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Assessment of Indian Ocean longtail tuna (*Thunnus tonggol*) using data poor catch-based methods

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IOTC Secretariat[1]

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Introduction

Assessing the status of the stocks of neritic tuna species in the Indian Ocean is fairly challenging due to the lack of available data. This includes limited information on stock structure, a lack of standardised CPUE series and biological information. Data poor stock assessments were conducted for longtail tuna (*Thunnus tonggol*) in 2013 (IOTC–2013–WPNT03–25) and again in 2014 (IOTC–2014–WPNT04–25). This paper provides an update to these assessments based on the recent new catch information.

In this paper, two methods were used to assess the status of *T. tonggol*: (i) Stock reduction analysis or Catch MSY method (Kimura and Tagart 1982; Walters et. al. 2006; Martell and Froese 2012) and (ii) a recently developed posterior-focussed catch method OCOM (Zhou et al., 2013). Other neritic species investigated using the same methods included: Indian Ocean kawakawa, (*Euthynnus affinis*) (IOTC-2015-WPNT05-21), narrow-barred Spanish mackerel (*Scomberomorus commerson*) (IOTC-2015-WPNT05-23) and Indo-Pacific king mackerel *(Scomberomorus guttatus)* (IOTC-2015-WPNT05-24). Catch data for bullet tuna (*Auxis rochei*) and frigate tuna (*Auxis thazard*) were considered too incomplete for the use of catch-based assessment methods.

Basic Biology

Longtail tuna (*Thunnus tonggol*) is an epipelagic species inhabiting tropical to temperate provinces of the Indo-Pacific, found almost exclusively in the neritic waters close to the shore, avoiding estuaries, turbid wasters and open ocean (Froese & Pauly 2015). It is one of the smallest species of the genus *Thunnus*, but relatively large compared with other neritic species with a maximum length of 145cm. Longtail tuna is primarily caught by gillnet fleets operating in coastal waters with the highest reported catches form Iran, Indonesia, Pakistan, Malaysia and, to a lesser extent, Oman, Yemen, India and Thailand (Pierre et al. 2014). Most research on longtail tuna has been focussed in these areas where there are important fisheries for the species, with the most common methods used to estimate growth being through length-frequency studies. These studies have provided varied estimates of growth, with von Bertalanffy *k* values ranging from 0.18 (Ghosh et al. 2010) – 1.5 (Itoh et al. 1999) with the majority of estimates somewhere in between. Some of these differences may be due to the different estimation techniques, due to regional differences in the maximum size of fish in the areas and due to differences in the size selectivity of the different fish sampling methods.

Fisheries and catch trends

Nominal catch data were extracted from the IOTC Secretariat database for the period 1950–2013, given that records for 2014 were still incomplete at the time of writing. Gillnet fleets are responsible for the vast majority of reported catches of longtail tuna with a much smaller proportion caught by purse seine and line gear, with the majority of catches taken by coastal country fleets (Figure 1).

Figure 2 shows the increase in total catches since 1950, highlighting a particularly rapid increase between 2004 and 2012, falling slightly in 2013 to 159 313 t (Table 1). Some revisions have been made to the nominal catch series since the assessment that took place in 2014, including an increase in the estimated catch for 2012 from 160 500 t to 170 000 t and a new catch estimate for 2013. These changes are shown in Figure 3.

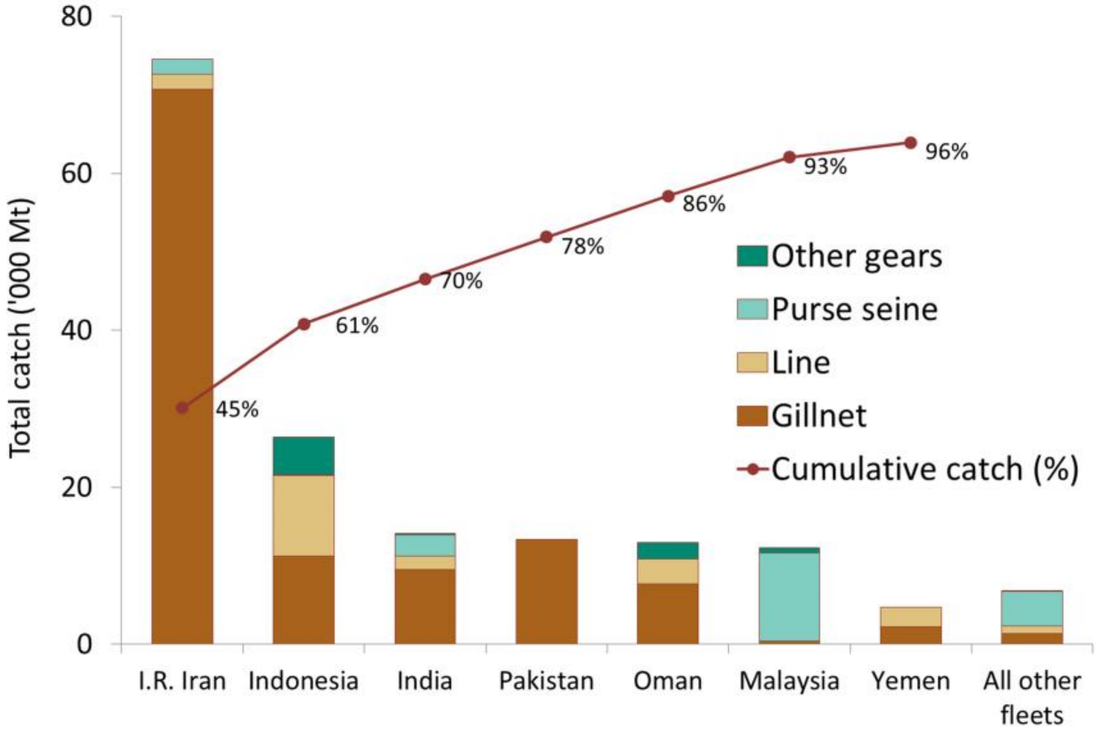

Figure 1. Average catches in the Indian Ocean over the period 2010-2013, by country. Countries are ordered from left to right, according to the level of catches of longtail tuna reported. The red line indicates the (cumulative) proportion of catches of longtail tuna for the countries concerned, over the total combined catches of this species reported from all countries and fisheries.

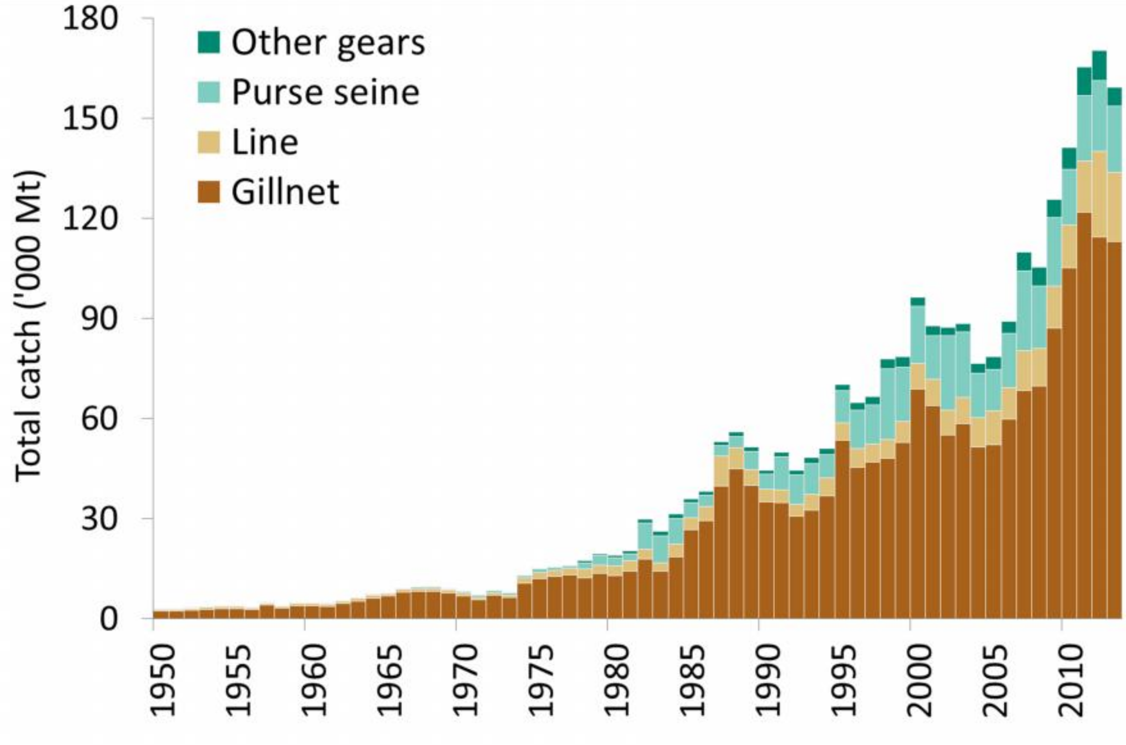

Figure 2. Annual catches of longtail tuna by gear as recorded in the IOTC Nominal Catch database (1950–2013)

Table 1. Catch data for *T. tonggol* in the Indian Ocean, 1950-2013 (source IOTC Nominal Catch Database)

Year	Catch (t)	Year	Catch (t)
1950	2,850	1982	29,810
1951	2,826	1983	26,264
1952	3,106	1984	31,392
1953	3,373	1985	35,850
1954	3,616	1986	38,147
1955	3,651	1987	52,963
1956	3,327	1988	55,950
1957	4,706	1989	51,474
1958	3,751	1990	44,448
1959	4,534	1991	49,813
1960	4,545	1992	44,413
1961	4,460	1993	48,238
1962	5,342	1994	51,112
1963	6,137	1995	70,252
1964	7,201	1996	64,759
1965	7,783	1997	66,500
1966	9,125	1998	77,807
1967	9,439	1999	78,556
1968	9,476	2000	96,315
1969	8,889	2001	87,671
1970	8,240	2002	87,260
1971	7,032	2003	88,443
1972	8,426	2004	76,392
1973	7,676	2005	78,498
1974	12,854	2006	89,081
1975	15,019	2007	109,851
1976	15,310	2008	105,260
1977	15,782	2009	125,601
1978	17,346	2010	141,115
1979	19,541	2011	165,327
1980	19,010	2012	170,348
1981	20,287	2013	159,313

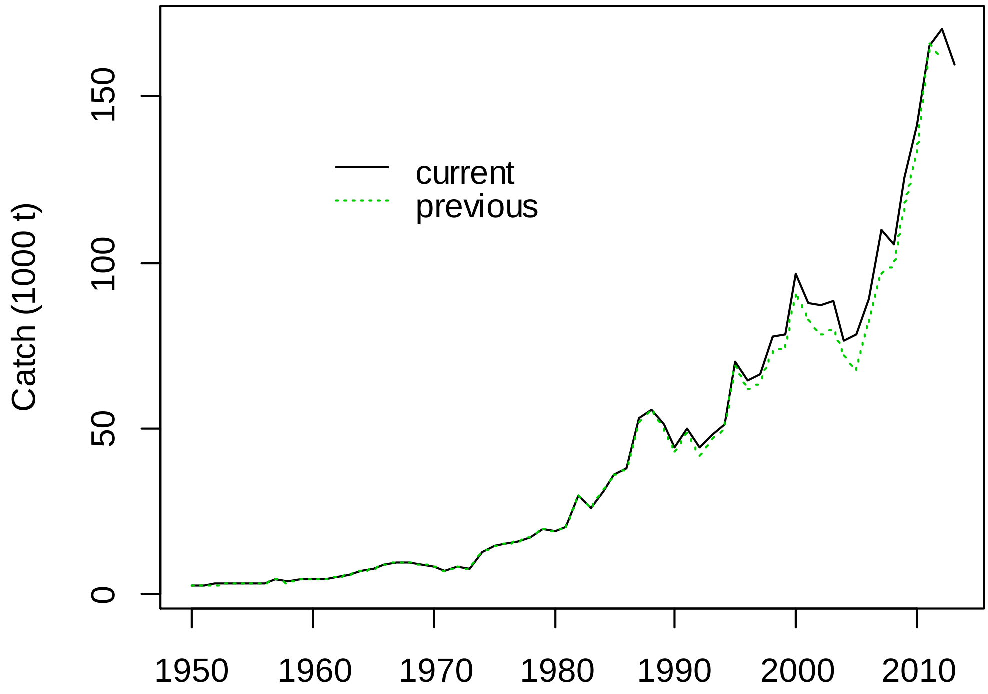

Figure 3. Revisions to longtail tuna nominal catch time series since the assessments in 2014

Methods

1) Catch-MSY method

This method, developed by Martell and Froese (2012) relies on only a catch time series dataset, which was available from 1950–2013, prior ranges of r and k and possible ranges of stock sizes in the first and final years of the time series. The Graham-Shaefer surplus production model (Shaefer 1954) is then used (Equation 1), where B_t is the biomass in time step t, r is the population growth rate, B_0 is the virgin biomass equal to carrying capacity, K, and C_t is the known catch at time t. Annual biomass quantities can then be calculated for every year based on a given set of r and K parameters.

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{B_0}\right) - C_t$$

Equation 1.

There are no known prior distributions of the parameters r and K, so a uniform distribution was used from which values were randomly drawn. A reasonably wide prior range was set for r based on the known level of resilience of the stock as proposed by Martell and Froese (2012) where stocks with a very low resiliency are allocated an r value from 0.015 - 0.1, low resiliency 0.05 - 0.5, medium resiliency 0.2 – 1 and high resiliency 0.6 – 1.5. Based on the FishBase classification, *T. tonggol* has a high level of resilience and so a range of 0.6 - 1.5 was used.

A reasonably wide prior range was also used for *K*, which ranged from the minimum catch in the times series to the maximum multiplied by 50, i.e. *K* = min(C) – 50*max(C). The ranges for starting and final depletion levels were based on the ratio of starting and final catch to the maximum as in Table 2. This essentially gives a lower initial biomass if the initial catch was large, relative to the maximum, and gives a higher initial biomass if the initial catch was relatively lower. Conversely, in terms of the final biomass, a higher biomass is expected with a high final catch (relative to the maximum) and a lower biomass if the final catch is lower relative to the maximum (Martell and Froese (2012).

Table 2. Rules to determine starting and final biomass levels were B is biomass and k is carrying capacity

	Catch/max catch	***B/k***
First year	<0.5	0.5 – 0.9
	≥0.5	0.3 – 0.6
Final year	>0.5	0.3 – 0.7
	≤0.5	0.01 – 0.4

This resulted in the prior ranges used for each species as specified in Table 3. The model worked sequentially through the range of initial biomass depletion level at intervals of 0.05 and random pairs of *r* and *K* were drawn based on the uniform distribution for the specified ranges. A Bernoulli distribution was then used as the likelihood function for accepting each *r*-*k* pair at each given starting biomass level based on the assumptions that the stock has never collapsed or exceeded carrying capacity and that the final biomass estimate which falls within the assumed depletion range. All *r*-*k* combinations for each starting biomass which were considered feasible were retained with the corresponding biomass trajectories.

Table 3. Prior ranges used for each species (Catch – MSY method)

Species	**Initial *B/k***	**Final *B/k***	***r***	***K (1000 t)***
Longtail – run 1	0.5 - 0.9	0.5 – 0.9	0.6 - 1.5	170 - 8517
Longtail – run 2			0.6 - 1.76	310 - 623

Management quantities were calculated based on geometric means of the standard Schaefer model equations, i.e.:

$MSY = \frac{rk}{4}$, $B_{MSY} = \frac{k}{2}$ and $F_{MSY} = -ln\left|1 - \left|\frac{MSY}{(Bmsy+MSY)}\right|\right|$

2) Optimised Catch Only Method (OCOM)

The Optimised Catch-Only Method was developed by Zhou *et al*. (2013) and also relies on only a catch time series dataset without necessary knowledge of prior distributions. The idea behind this approach is to use unconstrained priors on both r and K, that is $0 < K < \infty$ and $0 < r < \infty$. Because the two parameters are negatively correlated, the maximum K is constrained by $r = 0$ and maximum r is constrained by the minimum viable K. The aim of this approach is to identify the likely range of both r and K and the most likely $r \sim K$ combination on the curve which retain a viable population over time (i.e. where $Bt > Ct$, $Bt \leq K$ *and* $Bt > 0$ always hold true). This approach produces results from a number of trials are produced and the improbable values are then excluded, so the method is referred to as a posterior-focused catch-based method for estimating biological reference points (Zhou *et al.*, 2013).

The approach uses an optimisation model to estimate the feasible r value corresponding to a fixed final depletion level and a sampled K value by minimising the difference between the final biomass and the given depletion level (i.e. minimising the objective function $|B_{2013}– DK|$ where B_{2013} is the biomass in the final year). All feasible combinations of r and K are retained and the biomass dynamics model is re-run without any further constraints for a large number of simulations (500). The biomass trajectories are stored and those which are considered unfeasible according to the biomass constraints described above are removed.

Max K was set at 50 * max(C) and minimum K was set at max(C). The starting K population was set as a logarithmic sequence between these two values to obtain a higher density of low K values. Starting depletion levels comprised the range 0.05 to 0.8 in steps of 0.05. A wide prior range of r values was used, from 0.1 to 2. A biomass dynamics model was then run with the associated constraints: $Bt \leq K$, $Bt > 0$, $B > C$. The model assumed that the biomass in 1950 was equal to the carrying capacity ($Bt_{1950} = K$). The optimisation routine was then used to retain the r values which result in a biomass closest to the fixed final biomass by minimising the difference between B_{2013} and DK. Where the difference between the final biomass and the specified depletion level was >10% of K, the values were considered unfeasible and were not retained. This resulted in a matrix of r values for each combination of K and final depletion level.

As a second step in the method, estimates of the von Bertalanffy parameters L_∞ and K were derived from the literature (IOTC–2015–WPNT05–DATA13). Five different methods were then used to derive possible range for the intrinsic population growth rate r as used in IOTC–2014–WPNT04–25.

$r = 2$ µ‐M, where $\ln(M) = 1.44 – 0.982 \ln(t_m)$ (Hoenig 1983).

$r = 2$ µ‐M, where $\log(M) = 0.566 - 0.718 Log(L_\infty) + 0.02T$ (www.Fishbase.org);

$r = 2$ µ‐M, where $M = 1.65/t_{mat}$ (Jensen 1996).

$r = 2$ µ M, where $\ln(M) = 0.55 - 1.61 \ln(L) + 1.44 \ln(L_\infty) + \ln(©)$ (Gislason et al. 2010).

$r = 2\ \mu\ M$, where $M = (L/L_\infty)^{-1.5}$ © (Charnov et al. 2012).

This resulted in a set of estimated r values ranging from 0.47 to 1.74 with a mean of 1.04 ± 0.19 (2 s.d.). Values which were more or less than 2 s.d. removed from the mean were dropped so that ($0.66 \geq r \leq 1.42$). While depletion levels were originally set ranging up to 0.8, it is fairly unlikely that any tuna stock is only 20% depleted so a range of alternative maximum depletion levels were also explored (Table 4).

Table 4. Prior ranges used for each species (OCOM method)

Species	Initial *B/k*	Final *B/k*	*r*	*K (1000 t)*
Longtail	1	0.05 – 0.8	0.1 – 2	170 - 8517
		0.05 – 0.7	0.66 – 1.42	
		0.05 – 0.6		
		0.05 – 0.5		

As before, median *MSY* was calculated from *r* and *K* $MSY = \frac{rK}{4}$,

While median B_{MSY} and F_{MSY} were calculated from the equations $B_{MSY} = \frac{K}{2}$ and

$$F_{MSY} = -ln\left|1 - \left|\frac{MSY}{(Bmsy+MSY)}\right|\right|$$

The range of *r* and *K* values were further reduced by selecting only those combinations corresponding to the 25th - 75th percentile values of *MSY* and the biomass dynamics simulation model was run again for each retained combination of *r* and *K* values with no constraints on the final depletion level this time. While the three base parameters, r, K and MSY were obtained at the first step, the final biomass and depletion are largely controlled by the limiting conditions (i.e., the assumed depletions levels) imposed at this step so these were instead derived subsequently by re-running the model without a pre-defined depletion level. Uncertainty was introduced in terms of the variability in values of k and r used in each run as well as each year within model runs. For base runs, the maximum upper depletion level was set at $D \leq 0.7$ which seemed a fairly reasonable assumption.

Results

Catch-MSY method

The feasible *K* values did not reach the maximum available limit, instead ranging from 309 892 – 1 127 311 t while possible r values spanned through the full range possible under the assumptions (0.6 – 1.5). Given that r and *K* are confounded, a higher *K* generally gives a lower *r* value. At the extreme ends of the tail a very small change in *r* necessitates a large change in *K* to maintain a viable population and so these values are unlikely (Zhou et al. 2013). Therefore, the upper *K* boundary was reduced to the smallest *K* corresponding to the lowest r values to remove the less probable tail of the distribution, 623 411 (Figure 4) (Zhou et al., 2013) and the range for *r* was expanded to 1.2 multiplied by the maximum *r* (0.6 - 1.76). This resulted in slightly higher *r* and lower *K* estimates with little change in MSY (Figure 5). This was taken as the base model run and the results for this simulation are presented.

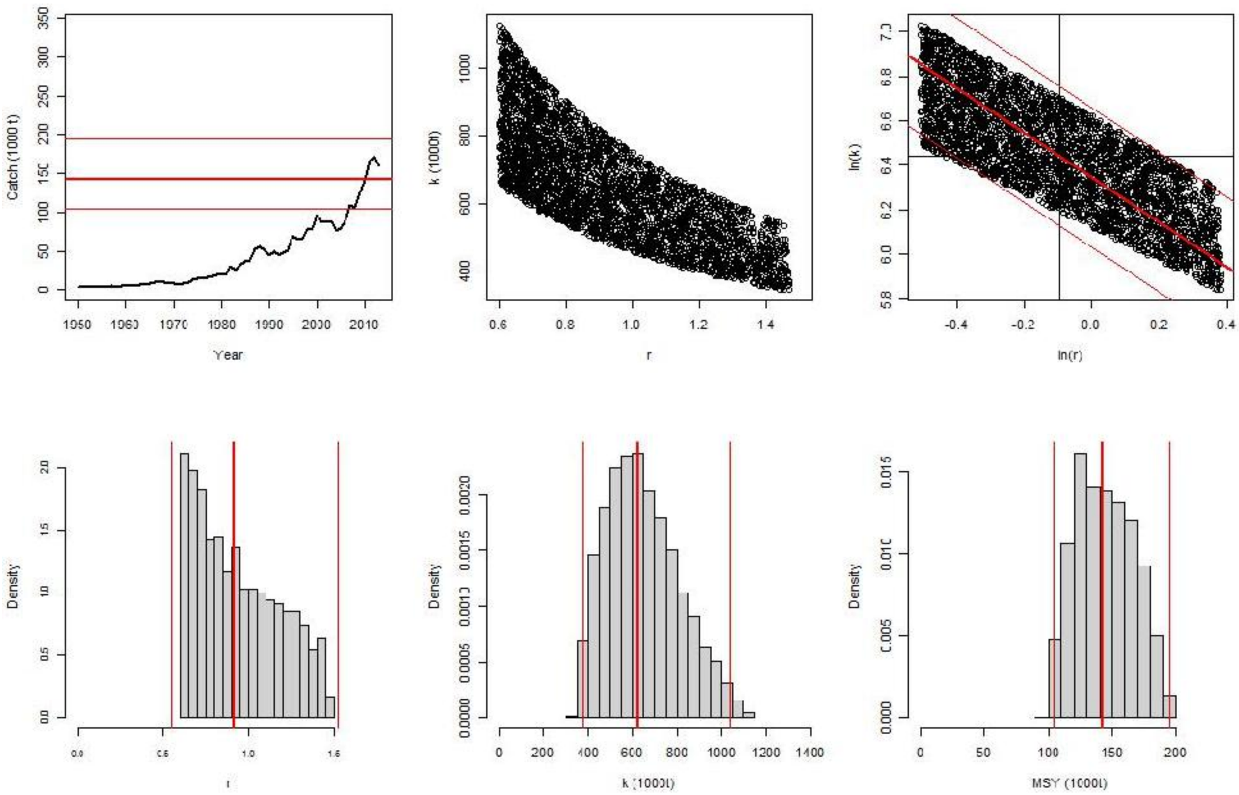

Figure 4. All feasible *r* and *K* combinations resulting from model simulations based on the original parameter constraints

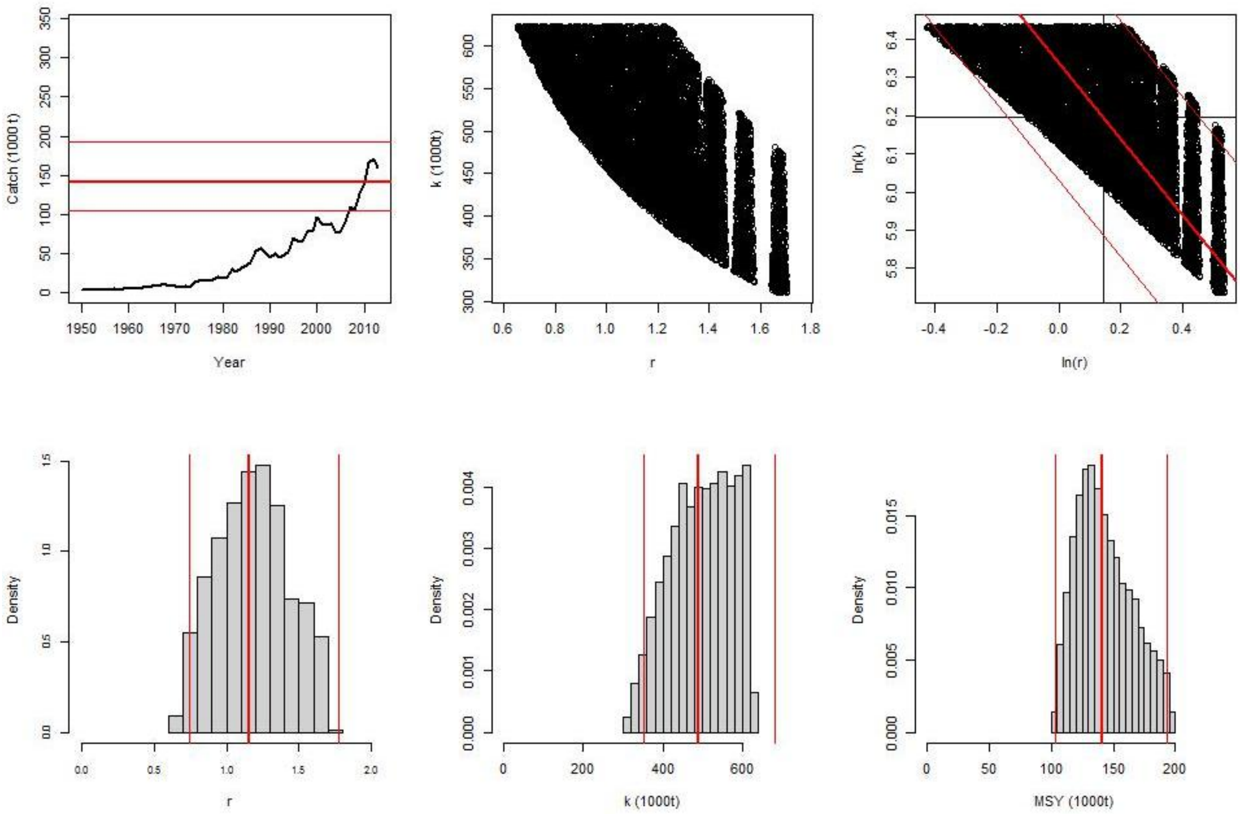

Figure 5. All feasible *r* and *K* combinations with further parameter constraints on max(K)

Results are provided for the simulated biomass trajectories for all plausible *r*, *K* and starting biomass combinations. While the absolute values are highly dependent on the prior ranges set, the results all suggest a slight increase in biomass in the early 2000s followed by a rapid decline. These results are a reflection of the trend in catches (Figure 2). Table 6 provides a summary of the distributions of the key biological parameters across all feasible runs at all starting depletion levels. Table 7 provides a further breakdown of these results based on the assumed initial biomass level with median values highlighted in bold. The similarity of these results indicates the robustness of this approach to the assumed starting biomass level, particularly with respect to the key reference point median MSY estimate which remains at approximately 130 000 t across all starting biomass levels. Management quantities based on geometric means and plausible ranges are provided in Table 8 which give a slightly higher average MSY, 133 044.

The IOTC target and limit reference points for longtail tuna have not yet been defined, so the values applicable for all other IOTC species are used as in Table 5. The KOBE matrix plot indicates that based on the Catch-MSY model results, longtail is overfished (B2013/Bmsy = 0.92) and is subject to overfishing (F2013/Fmsy = 1.23) (**Figure 6**).

Table 5. IOTC reference points for *T. tonggol* (IOTC–2015–WPNT05–INF01)

Stock	Target Reference Point	Limit Reference Point
Other IOTC species	B_{MSY}; F_{MSY}	50% of B_{MSY}; 20% above F_{MSY}

Table 6. Key biological parameters from the Catch-MSY assessment for all starting depletion levels (0.5-0.9)

Quantile	K	r	Bmsy	MSY	Bend	Final D
0%	306 045	0.65	153 022	101 411	93 473	0.31
25%	482 999	0.90	241 500	119 689	195 268	0.40
50%	**536 837**	**1.03**	**268 418**	**130 330**	**243 254**	**0.45**
75%	582 219	1.14	291 109	146 219	304 213	0.52
100%	621 295	1.70	310 648	199 152	433 228	0.70

Table 7. Key biological parameters from the Catch-MSY assessment under four assumed starting depletion levels

Initial D	Quantile	K	r	Bmsy	MSY	Bend	Final D
0.8	0%	375 135	0.65	187 568	101 411	114 019	0.30
0.8	25%	482 805	0.92	241 403	120 629	197 102	0.41
0.8	50%	536 113	1.05	268 057	131 699	247 539	0.46
0.8	75%	582 289	1.18	291 145	148 400	311 100	0.53
0.8	100%	621 295	1.30	310 648	193 791	433 228	0.70
0.7	0%	342 270	0.65	171 135	101 411	102 956	0.30
0.7	25%	470 535	0.90	235 268	119 670	190 850	0.41
0.7	50%	528 209	1.03	264 104	130 304	237 836	0.45
0.7	75%	578 257	1.14	289 128	145 649	297 723	0.51
0.7	100%	621 295	1.47	310 648	196 578	410 232	0.66
0.6	0%	306 045	0.65	153 022	101 411	93 473	0.31
0.6	25%	478 405	0.89	239 203	119 143	192 797	0.40
0.6	50%	537 137	1.02	268 569	130 115	239 737	0.45
0.6	75%	583 029	1.13	291 514	145 576	299 198	0.51
0.6	100%	621 295	1.70	310 648	199 152	418 371	0.67
0.5	0%	381 563	0.65	190 782	101 411	116 742	0.31
0.5	25%	485 570	0.91	242 785	120 177	197 027	0.41
0.5	50%	537 942	1.04	268 971	130 884	246 912	0.46
0.5	75%	583 325	1.16	291 663	147 274	310 029	0.53
0.5	100%	621 295	1.28	310 648	193 791	433 228	0.70

Table 8. Key management quantities from the Catch MSY assessment for Indian Ocean logntail tuna. Geometric means and plausible ranges across all feasible model runs. n.a. = not available.

Management Quantity	Aggregate Indian Ocean
Most recent catch estimate (2013)	159 312 t
Mean catch from 2009–2013 (5-yrs)	142 101 t
MSY (plausible range)	133 044 (101 411 - 199 152)
Data period used in assessment	1950 - 2013
F_{MSY} (plausible range)	0.41 (0.28 - 0.62)
B_{MSY} (plausible range)	261 900 (153 022 – 310 648)
F_{2013}/F_{MSY} (plausible range)	1.23 (0.64 – 2.17)
B_{2013}/B_{MSY} (plausible range)	0.92 (0.60 – 1.40)
SB_{2013}/SB_{MSY} (80% CI)	n.a
B_{2013}/B_0 (plausible range)	0.46 (0.30 - 0.70)
SB_{2013}/SB_0 (80% CI)	n.a
$B_{2013}/B_{0,\ F=0}$ (80% CI)	n.a
$SB_{2013}/SB_{0,\ F=0}$ (80% CI)	n.a

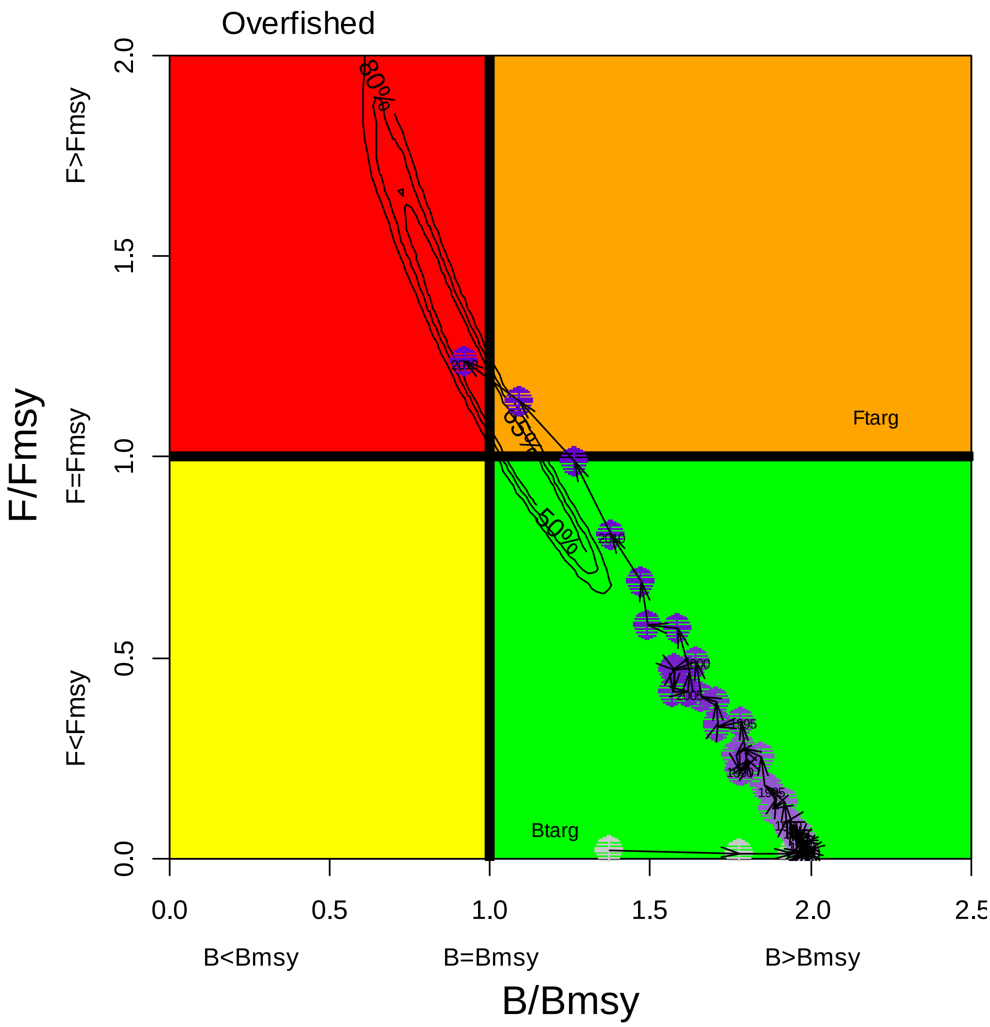

Figure 6. Longtail tuna. Catch-MSY Indian Ocean assessment Kobe plot for longtail tuna**.** The Kobe plot presents the trajectories for the range of plausible model options included in the formulation of the final management advice. The trajectory of the geometric mean of the plausible model options is also presented.

OCOM method

Figure 7 shows the initial plausible range of *r* and *K* parameter values retained by the biomass dynamics model. This range was further narrowed with the introduction of informative priors based on the literature Figure 8.

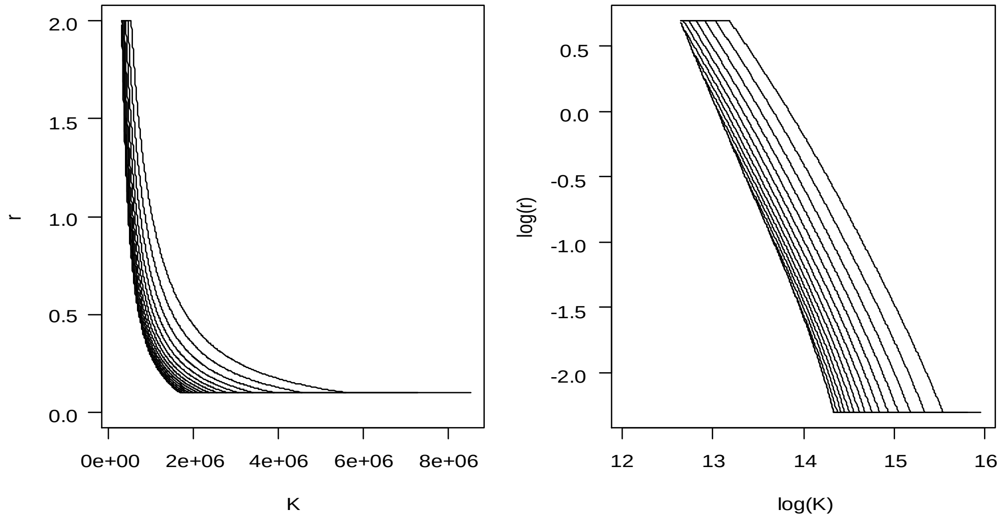

Figure 7. Initial plausible range of r and K values (non-informative priors)

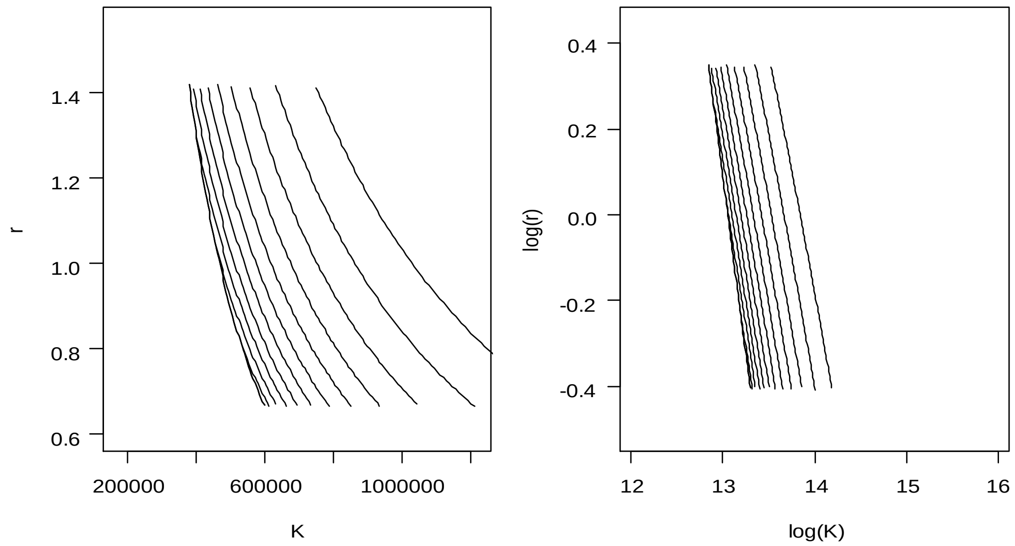

Figure 8. Plausible range of r and K with informative priors on r (0.66 – 1.42)

The range of values was dependent on the level of stock depletion assumed for the final year, with *r*, *K* and *MSY* all positively correlated with the depletion level (Figure 9). There were no feasible solutions found when the depletion level was assumed to be lower than 0.2.

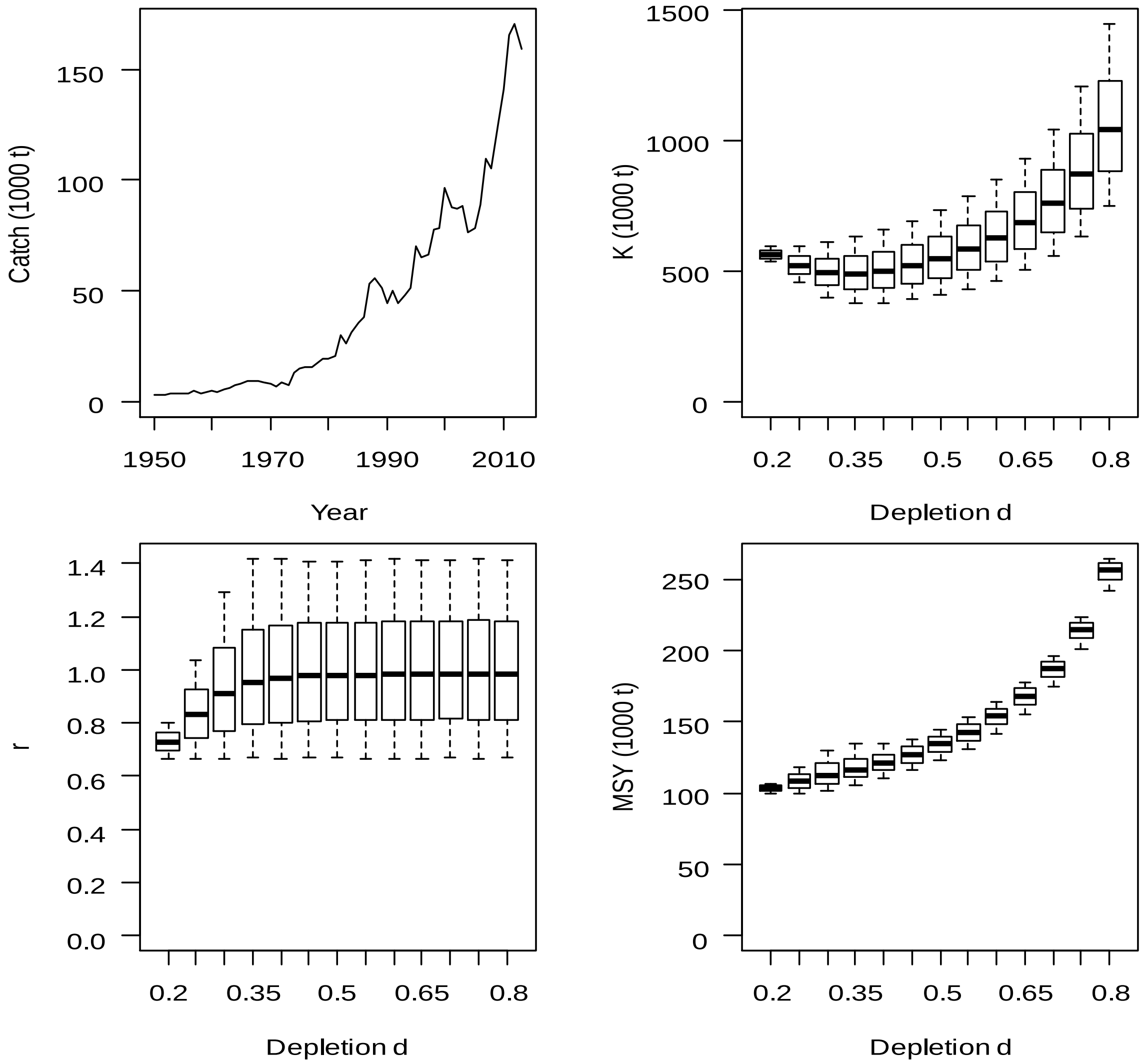

Figure 9. Longtail tuna catch history, feasible carrying capacity, population growth rate and MSY at each assumed depletion level. There is no feasible solution when the depletion is assumed to be below 0.2.

Base case model results (for a maximum depletion level of 0.7) indicate that the biomass was nearly 565 000 t in 1950 and declined to approximately 294 000 t in 2013 (Figure 10). The estimated MSY associated with this projection is 134 437 t and ranges from approximately 100 000 t to 196 000 t based on the assumed depletion level (Table 9).

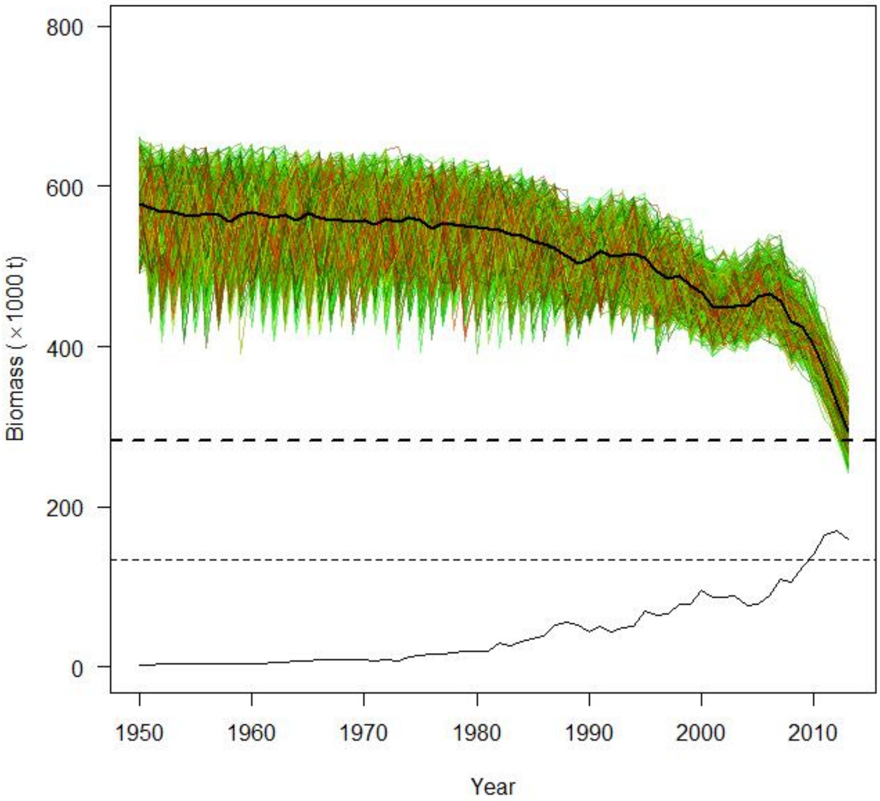

Figure 10. Longtail tuna biomass trajectories from 500 simulations with upper depletion = 0.7.

Table 9. OCOM key biological parameters for longtail tuna under four assumed upper depletion levels[2]

Upper d	Quantile	K	r	MSY	B_{2013}	D
0.8	0%	378 984	0.67	99 657	291 367	0.46
0.8	25%	510 506	0.79	123 765	338 765	0.53
0.8	50%	601 867	0.96	143 860	359 289	0.56
0.8	75%	767 446	1.16	184 534	383 123	0.60
0.8	100%	1 448 213	1.42	264 643	463 403	0.71
0.7	0%	378 983	0.67	99 657	242 878	0.42
0.7	25%	490 882	0.79	119 820	278 992	0.48
0.7	**50%**	**565 279**	**0.95**	**134 437**	**293 671**	**0.51**
0.7	75%	661 238	1.15	157 928	308 447	0.53

[2] NB While K, R and MSY are derived from the optimisation model, B_{2013} and the final depletion level, D are highly dependent on the fixed assumptions and so the values presented here are from a further, unconstrained model run.

0.7	100%	1 041 917	1.42	196 480	358 682	0.61
0.6	0%	378 984	0.67	99 657	192 789	0.36
0.6	25%	471 091	0.78	116 499	235 261	0.44
0.6	50%	537 199	0.94	128 101	243 977	0.45
0.6	75%	606 604	1.14	141 006	255 470	0.47
0.6	100%	849 786	1.42	163 591	301 384	0.55
0.5	0%	378 984	0.67	996 57	157 719	0.31
0.5	25%	453 868	0.78	112 671	194 770	0.38
0.5	50%	518 573	0.93	121 771	203 369	0.39
0.5	75%	578 731	1.12	129 580	214 555	0.41
0.5	100%	732 182	1.42	144 335	246 251	0.47

Future projections were run up to 2020 based on two different catch scenarios. The first scenario assumes the future catch remains constant. This was simulated as a constant catch tonnage, equal to the catch in 2013, and resulted in a very rapid decline of the stock (Figure 11). This is an unlikely scenario given that catch rates generally decline with decreasing biomass, so as an alternative this was also simulated as the catch relative to the target biomass level remains at the current level, i.e. a constant catch rate of $C2013/B_{MSY}$. This is more intuitive than projecting a constant catch level into the future as factors such as changing catchability based on availability are likely to affect the rate at which a stock can decrease, so a catch rate projection provides a more realistic scenario. This projection predicts that the catch decreases from the 2013 level but remains at a relatively high level, resulting in a stock biomass which stabilises somewhat below B_{MSY} (Figure 12).

The second set of projections were based on the assumption that a constant catch of MSY was achieved annually. This was also simulated as a fixed future catch level (Figure 13) as well as a fixed future catch rate equal to the optimum rate for achieving the target biomass, i.e. MSY/ B_{MSY} (Figure 14). While both of these projections result in a biomass which rapidly stabilises at the corresponding B_{MSY} level there is more uncertainty associated with the fixed catch level compared with the fixed catch rate. This is due to the high uncertainty in the biomass level and so here a fixed catch level is more indicative of a management scenario, whereas achieving a fixed catch rate would be extremely difficult to achieve in practice and so provides a less realistic scenario.

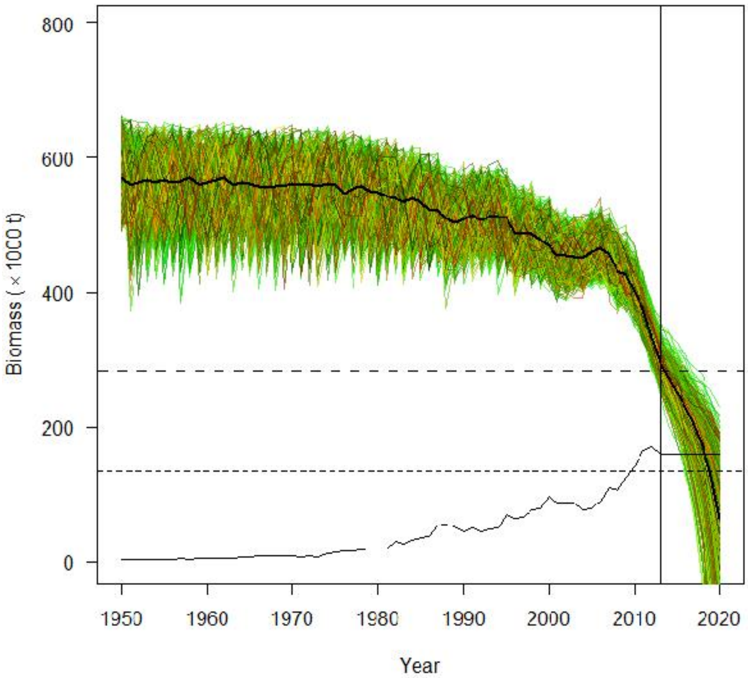

Figure 11. Projected longtail biomass trajectories under hypothetical annual catches equivalent to those of the final year (C2013) until 2020. The vertical line is the last year (2013) for which catch data are available.

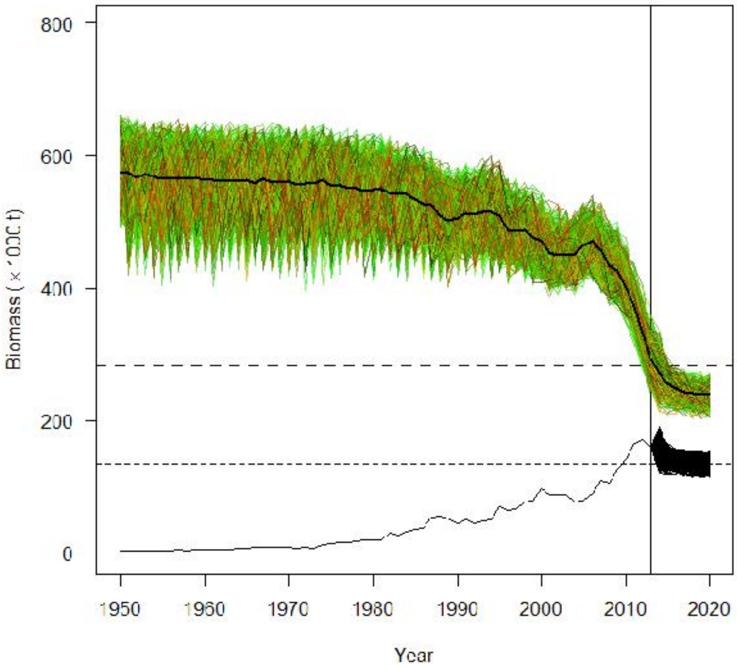

Figure 12. Projected longtail tuna biomass trajectories under hypothetical annual catch rate (C2013/B_{MSY}) at 2013 level until 2020. The vertical line is the last year (2013) for which catch data are available.

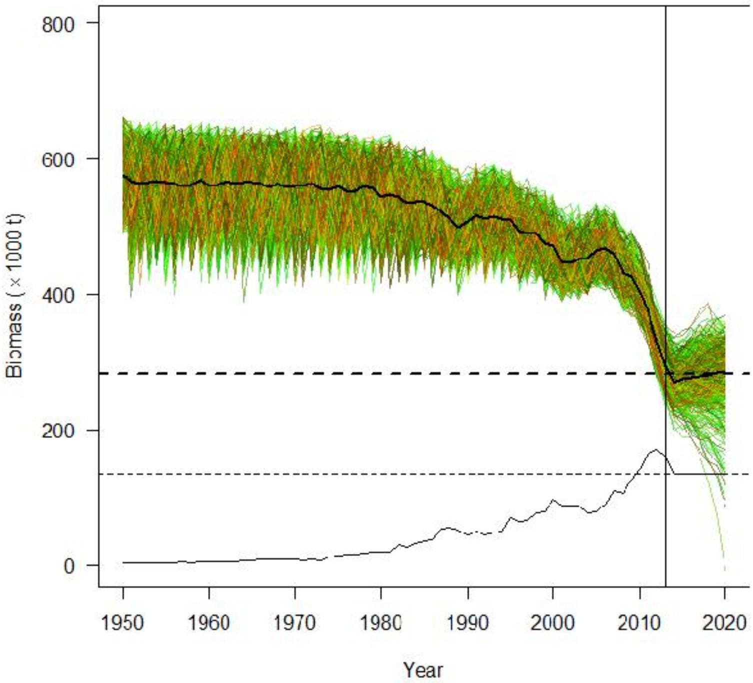

Figure 13. Projected longtail tuna biomass trajectories under hypothetical future annual catch equivalent to MSY until 2020. The vertical line is the last year (2013) for which catch data are available.

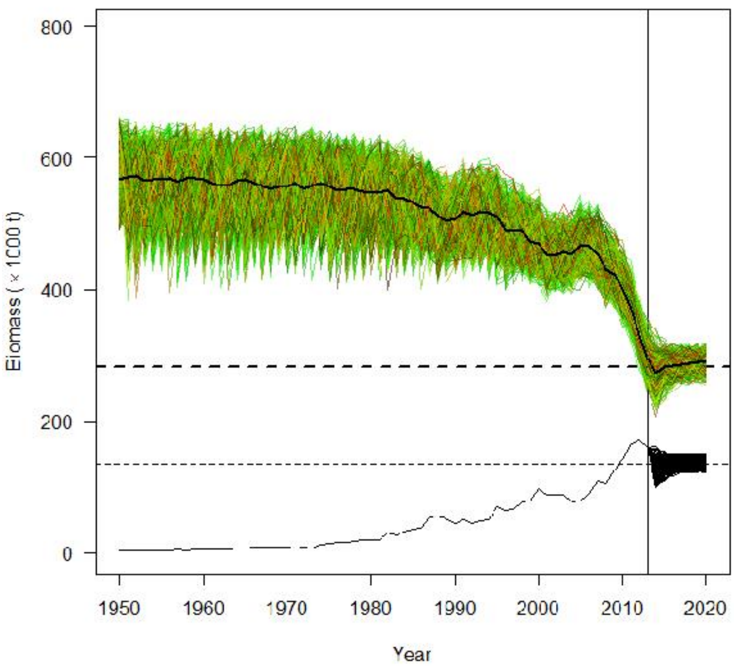

Figure 14. Projected longtail tuna biomass trajectories under hypothetical annual catch rate at MSY level (C_{MSY}/B_{MSY}) until 2020. The vertical line is the last year (2013) for which catch data are available.

Management quantities based on geometric means and plausible are provided in Table 10. The geometric mean MSY, 137 687 t, is slightly higher than the median. The KOBE matrix plot based on the OCOM model results indicates that longtail is not currently overfished ($B_{current}$ /B_{MSY} = 1.02) but is subject to overfishing ($F_{current}$/F_{MSY} = 1.11) (**Figure 15**).

Table 10. Key management quantities from the OCOM assessment for Indian Ocean longtail tuna, using a base case with maximum depletion of 70%. Geometric means and plausible ranges in brackets. n.a. = not available.

Management Quantity	**Indian Ocean**
Most recent catch estimate (2013)	159 313 t
Mean catch from 2009–2013 (5-yrs)	142 457 t
MSY (plausible range)	137 687 t (99 657 –196 480)
Data period used in assessment	1950 – 2013
F_{MSY} (plausible range)	0.39 (0.29 – 0.54)
B_{MSY} (plausible range)	287 920 (189 492 – 520 958)
F_{2013}/F_{MSY} (plausible range)	1.11 (0.94 – 1.29)
B_{2013}/B_{MSY} (plausible range)	1.02 (0.84 - 1.25)
SB_{2013}/SB_{MSY} (80% CI)	n.a
B_{2013}/B_0 (plausible range)	0.56 (0.33 - 0.86)
SB_{2013}/SB_0 (80% CI)	n.a
$B_{2013}/B_{0,\ F=0}$ (80% CI)	n.a
$SB_{2013}/SB_{0,\ F=0}$ (80% CI)	n.a

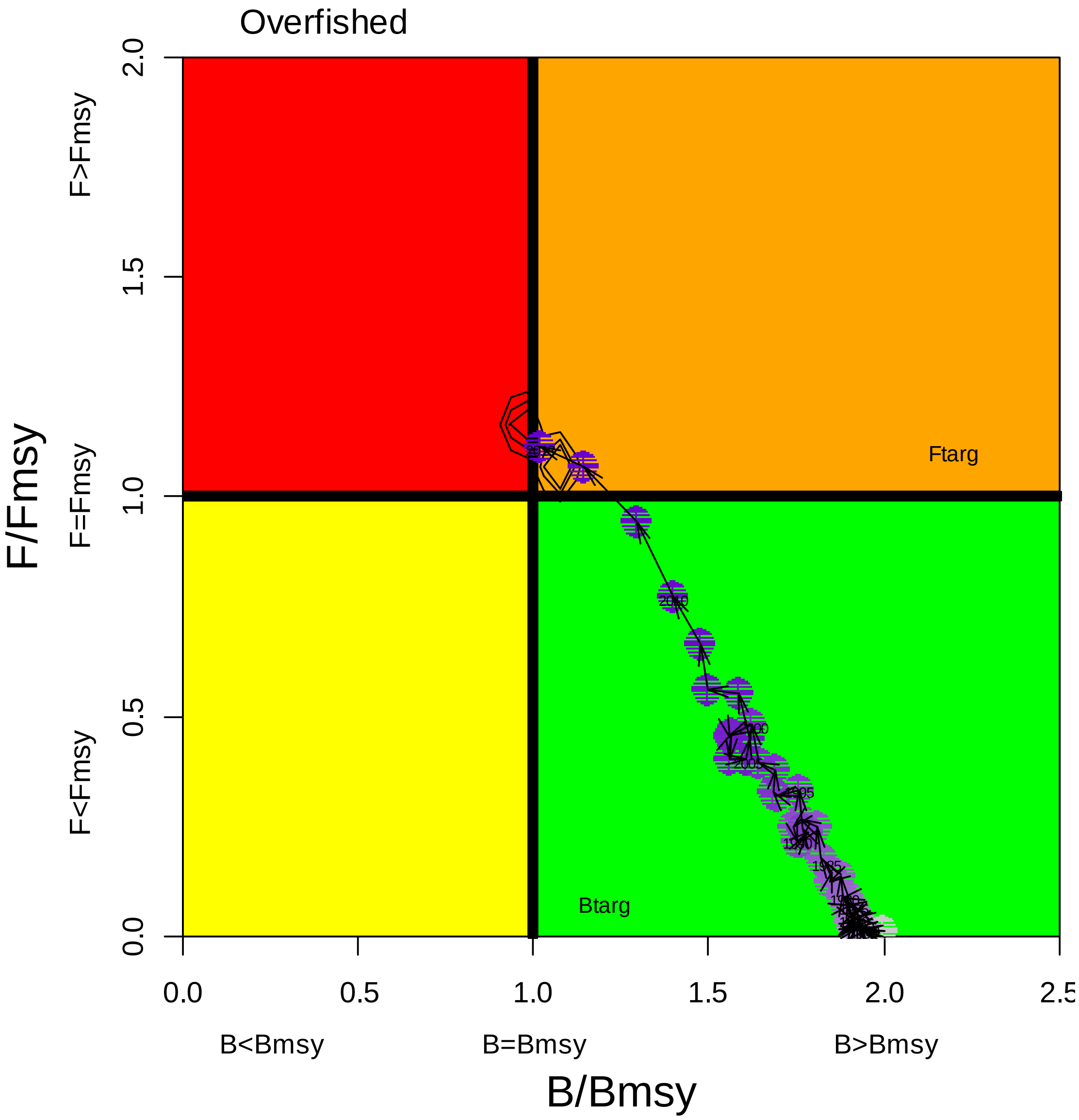

Figure 15. Longtail tuna OCOM Indian Ocean assessment Kobe plot. The Kobe plot presents the trajectories for the range of plausible model options included in the formulation of the final management advice. The trajectory of the geometric mean of the plausible model options is also presented.

Discussion

Both models provided relatively robust estimates of MSY with respect to the different assumptions tested in terms of prior ranges set on key parameter values. The OCOM method resulted in a median MSY estimate of 134 000 t while the Catch-MSY method estimated MSY at 130 000 t. These estimates are both within the boundaries of the estimates produced in 2014 which were 120 000 and 135 000 for the OCOM and Catch-MSY methods respectively (IOTC–2014–WPNT04–25). Although total catches decreased between 2012 and 2013 from 170 000 to 159 000 t, catches are still well above the estimated level of MSY. This is reflected in the key management reference points which are also similar between models. The stock is likely to be subject to overfishing with an F_{2013}/F_{MSY} ratio of 1.23 and 1.11 for the Catch-MSY and OCOM models respectively. These estimates also correspond well to those of the previous assessments in 2014 which were 1.08 and 1.23 (IOTC–2014–WPNT04–25).

Estimates of the B_{2013}/B_{MSY} ratio were slightly lower this year, however, at 0.92 and 1.02 for the Catch-MSY and OCOM models respectively compared with 1.12 and 1.05 from the previous assessments (IOTC–2014–WPNT04–25). This may potentially be reflective of the drop in catches which took place between the two assessments from 2012 to 2013. Thus, on the weight-of-evidence currently available, and using the precautionary lower estimates, the stock is considered to be '*overfished*', though there are substantial uncertainties which are described throughout this paper.

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