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Update of CPUE of blue shark caught by Japanese longliner and estimation of annual catch series in the Indian Ocean

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Summary

In the present study, the standardized CPUE of blue shark caught by Japanese longliners is re-estimated and updated with modified method from the previous study by Hiraoka and Yokawa (2011). The re-estimated standardized CPUE shows rather stable trend in the first period of 1971 – 1993, and general increasing trend in the second period of 1994 – 2011. Though some unnatural fluctuation are observed in the second period, the estimated standardized CPUE believed to be reflecting general trend of the blue shark stocks in the period of analysis. This study also estimated the total annual catch number in the period analyzed, which could be directly used for the estimation of total annual catch weight using information about seasonal and areal average weight. Same method would also be applied for the estimate of total annual catch of other longline fleet with no historical catch data but effort data of blue shark. Thus the results of this study could offer the basic information for some simple stock analysis like surplus production model on blue shark stocks. The observed fluctuation of the standardized CPUE in the second period supposed not to reflect the actual fluctuation of the stock but to be caused by the somewhat simpler method of data selection or the model structure of GLM. The improvement of data selection and analysis method would enable us to estimate less fluctuating trend of the standardized CPUE.

Keywords

Blue shark, CPUE, Longline, Reporting rate

1.Introduction

In the previous study by Hiraoka and Yokawa (2011), the standardized CPUEs of blue shark caught by Japanese tuna longline fishery in the Indian Ocean was calculated using logbook data during 1971-1993 and 1994-2010 using filtering method by Nakano and Honma (1996) and GLM-tree methods by Ichinokawa and Brodziak (2010). It also showed the CPUE trends estimated from the data sets filtered by the every 10% reporting categories, and concluded that the results using ≥80% filter, which is the criteria of data selection verified in the Atlantic, could be represent the trend of abundance of blue shark in the Indian Ocean. However, a problem in the method of the previous study was found in the aspects of 0 catch treatment, i.e. the data excluding 0 catch was utilized. Therefore, in this report, we recalculated and updated the standardized CPUEs of blue shark with ≥80% filtering data including 0 catch, then estimated the total annual catch number of blue shark using this result.

2.Material and Methods

The standardized CPUEs and estimated catch during 1971-1993 and 1994-2010 were calculated respectively because only shark species aggregated data were available before 1993. The data for 2010 an 2011 were provisional.

For the standardizing CPUE, the same methods as Hiraoka and Yokawa (2011) were applied. The data set with reporting rates (percentage of operations with shark catch to total operations per cruise) greater than 80% were used because it is assumed that ≥80% filtering data could rid of underreporting data and correspond with only blue shark catch when species-specific data were not available (Nakano and Clark, 2005; Matsunaga, 2007; Hiraoka and Yokawa, 2011). The generalized liner model same as Matsunaga (2007) were used both periods in 1971-1993 defined as first period and in 1994-2010 as second periods for standardized CPUEs. The equations were as follows:

$$\ln(\mathrm{CPUE}+\mathrm{constant}) = \mathrm{YR} + \mathrm{QT} + \mathrm{AR} + \mathrm{BR} + \mathrm{QT}*\mathrm{AR} + \mathrm{QT}*\mathrm{BR} + \text{nominal error}$$

where ln: natural logarithm, CPUE: nominal CPUE (catch in number per 1,000 hooks), constant: 0.2, YR: effect of year, QT: effect of quarter, AR: effect of area, BR: branch line criteria (number of lines between floats; <9, 9-14, 13<). The GLM-tree methods (Ichinokawa and Brodziak, 2010) were used to describe the optimal area stratification for CPUE series in two periods, respectively.

Total catch of all operation including < 80% reporting ratio are estimated by applying each variables from each operation to the CPUE standardization model described above and aggregated every year.

3. Result

The step of area stratification and AIC values of each step of area stratification by GLM-tree showed in Figs.1 and 2. The AIC values of both time periods (first: 1971-1993, second: 1993-2011) were continuously decreased until 16 area strata but relatively gradual slopes were found after eight splits. we arbitrarily decided to conduct CPUE standardization with eight areas designated by the GLM-tree analysis for both first and second periods.

The trend of standardized CPUEs of blue shark was quite stable and flat in the first period compared to those in the second period which was showing general increasing trend since 1997 with some ups and downs (Tables 1, Figs. 3 and 4). The nominal CPUEs were also stable and flat trend in the first period but fluctuated in the second periods (Table 1 and Fig. 3). The largest estimated catch was obtained in 1985 (201,022 inds.) and then subsequent decline until 1990 (76,484 inds.). Soon after that, the lowest estimated catch before 2009, excluded the provisional data (2010 and 2011), was found in 1996 (36,977 inds.) and recovered up to 1999 (143,358 inds.; Fig 4) . The residuals of the GLMs for CPUE standardization in the tow time periods showed the normal distributions (Fig. 5).

Annual unfiltered fishing effort (number of hooks) increased from the end of 1970's to 1985 but the drastic decreasing trend were found during 1985 to 1989 (Fig. 6). After 1993, the unfiltered effort increased until1998 (Fig. 6) while the percentage of 80% filtered effort sharply increased from 2008 to date. The spatial distribution of unfiltered effort were relatively higher around 40S-45S line before 1990 then expanded to north side such as off Mombasa and/or off Fremantle(Fig. 7). The 80% filtered effort distributed almost equally compared to unfiltered effort before 2005 and higher locations were found in off Freemantle after 2006.

The distribution of estimated catches was not remarkably changed through all periods. The higher estimated catch was found southern part of the Indian Ocean and this distribution gradually expanded to the north side year after year.

4. Discussion

The eight area strata were arbitrarily selected for the CPUE standardization in the both period (Figs. 1 and 2). The lowest AIC values obtained by GLM-tree model were 16 area stratifications for both periods and these stratifications give statistically best fits. But too many strata would cause shortage of data coverage and prevent to introduce some important interactions such as area*quarter into the GLM model, so the 8 area strata were assumed to be appropriate in this report.

The unstable trends of standardized and nominal CPUE in the second period (1994 – 2011) is supposed be, at least partially, caused by the variability of the operation pattern (described below) of Japanese longliners in the second period. In the first period, when rather smooth CPUE trend is observed, main target species of Japanese longliners was southern bluefin tuna (SBT), and thus, majority of efforts was deployed in the higher latitude of southern Indian Ocean (40S – 50S, Fig. 7) where blue shark was also abundant. In the period of 1991 – 1995 and after, the distribution of fishing effort in 45S-50S is almost disappeared and instead of it, the amount of effort in the lower latitudinal area (15N – 40S) started to increase rapidly. Coinciding with this geographical effort shift, amount of total effort shows drastic up and down, i.e., the total amount of effort dropped sharply in 1985 – 1990, stayed low level in 1990 – 1993, and increased rapidly in 1993 – 1997 (Fig. 6). The sharp drop of the total effort in 1985 – 1990 would be due to the introduction of SBT catch quotas by three main SBT fishing nations (Japan, Australia and New Zealand) started in 1989 to conserve SBT stock (CCSBT, 2012). -Sakai et al. (2011) reported the effort targeting SBT steeply decreased from 1983 to 1994 and kept lower level in the SBT fishing ground until now. Thus, the rapid increasing trend of the effort in 1993 – 1997 and higher level of it in the following period of 1997 – 2007 should be not targeting SBT but targeting other fishes such as Bigeye and Yellowfin tunas. The increment of effort after 1993 was mainly occurred in the off Mombasa, off Freemantle and off Somalia where the fishing ground for Bigeye and Yellowfin Tunas, and these catches caught by longline in the Indian Ocean sharply increased from 1993 to 1997 (NFIFSF et al., 2011).

In spite of these drastic changes of operational pattern of Japanese longliners, single criterion of 80% reporting ratio supposed to be too simple to select out reliable shark catch and effort data. In addition to this, gear configuration of Japanese longliners targeting Bigeye and Yellowfin Tunas are generally more variable than those targeting SBT as the environmental conditions and swimming behaviors of target fishes of tropical tuna fishing grounds are more variable than those of SBT (Japan Tuna Fishing Cooperation, person. comm.). Thus, the model structure of GLM in the second period would be too simple to adjust the effects of variable configurations of fishing gear on the CPUE of blue sharks, and this supposed to be, at least partially, the reason of the unnatural fluctuations of blue shark CPUE in the second period. Especially, the rapid increasing trend of standardized CPUE obtained in the late 1990s may not reflect actual trend of the blue shark abundance as this period coinciding with the period of effort expansion in the tropical tuna fishing ground.

In the present study, the standardized CPUE of blue shark caught by Japanese longliners is re-estimated and updated with modified method from the previous study by Hiraoka and Yokawa (2011). The re-estimated standardized CPUE shows rather stable trend in the first period of 1971 – 1993, and general increasing trend in the second period of 1994 – 2011. Though some unnatural fluctuation are observed in the second period, the estimated standardized CPUE believed to be reflecting general trend of the blue shark stocks in the period of analysis. This study also estimated the total annual catch number in the period analyzed, which could be directly used for the estimation of total annual catch weight using information about seasonal and areal average weight. Same method would also be applied for the estimate of total annual catch of other longline fleet with no historical catch data but effort data of blue shark. Thus the results of this study could offer the basic information for some simple stock analysis like surplus production model on blue shark stocks. The observed fluctuation of the standardized CPUE in the second period supposed not to reflect the actual fluctuation of the stock but to be caused by the somewhat simpler method of data selection or the model structure of GLM. The improvement of data selection and analysis method would enable us to estimate less fluctuating trend of the standardized CPUE.

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Received: 12 September, 2012
IOTC–2012–WPEB08–28

Table 1. Annual, standardized CPUEs, nominal CPUEs and estimated catch in number

Year	standarized CPUE	nominal CPUE	estimatd catch
1971	1.153	2.238	109272
1972	1.590	2.647	108241
1973	1.067	2.361	94259
1974	1.285	3.038	130052
1975	1.279	3.509	131595
1976	1.107	3.265	100447
1977	1.245	3.735	89489
1978	1.443	3.587	113961
1979	1.487	3.650	128937
1980	1.678	3.375	183043
1981	1.281	2.669	139686
1982	1.297	2.521	141408
1983	1.507	3.023	197228
1984	1.366	3.118	190838
1985	1.317	2.537	201022
1986	1.251	2.426	181887
1987	1.446	3.693	181300
1988	1.432	3.078	144421
1989	1.277	3.071	114604
1990	1.228	2.497	76484
1991	1.292	3.089	97376
1992	1.138	2.534	80123
1993	1.331	3.350	82917

Year	standarized CPUE	nominal CPUE	estimated catch
1994	0.4901175	3.278	55288
1995	0.3939367	2.457	54476
1996	0.2296933	3.551	36977
1997	0.5527167	2.694	85189
1998	0.7788196	2.639	100438
1999	1.162124	5.805	143358
2000	0.6147562	2.676	69510
2001	0.7649316	2.343	98884
2002	0.5454057	1.953	64064
2003	0.8086108	3.942	58876
2004	0.5260523	2.285	57203
2005	0.7229144	2.550	83213
2006	0.5129573	2.335	56585
2007	0.9919491	4.001	86680
2008	1.0445998	3.202	74486
2009	0.8651237	2.505	58717
2010	0.8812494	2.865	40796
2011	0.9480562	3.413	30868

Received: 12 September, 2012
IOTC–2012–WPEB08–28

Table 2. 80% filtered and unfiltered effort (million hooks), and those of operation

	Effort (million hooks)		Operation	
	80% filtered	unfiltered	80% filtered	unfiltered
1971	12.3	71.6	3984	31502
1972	10.2	55.9	2764	23971
1973	6.2	66.7	2295	30267
1974	8.7	72.3	3781	32574
1975	6.3	74.4	3021	34105
1976	4.2	70.1	1944	31030
1977	2.8	59.0	1321	25840
1978	4.5	62.9	2040	27421
1979	4.2	65.8	1954	27470
1980	6.0	85.4	2772	35133
1981	6.2	85.5	2861	34535
1982	5.3	86.9	2399	34378
1983	5.7	104.7	2521	40922
1984	6.5	112.5	2725	42789
1985	9.6	125.4	3995	47074
1986	8.3	117.6	3349	43345
1987	6.8	102.0	2682	37009
1988	6.8	82.9	2700	30341
1989	6.0	71.9	2279	25958
1990	4.3	48.3	1674	17818
1991	3.8	55.5	1408	19777
1992	4.7	54.0	1753	19351
1993	4.2	46.9	1533	16770
1994	5.2	71.2	1917	25416
1995	5.0	87.0	1832	30481
1996	4.6	103.3	1603	35706
1997	6.9	113.6	2395	39268
1998	4.8	108.2	1707	36674
1999	2.5	95.5	883	32447
2000	3.3	91.8	1149	31092
2001	4.1	100.6	1431	33484
2002	4.7	93.0	1570	30657
2003	2.6	69.3	891	22798
2004	3.5	87.7	1227	28911
2005	4.4	99.1	1517	32561
2006	4.4	105.5	1457	33490
2007	3.9	98.0	1252	30685
2008	20.6	81.5	6442	25281
2009	22.4	66.0	7034	20417
2010	16.0	40.1	5046	12277
2011	10.9	25.2	3532	8092

Received: 12 September, 2012
IOTC–2012–WPEB08–28

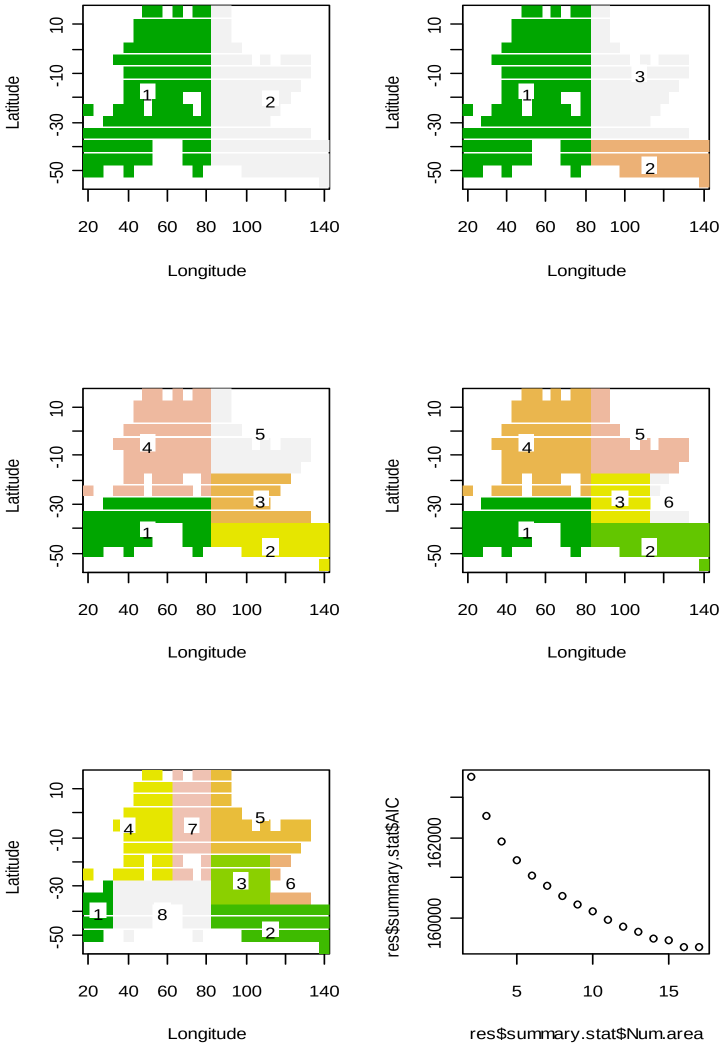

Figure 1. The 1st to 7th steps of area stratification and AIC values of GLM models with the each steps of area stratification by the GLM-tree using the data categorized as "sharks" and filtered by >=80% reporting rate between 1971 and 1993. The area stratification by 7th step (left bottom panel) were used in the CPUE standardization.

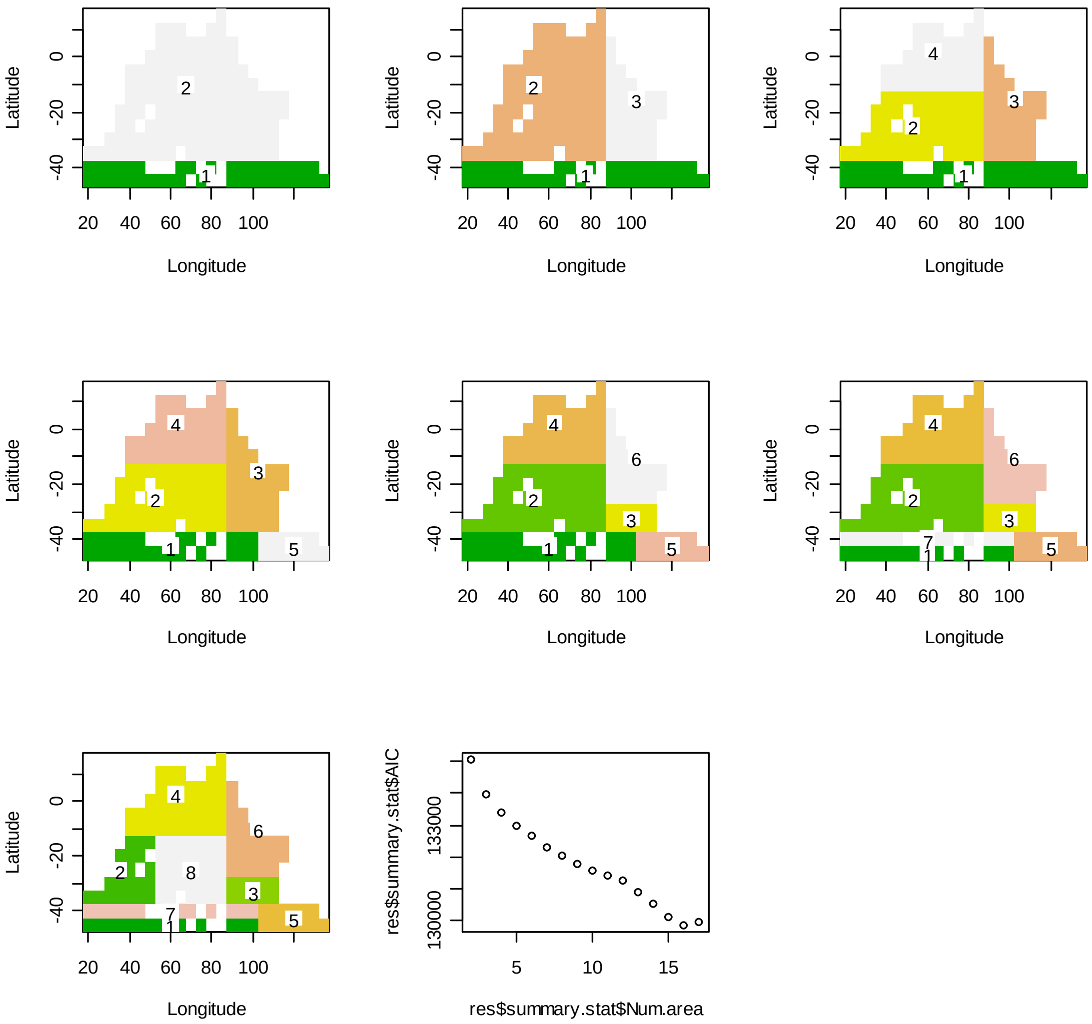

Figure 2. The 1st to 7th steps of area stratification and AIC values of GLM models with the each steps of area stratification by the GLM-tree using the data categorized as "blue sharks" and filtered by >=80% reporting rate between 1994 and 2011. The area stratification by 7th step (left bottom panel) were used in the CPUE standardization.

Received: 12 September, 2012
IOTC–2012–WPEB08–28

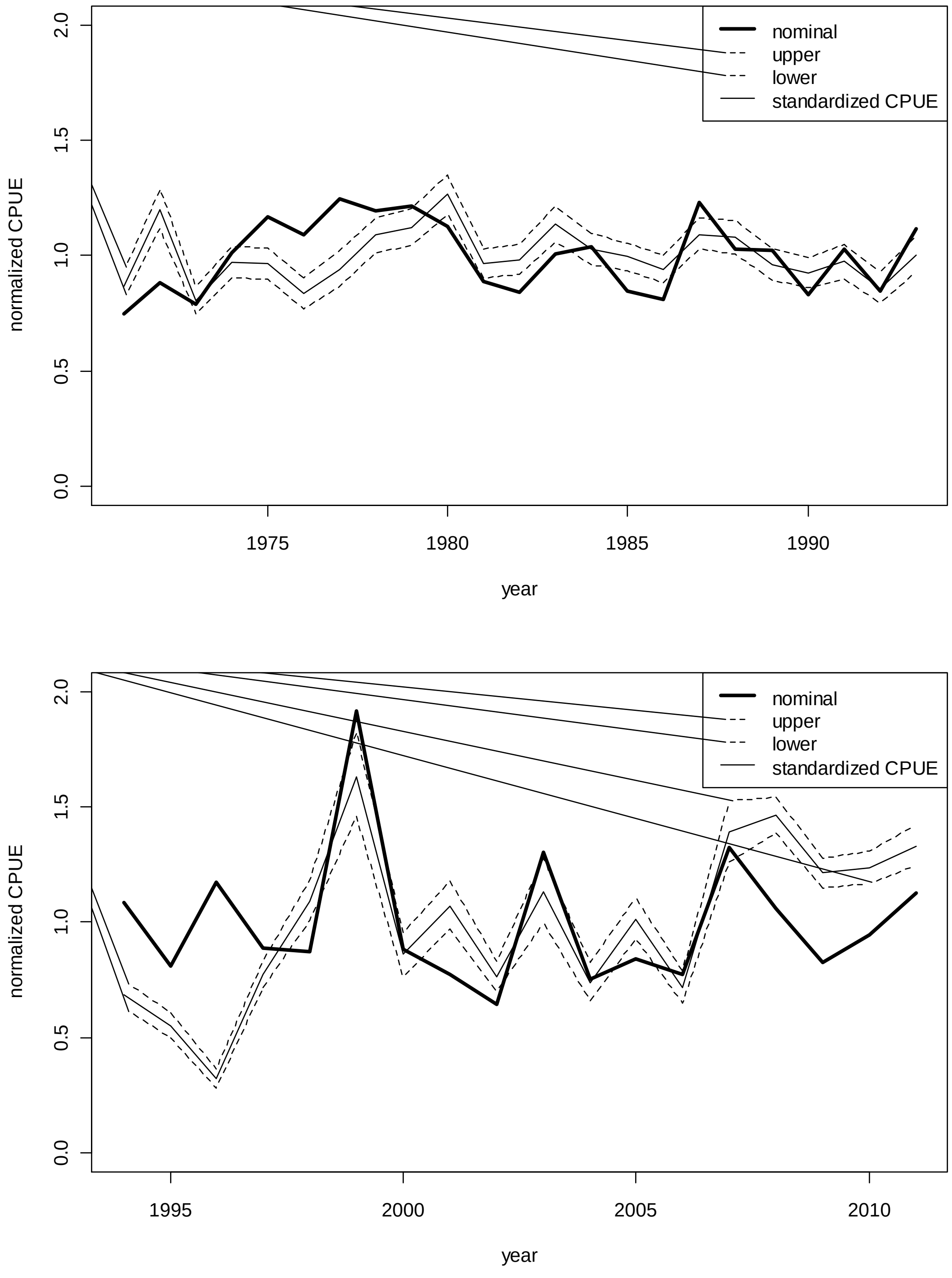

Figure 3. Nominal CPUE, standardized CPUE and its 95% confidence interval for blue shark in the Indian Ocean (upper: 1971-1993, lower: 1994-2011).

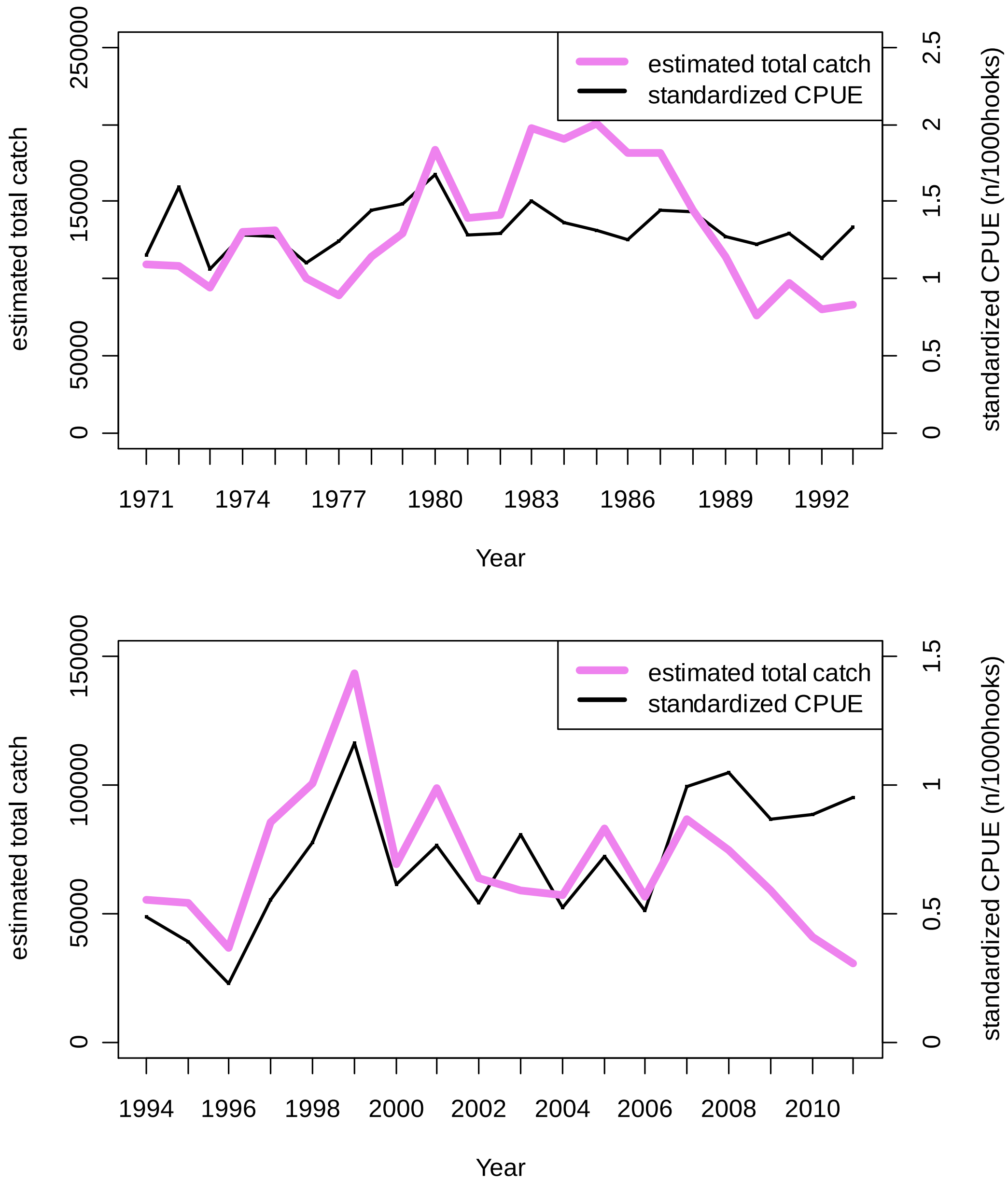

Figure 4. Estimated catch in number and standardized CPUE for blue shark in the Indian Ocean (upper: 1971-1993, lower: 1994-2011).

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IOTC–2012–WPEB08–28

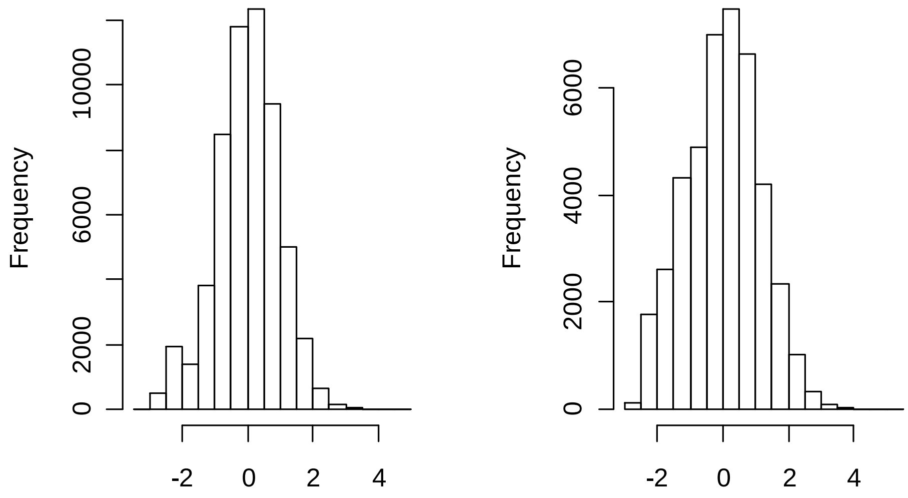

Figure 5. Standardized residuals for CPUE analysis of blue shark (left: 1971-1993, right: 1994-2010).

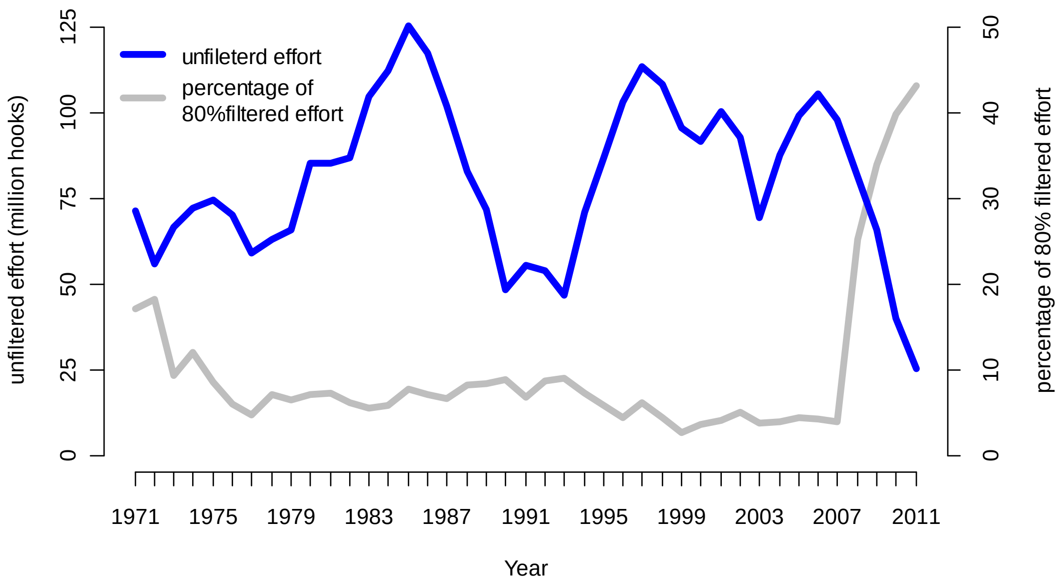

Figure 6. Annual unfiltered effort (million hooks) and percentage of 80% filtered effort to unfiltered effort during 1971 -2011.

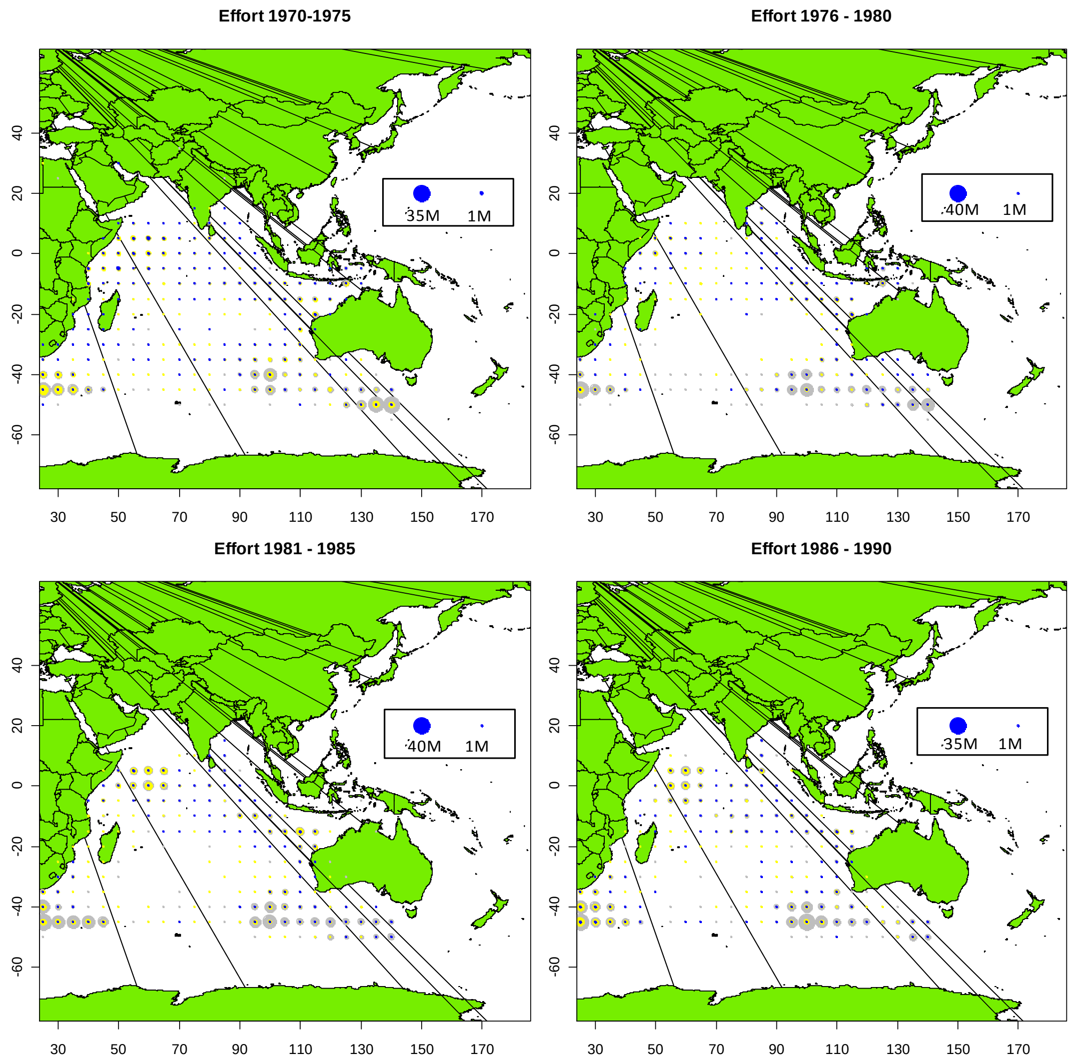

Figure 7. Distribution of unfiltered (grey circle), 10% filtered (yellow circle) and 80%filtered (blue circle) effort (million hooks) for each time periods. Size of the circle correspond to the proportion of total effort (million hooks) by 5 x 5 degree.

Received: 12 September, 2012
IOTC–2012–WPEB08–28

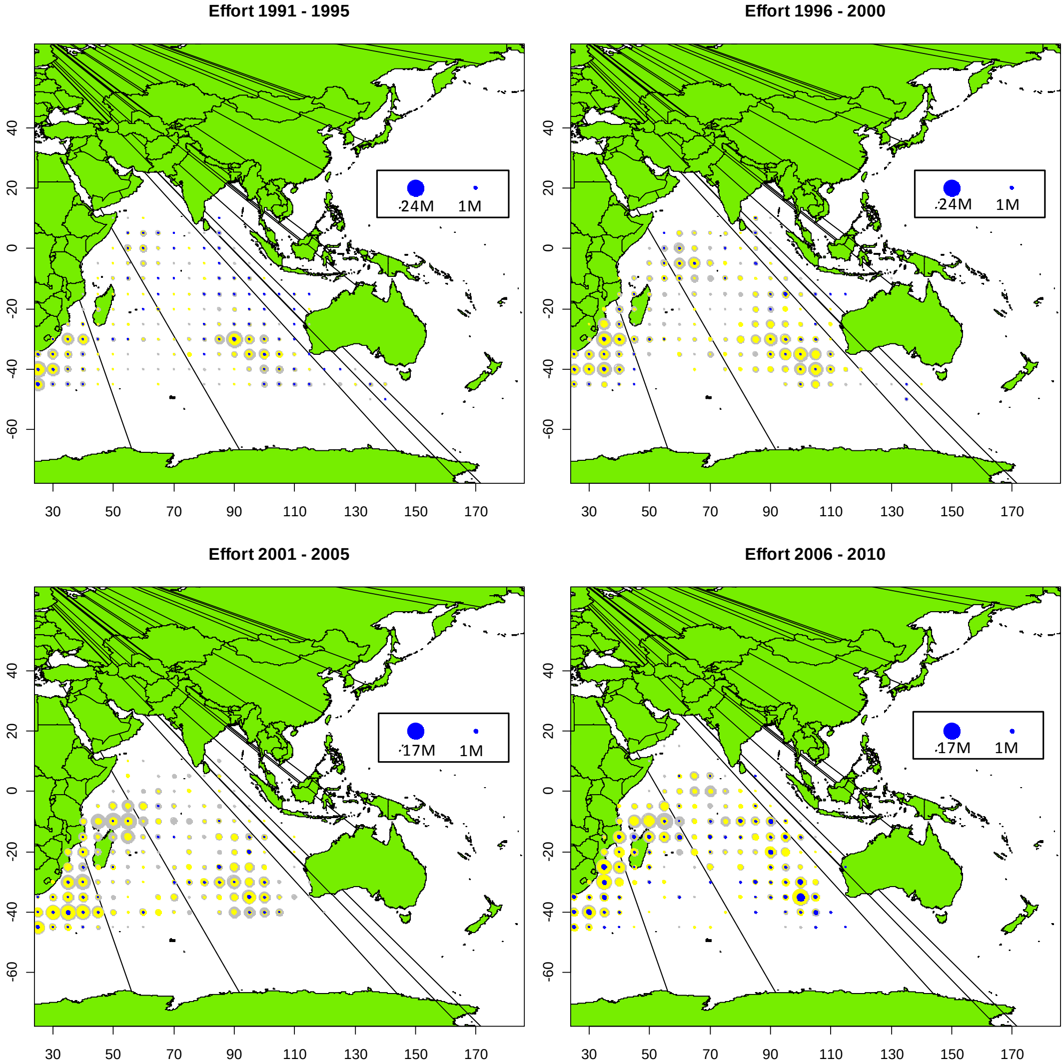

Figure 7. Continued.

Received: 12 September, 2012
IOTC–2012–WPEB08–28

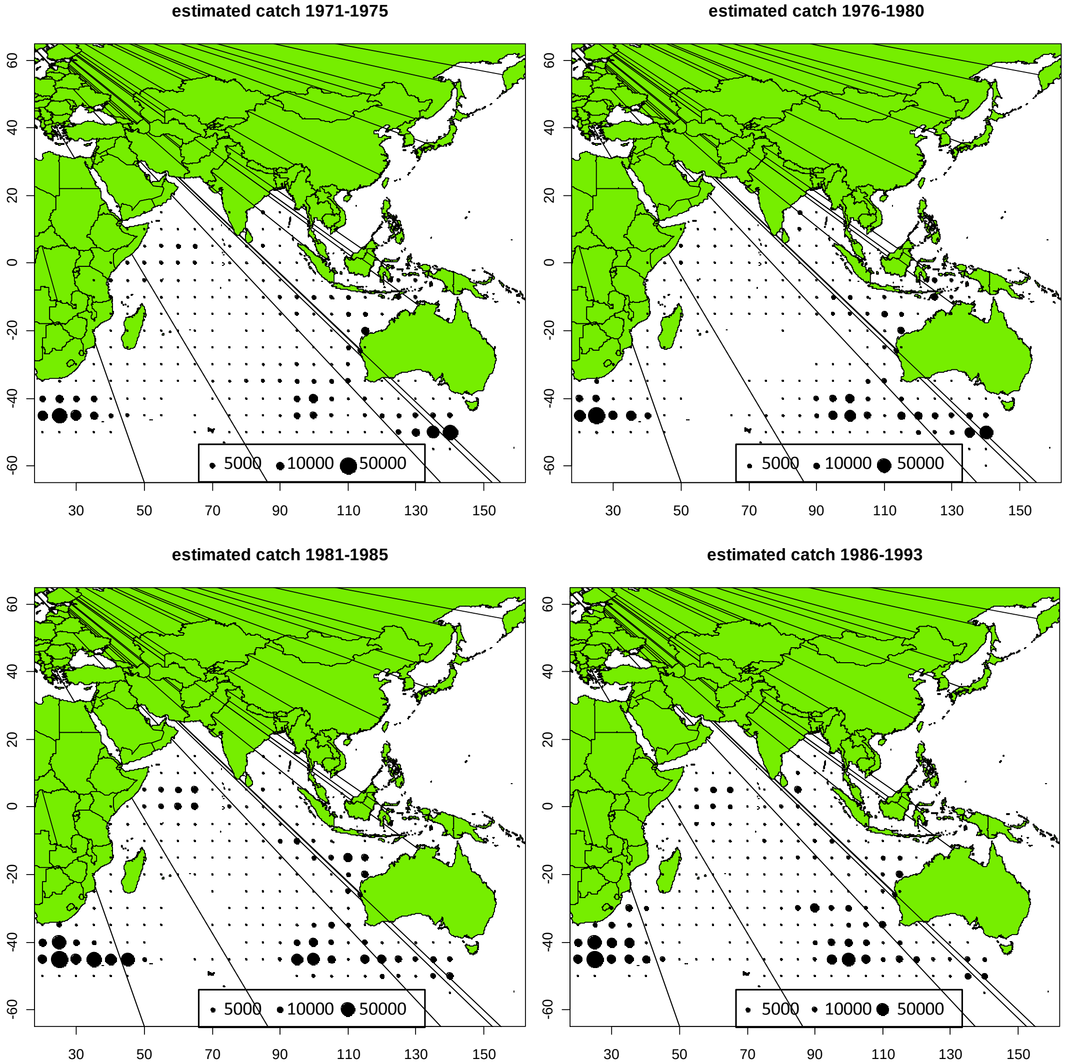

Figure8. Distribution of estimated catch for each time periods. Size of the circle correspond to the proportion of total catch by 5 x 5 degree.

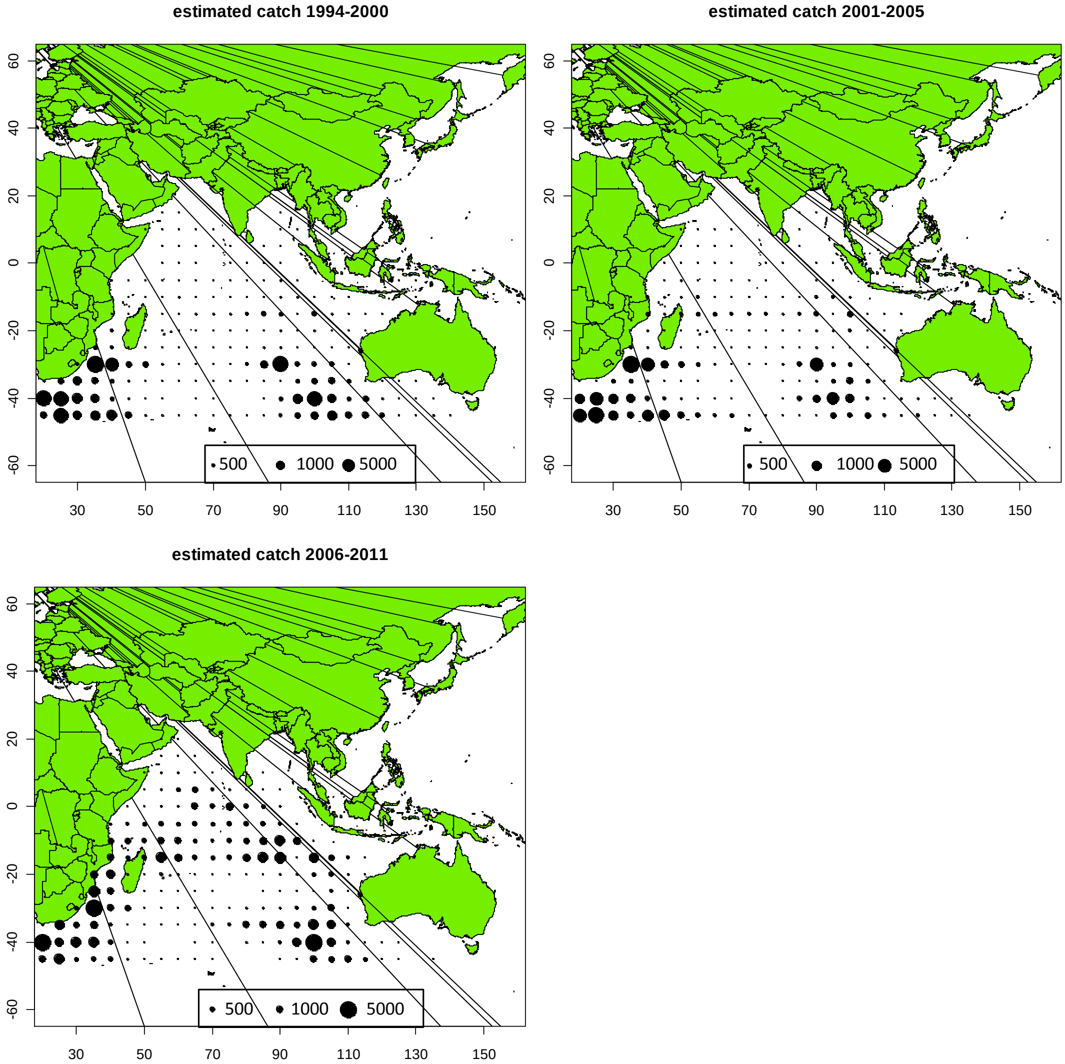

Figure 8. Continued.