IOTC–2013–WPB11–28_Rev1

STOCK ASSESSMENT OF THREE BILLFISH SPECIES IN INDIAN OCEAN, BLUE, BLACK AND STRIPED MARLIN USING STOCK REDUCTION METHODS

PREPARED BY: IOTC SECRETARIAT, 3 SEPTEMBER 2013
Dr. Rishi Sharma

Abstract

We conduct stock assessments for three Indian Ocean billfish; blue, black and striped marlin. We used a catch-based stock reduction analysis method. The method is based on a classical biomass dynamics model, requires only catch history but not fishing effort or CPUE. Known population growth rate will improve the assessment result. In this paper, we assume that all three species in the whole Indian Ocean belong to a single stock and the population size in 1950 is the virgin biomass equal to their carrying capacities. We use recently updated catch data in the analysis.

The preliminary results show that for blue marlin the geometric mean virgin biomass is about 86-432 thousand tonnes using the assumption that depletion in 2011 is between 30% and 70%. The combination of such carrying capacity and growth rate can support a maximum sustainable yield (MSY) of 6-15.1 thousand tonnes. This means that catch levels in recent years may have exceeded MSY. Overfishing maybe occurring on the stock though the stock does not appear to be overfished.

The situations are similar for Black marlin. The geometric mean virgin biomass was about 30.8 to 115 thousand tonnes, and the intrinsic population growth rate is about 0.58 (0.25-1.3 95% CI. The entire stock can support a MSY of nearly 8.6 thousand tonnes. The stock appears to be healthy and approaching optimal fishing levels in recent years.

Finally for striped marlins, the outcome is not optimistic. The geometric mean virgin biomass was about 37.5 to 85.4 thousand tonnes, and the intrinsic population growth rate is about 0.29 (0.18-0.49 95% CI. The entire stock can support a MSY of nearly 4.2 thousand tonnes. Catch levels in recent year may have been too high, and likely overfishing is occurring on the stock.

Introduction

In standard stock assessments conducted in the IO region, a index of abundance is essential to capture trends in biomass over time. In 2012, the CPUE trends derived on Blue and Striped marlin were indicating downward trends in abundance, and this year a standardized CPUE trend was estimated for blue, and striped marlin (WPB 11-23 WPB 11-24).

Methods developed by CSIRO (draft report "Quantitatively defining biological and economic reference points in data poor fisheries" by Zhou et. al. 2013) highlights some methods developed for data poor fisheries using data rich fisheries as a testing platform. The primary method that is of use there is a technique called Stock reduction Analysis (Zhou et. al. 2012,Walters et. al. 2006, Martell and Froese 2012, Kimura and Tagart 1982) making assumptions about initial state of the Biomass, middle of the time series what the biomass levels are and the biomass level ranges for the last year. The technique builds on simple surplus production models (like Shaefer, 1954), that use removal data and some estimate of carrying capacity and k. Ideally, these models should have some measure of the changes in abundance over time, but as shown in Martell and Froes 2012, and Walters et. al. 2006, a narrow range of r-K parameter can be obtained through simulation techniques that maintain the population, so that it neither collapse or exceeds the carrying capacity, K. This is the primary basis of the method developed an used here.

Blue Marlin (*Makaira mazara*)

Basic Biology

This species is basically found in the epipelagic zone and found mostly in tropical/equitorial waters on the warmer side of 24 degrees. It is seen primarily in the Pacific and Indian Oceans.The Atlantic species is quite similar to the Indo_Pacific and they have now been considered as a single pantropical species occurring in the Atlantic, Pacific and Indian Oceans (www.fishbase.net). The tend to school very minimally, are primarily solitary in their ocean distributions, and feed on squids, tuna-like species, crustaceans and cephalopods (Nakamura 1985). See Appendix 1 on Catch trends of Blue Marlin.

Black Marlin (*Makaira indica*)

Basic Biology

This species is basically oceanic, usually found in surface waters above the thermocline, often near shore close to land masses, islands and coral reefs in tropical and subtropical waters of the Indian and Pacific oceans. They feed on fishes, squids, cuttlefishes, octopods, large decapod crustaceans and mostly on small tunas when abundant (Nakamura 1985). Occasionally stray individuals migrate into the Atlantic Ocean by way of the Cape of Good Hope, but are not seen as a distinct breeding population there (www.fishbase.net). See Appendix 1 on Catch trends of Black Marlin.

Striped Marlin (*Tetrapturus audax*)

Basic Biology

Epipelagic and oceanic species, usually found above the thermocline in tropical waters of the Indian and Pacific oceans. They generally inhabit cooler water than either black (*Makaira indica*) or blue marlin (*M. mazara*) and are the most dominant and widely distributed of all billfishes. Their abundance increases with distance from the continental shelf. They don't school are normally solitary and feed on fishes, crustaceans and squids (www.fishbase.net) . In the Indian Ocean, fish are more densely distributed in equatorial regions with higher concentrations off eastern Africa, in the western

Arabian Sea, the Bay of Bengal and off northwestern Australia (Nakamura 1985). See Appendix 1 on Catch trends of Striped Marlin.

Catch Trends (See Table 1 and Appendix 1 for Catch trends on Marlins)

Table 1: Catch data on IO Blue, Black and Striped Marlin from 1950-2011 (source IOTC Database)

Year	SWO(t)	BLM(t)	BUM(t)	MLS(t)	SFA(t)		Year	SWO(t)	BLM(t)	BUM(t)	MLS(t)	SFA(t)
1950	43	49	1	1	336		1981	2,767	1,260	3,592	5,996	1,941
1951	41	48	6	6	317		1982	3,609	2,332	4,267	3,250	4,321
1952	44	179	396	85	359		1983	4,132	2,573	4,996	3,946	3,085
1953	65	535	1,268	274	428		1984	3,943	2,347	5,095	3,849	3,318
1954	215	877	3,011	819	577		1985	4,994	2,337	6,302	4,863	3,356
1955	286	985	3,515	865	804		1986	5,766	2,581	7,097	7,271	3,800
1956	621	1,484	4,955	1,921	1,010		1987	6,598	2,801	8,280	6,412	3,844
1957	448	1,680	3,794	1,903	788		1988	9,188	2,641	6,427	4,824	5,135
1958	665	1,567	4,193	1,905	700		1989	8,125	2,789	8,004	4,660	4,990
1959	768	1,559	4,558	2,535	1,023		1990	8,545	2,577	6,381	2,717	5,129
1960	812	1,741	3,921	2,314	1,311		1991	9,362	2,756	6,612	3,809	5,263
1961	969	1,768	3,454	2,689	1,260		1992	15,742	3,969	9,018	3,724	6,885
1962	1,177	1,908	3,335	2,023	1,186		1993	25,934	4,429	10,073	7,960	8,498
1963	1,128	1,325	2,248	1,848	1,063		1994	27,408	6,013	9,400	5,735	10,705
1964	1,428	1,619	3,506	2,079	1,062		1995	32,002	5,197	8,972	6,546	12,138
1965	1,556	1,397	3,743	3,486	1,065		1996	36,262	5,972	10,378	6,338	13,385
1966	1,512	1,311	3,572	4,249	1,235		1997	35,879	6,853	12,471	5,152	14,216
1967	1,882	1,518	4,133	4,568	1,357		1998	38,173	5,779	12,972	5,506	11,574
1968	1,968	2,188	3,829	3,416	1,430		1999	36,246	6,037	12,145	4,596	12,146
1969	2,217	2,144	3,506	4,221	1,156		2000	35,543	7,948	11,625	4,259	15,079
1970	2,756	2,471	4,432	3,924	1,137		2001	32,545	7,378	8,667	3,458	14,566
1971	2,232	1,812	3,651	2,458	1,170		2002	33,602	6,490	10,193	3,430	13,845
1972	2,090	1,448	3,811	2,311	1,137		2003	38,424	7,736	12,642	3,445	17,940
1973	1,747	959	2,709	1,769	849		2004	41,489	9,836	15,417	4,170	19,844
1974	2,194	1,678	3,755	3,643	1,402		2005	36,318	7,451	16,090	3,304	15,772
1975	2,528	1,599	3,716	2,944	1,472		2006	33,799	8,585	14,080	3,520	17,185
1976	2,126	912	2,687	3,278	1,654		2007	30,561	8,182	10,514	2,766	19,569
1977	2,207	847	2,671	4,601	1,678		2008	24,961	9,548	9,884	2,731	20,831
1978	2,685	1,066	3,962	6,935	1,678		2009	25,261	9,925	10,230	2,324	24,972
1979	2,635	978	4,837	4,493	1,677		2010	24,613	8,777	9,402	2,397	28,276
1980	2,759	1,536	4,342	5,889	2,404		2011	21,838	10,291	10,340	2,470	28,821

Methods

We use a newly developed stock assessment method in this paper. This method is based on catch data and does not require fishing effort or CPUE data. The method involves several steps. It applies a simple population dynamics model, starts with wide prior ranges for the key parameters, and includes the available catch data in the model. Then the model systematically searches through possible parameter spaces and retains feasible parameter values. Mathematically and biologically unfeasible values are excluded from the large pool of data. We progressively derive basic parameters, and carry out stochastic simulations using these base parameters to get biomass trajectories and additional parameters. Finally, we project to future biomass to explore alternative harvest policies.

We use following Graham-Shaefer surplus production model (Shaefer 1954):

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

Where B_t is biomass in time step *t*, *r* is the population growth rate, B_0 is the virgin biomass equal to carrying capacity K, and C is the known catch.

This simple model has two unknown parameters, r and K. We set reasonably wide prior range, for example, *K* between C_{max} and 500 * C_{max}. We used the approach proposed in Martell and Froese (2012) for "resiliency" estimates that tied to the productivity parameter r (low resiliency levels indicated r between 0.05-0.5, medium resiliency indicated a r between 0.2-1, and high between 0.5-1.5). These were compared to values obtained in the literature and alternative methods.

We run model (1) to find all mathematically feasible *r* values by searching through wide range of Ks for all depletion levels. If the feasible choice of r and k chosen meets the intermediate (0.1 and 1 level of depletion in 1980), and last point depletion levels (the range specified was 0.3-0.7 level of depletion for the Marlin stocks) it is kept. The summary of all runs which meet these criteria are then used, and geometric mean values are reported to be the better representation of yield targets (Martell and Froese 2012). Biological parameters, including K, r, MSY, are derived from the retained pool of [r, K] values. The geometric mean values of these are then used to assess the stock dynamics over time and reported using a phase plot.

Results

Blue Marlin:

Catches of Blue Marlin appear to be increasing steadily over the last 50 years in the Indian ocean region. Based on assumptions used in the simulation (see methods above), the following can be ascertained about Blue Marlin (Table 2, Figure 2). Note, while the estimates of yield are quite useful relative reference points are difficult to estimate, but are useful as an indicator for the stock. It appears (Figure 2) that these stocks were overfished in the early 2000's when the catches were high, but biomass never really declined below optimal levels. Catch levels in 2011 may still be too high though nearer to the median estimate, and within the 95% Confidence interval.

Table 1: Key parameters associated with the stock production analysis for Blue Marlin

Parameter	Lower 95% CI	Geometric Mean	Upper 95% CI
r	0.06	0.19	0.6
K	86800	193823	433805
MSY	6004	9524	15105
B_{MSY}	43400	96913	216903
B_{2011}/B_{MSY} *	0.03	1.03	2.31
F_{2011}/F_{MSY} *	0.63	1.05	1.47

* Uncertainty approximated on all combinations that fit the criteria

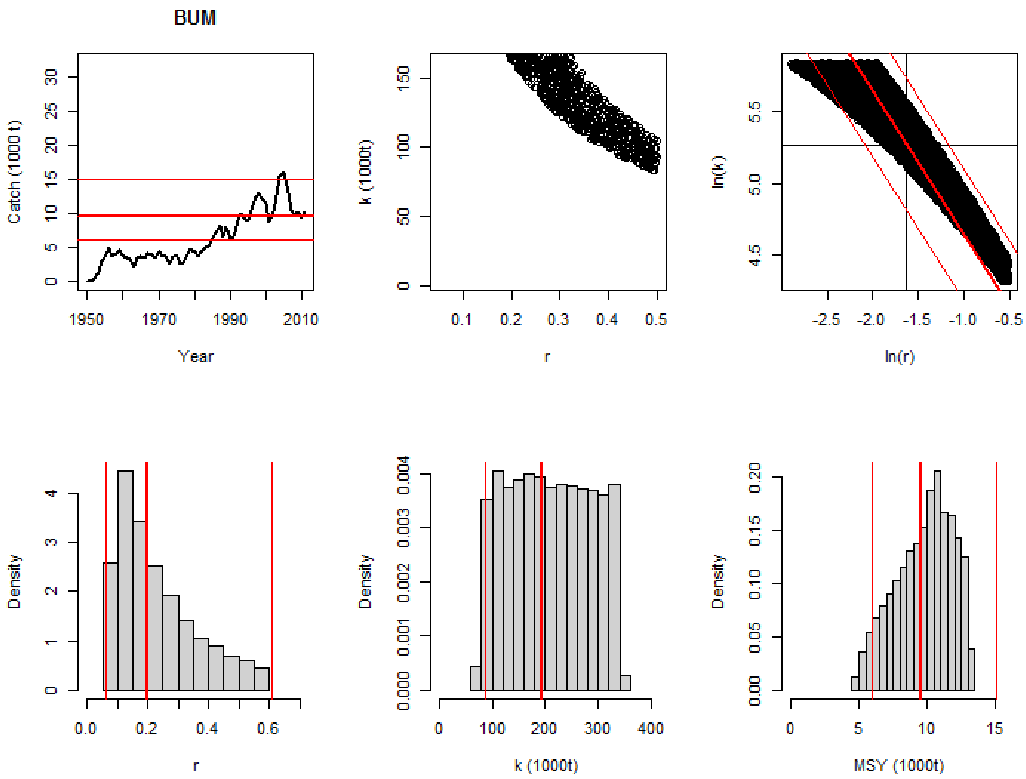


Figure 1: Blue Marlin reference points derived from Stock Reduction approaches

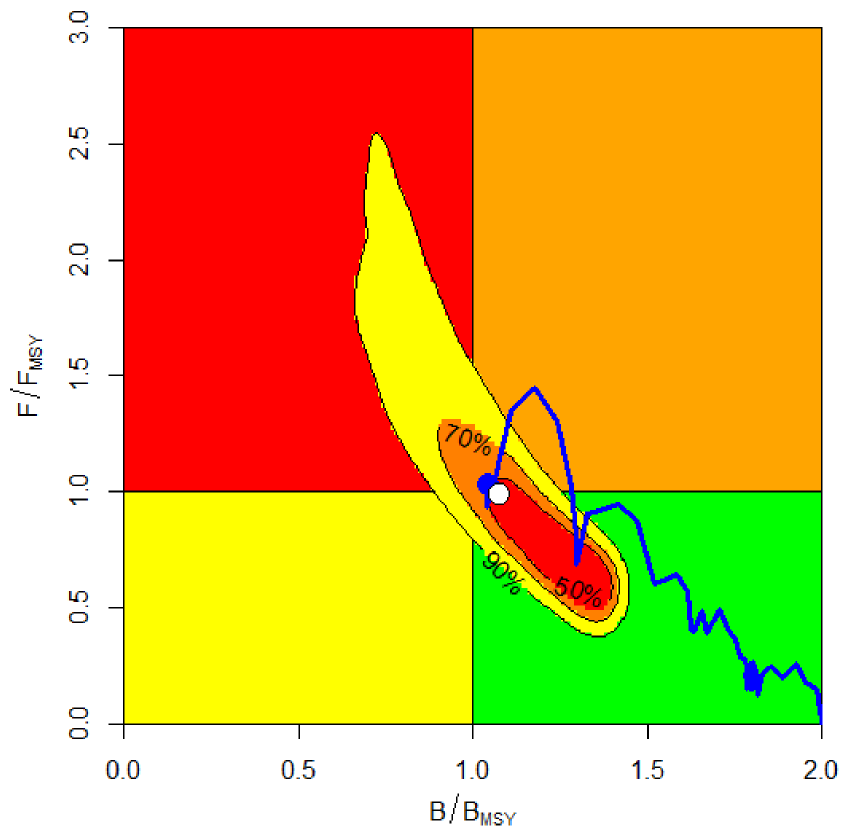


Figure 2: Phase plot of SMSY and FMSY Trajectory for Blue Marlin

Black marlin

Based on information in Fish Base, Black Marlin appears to be a more resilient stock and therefore has not been subjected to overfishing till recent years. In contrast Blue Marline has a lower resiliency and in the late 1990's to early 200's catch levels may have been too high and caused the stock to decline (Figure 2). These trends are not apparent for Black Marlin (Figure 3 and 4). Current catch levels are exceeding MSY targets, but within the 95% confidence interval.

Table 3: Key parameters associated with the stock production analysis for Black Marlin

Parameter	Lower 95% CI	Geometric Mean	Upper 95% CI
r	0.25	0.58	1.32
K	30755	59470	114996
MSY	6278	8605	11793
B_{MSY}	15378	29735	57498
B_{2011}/B_{MSY} *	1.75	1.17	1.55
F_{2011}/F_{MSY} *	0.15	1.03	2.19

* Uncertainty estimated from all possible combinations that fit the criteria

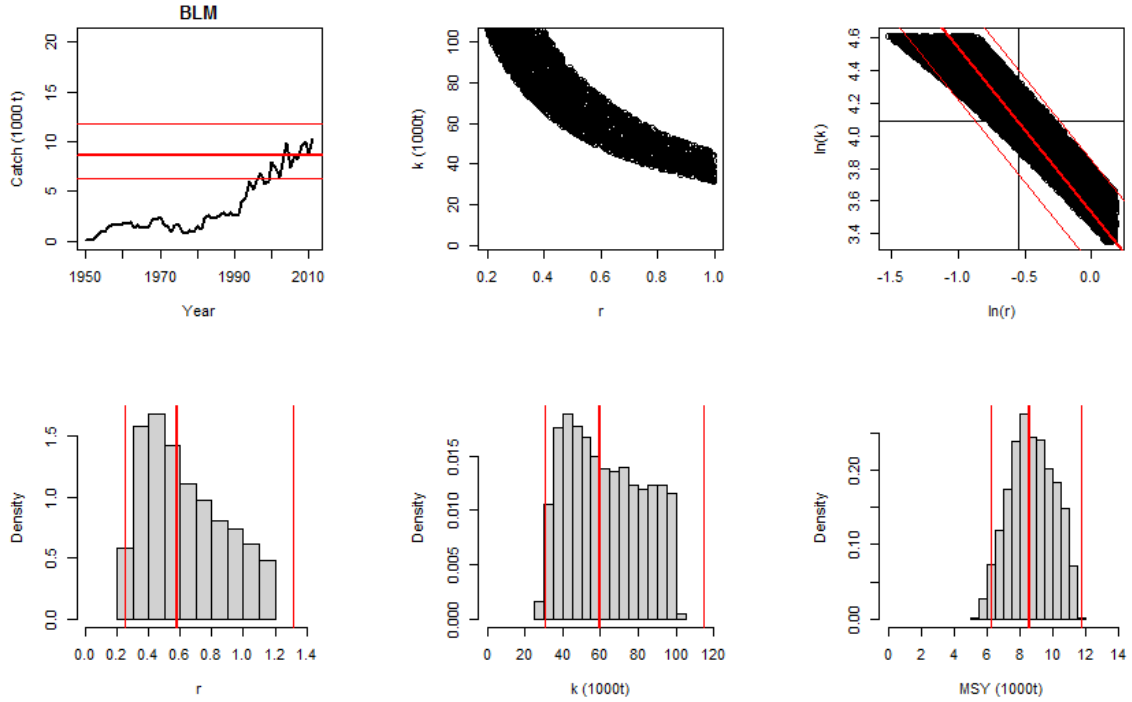


Figure 3: Black Marlin reference points derived from SRA Approaches

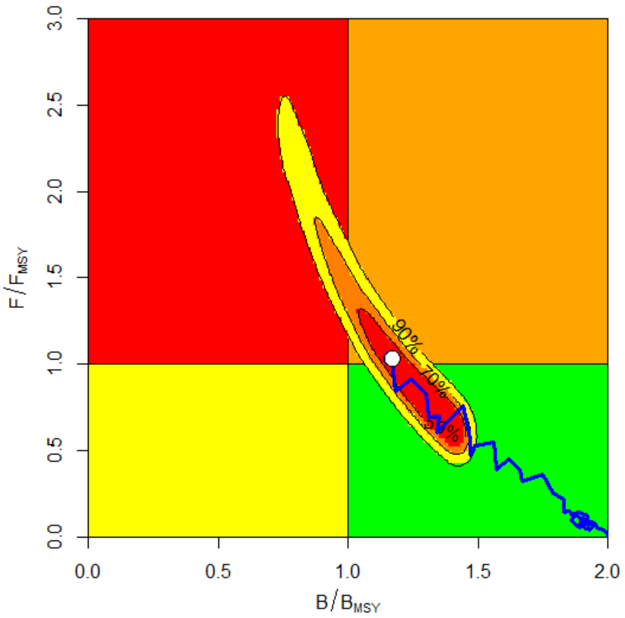


Figure 4: Phase plot of SMSY and FMSY Trajectory for Black Marlin

Striped Marlin

Although striped marlin are also quite resilient (www.fishbase.org), the stock has suffered from high fishing pressure through most of the 1990's and 2000's. Using the 95% Confidence intervals gives us undefined solutions for the stock (i.e. the stock is going to 0, extinction) and is thus unreported (Table 4). Unlike the other two marlins, this is in between the Blue and black marlin in terms of resiliency and is not capable of high fishing pressure that was seen through the 1960's 1970's and then 1990's. In the mid 1990's the stock may have been overfished (Figure 6) and has not really responded to recovery since then as the catches have declined since then but may still be fairly high (Figure 5 and 6).

Table 4: Key parameters associated with the stock production analysis for Black Marlin

Parameter	Lower 95% CI	Geometric Mean	Upper 95% CI
r	0.18	0.29	0.49
K	26432	56626	71701
MSY	3831	4218	4645
B_{MSY}	13216	28313	35851
B_{2011}/B_{MSY} *	0.08	0.52	0.82
F_{2011}/F_{MSY} *	0.74	1.12	5.94

*Plausible range of values due to large uncertainty in results

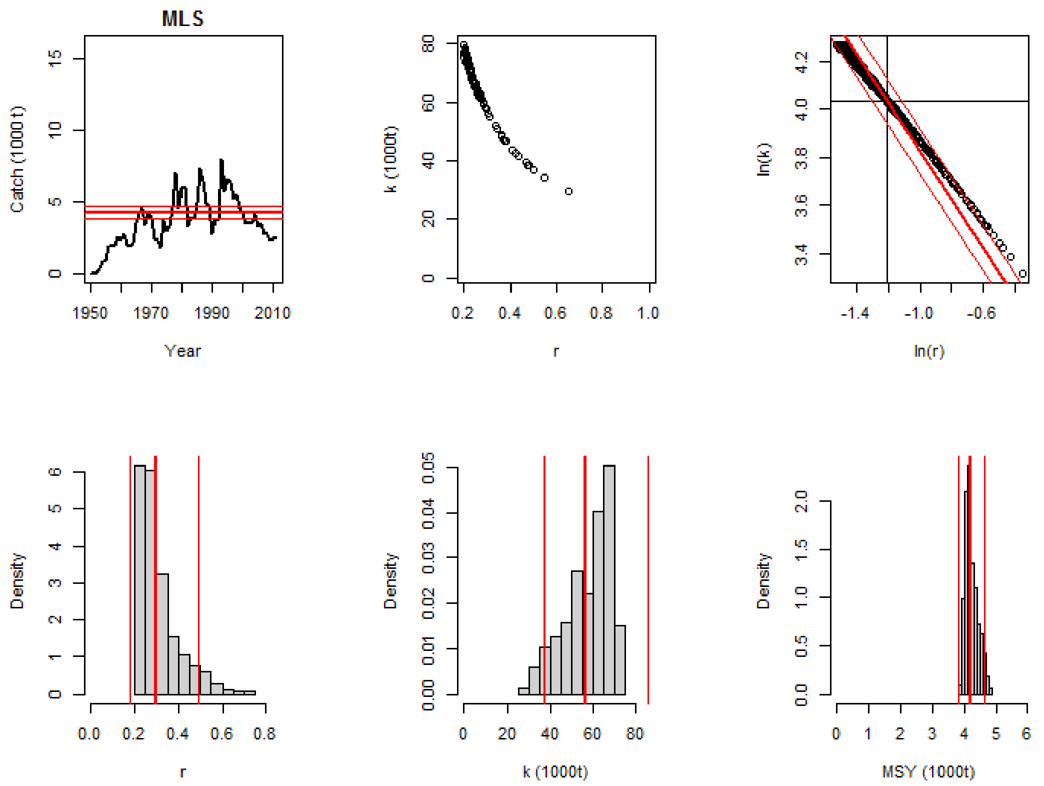


Figure 5: Striped Marlin reference points based on SRA Approach.

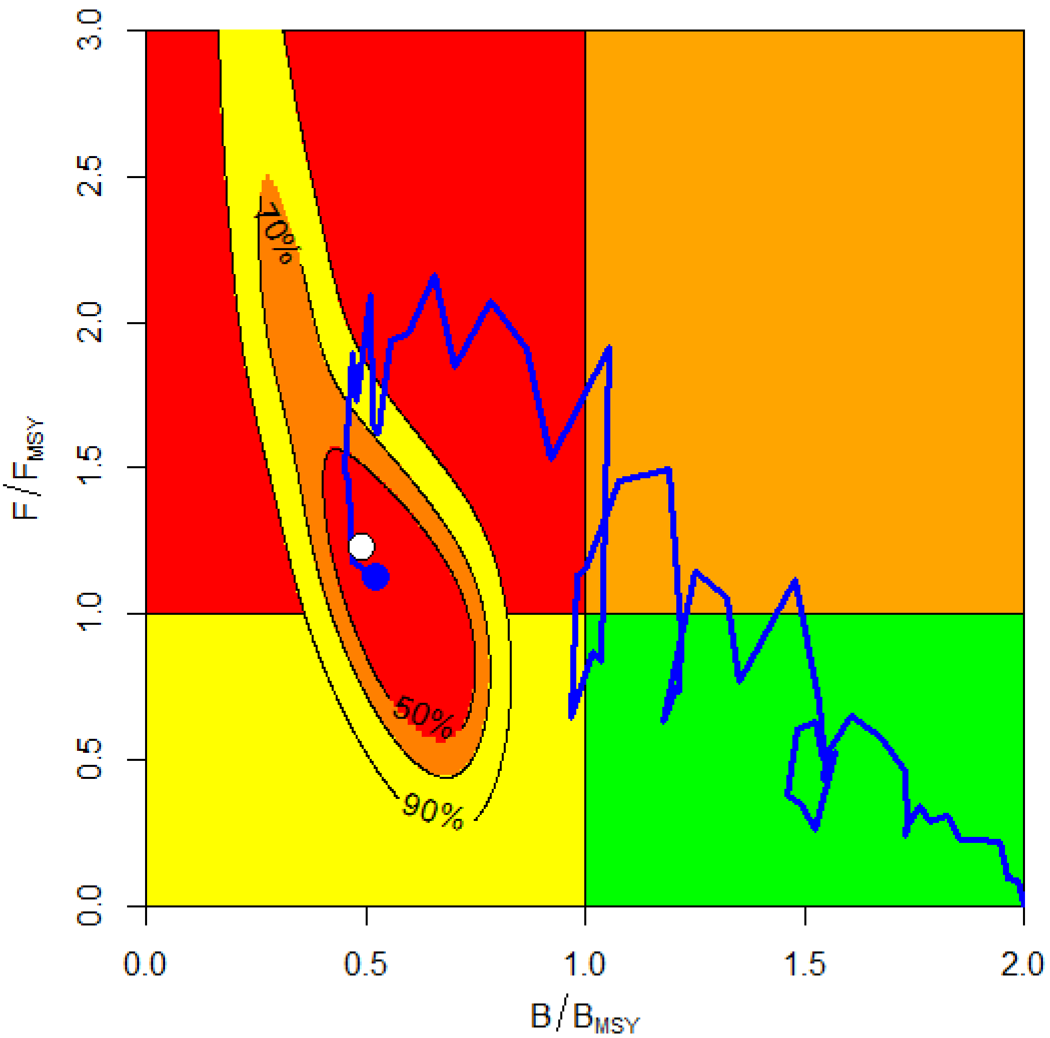


Figure 6: Phase plot of SMSY and FMSY Trajectory for Striped Marlin

Discussion

While these analyses are by no means conclusive, they still match the trends on stock trajectories and reference points that maybe useful for management (Figure 7 comparison of the SRA approach phase plot with the ASPIC assessment, Nishida and Wang 2010). A simple approach like this was compared to the complex programs for swordfish and gave very similar trajectories (left panel SRA approach vs. right panel ASPIC based approach). In terms of target yield levels, the SC recommends a range of 29,900 to 34,200 using the age structured modelling approach developed by Kolody et. al. (2010). This approach which is a whole lot simpler, recommends target yield estimate of 25K Tons with a 95% confidence interval of 15K-41K Tons (Figure 8).

Thus, while being conservative in nature (as Figure 7 and 8 show), this approach could provide some guideline for yield/by-catch levels in these fisheries. Based, on these simplistic models the following could be recommended as target yield levels on Marlins:

i) Yield not to exceed 10k Tons for Blue Marlin; ii) Yield not to exceed 9k Tons for Black Marlin and iii) yield not to exceed 4.5k Tons for Striped Marlin in the Indian Ocean Region.

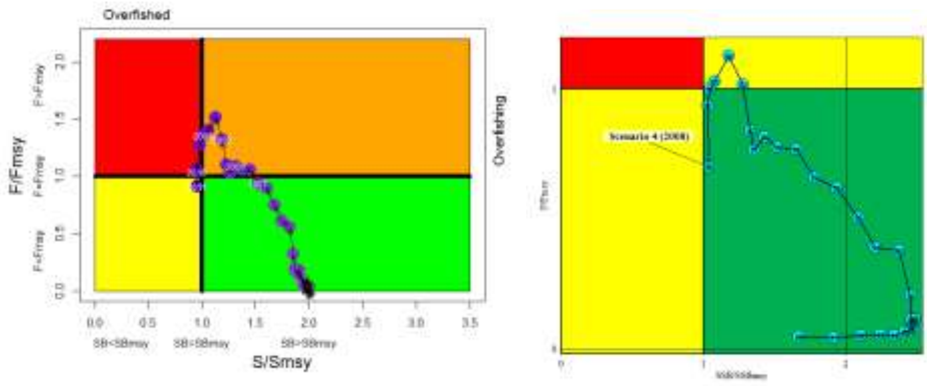
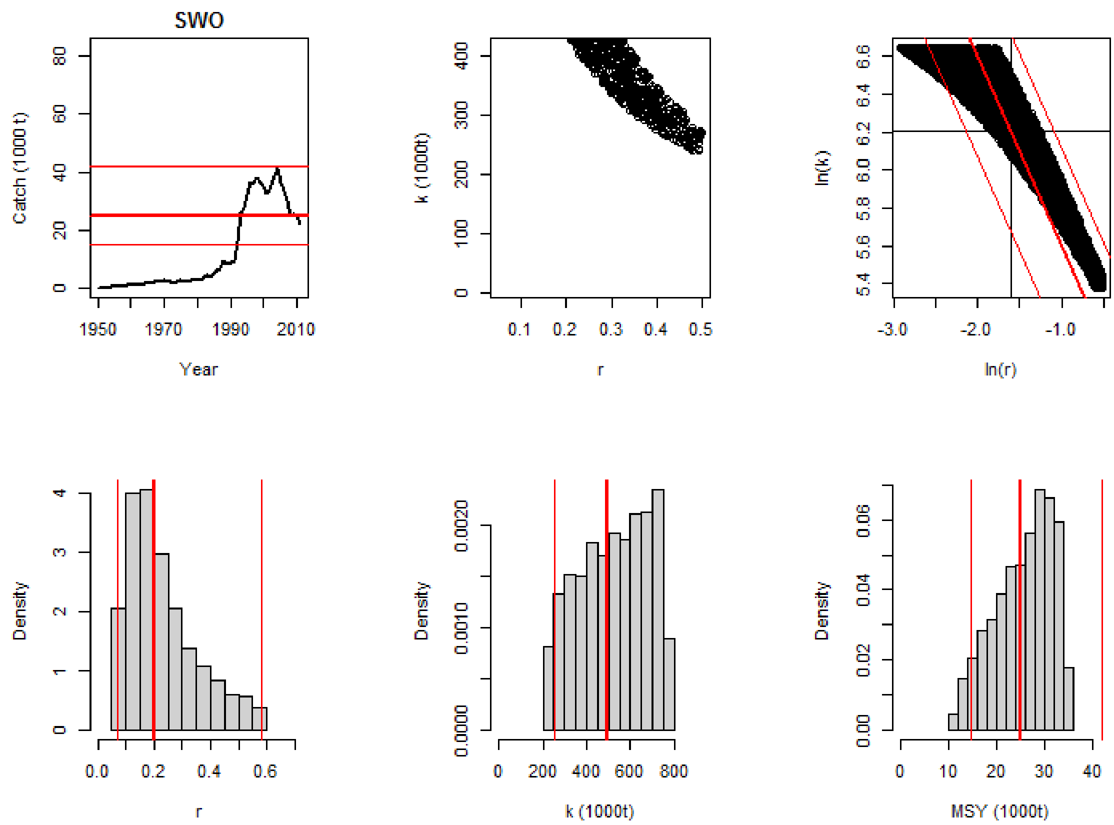


Figure 7: Comparisons of SRA approach on IO Swordfish data using SRA (left panel) vs ASPIC (right panel).



<u>Figure 8: Swordfish reference points derived from SRA Approaches</u>

References

Charnov, E.R., Gislason, H., & Pope, J.P. 2012. Evolutionary assembly rules for fish life histories. Fish and Fisheries. DOI: 10.1111/j.1467-2979.2012.00467.x

Gislason, H., Daan, N., Rice, J.C. and Pope, J.G. (2010). Size, growth, temperature, and the natural mortality of marine fish. Fish and Fisheries 11 149–158.

Haddon, M. 2011. Modeling and Quantitative Methods in Fisheries. 2nd Ed.Chapman & Hall, Inc., New York.

Hilborn, R., and Walters, C. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman & Hall, Inc., New York.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82: 898–903.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal tradeoff of reproduction and survival. Can. J. fish. Aquat. Sci. 53, 820-822.

Kimura, D.K., and Tagart, J.V. 1982. Stock reduction analysis, another solution to the catch equations. Can. J. Fish. Aquat. Sci. **39**: 1467–1472.

Kolody, D. 2010. A Spatially-Structured Stock Synthesis Assessment of the Indian Ocean Swordfish Fishery 1950-2008, including Special Emphasis on the SW Region. IOTC-2010-WPB-05.

Martell, S. and Froese, R. 2012. A simple method for estimating MSY from catch and resilience. Fish and Fisheries. doi: 10.1111/j.1467-2979.2012.00485.x

Nakamura, I., 1985. FAO species catalogue. Vol. 5. Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fish. Synop. 125(5):65p. Rome: FAO.

Walters, C. Martell, S., and Korman, J. 2006. A stochastic approach to stock reduction analysis. Can. J. Fish. Aquat. Sci. 63: 212-223.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Bulletin, Inter-American Tropical Tuna Commission 1:27-56.

Zhou, S., Yin, S., Thorson, J.T., Smith, A.D.M., Fuller, M. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Canadian Journal of Fisheries and Aquatic Science, 69: 1292–1301.

Zhou, S., Pascoe, S., Dowling, N., Haddon, M., Klaer, N., Larcombe, J., Smith, A.D.M., Thebaud, O., and Vieira, S. 2013. Quantitatively defining biological and economic reference points in data poor and data limited fisheries. Final Report on FRDC Project 2010/044. Canberra, Australia.

Appendix 1: Catch Trends from the Statistics Report (Blue Marlin)

Blue marlin are caught mainly under drifting longlines (65%) and gillnets (30%) with remaining catches recorded under troll and hand lines (**Table 3**, **Fig. 11**). Blue marlins are considered to be a bycatch of industrial and artisanal fisheries. The catches of Blue marlin are typically higher than those of black marlin and striped marlin combined. In recent years, the fleets of Taiwan,China (longline), Indonesia (longline and handline), Iran, (gillnet) Sri Lanka (longline gillnet) account for around 75% of the total catch of blue marlin (**Fig. 12**). The distribution of blue marlin catches has changed since the 1980’s with most of the catch now taken in the western areas of the Indian Ocean (**Figs. 13 & 14**).

Catch trends for blue marlin are variable; however, this may reflect the level of reporting. The catches of blue marlin under drifting longlines were more or less stable until the mid-80’s, at around 3,000 t to 4,000 t, and have steadily increased since then to between 6,000 t to 8,000 t. The largest catches reported by longlines were recorded in 1998 (~11,000 t). Catches under drifting longlines have been recorded under **Taiwan,China** and **Japan** fleets and, recently, **Indonesia**, **India**, **Sri Lanka** and several **NEI** fleets (**Fig. 12**). In recent years, the deep-freezing longliners from **Taiwan,China** and **Japan** have reported most of the catches of blue marlin in waters of the western and central tropical Indian Ocean and, to a lesser extent, the Mozambique Channel and the Arabian Sea (**Fig. 13 & 14**).

TABLE 3: Best scientific estimates of the catches of blue marlin by type of fishery for the period 1950–2011 (in metric tons). Data as of July 2013.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LL	2,563	3,515	3,488	4,983	7,426	7,814	7,851	9,208	9,367	8,006	8,252	6,666	6,573	7,018	6,356	6,661
GN	1	2	124	755	2,265	3,992	2,258	3,349	5,945	7,997	5,706	3,723	3,099	2,944	2,572	3,144
HL	5	9	17	105	149	120	76	81	95	85	121	122	201	250	271	265
OT	0	0	0	2	4	7	4	5	5	5	7	7	12	15	15	16
Total	**2,570**	**3,526**	**3,629**	**5,845**	**9,844**	**11,934**	**10,189**	**12,643**	**15,412**	**16,093**	**14,086**	**10,518**	**9,884**	**10,226**	**9,214**	**10,086**

Fisheries: Gillnet (**GN**); Longline (**LL**); Hook-and-Line (**HL**), including handline, trolling, baitboat, and sport fisheries; Other gears (**OT**)

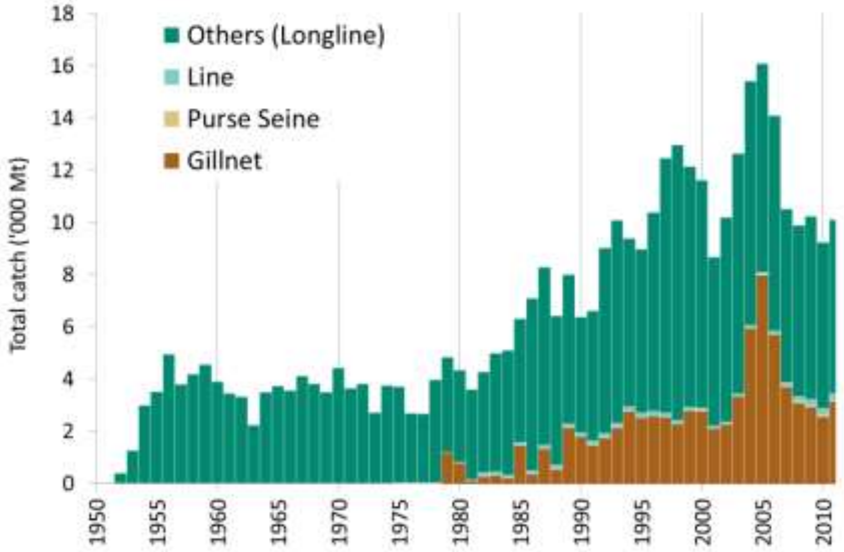


Fig. 11. Catches of blue marlin by gear and year recorded in the IOTC Database (1960–2011).

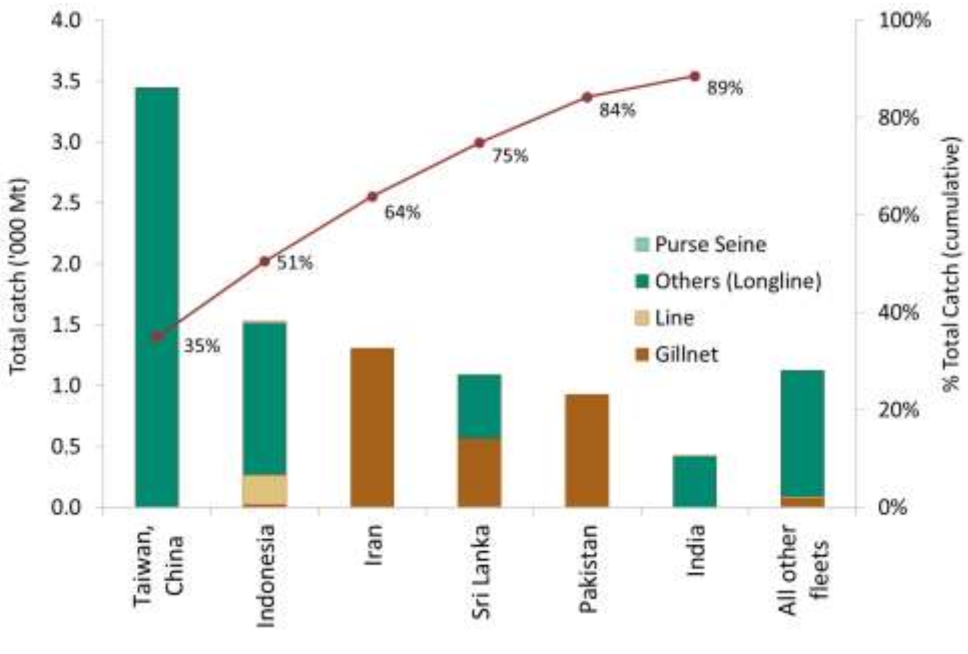


Fig. 12: Blue marlin: average catches in the Indian Ocean over the period 2009–11, by country. Countries are ordered from left to right, according to the importance of catches of blue marlin reported. The red line indicates the (cumulative) proportion of catches of blue marlin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries.

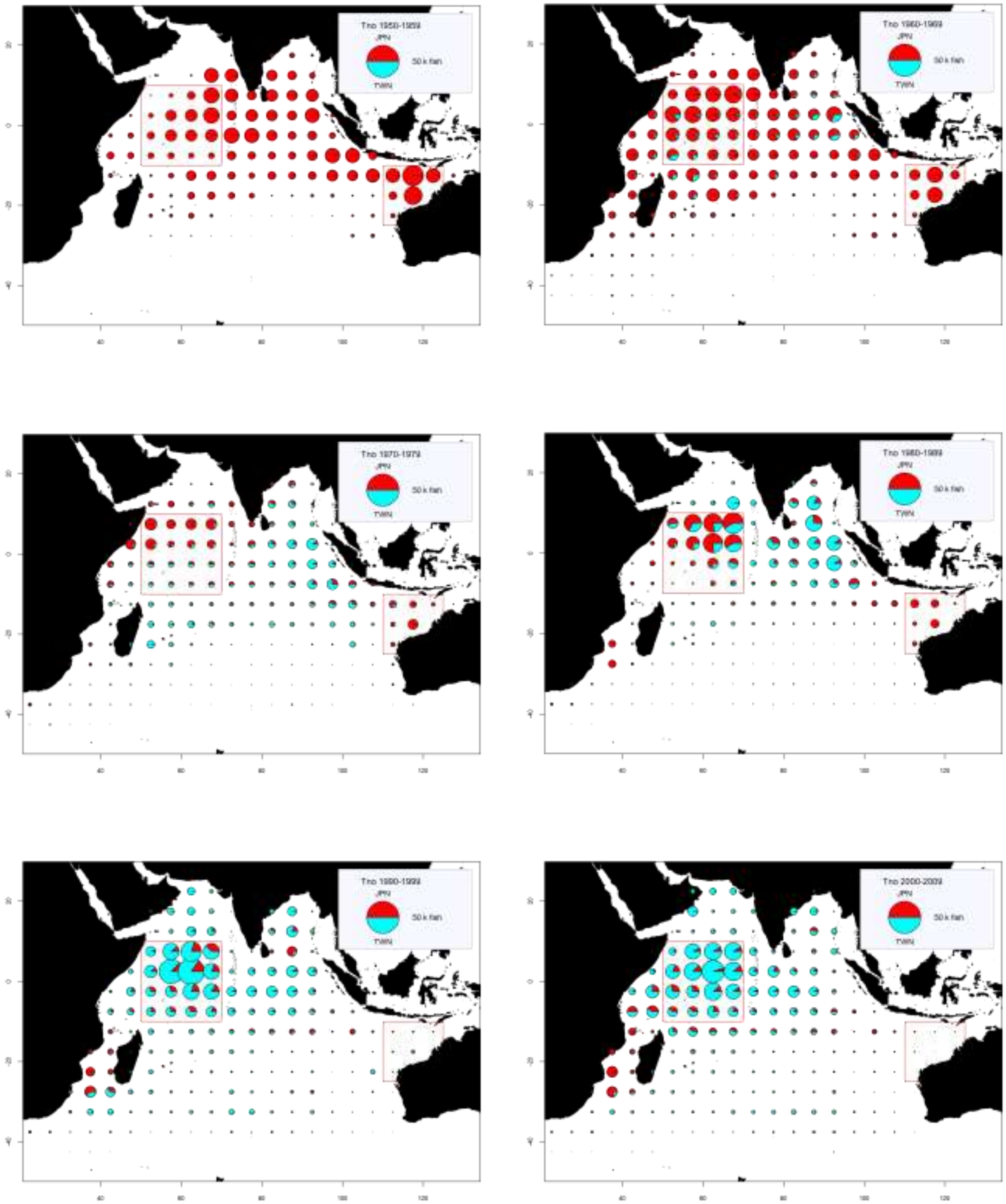


Fig. 13a-f. Time-area catches (in number of fish) of blue marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 1950-2009, by decade and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.

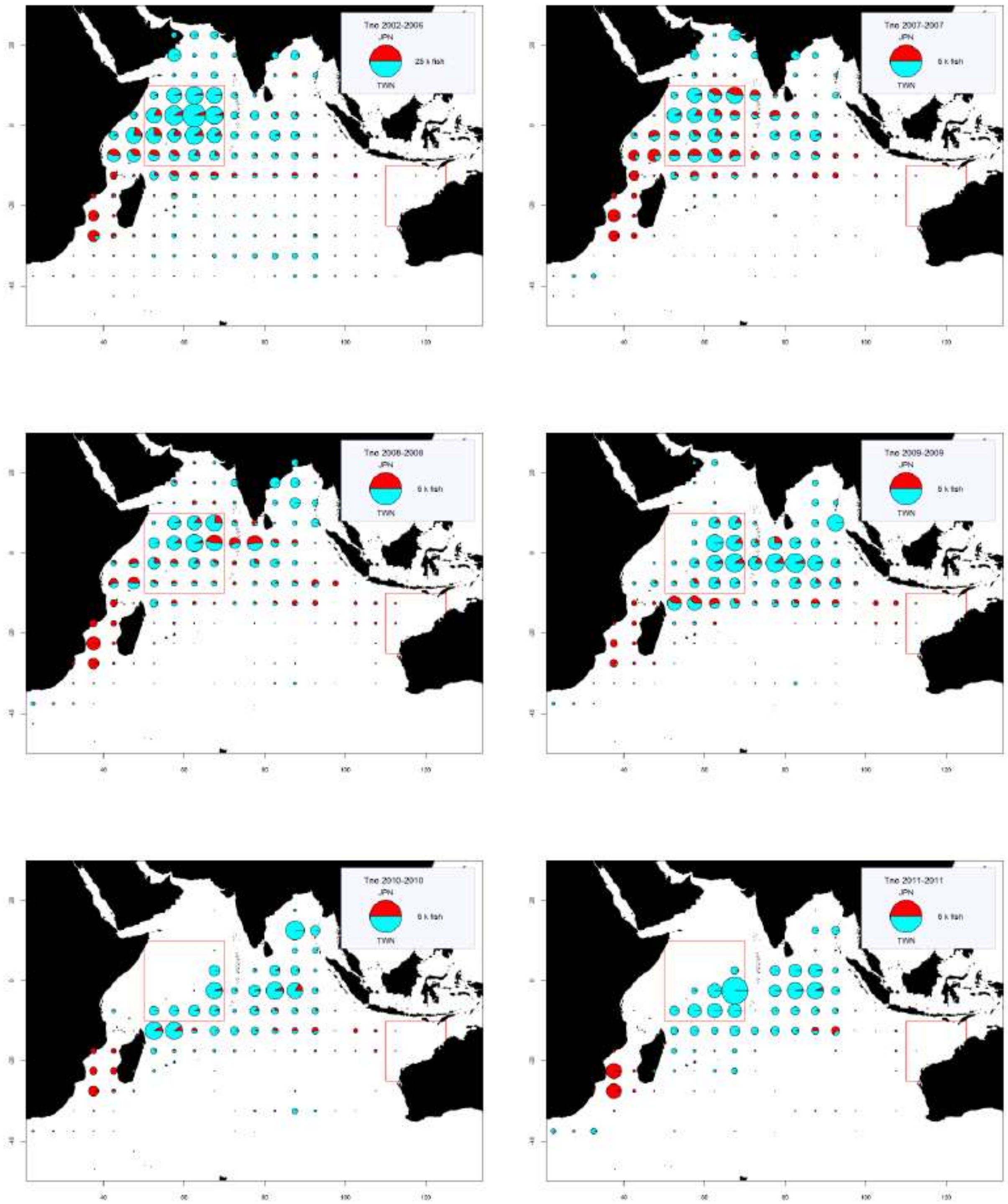


Fig. 14a-f. Time-area catches (in number of fish) of blue marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 2002–06 by fleet and for 2007–11, by year and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.

Catch Trends from the Statistics Report (Black Marlin)

- **Catch trends –**

Black marlin are caught mainly under drifting longlines (37%) and gillnets (38%) with remaining catches recorded under troll and hand lines (**Table 4, Fig. 17**). Black marlin are the bycatch of industrial and artisanal fisheries. In recent years, the fleets of **Sri Lanka** (longline and gillnet), **Indonesia** (troll and hand lines) and **India** (gillnet and troll) account for around 77% of the catch of black marlin (**Fig. 18**). Catches of black marlin have increased steadily since the 1990s, from 2,700 t in 1991 to over 10,000 t in 2011. Current annual catches are estimated at between 9,000 t to 10,000 t (**Table 4**).

TABLE 4. Best scientific estimates of the catches of black marlin by type of fishery for the period 1950–2010 (in metric tons). Data as of July 2013.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LL	846	1,633	1,287	1,397	2,342	3,701	2,914	3,810	4,201	3,439	3,833	3,771	4,544	3,701	3,399	3,795
GN	26	31	44	411	1,776	3,367	2,723	3,008	4,455	3,203	3,621	3,172	3,152	3,609	3,344	4,262
HL	24	27	42	446	727	1,020	714	775	1,008	652	913	1,018	1,479	2,159	1,669	1,882
OT			4	65	112	216	135	142	170	155	216	218	370	452	472	496
Total	**896**	**1,692**	**1,377**	**2,319**	**4,957**	**8,305**	**6,487**	**7,734**	**9,834**	**7,449**	**8,583**	**8,180**	**9,545**	**9,920**	**8,883**	**10,435**

Fisheries: Gillnet (**GN**); Longline (**LL**); Hook-and-Line (**HL**), including handline, trolling, baitboat, and sport fisheries; Other gears (**OT**)

Between the early-1950s and the late-1980s part of the Japanese fleet was licensed to operate within the EEZ of Australia, and reported very high catches of black marlin in that area, in particular in waters off northwest Australia (F**ig. 19**). In recent years, deep-freezing longliners from **Japan** and **Taiwan,China** have reported lower catches of black marlin, mostly in waters off the western coast of India and, to a lesser extent, the Mozambique Channel (**Fig. 20**).

The catches of black marlin in **Sri Lanka** have risen steadily since the mid-1990's as a result of the development of the fishery using a combination of drifting gillnets and longlines, from around 1,000 t in the early 1990s to over 4,500 t in 2011.

In recent years (2009–11) **India** has reported higher catches of black marlin for its fisheries, amounting to around 1,000 t to 2,000 t, largely from increases in catches from gillnet and troll).

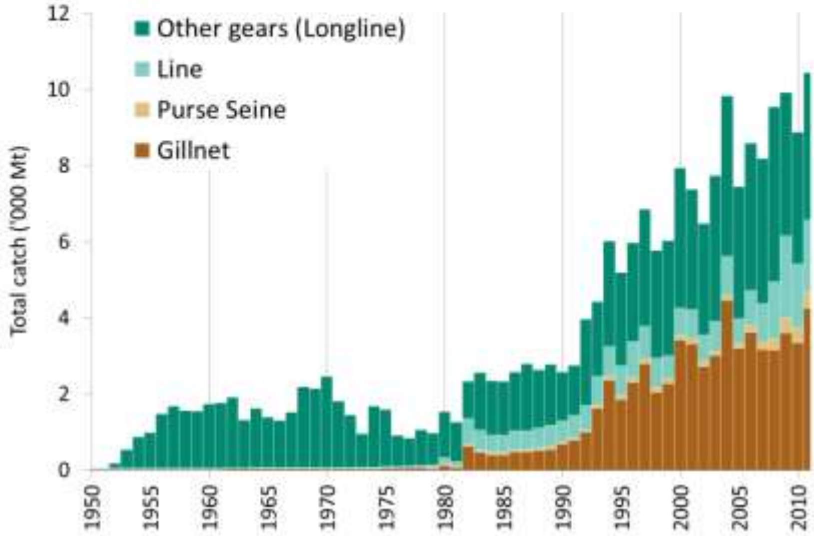


Fig. 17. Catches of black marlin by gear and year recorded in the IOTC Database (1960–2011).

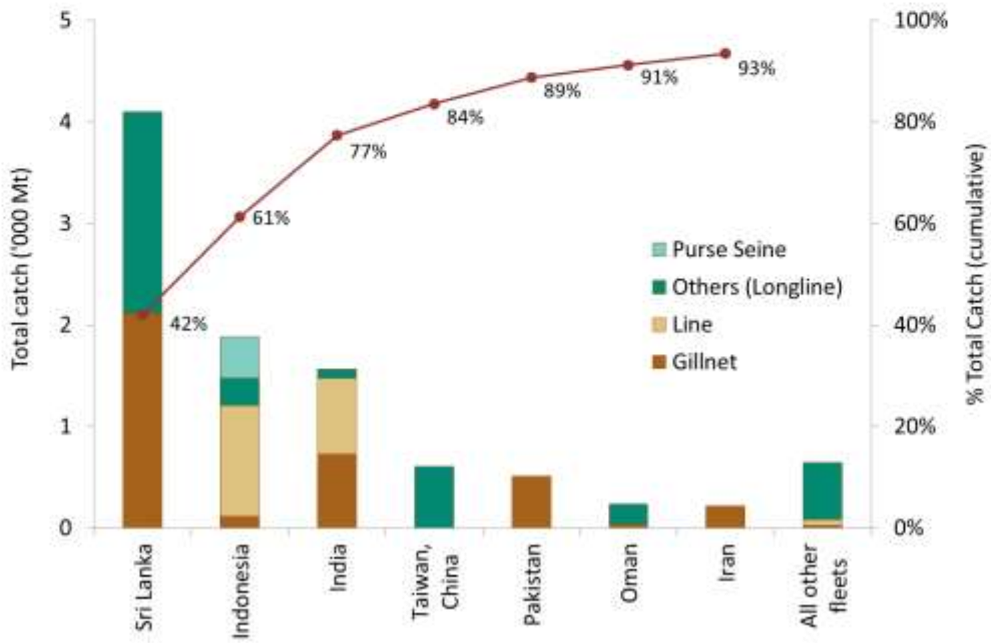


Fig. 18: Black marlin: Average catches in the Indian Ocean over the period 2009–11, by country. Countries are ordered from left to right, according to the importance of catches of black marlin reported. The red line indicates the (cumulative) proportion of catches of blue marlin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries.

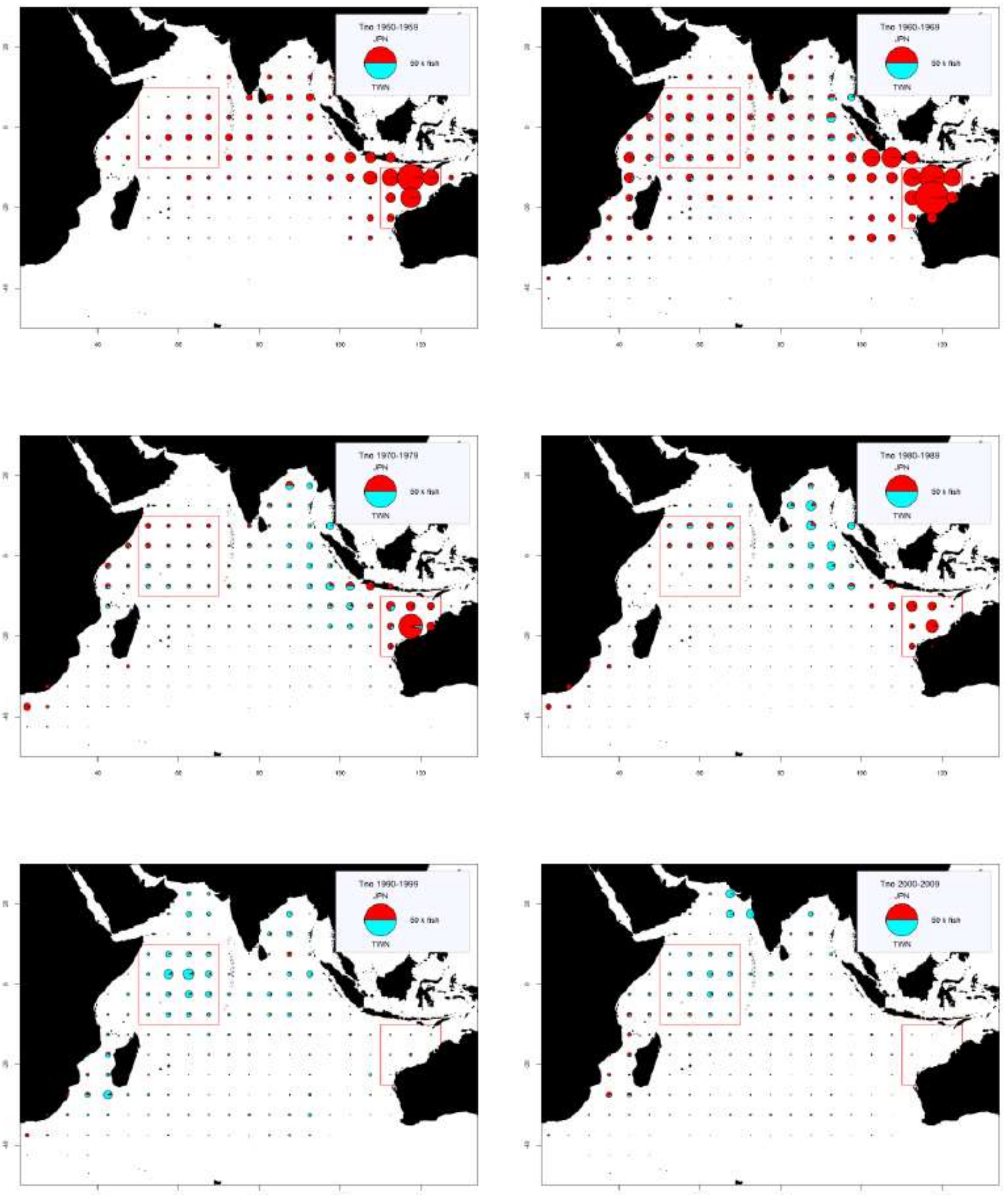


Fig. 19a-f. Time-area catches (in number of fish) of black marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 1950–2009, by decade and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.

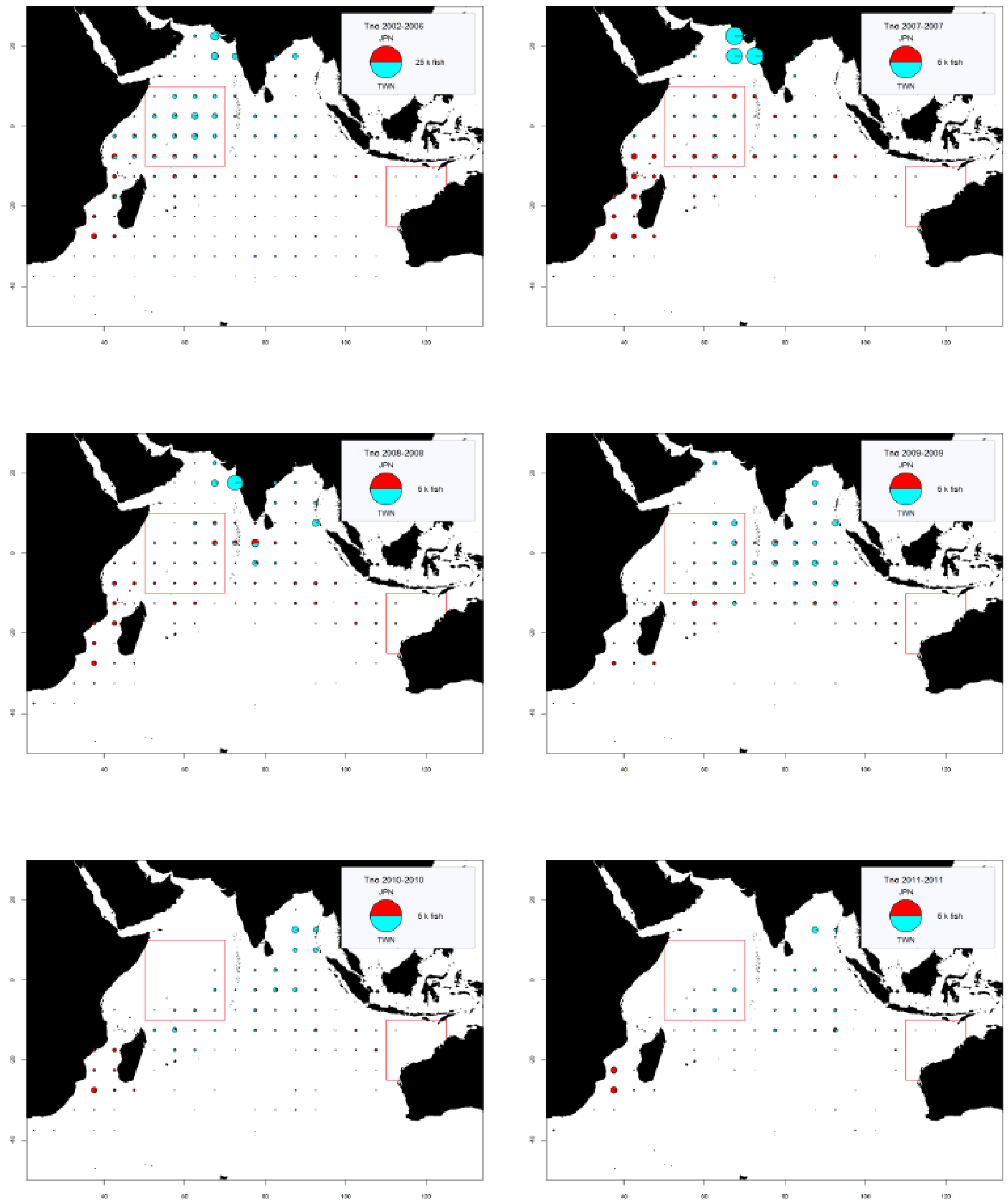


Fig. 20a-f. Time-area catches (in number of fish) of black marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 2002–06 by fleet and for 2007–11, by year and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.

Catch Trends from the Statistics Report (Striped Marlin)

- **Catch trends**

Striped marlin are caught almost exclusively under drifting longlines, which in previous years have accounted for as much as 98% of the catch. The remaining catches are recorded under gillnets and troll lines (**Table 5, Fig. 23**). Striped marlin are generally considered to be a bycatch of industrial fisheries. Catch trends for striped marlin are variable, ranging from 2000 t to 8000 t per year (**Fig. 24**); however, this may reflect the level of reporting. Similarly, catches reported under drifting longlines are highly variable, with recent falls since 2009 largely due to declining catches reported by Taiwan,China, deep-freezing and fresh-tuna longliners.

TABLE 5: Best scientific estimates of the catches of striped marlin by type of fishery for the period 1950–2010 (in metric tons). Data as of July 2013.

Fishery	By decade (average)						By year (last ten years)									
	1950s	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
LL	1,024	3,077	3,608	5,033	4,988	2,948	3,119	3,109	3,718	2,961	3,088	2,416	2,288	1,857	1,943	1,865
GN	5	8	16	22	139	245	225	237	331	235	280	198	196	163	188	450
HL	3	5	10	32	69	130	80	84	102	92	129	134	223	272	284	297
OT	0	0	0	6	10	19	12	13	15	14	19	19	33	40	42	44
Total	**1,032**	**3,089**	**3,634**	**5,093**	**5,205**	**3,342**	**3,437**	**3,443**	**4,166**	**3,302**	**3,517**	**2,767**	**2,740**	**2,332**	**2,458**	**2,656**

Fisheries: Gillnet (**GN**); Longline (**LL**); Hook-and-Line (**HL**), including handline, trolling, baitboat, and sport fisheries; Other gears (**OT**)

Catches under drifting longlines have been recorded under **Taiwan,China**, **Japan**, **Republic of Korea** fleets and, recently, **Indonesia** and several **NEI** fleets. Taiwan,China and Japan have reported large drops in the catches of striped marlin for its longline fleets since the mid-1980's and mid-1990's, respectively. The reason for such decreases in catches is not fully understood. Between the early-50s and the late-80s part of the Japanese fleet was licensed to operate within the EEZ of Australia, reporting relatively high catches of striped marlin in the area, in particular in waters off northwest Australia. High catches of the species were also reported in the Bay of Bengal during this period, by both Taiwan,China and Japanese longliners. The distribution of striped marlin catches has changed since the 1980's with most of the catch now taken in the western areas of the Indian Ocean (**Fig. 25**). These changes of fishing area and catches over the years are thought to be related to changes in the type of access agreements to EEZs of coastal countries in the Indian Ocean, rather than changes in the distribution of the species over time. However, since 2007, catches in the northwest Indian Ocean have dropped markedly, in tandem with a reduction of longline effort in the area as a consequence of maritime piracy off Somalia (**Fig. 26**).

Discards are believed to be low although they are unknown for most industrial fisheries, mainly longliners. Discards of striped marlin may also occur in the driftnet fishery of the I.R of Iran, as this species has no commercial value in this country.

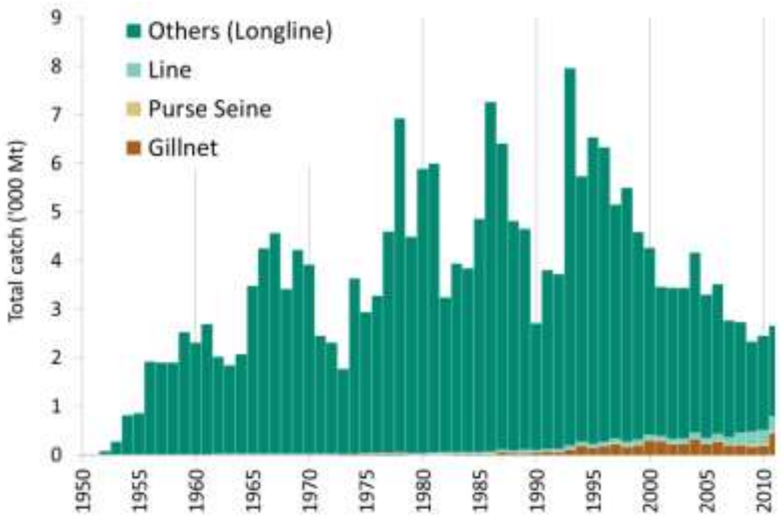


Fig. 23. Catches of Striped marlin by gear and year recorded in the IOTC Database (1960–2011).

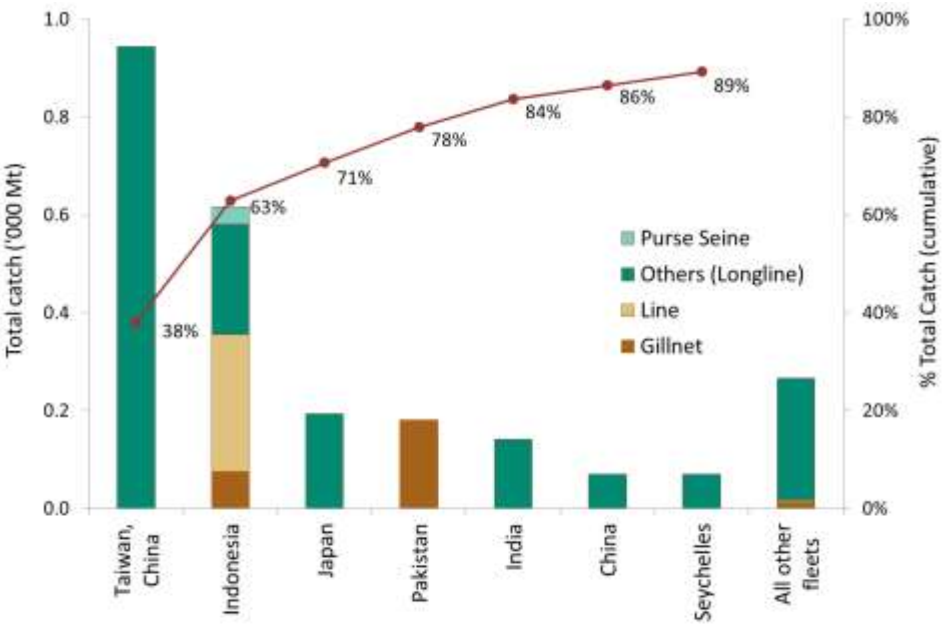


Fig. 24: Striped marlin: Average catches in the Indian Ocean over the period 2009–11, by country. Countries are ordered from left to right, according to the importance of catches of black marlin reported. The red line indicates the (cumulative) proportion of catches of Striped marlin for the countries concerned, over the total combined catches of this species reported from all countries and fisheries.

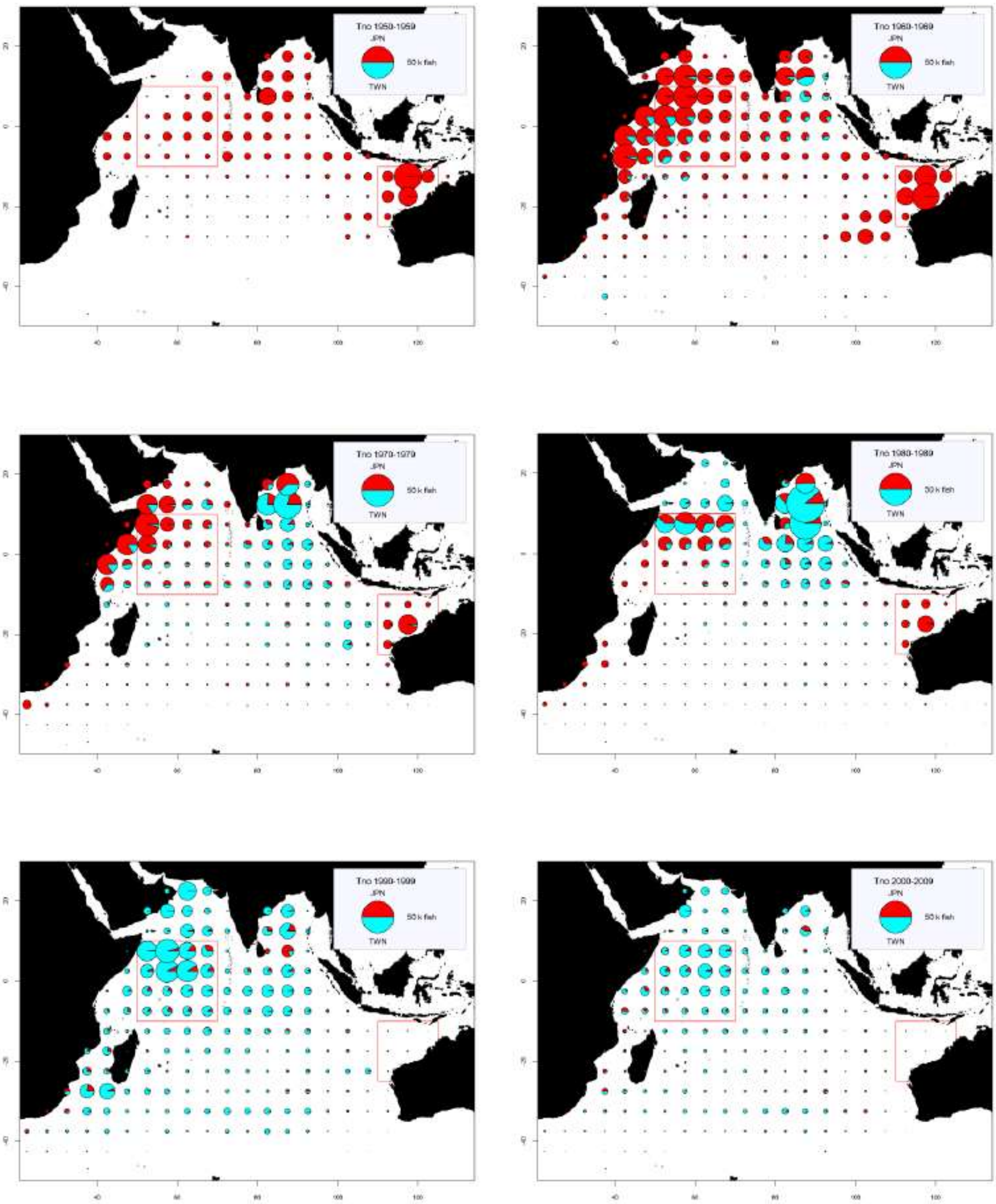


Fig. 25a-f. Time-area catches (in number of fish) of striped marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 1950–2009, by decade and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.

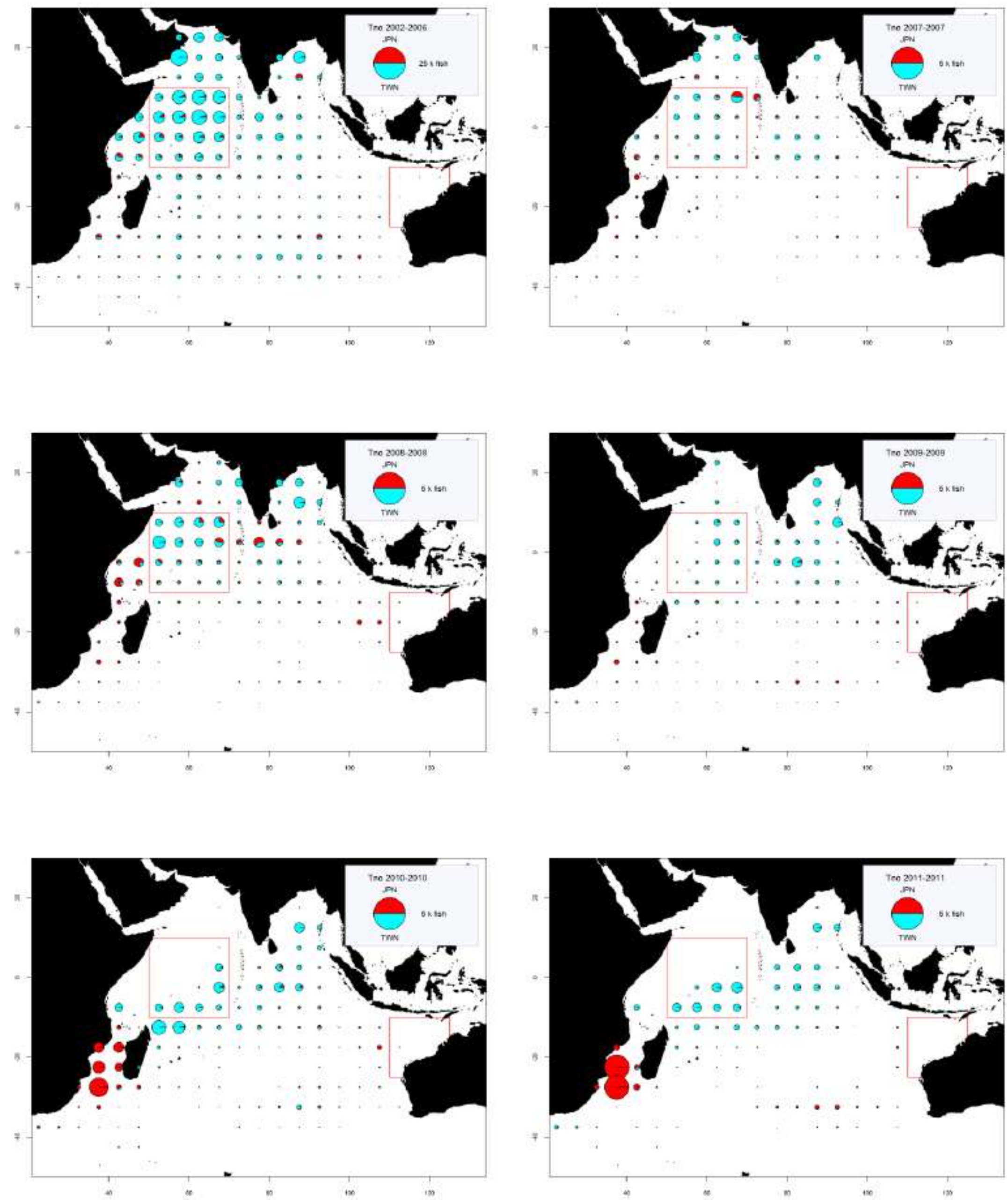


Fig. 26a-f. Time-area catches (in number of fish) of striped marlin as reported for the longline fisheries of Japan (JPN) and Taiwan,China (TWN) for the period 2002–06 by fleet and for 2007–11, by year and fleet. Red lines represent the boundaries of the marlin hot spots identified by the WPB.