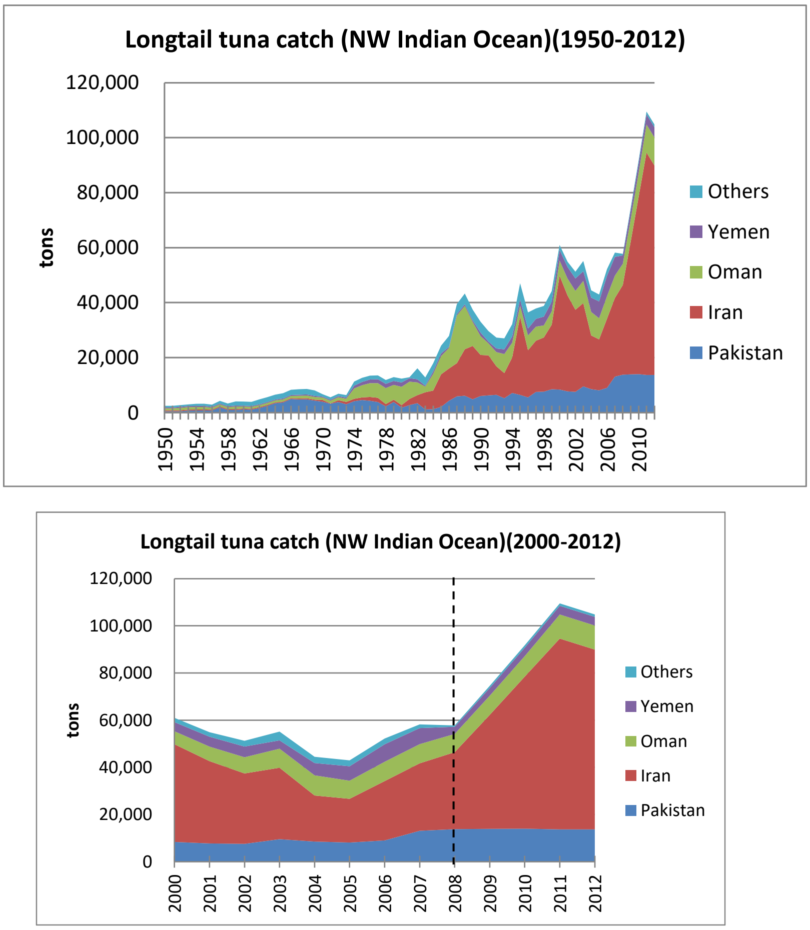


Fig. 9 Longtail catch in NW Indian Ocean

(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		

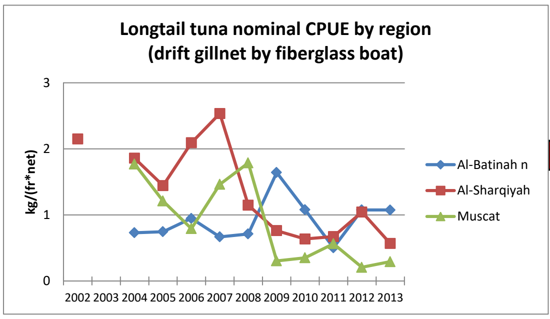
Drift Gillnet by fiberglass boat

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	483	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	13	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



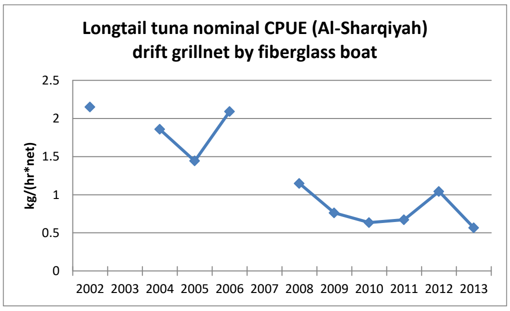


Fig. 10 (left) Trends of longtail tuna nominal CPUE for three region (drift gillnet by fiberglass boat) and (right) the selected nominal CPUE (Al-Sharqiyah).

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 n				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					

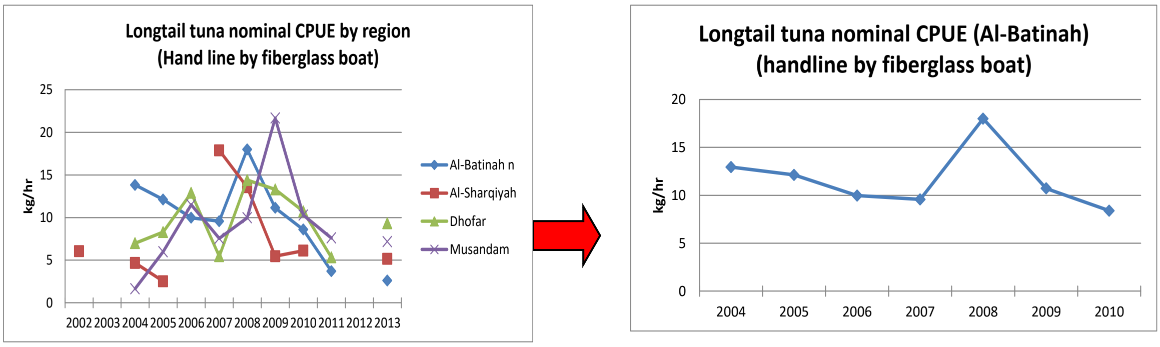


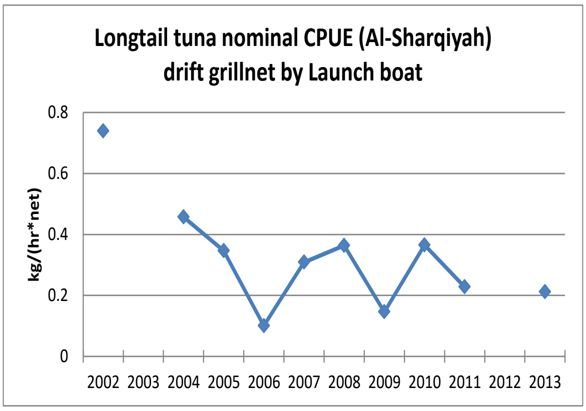
Fig. 11 (left) Trends of nominal CPUE for four regions (hand line fisheries by fiberglass boat) and (right) Selected nominal CPUE (Al-Batinah) (2011 and 2013 data are not included as their sample sizes are too few, i.e., n=1 and n=3 respectively.

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	



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

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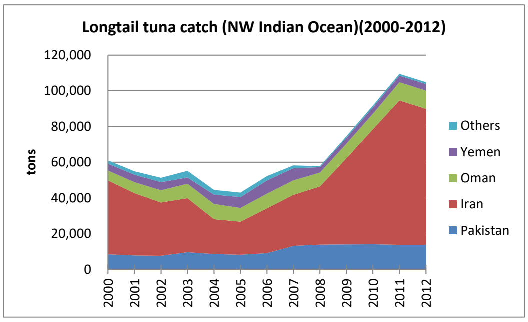
<td>
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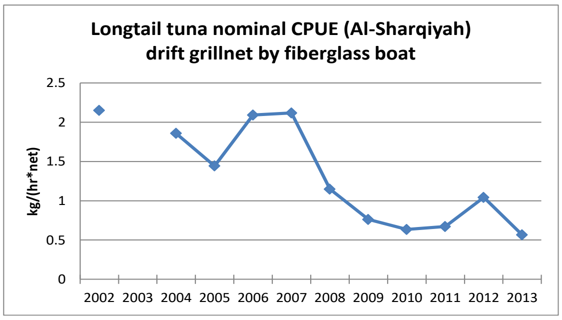
<td>
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<tr>
<td>Recent longtail tuna catch in the Oman and Gulf region.</td>
<td>Nominal longtail tuna CPUE (drift gillnet by fiberglass boat). Selected as the representative nominal CPUE for STD_CPUE.</td>
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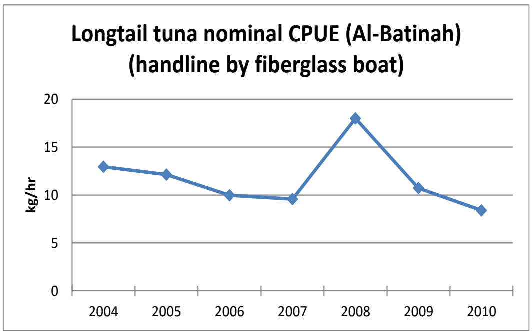
<td>
</td>
<td>No plausible nominal CPUE was found</td>
</tr>
<tr>
<td>Nominal CPUE (hand line fisheries by fiberglass boat). Not selected as the data points are not enough comparing to the one of drift gillnet by fiber glass boat.</td>
<td>Nominal longtail tuna CPUE (drift gillnet by launch boat)</td>
</tr>
</table>

(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)*

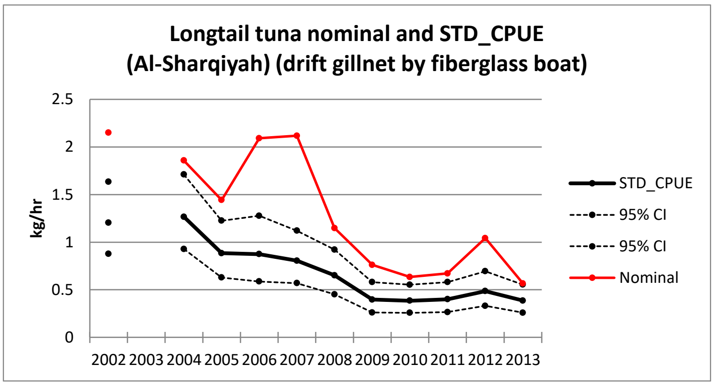
The GLM Procedure

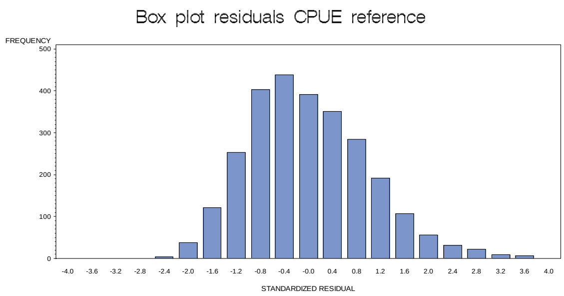
ependent Variable: L_CPUE

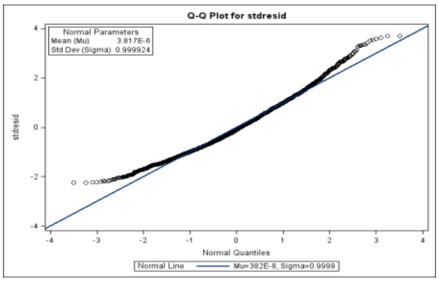
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	561.998414	25.545382	33.29	<.0001
Error	2688	2062.589716	0.767332		
Corrected Total	2710	2624.588130			

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.

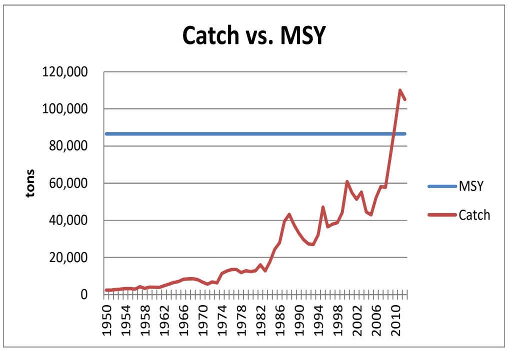
Table 6 ASPIC results based on various scenarios of K values.

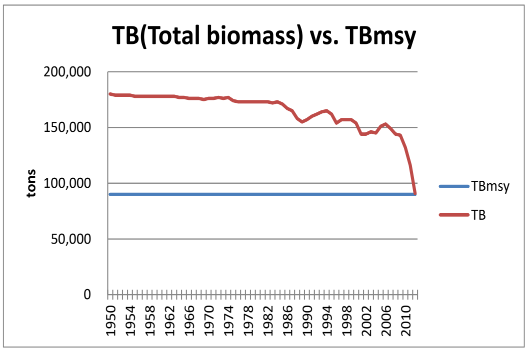
model	Schaefer					FOX
K (1000 tons)	R2	MSE	TB ratio	Fratio	MSY	NC
100	NC					NC
170	NC					NC
180 (best fit)	0.321	0.1483	0.789	1.379	86,490	NC
190	0.319	0.1488	0.780	1.409	85,160	NC
200	0.318	0.1493	0.770	1.440	83,770	NC

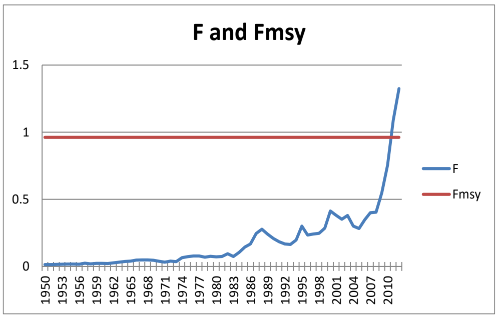
NC: Neither converged nor plausible parameters were estimated

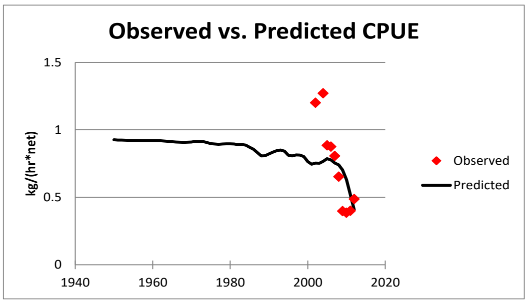
Box 3 shows results including graphs for catch vs. MSY, TB (total biomass) vs TBmsy, F vs. Fmsy, observed vs. predicted CPUE and Kobe plot (stock trajectory). Based on this ASPIC results, the stock status of longtail tuna (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond Fmsy (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.

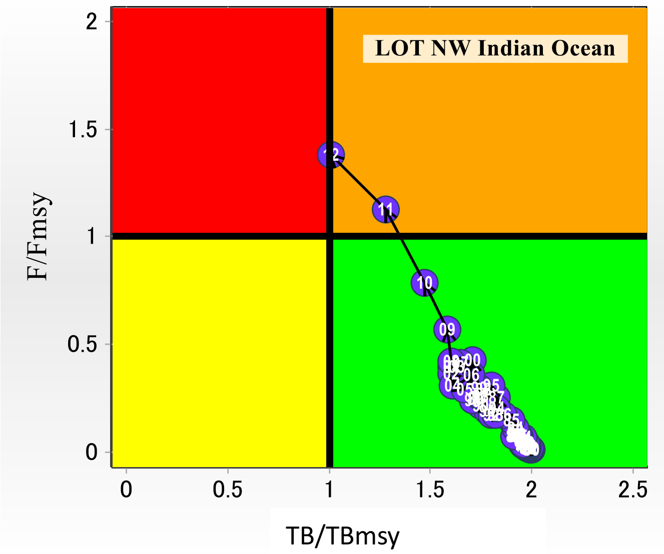
Box 3 Results of ASPIC (longtail tuna)











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).

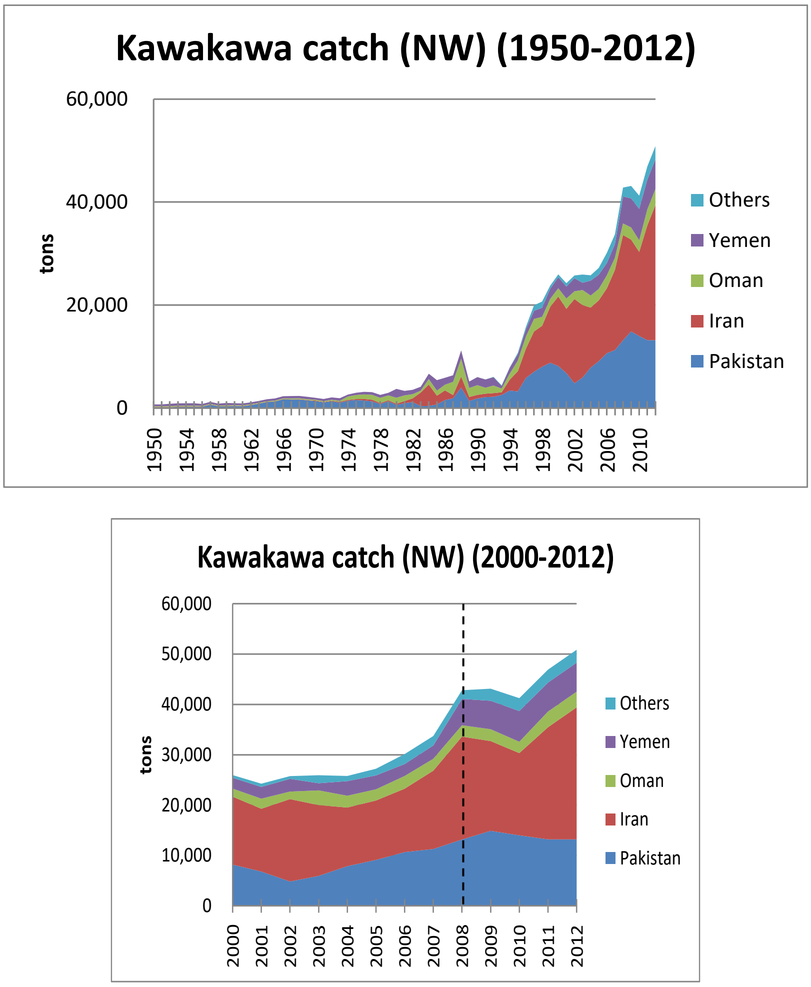


Fig. 13 Kawakawa catch in the NW Indian Ocean

(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	61	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

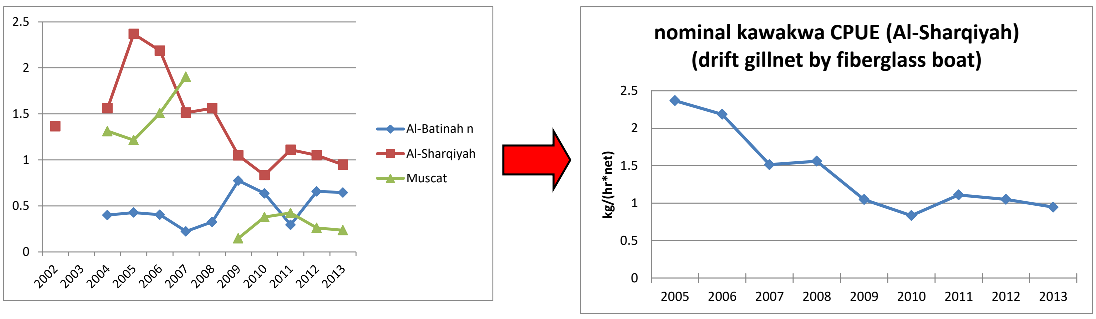


Fig. 14 Trends of nominal CPUE for three regions (drift gillnet fisheries by fiberglass boat) (left) and selected nominal CPUE (Al-Sharqiyah) (2005-2013).

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

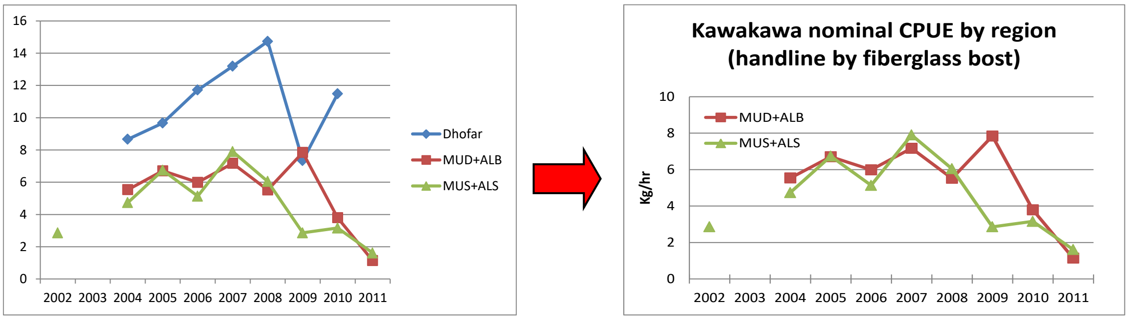


Fig.15 (left) Trends of nominal CPUE for three region (hand line fisheries by fiberglass boat) and (right) selected nominal CPUE (two regions).

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	

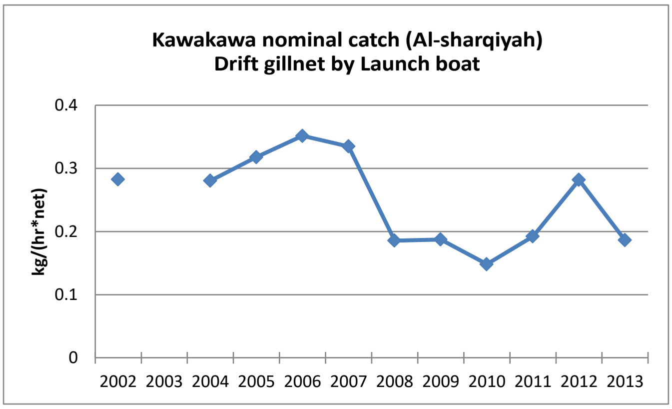


Fig.16 Trends of nominal kawakawa CPUE for Al-Sharqiyah (drift gillnet fisheries by launch boat)

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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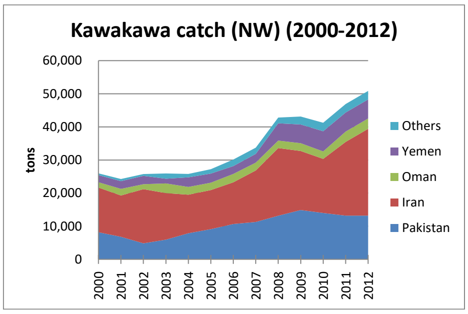
<td>
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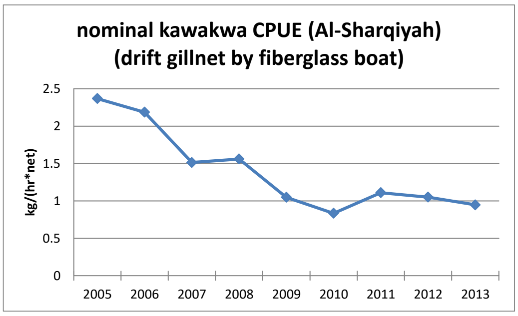
<td>
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<tr>
<td>Recent kawakawa catch in the Oman and Gulf region.</td>
<td>Nominal kawakawa CPUE (drift gillnet fisheries by fiberglass boat). Selected as the representative nominal CPUE for STD_CPUE.</td>
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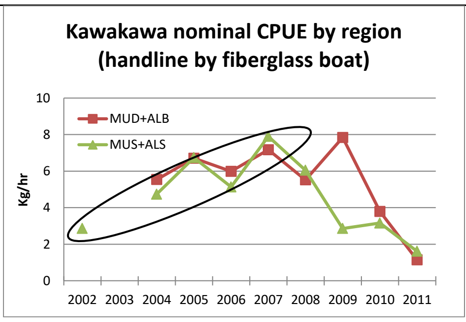
<td>
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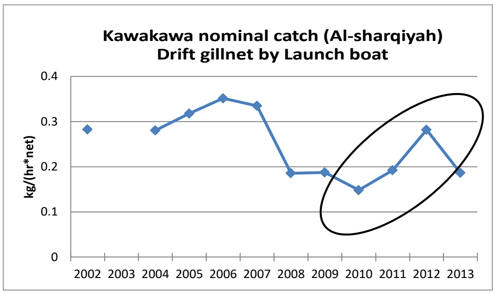
<td>
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<td>Nominal kawakawa CPUE (hand line by fiberglass boat) (trend for 2002-2007 is not plausible).</td>
<td>Nominal kawakawa CPUE (drift gillnet fisheries by launch boat) (trend 2010-2012 is not plausible).</td>
</tr>
</table>

(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)*

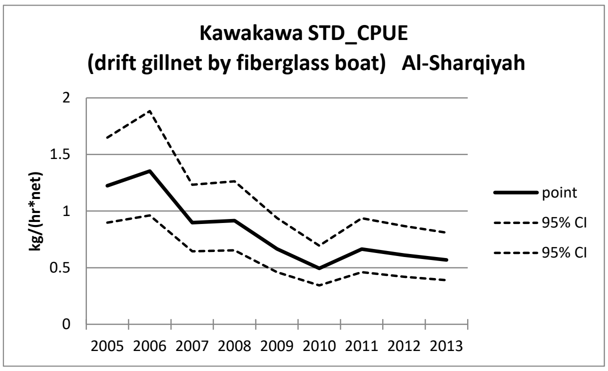
The GLM Procedure

Dependent Variable: L_CPUE

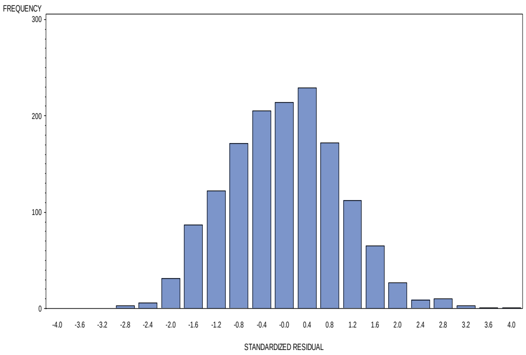
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	219.513958	11.553366	18.75	<.0001
Error	1450	893.431919	0.616160		
Corrected Total	1469	1112.945877			

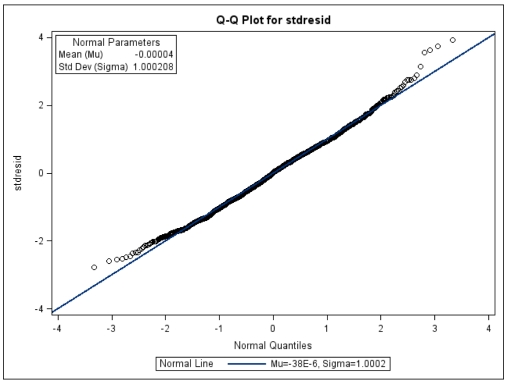
R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.197237	1580.033	0.784959	0.049680

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

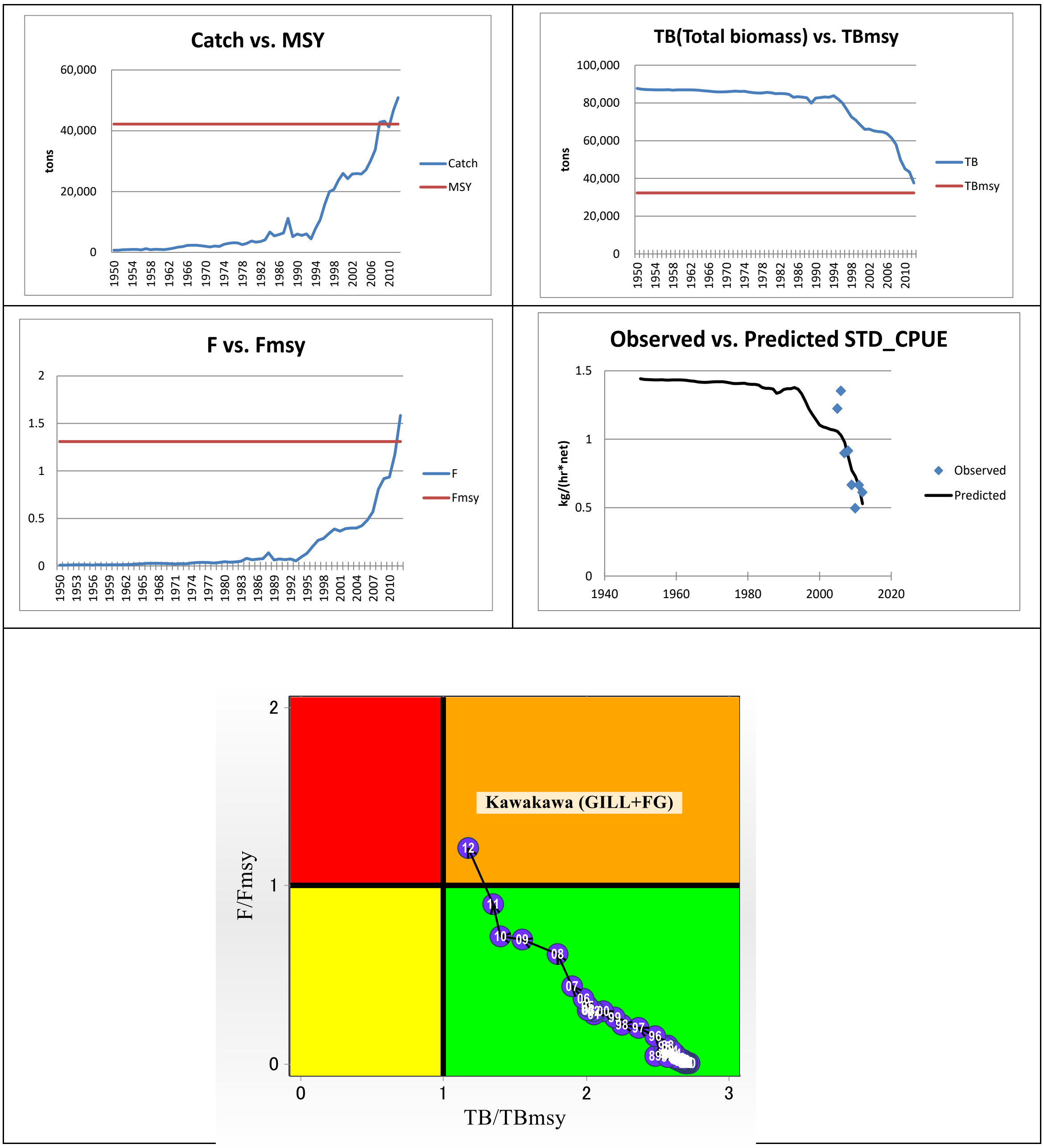


Box plot residuals CPUE reference





Box 6 Results of ASPIC (Kawakawa)

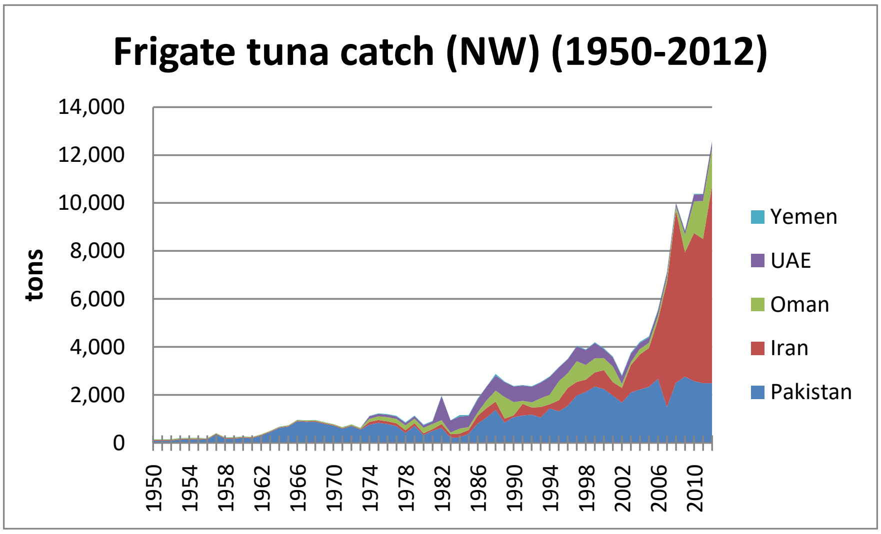


Based on the ASPIC results, the stock status of kawakawa (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond the Fmsy level (21% higher), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (still in the safe level). It is clear if the current F 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).



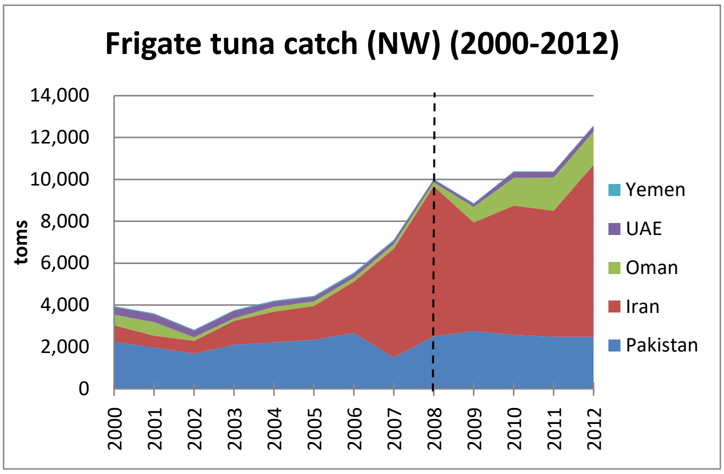


Fig. 17 Frigate tuna catch in the NW Indian Ocean

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

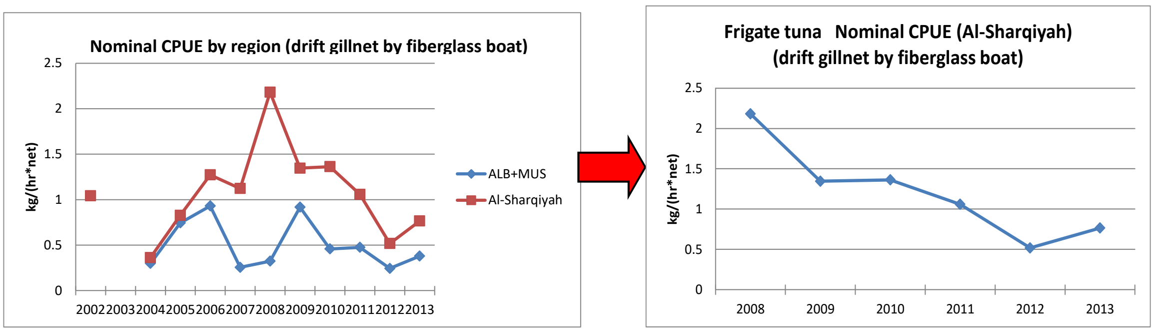


Fig.18 (left) Trends of frigate tuna nominal CPUEs in two region (ALB+MUS and Al-Sharqiyah) (drift gillnet by fisheries fiberglass boat) and (right) selected nominal CPUE (Al-Sharqiyah) as the representative ones. ALB: Al-Batinah and MUS: Muscat

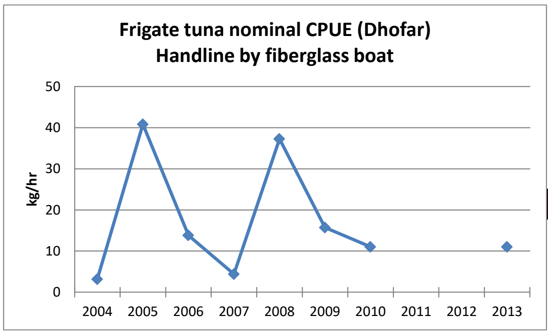
Hand line fisheries by fiberglass boat

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,

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

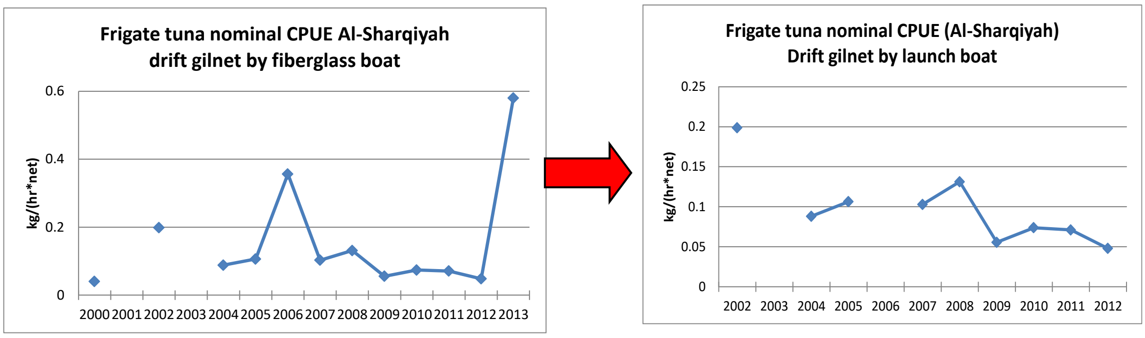


Fig.20 (left) Trends of nominal frigate tuna CPUE in Al-Sharqiyah (hand line fisheries by launch boat) and (right) selected nominal CPUE without 2000, 2006 and 2013 data points as the representative one.

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

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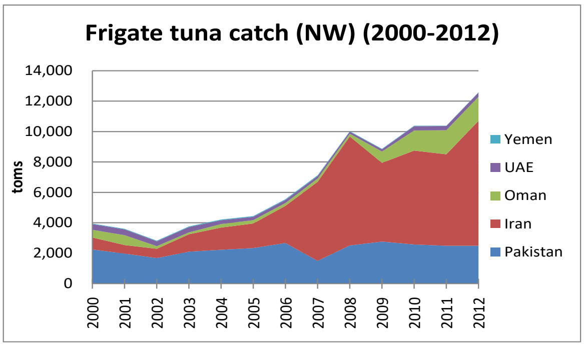
<td>
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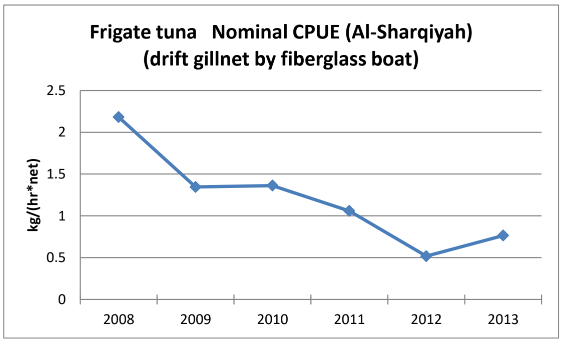
<td>
</td>
</tr>
<tr>
<td>Recent kawakawa catch in the Oman and Gulf region.</td>
<td>Nominal frigate tuna CPUE (drift gillnet fisheries by fiberglass boat). Not selected as the data points are not enough comparing to the one of drift gillnet fisheries by launch boat (below).</td>
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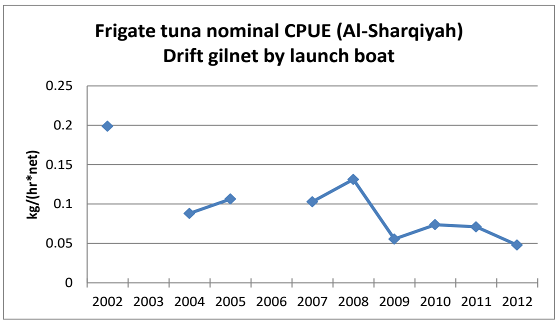
<td>
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<tr>
<td>Nominal CPUE (hand line fisheries by fiberglass boat). Not selected as the trends are not realistic.</td>
<td>Nominal frigate tuna CPUE (drift gillnet fisheries by launch boat) Selected as the representative nominal CPUE as this includes longer time series than the one in drift gillnet fisheries by fiberglass boat (above).</td>
</tr>
</table>

(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)*

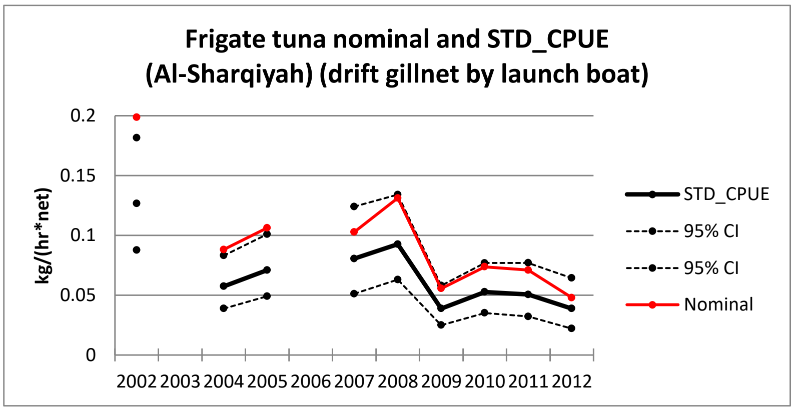
The GLM Procedure

Dependent Variable: L_CPUE

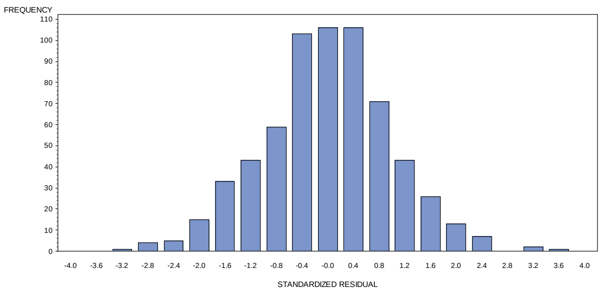
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	77.8165975	4.3231443	7.71	<.0001
Error	621	348.3639012	0.5609725		
Corrected Total	639	426.1804987			

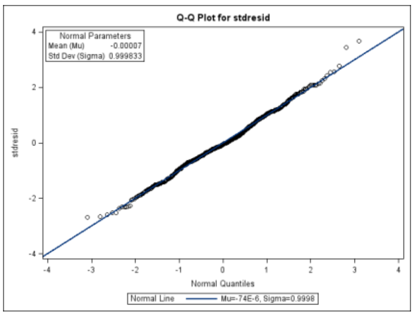
R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.182591	-29.68830	0.748981	-2.522815

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



Box plot residuals CPUE reference





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.

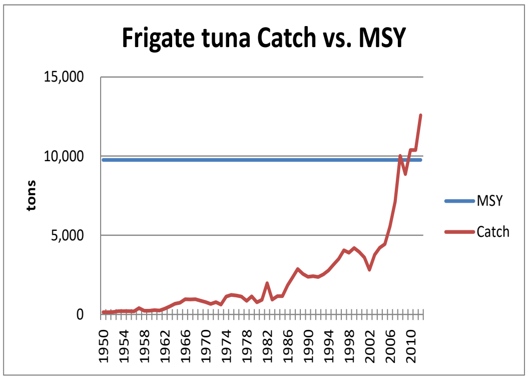
Table 15 ASPIC results based on various scenarios of K values.

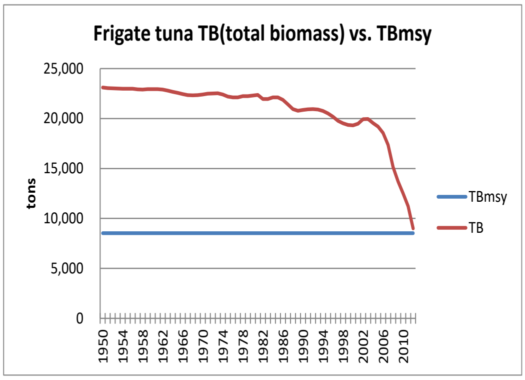
model	Schaeffer					FOX
K (1,000 tons)	R2	MSE	TB ratio	Fratio	MSY	NC
10	NC					NC
17	NC					NC
18 (best fit)	0.321	0.1483	0.789	1.379	86,490	NC
19	0.319	0.1488	0.780	1.409	85,160	NC
20	0.318	0.1493	0.770	1.440	83,770	NC

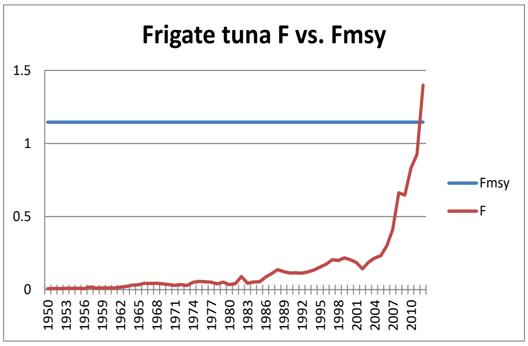
NC: Neither converged nor plausible parameters estimated

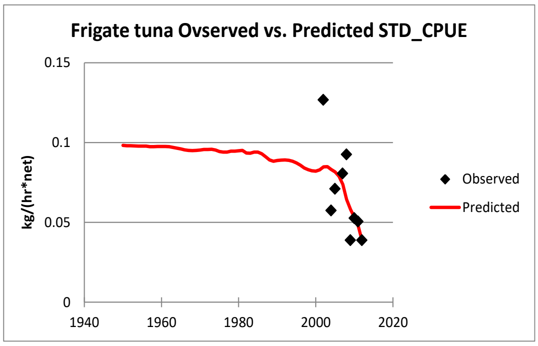
Box 9 shows results including graphs for catch vs. MSY, TB (total biomass) vs TBmsy, F vs. Fmsy, observed vs. predicted CPUE and Kobe plot (stock trajectory). Based on this ASPIC results, the stock status of frigate tuna (2012) in the NW Indian Ocean is that F (fishing mortality rate) is beyond Fmsy (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.

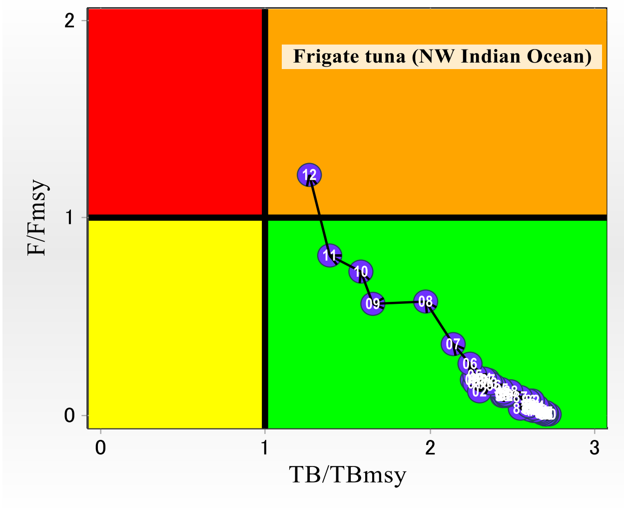
Box 9 Results of ASPIC (frigate tuna)







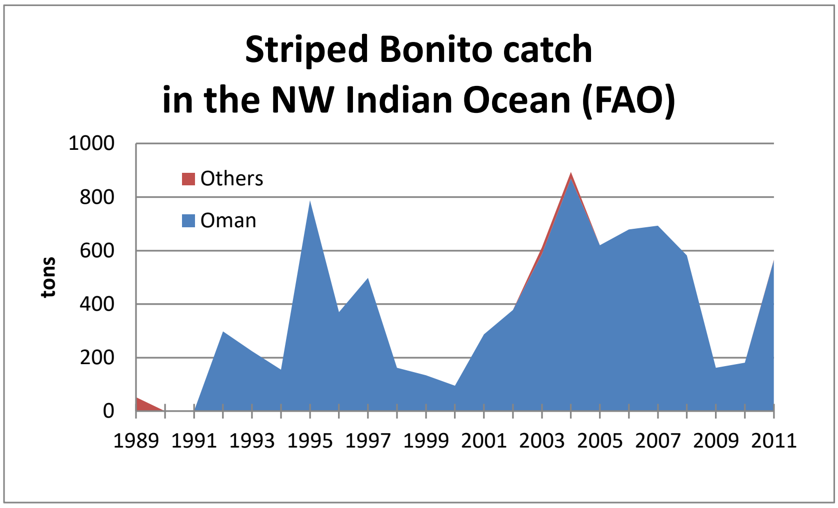




4.4 STRIPED BONITO

(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).



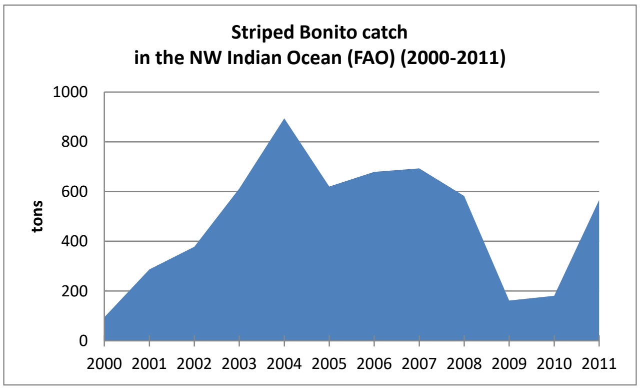


Fig. 21 Striped bonito catch in NW Indian Ocean

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

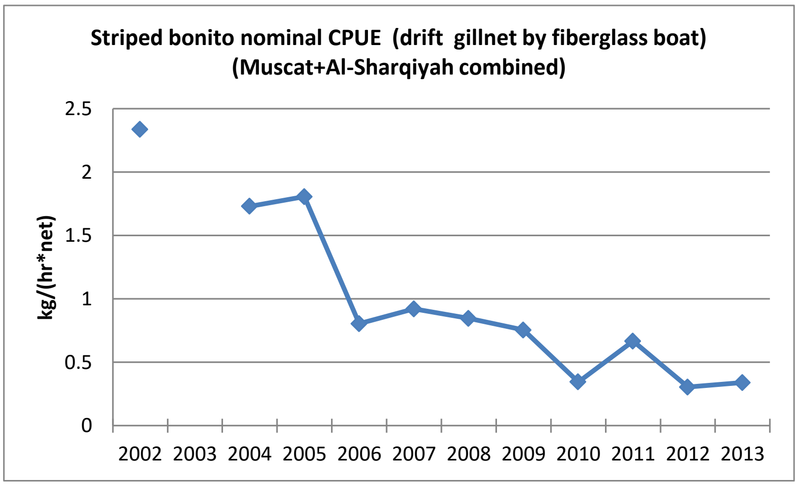


Fig.22 Trend of Striped bonito nominal CPUE in drift gillnet fisheries by fiberglass boat (Al-Sharqiyah and Muscat combined)

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

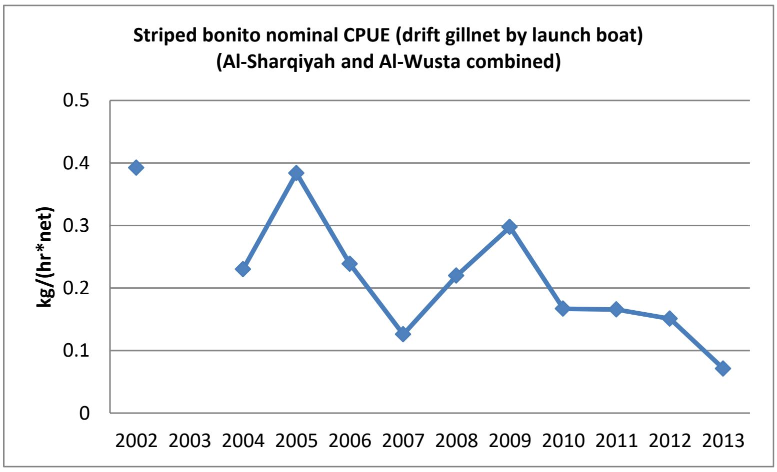


Fig.23 Trend of nominal CPUE (drift gillnet by launch boat)
(Al-Sharqiyah and Al-Wusta combined)

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)

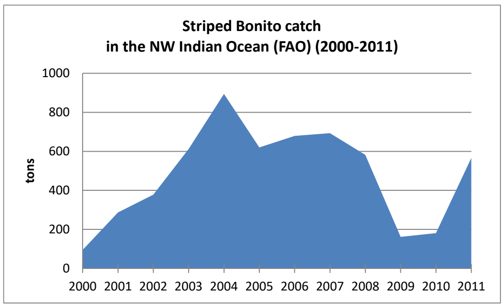
	Al-Batinah n			Al-Sharqiyah				Al-Wusta			Dhofar				Musandam	Muscat		
Q	1	2	4	1	2	3	4	1	2	3	1	2	3	4	3	1	2	4
2002				6	21	6	10											
2004				39	15	9	2				23	27	2	36				3
2005				30	16		9				19	7	1	2				
2006														2				
2007				8	5	1					3	2	1	2				
2008					1						4							
2009	1	2	1	2	2	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

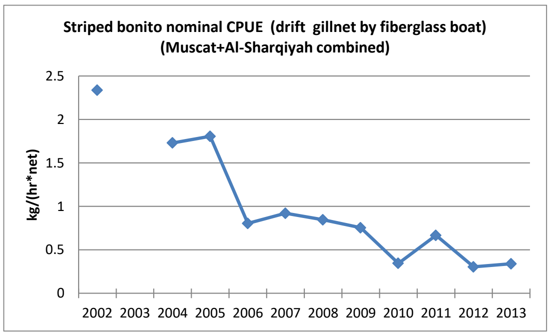
Summary of nominal CPUE

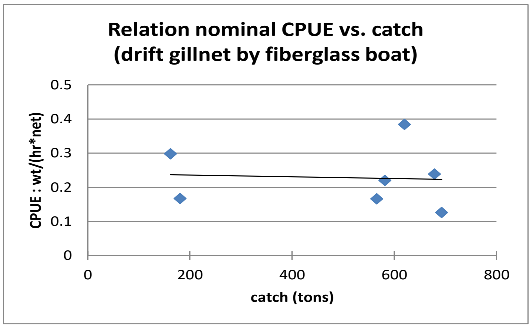
We now compare and evaluate selected nominal CPUE for 2 gear-boat types in order to choose the most plausible one to be used for STD_CPUE. Box 11 shows recent catch trend with three nominal CPUE for two different gear-boat types. As the catch trend of striped bonito is incomplete and unstable, which 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

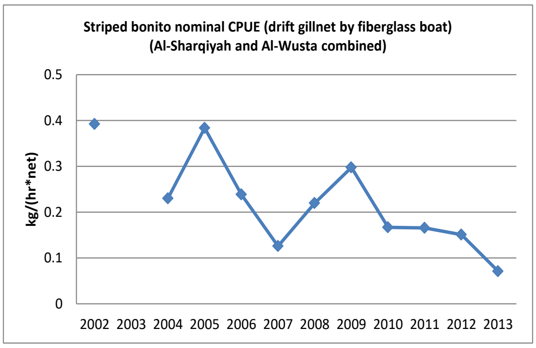


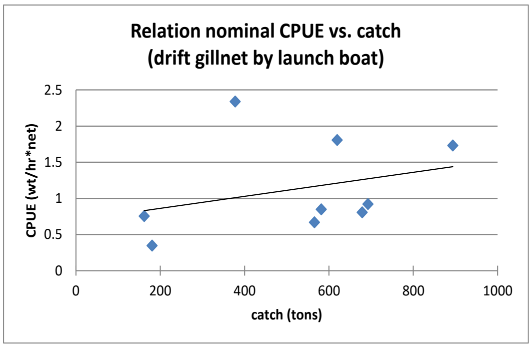
Recent striped bonito catch in NW Indian Ocean (Oman)





(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)

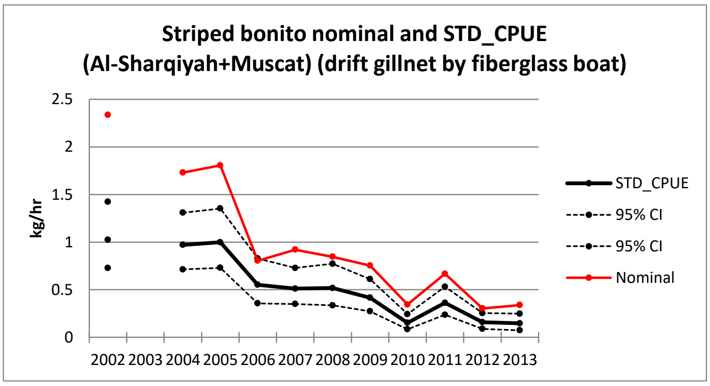
(top: ANOVA, middle: graphs and bottom: residuals)

Dependent Variable: L_CPUE

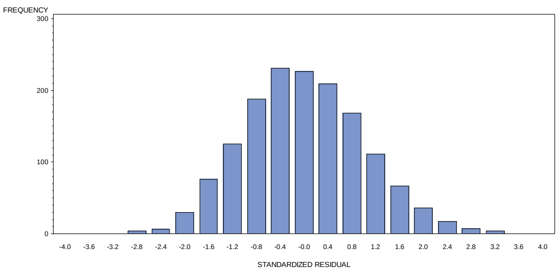
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	633.480501	31.674025	50.21	<.0001
Error	1485	936.818747	0.630854		
Corrected Total	1505	1570.299248			

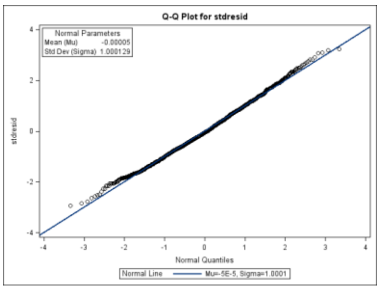
R-Square	Coeff Var	Root MSE	L_CPUE Mean
0.403414	-319.1212	0.794263	-0.248891

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

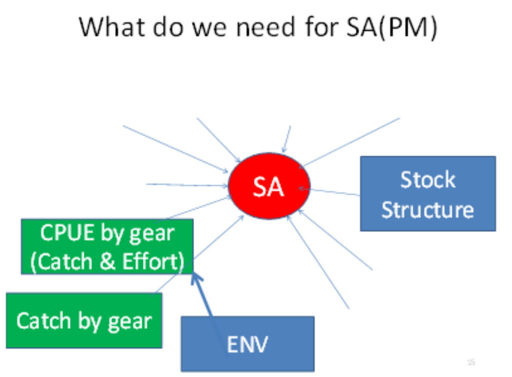
Based on our works, we put a list on number of recommendations as below, which are collected from the text:

Data and CPUE

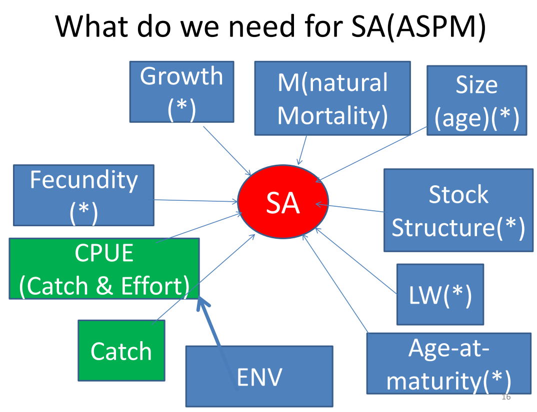
- We could get good quality of catch and effort data from Al-Sharqiyah. Other regions also produce good quality of catch and effort data only for some limited cases. It is recommended to improve the data collection in five regions (Musandam, Muscat, Al-Wusta and Dhofar) as in Al-Sharqiyah.
- Boat type: "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

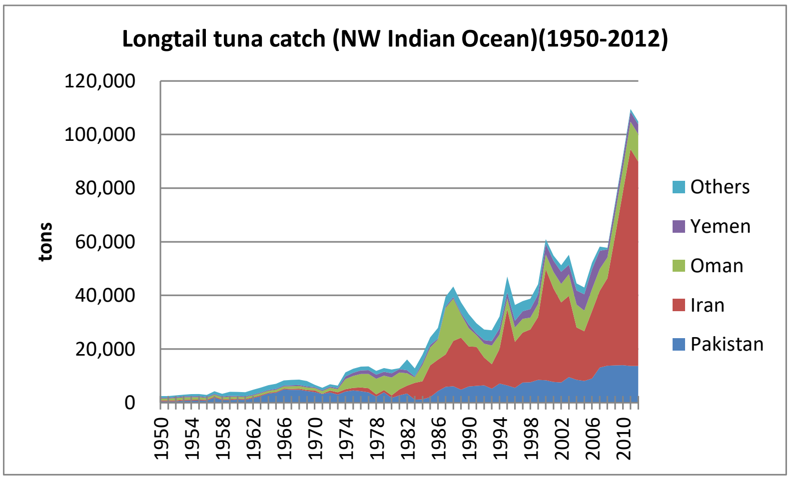


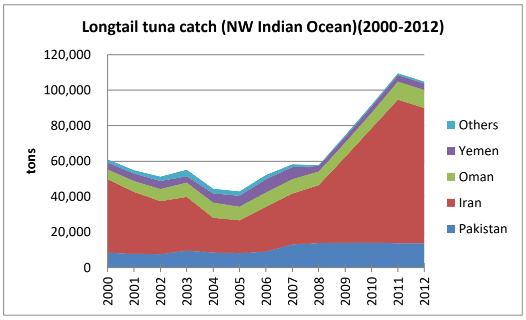
ASPM

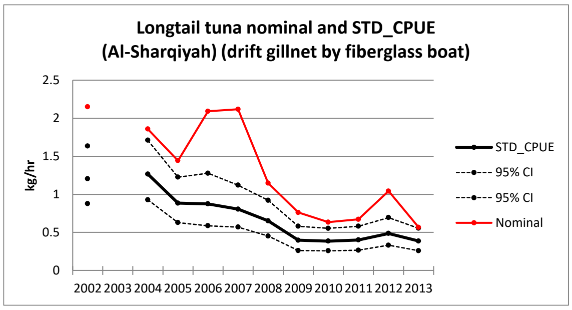
This is because of following two reasons, i.e., (a) this project has been collecting large numbers of biological data and (b) it is important to cross checks results of stock assessments by a few different models to evaluate and confirm results as production model using only catch and CPUE may produce biased results because no biological (realistic) information and S-R relation are used.

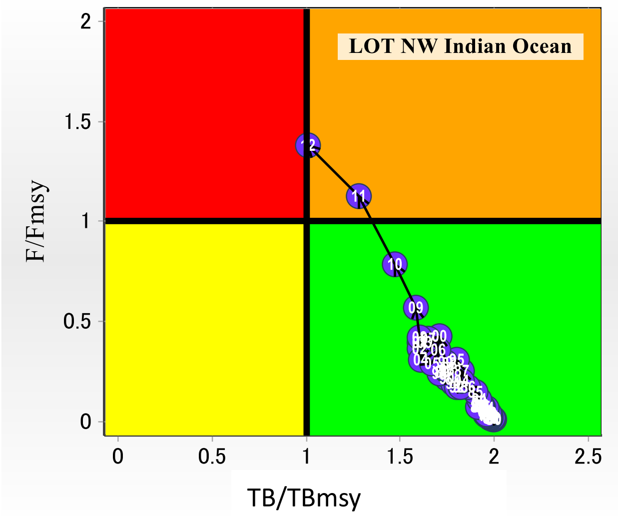
However, ASPIC is useful in the data limited situation to learn the quick and rough stock status. Thus ASPIC has been recommended for many different species world-widely. So in our case, it will be no problem as a first step of the stock assessment using ASPIC.

Box 12 Summary of longtail stock assessment and status of stock



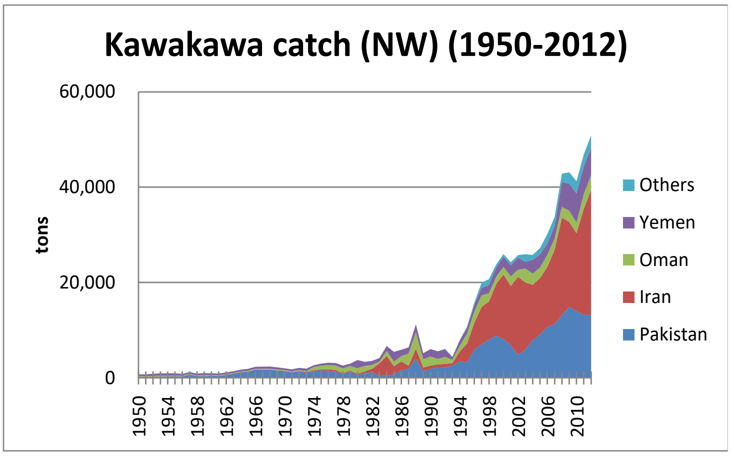


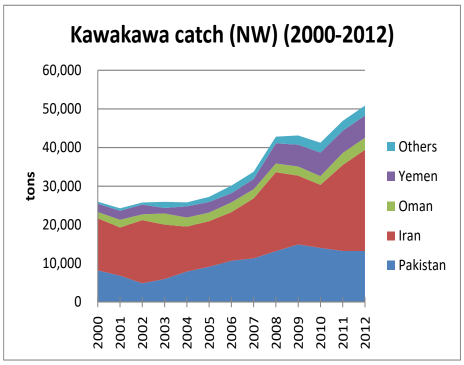


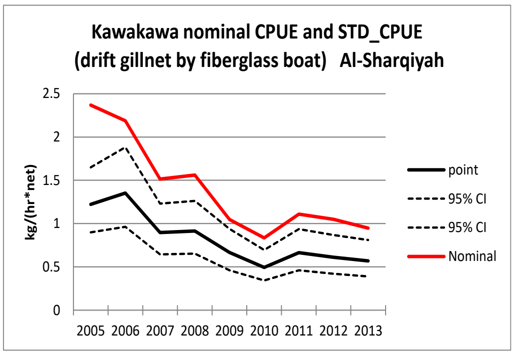


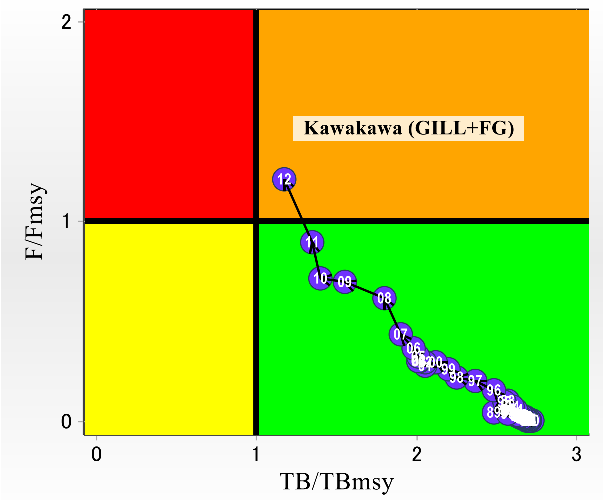
In 2012, F (fishing mortality rate) is beyond Fmsy (38% higher than the MSY level), i.e., high fishing pressure, while the total biomass is about in the MSY level. It is clear if current F level continues, longtail tuna stock will be entering the overfishing stage from 2013.

Box 13 Summary of kawakawa stock assessment and status of stock



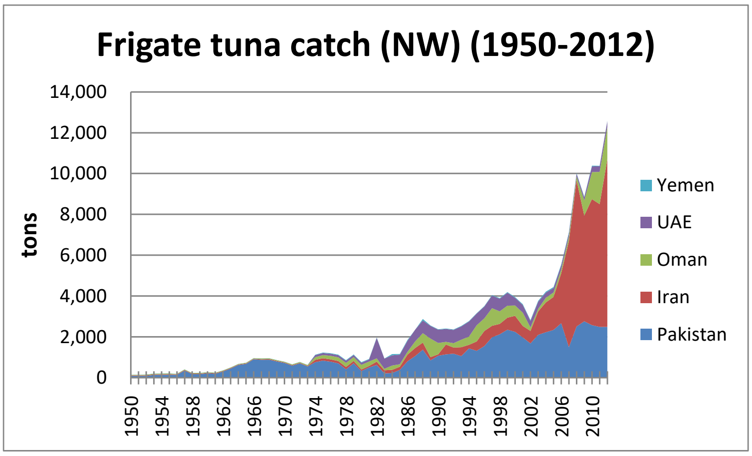


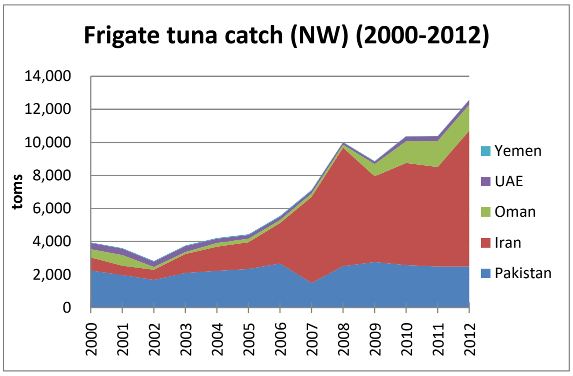


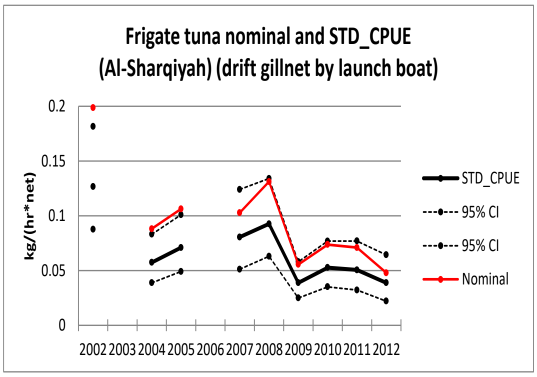


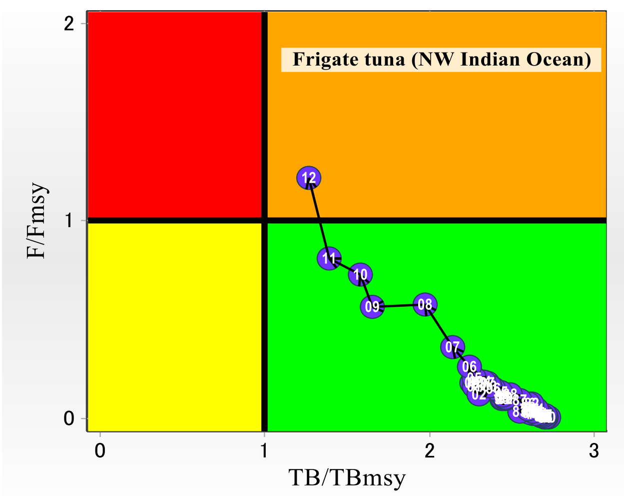
In 2012, F (fishing mortality rate) is beyond the Fmsy level (21% higher than the MSY level), i.e., high fishing pressure, while the total biomass is 12% more than its MSY level (still in the safe level). It is clear if the current F level continues, kawakawa stock will be entering the overfishing stage in the near future.

BOX 14 SUMMARY OF FRIGATE TUNA STOCK ASSESSMENT AND STATUS OF THE STOCK



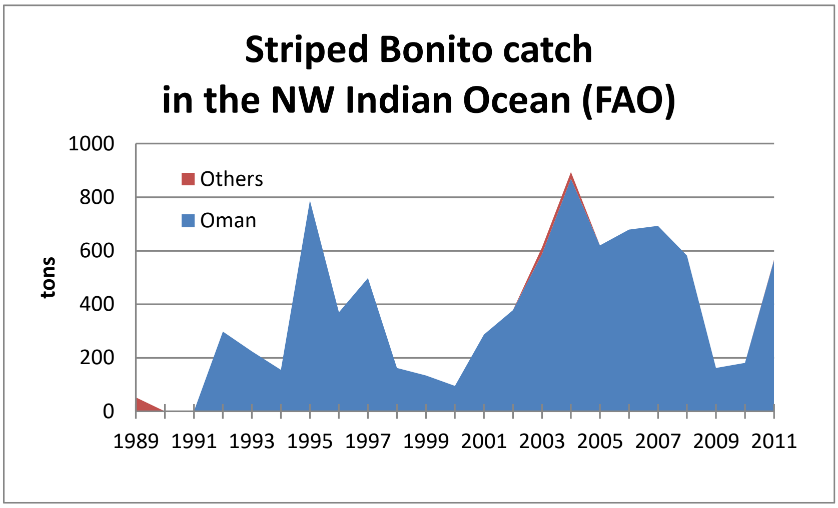


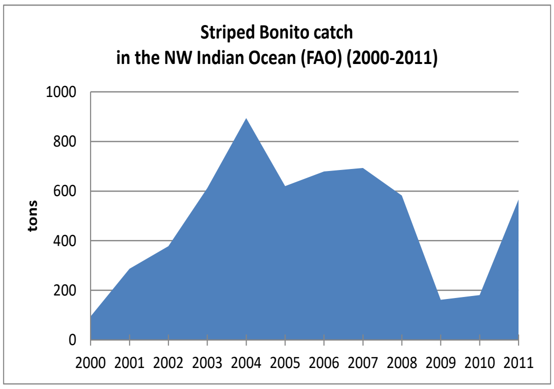


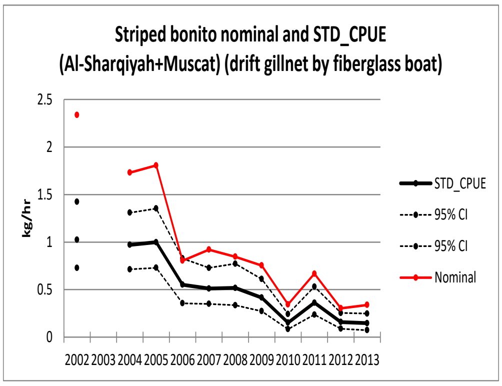


In 2012 F (fishing mortality rate) is beyond Fmsy (22% higher than the MSY level), i.e., high fishing pressure, while the total biomass is still in the safe zone, i.e., beyond the MSY level (27% higher). However, it is clear if current F level continues, frigate tuna will be entering the overfishing 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.

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REFERENCES

Al-Kiyumi F. R, Al-kharusi, L., Nishida, T. and B. Al-Siyabi (2013a). Standardization of kawakawa (*Euthynnus affinis*) catch rates of drift gillnets fisheries in Sultanate of Oman (IOTC–2013–WPNT03–31 Rev_2).

Al-Kiyumi F. R, Al-kharusi, L., Nishida, T. and B. Al-Siyabi (2013b). Preliminary kawakawa (*Euthynnus affinis*) stock assessment by ASPIC using standardized CPUE of drift gillnet fisheries in Sultanate of Oman (IOTC–2013–WPNT03–32 Rev_1).

Anon (2011). Project proposal on “Management of the exploited coastal tuna fisheries resources of the sultanate of Oman”. Marine Science and Fisheries Centre and Ministry of Agriculture & Fisheries, Sultanate of Oman.

FAO (2013). FISHSTAT database. FAO, United Nations, Rome, Italy (internet).

IOTC (2011). Report of the First Working Party on Neritic Tuna meeting (Chennai, India) (IOTC-2011-WPNT01-R[E]).

IOTC (2012). Report of the Second Working Party on Neritic Tuna meeting (Penang, Malaysia) (IOTC-2012-WPNT02-R [E]).

IOTC (2013). Report of the Third Working Party on Neritic Tuna meeting (Bali, Indonesia) (IOTC-2013-WPNT03-R [E]).

IOTC (2013). Nominal catch database (September, 2013). Victoria, Mahe, Seychelles (internet).

Kliumuang, H. 1978. Preliminary studies on the biology of tunas in the west coast of Gulf of Thailand off the east coast of Peninsular Malaysia. *Tech. Rep. Pelagic Fish. Unit Mar. Fish. Div., Bangkok* (5): 25 p.

Nishida, T. (2013) First consultant report on "Management of the exploited coastal tuna fisheries resources of the sultanate of Oman". Marine Science and Fisheries Centre and Ministry of Agriculture & Fisheries, Sultanate of Oman.

Prager, M.H. (2004). User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs, Center for Coastal Fisheries and Habitat Research, National Oceanic and Atmospheric Administration, Beaufort, North Carolina USA.

Shono H. (2004). A review of some statistical approaches used for CPUE standardization. Bull. Jpn. Soc. Fish. Oceanography. 68(2),106-120.

Sivasubramaniam, K., 1981. Large pelagic in the Gulf and Gulf of Oman. *In: Pelagic resources of the Gulf and Gulf of Oman.* FAO/UNDP, FI: DP/RAB/71/278/ 11:122-144, Rome.

Stéquert, B. and F. Marsac, 1989. Tropical tuna surface fisheries in the Indian Ocean. *FAO Fish. Tech. Paper, No. 282.* Rome, FAO, 238 p.

Yesaki, M., 1982. *Thailand. Biological and environmental observations. A report prepared for the pole and line tuna fishing in southern Thailand Project.* Rome, FAO; FI: DP/THA/77/008, 3:46 p.

Pictures


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