Review of Japanese fisheries and tropical tuna catch in the Indian Ocean

by

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Summary

Japanese longline vessels have been targeting bigeye and yellowfin tunas along with albacore and southern bluefin tuna. The fishing effort for longline fishery fluctuated and sharply decreased in recent years, which is mainly by the decrease in the northwestern part due to piracy activities. Both bigeye and yellowfin tuna catch peaked in 1968, sharply decreased in the 1970s, fluctuated after that, and sharply decreased around late 2000s. High CPUE for bigeye and yellowfin tuna was observed mainly in the eastern and western Indian Ocean, respectively. Japanese purse seine vessels have been targeting skipjack, yellowfin and bigeye tuna since 1970s. Fishing effort of purse seine peaked in 1992, and then decreased until 2000, after that it kept low level. The annual catch of tropical tuna coincided with the trend of effort. The vessels mainly operated in the eastern part after 2000s. Set for logs or natural objects was main component before mid-1980s, and then FAD associated schools become dominant.

1. Introduction

There are two kinds of Japanese tuna fisheries in the Indian Ocean, i.e. longline and purse seine fisheries. Both fisheries catch tropical tunas. The longline fishery commenced in 1952 in the eastern equatorial waters in the Indian Ocean. The fishing effort of the longline first expanded westward, and then southward. In the late 1960s, the effort covered entire fishing ground of the longline in the Indian Ocean. The annual amount of the effort has changed since the late 1960s. Also, annual catch of bigeye and yellowfin tuna have considerably changed especially as for yellowfin, which varied from 2,100 t to 59,000 t (Table 1), as well as catches of other tunas.

The purse seine fishery commenced in 1950s. In the early period, as far as data exist, operations were conducted in the eastern equatorial waters in the Indian Ocean. After 1978 the fishery in the Indian Ocean gradually developed and from the late 1980s to the middle 1990s the effort covered entire the Indian Ocean. After that the fishery was considerably contracted and stable but low level in effort after 2000. The annual catch of the tropical tuna were coincided with the trend of effort.

In this document, historical and spatial changes of tropical tuna catch and the fishing effort by longline and purse seine fisheries, including recent situation, are described in conjunction with the catches of the other tunas and tuna-like species.

2. Data source

In order to count the effort (number of hooks for longline and number of sets for purse seine) and catches (in number by longline and in weight by purse seine), basic data used here is the logbook data that have been compiled at National Research Institute of Far Seas Fisheries (NRIFSF) based on the logbooks mandatory submitted by the fishermen of the longline and purse seine vessels larger than 20 gross ton (GRT). The data for longline fishery are so-called “raised” data, which is aggregated by month and 5˚x5° block, and then expanded

with coverage rate of the logbook. As for purse seine fishery, logbook coverage is 100%. The basic data is available for 1952-2019 for longline and 1967-2019 for purse seine. Data for 2019 are preliminary especially for purse seine. The geographical range as the "Indian Ocean" to count the amount of the effort and the catches from the basic data is shown in Fig. 1. As for catch in weight by area for longline fishery, IOTC database was used.

3. Trend of catch and effort

3.1. Longline fishery

Table 2 and Fig. 2a indicate that after the beginning of the exploitation by longline fishery in the Indian Ocean, annual fishing effort increased until 1967 and then fluctuated ranging from 40% to 99% of the peak year until 2009. However, fishing effort is decreasing trend since 2007, and in 2019 (preliminary) it decreased to about 16% of the peak value, and is lowest after 1960. Main reason of the decrease in recent years is the effects of piracy activities in the western Indian Ocean (around Somalia). Fishing effort after 2014 shows gradual decrease. Yellowfin tuna catch (in number) peaked (1,714 thousands fish) in 1968, then sharply decreased to 85 thousands fish in 1977, corresponding to 5% of the level in peaked year, and then gradually increased with fluctuation. The catch in 2006 was 708 thousand fish, which corresponds to 41% of peak value and was highest since 1970. After that the catch decreased again and kept in a low level since 2010. Catch in 2019 (62 thousands fish, preliminary) was historical low level. Bigeye tuna catch (in number) peaked (541 thousands fish) in 1968, then sharply decreased to 61 thousands fish in 1976, corresponding to 11% of the level in peaked year, and then fluctuated between about 100 and 400 thousands fish. Bigeye tuna catch also decreased recently (after 2007) and kept in a low level since 2010. Following is the description for the temporal and spatial changes of the catch and the effort including detailed description in recent years.

Fig. 3 shows geographical distribution of fishing effort (number of hooks), bigeye and yellowfin tuna CPUE by each decade. In the 1950s, when the effort increased (Fig. 2a), the effort was deployed mainly in the region north of 15˚S. The main component of the catch was yellowfin tuna in this fishing ground (Fig. 2b).

Following this period, the effort continued to increase up to 130 million hooks until the late 1960s (Fig. 2a). In this period, the total catch of four species of tunas, i.e., yellowfin, albacore, southern bluefin and bigeye tunas was historical highest, and species-specific catches were also the highest for yellowfin, albacore and bluefin tunas (Fig. 2b). Of the four species, yellowfin tuna was the most dominant catch in this period, followed by albacore and southern bluefin tuna. Also the catch of bigeye tuna in this period increased compared to the catch in the 1950s. In this period, fishing ground of this fishery expanded to southward, in the west side and the east side of the Indian Ocean, excluding the southern central of the Indian Ocean. Bigeye CPUE was high in the tropical area and in the region between 25˚S and 35˚S. The CPUE of yellowfin tuna was also high in the tropical area especially in the western part. In the west side of this region, main component of the catch was yellowfin tuna (Fig. 4), on the other hand, yellowfin and bigeye tunas were caught comparatively equally in the eastern equatorial area.

In the period from the late 1960s to the late 1970s, the effort decreased to about 60 million hooks, about 50% of the peak year (Fig. 2a). In this period, catch of yellowfin and bigeye drastically decreased compared to that in the previous period (Fig. 2b). This decrease was due to withdrawing in the effort from the fishing ground in the tropical area as well as decrease in CPUE.

In the period from the late 1970s to the mid 1980s, the effort increased again and reached to 130 million hooks (Fig. 2a), the same level as the previous peak in the 1960s. This increase was seen in the regions off Somalia and the south of 35˚S, targeting bigeye tuna and high quality (=oily) southern bluefin tuna, respectively.

In the period from the mid-1980s to the early 1990s, the effort decreased again (Fig. 2a). This decrease was

due to the decrease of the effort in the region south of 35˚S, corresponding to the fishing ground for southern bluefin tuna, by introduction of the TAC for southern bluefin tuna in 1986.

In the period from the early to late 1990s the effort increased (Fig. 2a). The increase was seen in the regions off west coast of Australia probably targeting bigeye tuna, and south of Madagascar Island where yellowfin, albacore and bigeye were mainly caught (Fig. 4). During 1980s - 1990s effort in the tropical area is higher in the western part than in the eastern part.

In the period of 2000s the effort kept high until 2007, and sharply decreased during 2008-2010 (Fig. 2a). The decrease has been seen especially in the regions off Somalia (Fig. 5, Fig. 6). This is due to the effect of piracy activities in this area as mentioned above. There is almost no fishing effort in this area in the 2010s (Fig. 3). However, high CPUE for bigeye and yellowfin tunas was seen in the eastern tropical area and in the area around Madagascar, respectively (Fig. 5). Recent situation of the distribution of effort by area due to piracy activities seems to be unusual. In recent years, the proportion of albacore is higher (Fig. 2b'). This is due to higher proportion of fishing effort in the temperate area as well as increased market demand and commercial value for this species, which increased targeting this species.

3.2. Purse seine fishery

Table 3 and Fig. 7 indicate effort and catch by species caught by Japanese purse seine fishery in the Indian Ocean. Annual fishing effort (number of set) increased in 1990s and marked historical highest value (1,372 sets) in 1992, and then decreased rapidly to 171 sets in 2000, after that it kept in a low level with fluctuation. The annual catch of the tropical tuna coincided with the trend of effort, which reached to 45,000 mt in 1992 and then decreased to 3,000 mt in 2001. After that it ranged between about 1,000 and 6,000 mt. Data for 2019 are very preliminary, and so catch and effort will increase. Usually 60 to 70% of the catch (excluding species other than tropical tuna) is skipjack tuna. In recent years, increasing and decreasing trend for the proportion of skipjack and bigeye tuna, respectively, is seen (Fig. 7).

The number of Japanese purse seine vessels in the Indian Ocean from 1991 to 1992 was 11, and then sharply decreased to 2 in 2000, and then ranged from 1 to 3 after 2001.

Fig. 8 shows the proportion of the number of set by school type. Associated schools with natural objects were dominant until mid-1980s, and then FAD associated schools became dominant. The proportion of free swimming school was low (mostly less than 10%) over the entire period. Fig. 9 shows historical trend of nominal CPUE for tropical tunas. Increasing trend with fluctuation is observed for skipjack and bigeye tuna until early 2010s, and then it decreased. although CPUE was comparatively stable for yellowfin tuna especially after early 1990s. In recent years, CPUE for tropical tunas combined is around 20 mt per set, which is lower than that in 2000s and early 2010s.

Fig. 10 and Fig. 11 show geographical distribution of catch by species for each decade and annual change in recent years, respectively. From late 1980s to mid-1990s, when the effort increased (Table 3), the effort was deployed in the whole equatorial area of the Indian Ocean, and then the effort mainly distributed in the eastern area of the Indian Ocean. The proportion of bigeye tuna was usually higher in the east side of the Indian Ocean. The change in fishing ground, along with the spread of FADs, may be the reason for increasing proportion and CPUE for bigeye tuna.

Table 1. Catch in weight (t) for bigeye and yellowfin tuna caught by Japanese longline fishery. Western: FAO area No. 51 (mostly west of 80°E), eastern: FAO area No. 57 (mostly east of 80°E). Data source: IOTC database.

	Bigeye tuna			Yellowfin tuna		
Year	Western	Eastern	Total	Western	Eastern	Total
1952		280	280		3,683	3,683
1953		1,653	1,653		6,757	6,757
1954	592	6,158	6,750	5,660	16,006	21,666
1955	4,045	5,494	9,539	32,404	11,759	44,163
1956	5,481	6,764	12,245	42,805	16,680	59,485
1957	3,811	7,279	11,090	15,291	16,573	31,864
1958	4,782	5,371	10,153	12,273	10,371	22,644
1959	4,056	4,310	8,366	14,379	7,803	22,182
1960	7,903	6,910	14,813	24,107	11,948	36,055
1961	5,918	7,130	13,048	24,862	7,868	32,730
1962	7,878	9,401	17,279	28,874	15,317	44,191
1963	5,296	6,304	11,600	16,052	5,929	21,981
1964	7,536	8,473	16,009	15,412	6,751	22,163
1965	9,100	8,467	17,567	18,522	6,404	24,926
1966	14,887	6,500	21,387	33,543	7,219	40,762
1967	13,102	8,697	21,799	22,223	7,940	30,163
1968	15,489	8,125	23,614	42,349	5,977	48,326
1969	10,860	3,493	14,353	19,625	3,489	23,114
1970	4,973	7,736	12,709	4,569	5,771	10,340
1971	6,901	4,285	11,186	9,793	3,577	13,370
1972	6,701	1,647	8,348	6,171	1,713	7,884
1973	3,395	1,767	5,162	2,472	1,462	3,934
1974	3,464	3,422	6,886	2,904	2,045	4,949
1975	2,972	2,552	5,524	4,304	2,116	6,420
1976	1,175	933	2,108	1,903	876	2,779
1977	2,030	1,107	3,137	1,656	444	2,100
1978	7,637	3,268	10,905	3,880	740	4,620
1979	2,297	1,910	4,207	2,583	712	3,295
1980	3,433	2,466	5,899	1,944	1,292	3,236
1981	5,860	1,915	7,775	3,855	1,060	4,915
1982	8,955	2,439	11,394	6,034	1,246	7,280
1983	13,744	4,588	18,332	5,979	1,814	7,793
1984	9,313	4,709	14,022	5,295	2,608	7,903
1985	13,647	3,592	17,239	7,205	2,260	9,465
1986	12,114	3,644	15,758	8,276	2,428	10,704
1987	11,179	4,330	15,509	5,723	2,586	8,309
1988	9,481	2,773	12,254	6,885	2,370	9,255
1989	6,269	1,432	7,701	3,443	1,149	4,592
1990	5,837	2,385	8,222	4,395	1,941	6,336
1991	4,915	2,853	7,768	3,487	901	4,388
1992	4,011	1,618	5,629	5,193	548	5,741
1993	4,243	4,074	8,317	5,349	365	5,714
1994	9,946	7,536	17,482	8,903	814	9,717
1995	7,742	9,469	17,211	6,265	1,761	8,026
1996	8,090	8,364	16,454	11,396	1,411	12,807
1997	10,741	8,063	18,804	13,942	1,658	15,600
1998	11,103	6,021	17,124	15,347	1,457	16,804
1999	6,234	7,762	13,996	11,990	2,673	14,663
2000	6,540	7,019	13,559	12,602	2,873	15,475
2001	5,441	7,601	13,042	11,858	2,082	13,940
2002	6,360	7,521	13,881	12,763	1,170	13,933
2003	6,715	3,251	9,965	16,598	560	17,159
2004	7,382	3,263	10,645	15,556	479	16,034
2005	10,840	1,704	12,544	21,178	314	21,492
2006	9,455	4,465	13,920	21,698	612	22,310
2007	13,072	5,096	18,168	17,800	792	18,592
2008	8,390	5,349	13,739	10,010	415	10,425
2009	3,761	5,232	8,993	4,437	441	4,878
2010	1,090	3,155	4,244	3,274	199	3,473
2011	792	2,962	3,754	4,364	177	4,541
2012	1,542	3,932	5,474	3,085	245	3,330
2013	981	4,602	5,582	4,003	156	4,158
2014	543	4,767	5,310	3,529	110	3,639
2015	334	4,543	4,876	3,025	115	3,140
2016	628	3,411	4,039	2,870	97	2,967
2017	1,052	2,688	3,739	3,202	89	3,291
2018	607	2,774	3,382	2,793	206	2,999

Table 2. Annual fishing effort (number of hooks) for the Japanese longline fishery and its catch in number by species.

	#of hook	Catch in number (thousand)										
	(thousand)	SBT	ALB	BET	YFT	SWO	STM	BUM	BKM	SAI	SBS*	SKJ
1952	2,021	6	3	21	131	0	3	9	6	16		31
1953	7,071	50	57	53	240	2	7	27	17	5		22
1954	12,557	31	142	137	472	4	21	47	25	4		9
1955	16,109	24	157	173	972	5	19	51	24	9		10
1956	30,064	119	258	281	1,245	10	45	74	41	10		6
1957	26,609	193	232	215	728	8	50	57	36	4		6
1958	23,269	120	301	191	556	12	46	62	30	2		1
1959	34,021	693	524	169	598	12	56	64	28	6		3
1960	52,554	1,072	574	314	962	15	52	56	41	2		3
1961	59,807	910	777	270	869	17	65	49	35	4		2
1962	65,755	432	1,010	419	1,331	22	48	46	45	4		1
1963	56,453	649	722	264	655	17	34	27	26	4		3
1964	68,342	490	1,010	334	594	21	38	43	34	6		4
1965	80,372	459	630	386	767	25	81	50	30	10		3
1966	93,511	428	752	479	1,156	29	105	50	31	7		5
1967	129,496	787	850	517	903	40	114	51	35	5		4
1968	124,438	689	623	541	1,714	30	63	34	44	4		2
1969	108,171	674	589	378	771	31	59	26	35	2		1
1970	89,731	454	304	342	375	27	45	17	25	1		1
1971	96,596	411	228	290	480	24	28	14	16	1		0
1972	80,158	467	100	212	294	21	21	14	6	0		0
1973	82,768	442	145	138	148	17	15	8	5	0		0
1974	88,397	476	182	190	200	18	38	13	10	0		0
1975	90,236	322	79	179	249	19	25	10	11	0		0
1976	80,284	452	99	61	95	9	14	4	4	1		1
1977	62,583	365	33	98	85	6	13	4	2	0		1
1978	69,281	259	32	312	170	23	44	13	7	1		6
1979	67,728	254	32	122	133	12	25	6	3	2		6
1980	91,661	357	47	161	106	13	24	8	4	2		6
1981	88,407	294	87	191	159	16	21	10	4	1		8
1982	88,257	238	105	283	228	22	15	15	4	0		5
1983	116,631	367	141	428	239	26	16	22	6	0		5
1984	118,289	296	136	346	245	28	25	19	11	1		4
1985	128,438	250	176	410	281	47	25	20	8	0		6
1986	123,252	181	204	382	311	30	24	17	5	1		8
1987	109,888	152	160	382	238	30	16	13	4	2		20
1988	93,254	141	99	295	266	33	6	10	3	2		28
1989	82,513	143	68	182	129	21	3	5	2	1		23
1990	52,576	86	68	199	175	23	2	4	1	1		7
1991	62,434	98	61	208	122	20	4	3	1	0		4
1992	59,284	102	127	133	142	25	3	3	1	0		3
1993	52,337	80	96	214	172	24	2	4	1	0		2
1994	81,656	90	141	393	252	39	4	7	0	0	0	1
1995	92,231	69	147	394	221	26	4	5	1	1	0	1
1996	107,874	79	179	384	325	33	6	7	0	1	0	0
1997	126,308	96	274	432	381	46	7	15	1	6	1	0
1998	124,225	135	236	406	442	39	6	15	2	6	0	0
1999	107,646	118	156	348	409	25	6	10	2	6	3	0
2000	103,462	65	200	336	432	25	7	12	1	8	1	0
2001	109,752	91	226	320	399	20	2	5	0	5	1	0
2002	105,989	61	221	327	396	22	3	6	0	5	1	0
2003	78,268	35	151	245	534	17	1	4	1	4	1	0
2004	98,236	91	280	259	497	19	1	5	0	6	2	0
2005	113,861	104	363	296	665	26	1	6	1	8	2	0
2006	118,365	71	481	341	707	33	2	10	2	20	7	2
2007	117,674	51	399	455	596	44	1	10	2	28	6	1
2008	89,517	22	362	335	332	32	3	8	1	23	7	6
2009	64,951	36	240	232	160	21	1	5	1	7	4	8
2010	36,569	30	282	119	113	11	4	3	0	4	5	2
2011	28,454	37	183	104	139	10	6	3	0	3	9	3
2012	31,466	28	257	139	112	10	3	2	0	2	4	2
2013	29,127	17	190	139	130	11	2	2	0	2	4	3
2014	31,786	19	309	132	98	13	1	1	0	3	5	3
2015	28,958	31	227	125	97	12	0	1	0	2	5	2
2016	27,049	23	195	109	84	12	2	1	0	1	3	1
2017	23,355	18	122	101	83	9	1	1	0	2	3	1
2018	22,207	31	123	93	74	8	0	1	0	2	2	1
2019	20,080	37	120	113	62	7	0	0	0	2	1	1

* Sailfish and spearfish were not separated until 1993

Table 3. Annual number of vessels operated, fishing effort (number of sets) and its catch in weight (t) by species for the Japanese purse seine fishery.

Year	Number of vessels	Number of set	Catch (mt)				
			SKJ	YFT	BET	Others	Total
1972	1	1	0	1	0	0	1
1973	0	0	0	0	0	0	0
1974	1	1	0	0	0	0	0
1975	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0
1977	1	1	1	0	0	0	1
1978	1	107	918	215	5	0	1,138
1979	1	56	566	103	1	8	678
1980	1	50	421	122	8	4	555
1981	1	8	46	32	1	7	85
1982	1	45	453	120	21	11	605
1983	1	52	592	198	54	1	845
1984	1	72	696	242	215	28	1,181
1985	1	19	315	75	168	12	570
1986	1	43	562	160	142	3	868
1987	1	82	884	260	122	18	1,284
1988	1	112	2,250	389	277	74	2,990
1989	3	225	3,449	883	581	73	4,986
1990	4	612	11,187	3,222	1,225	120	15,754
1991	11	899	15,877	5,061	1,269	36	22,242
1992	11	1,372	31,403	11,746	1,732	348	45,229
1993	11	1,329	31,485	11,086	1,984	64	44,618
1994	8	1,199	20,110	5,343	4,182	5	29,640
1995	6	1,229	15,972	4,719	3,576	7	24,274
1996	5	681	7,515	4,035	1,386	15	12,951
1997	3	526	6,713	2,612	1,251	20	10,596
1998	2	412	5,748	1,949	915	2	8,614
1999	3	376	4,588	1,501	899	11	6,999
2000	2	171	2,332	953	747	10	4,042
2001	2	161	1,830	603	592	2	3,027
2002	1	143	1,937	445	649	2	3,033
2003	1	167	2,443	651	812	0	3,906
2004	1	89	1,459	327	524	0	2,310
2005	1	141	3,149	894	849	0	4,892
2006	3	59	1,982	266	547	0	2,795
2007	3	178	4,297	958	987	0	6,242
2008	3	239	3,133	1,175	1,009	0	5,317
2009	2	185	3,434	557	1,571	0	5,562
2010	1	92	1,731	481	868	0	3,080
2011	1	105	1,675	352	1,130	0	3,157
2012	1	72	1,437	232	536	0	2,205
2013	1	27	861	95	197	0	1,153
2014	1	51	496	433	192	0	1,121
2015	3	154	2,140	338	294	0	2,772
2016	3	146	2,357	422	258	0	3,037
2017	3	201	3,129	712	424	0	4,265
2018	3	147	2,076	407	287	0	2,770
2019*	2	9	187	24	24	0	235

* Very preliminary

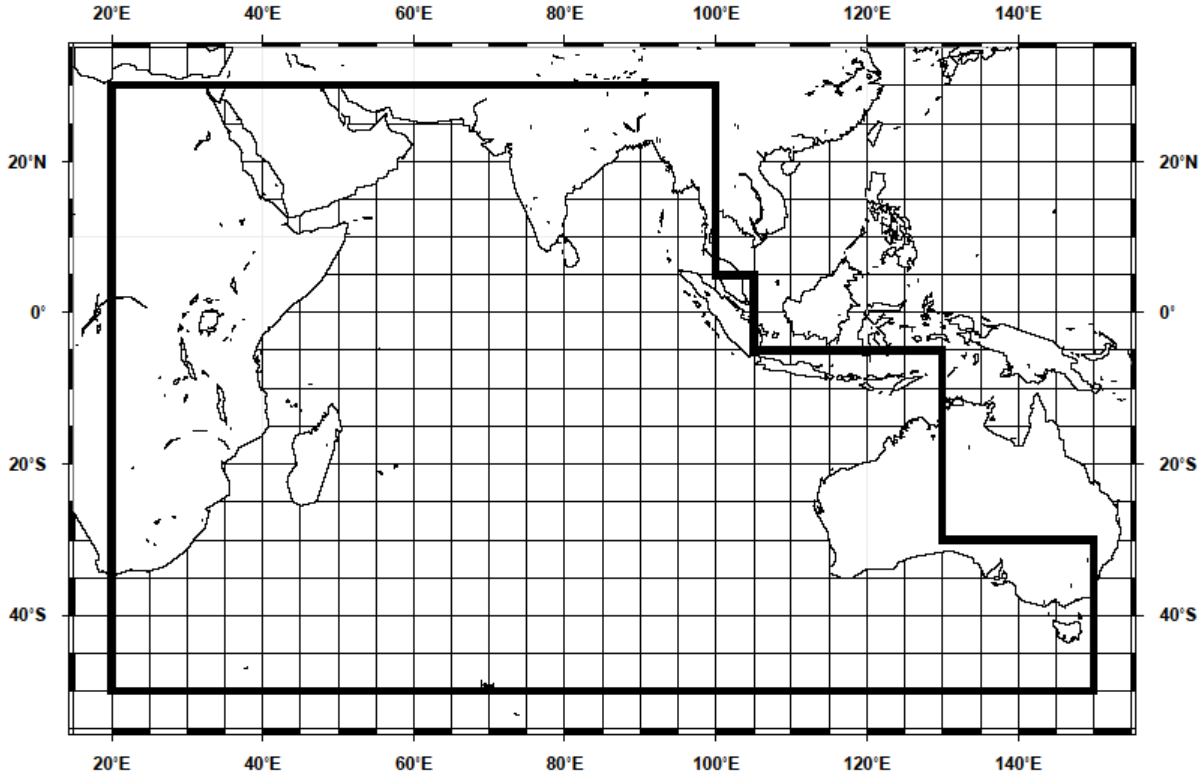


Fig. 1. The geographical range to count the amount of the effort and the catches.

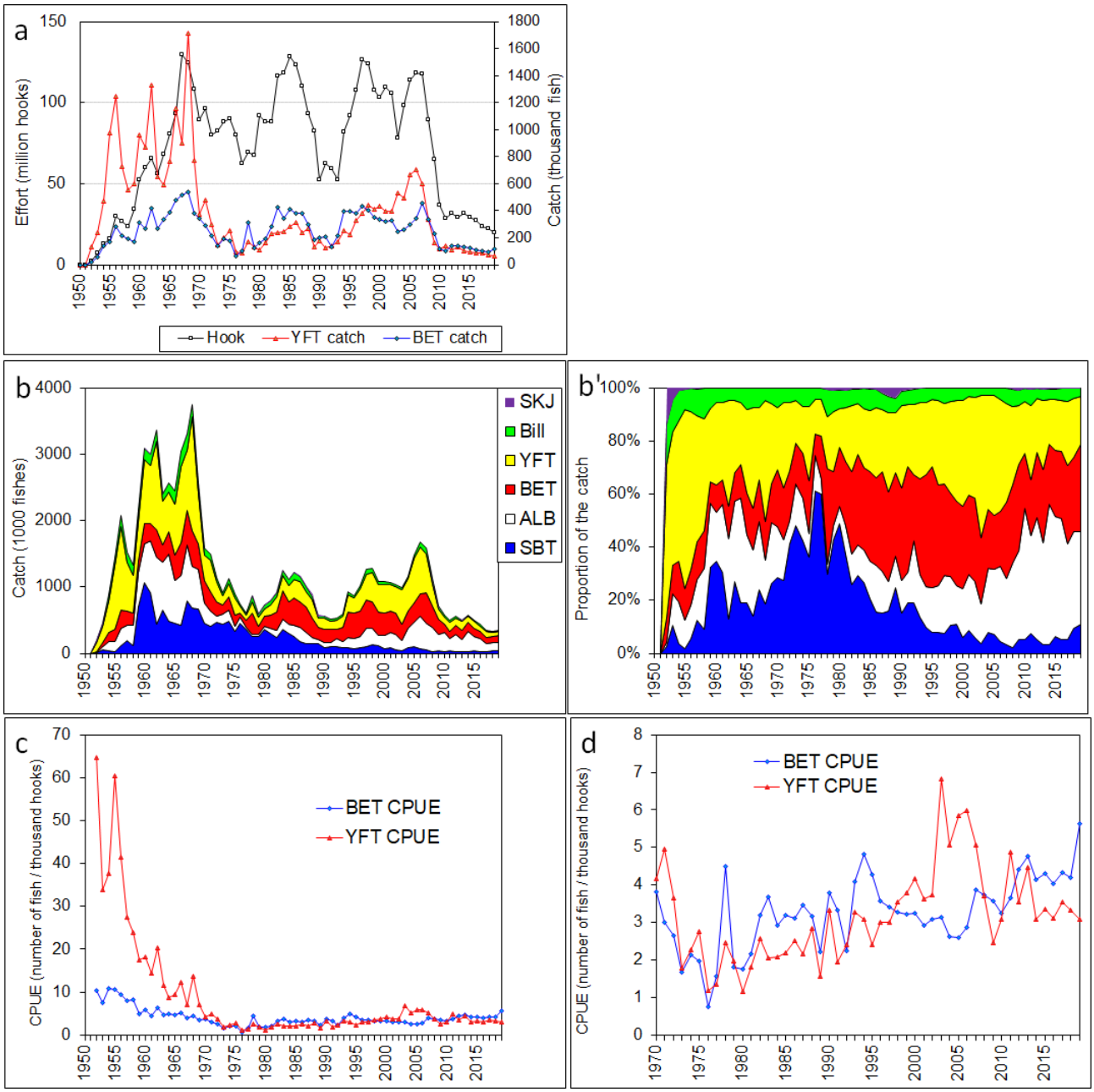


Fig. 2. The number of hooks employed and catch of bigeye and yellowfin tuna (a), catch by species in number (b), species composition in number (b'), and nominal CPUE of bigeye and yellowfin tuna for 1952-2019 (c) and for 1970-2019 (d) caught by Japanese longline fishery.

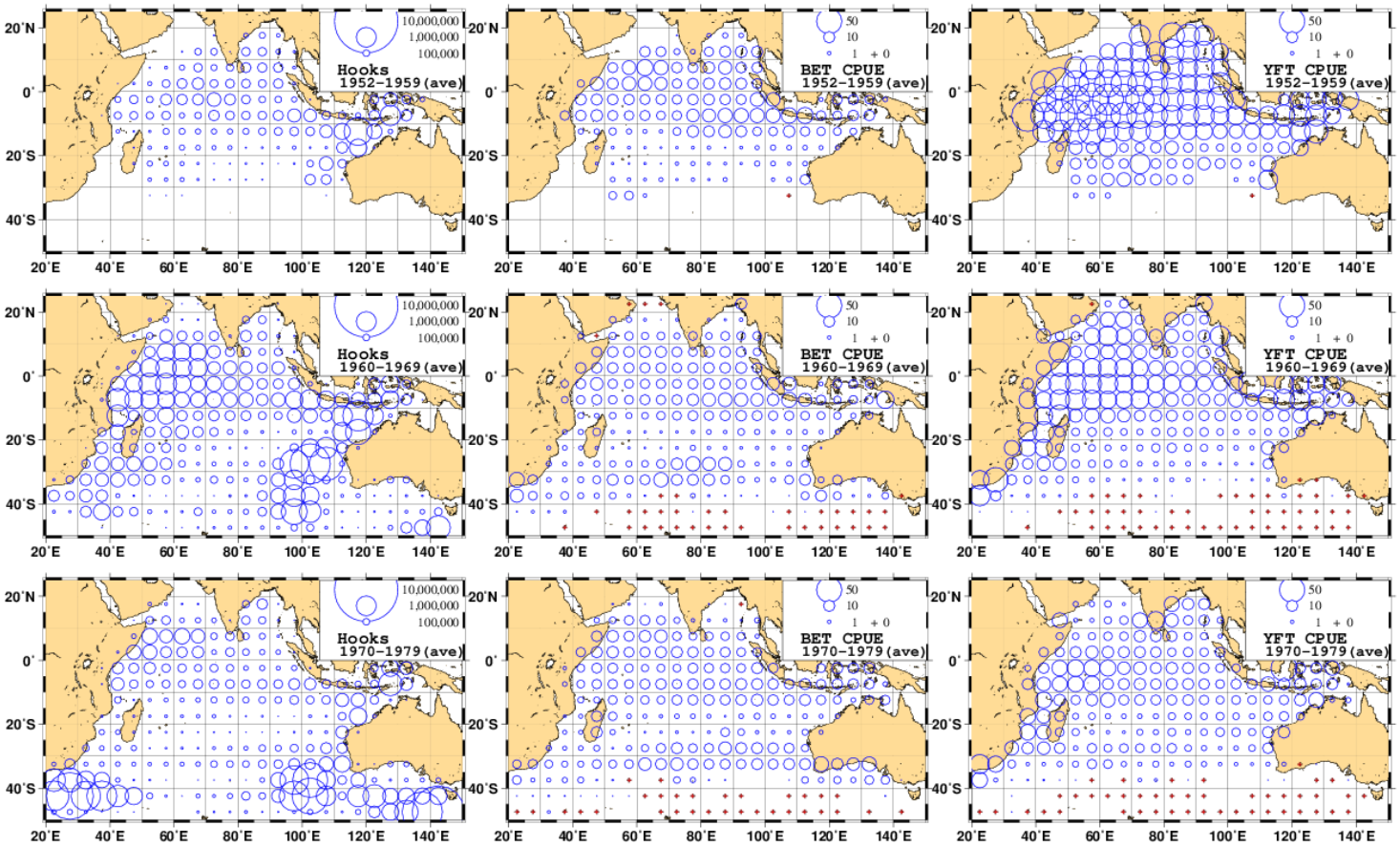


Fig. 3. The average distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) for each decadal period.

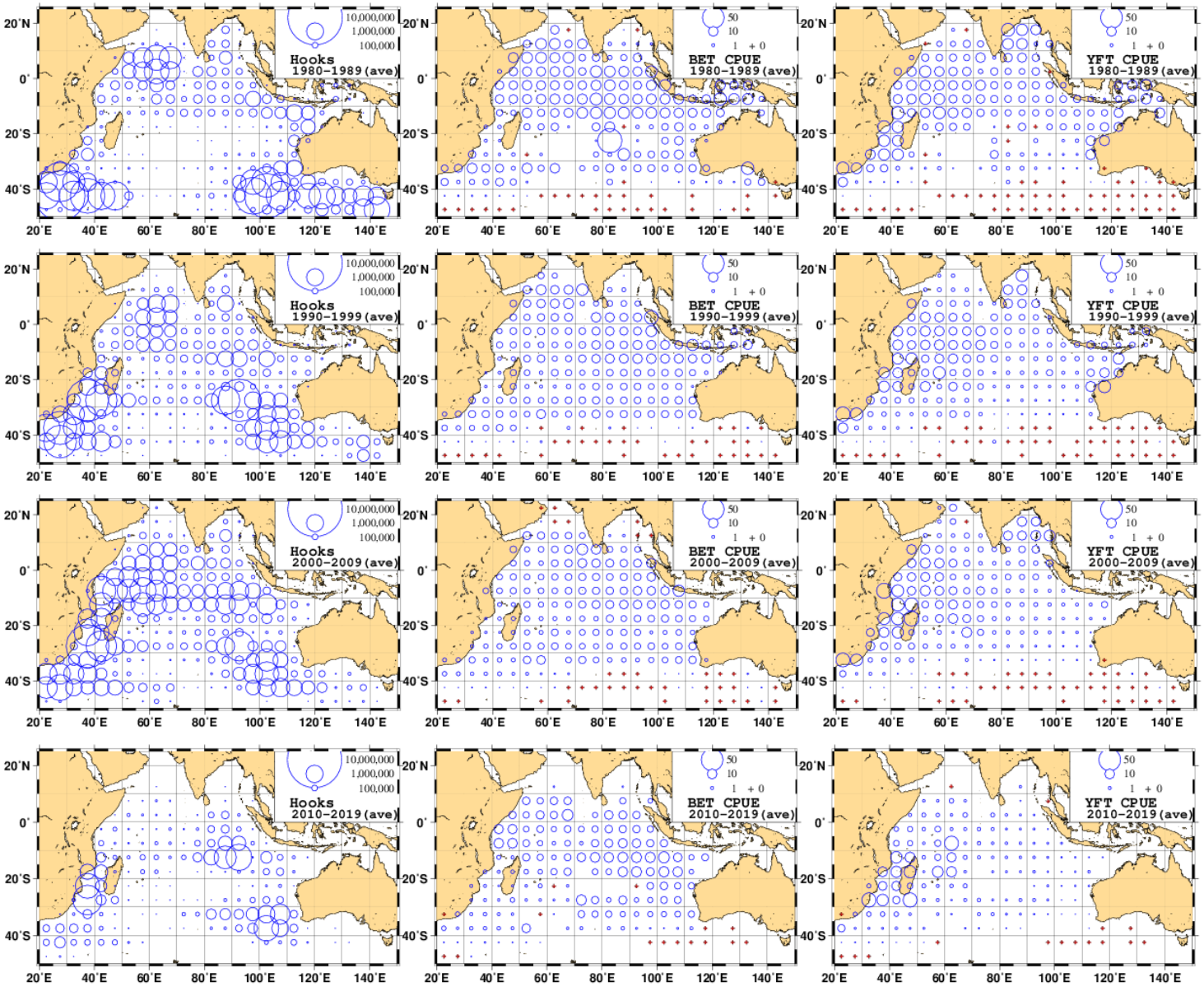


Fig. 3. The average distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) for each decadal period.(continued)

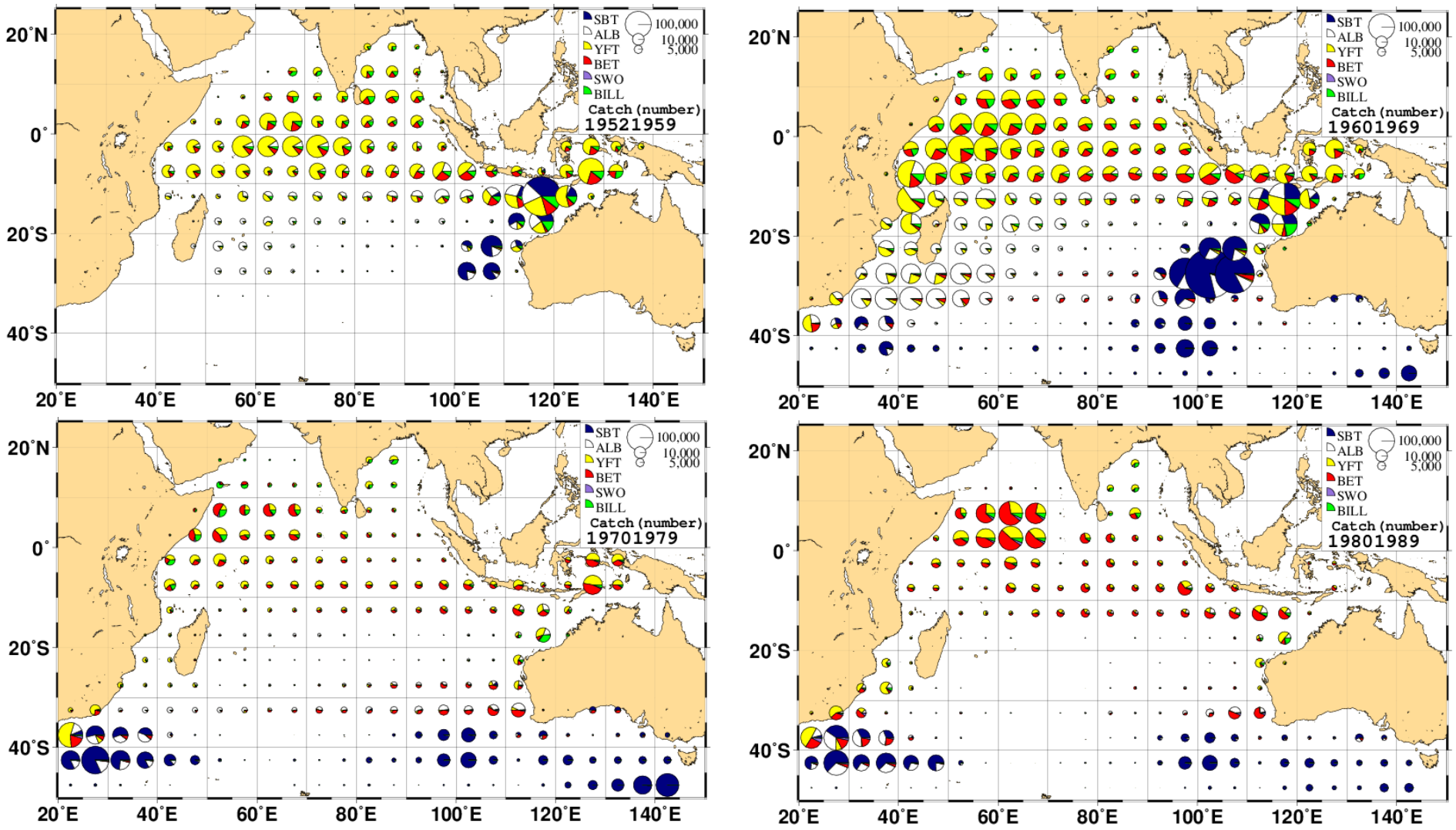
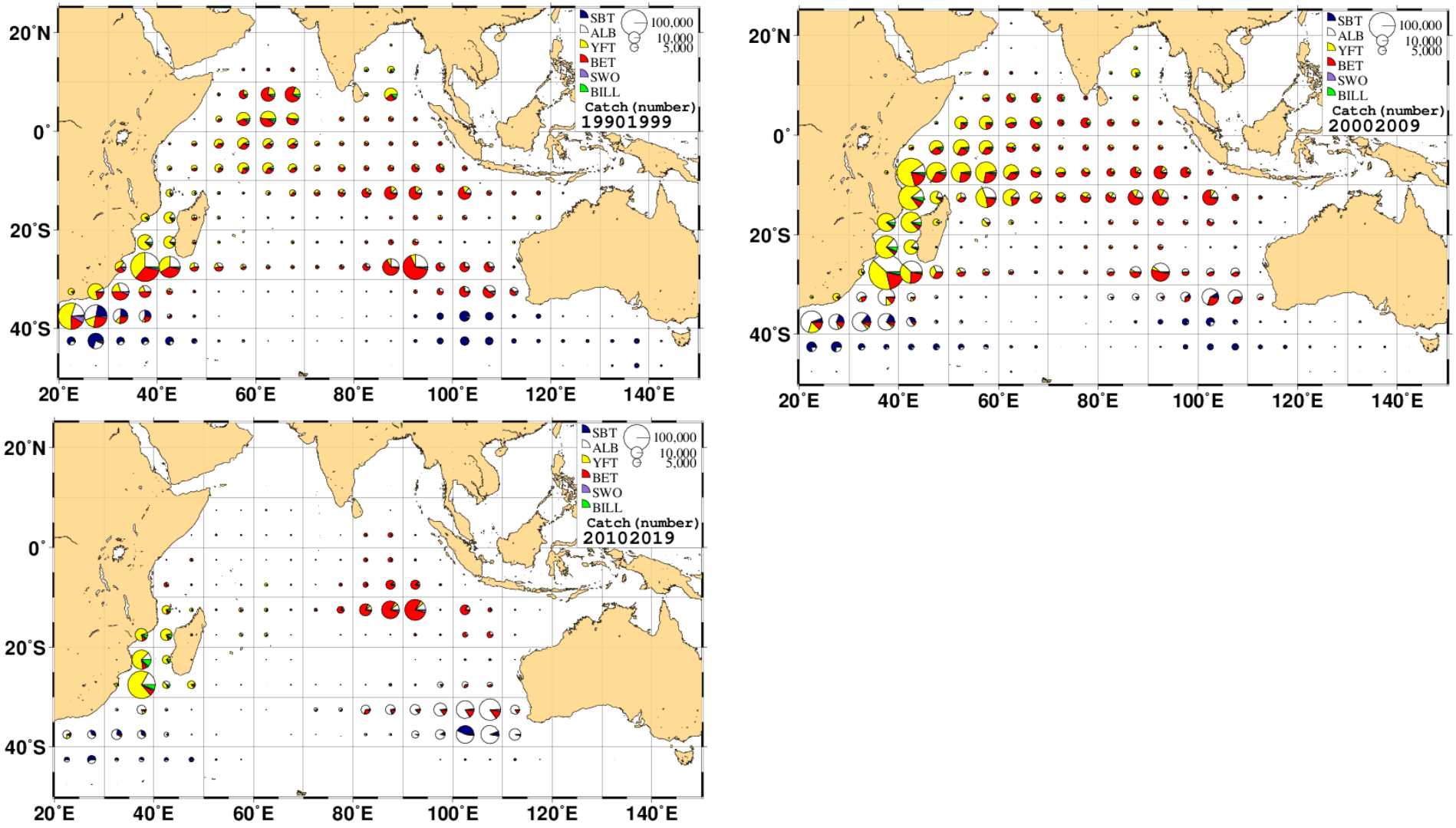


Fig. 4. The distribution of amount of catch in number by species for each decade. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (BILL).



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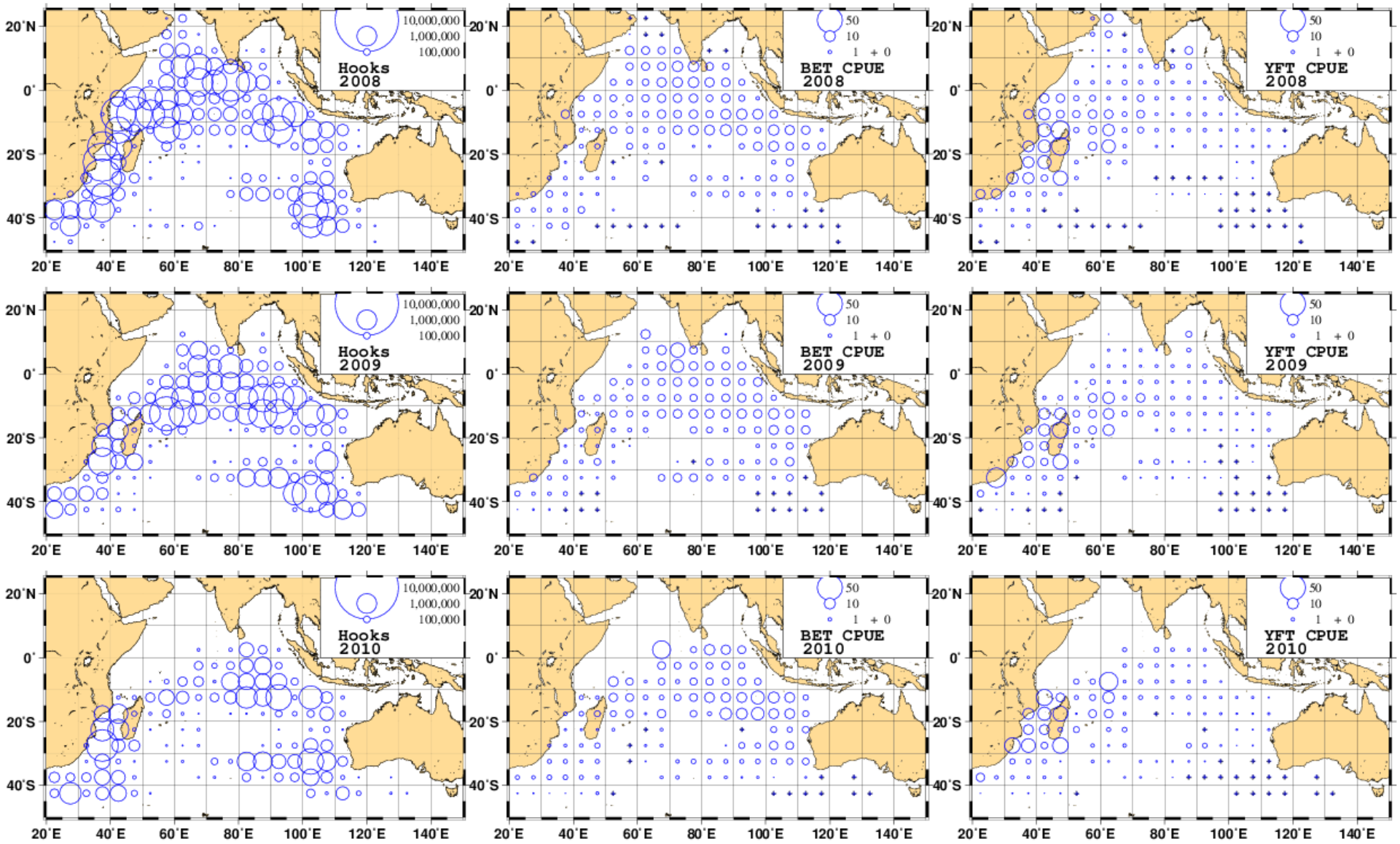

Fig. 5. The geographical distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) in recent years.

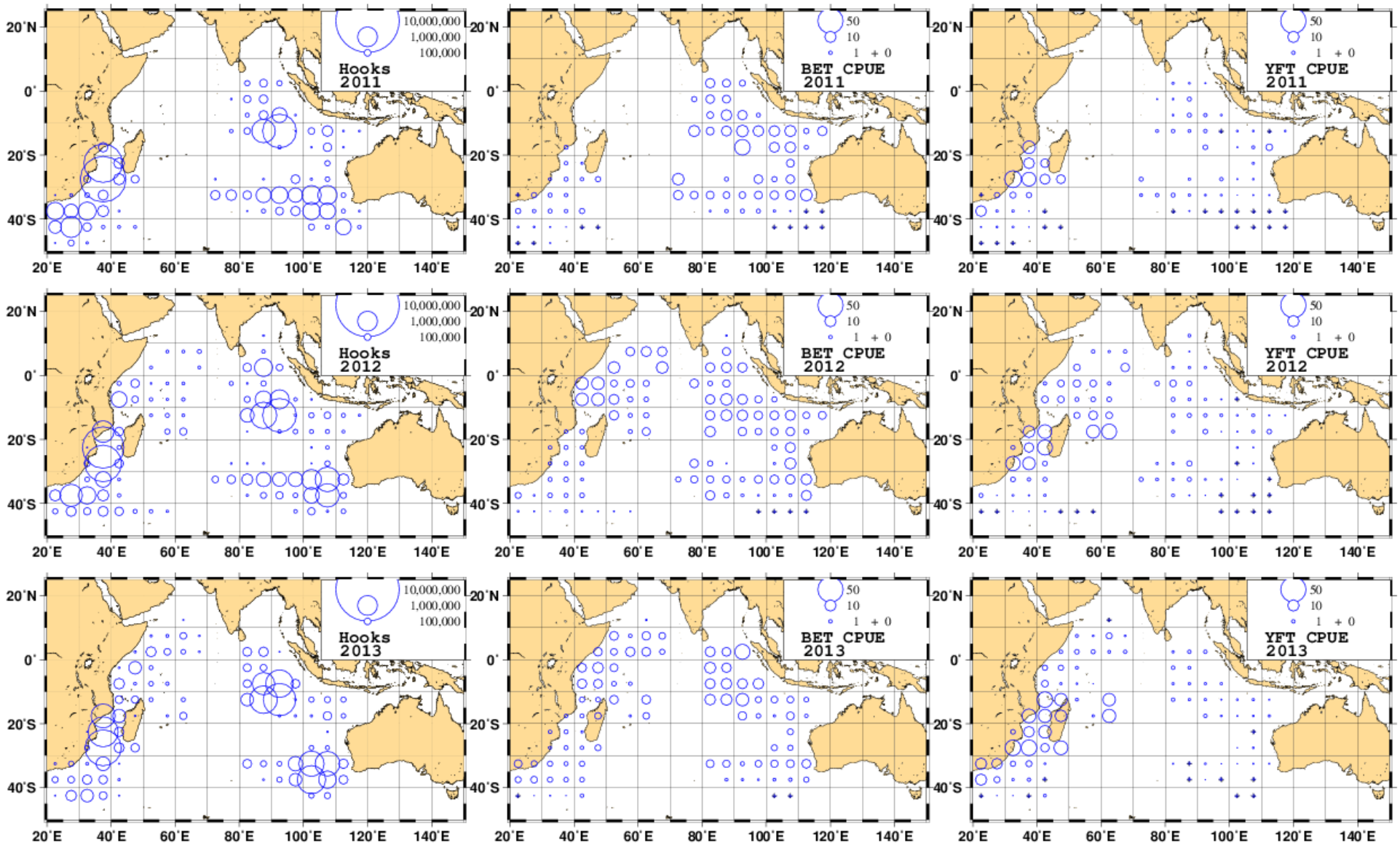

Fig. 5. The geographical distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) in recent years. (continued)

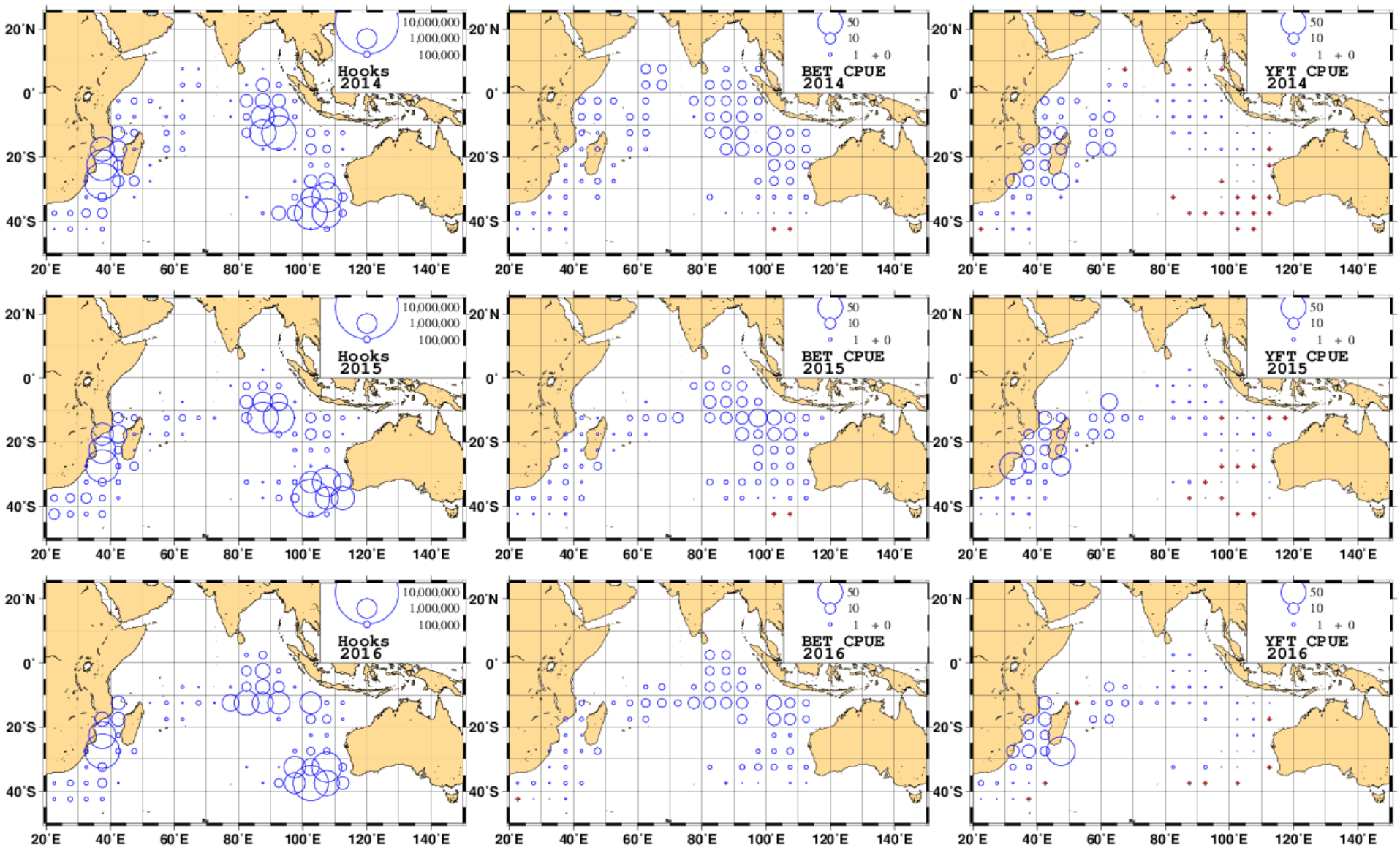

Fig. 5. The geographical distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) in recent years. (continued)

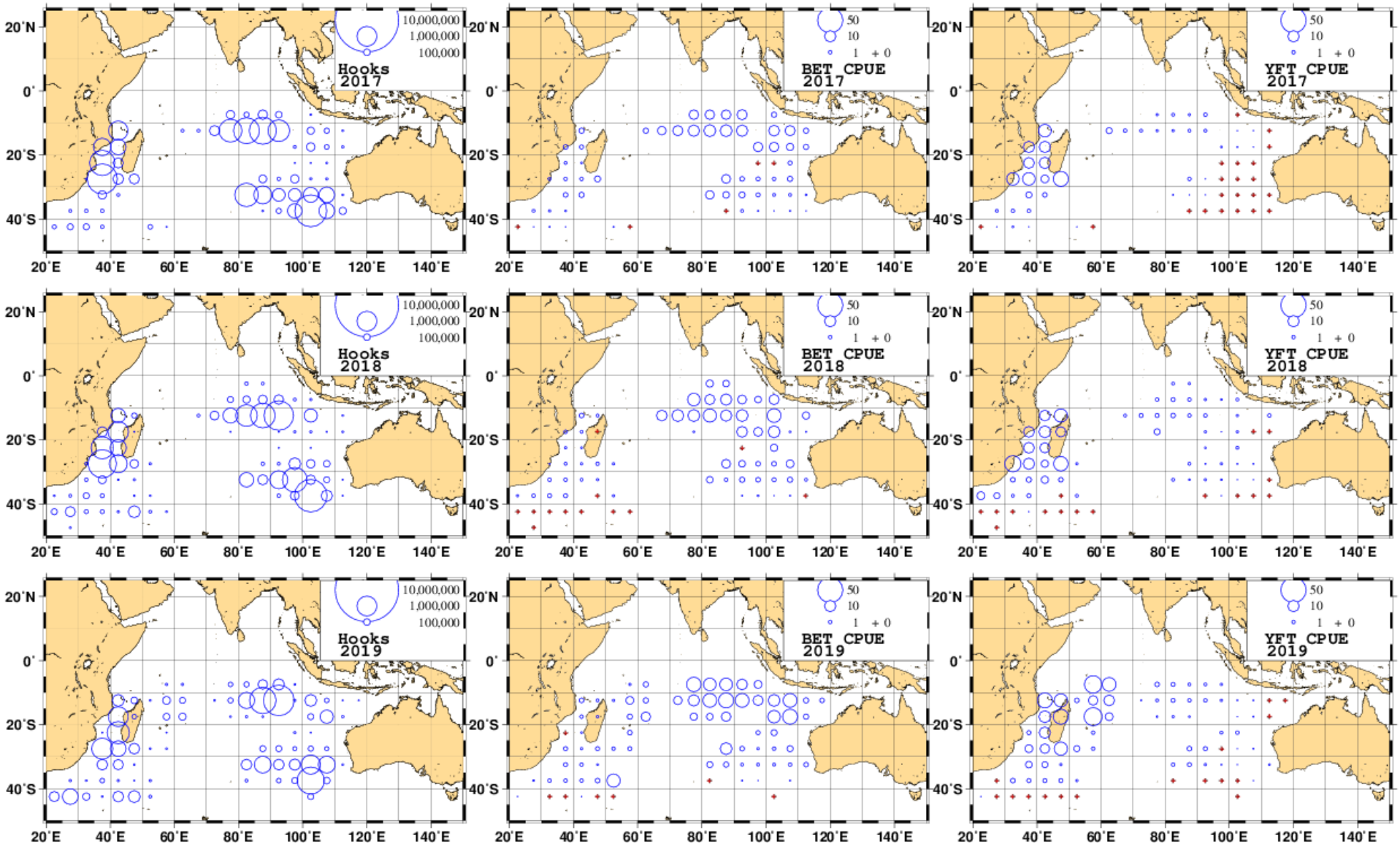

Fig. 5. The geographical distribution of the effort (number of hooks) and bigeye and yellowfin tuna CPUE (number of fish/1000hooks) in recent years. (continued)

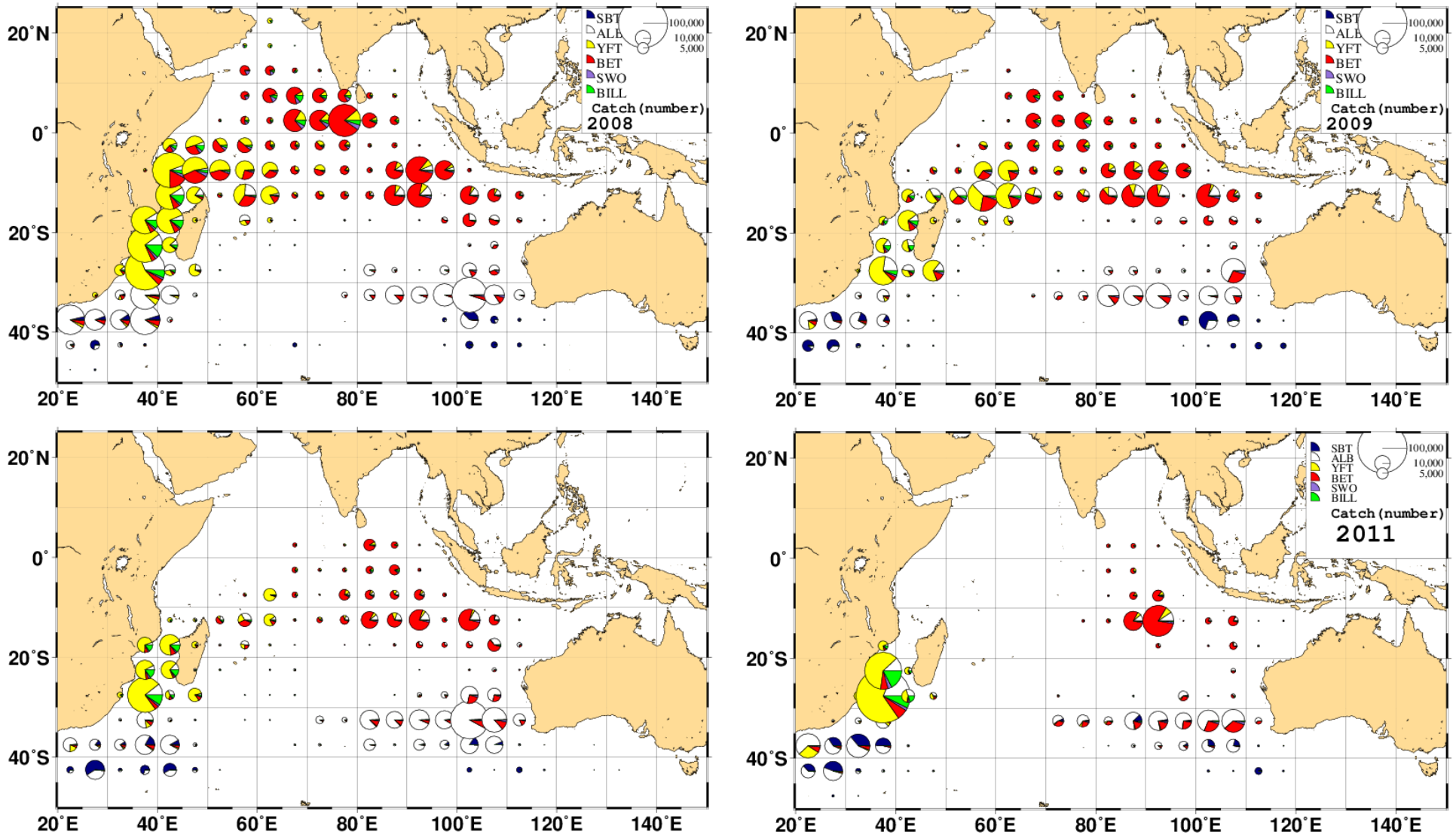

Fig. 6. Annual recent distribution of amount of catch in number by species. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (BILL).

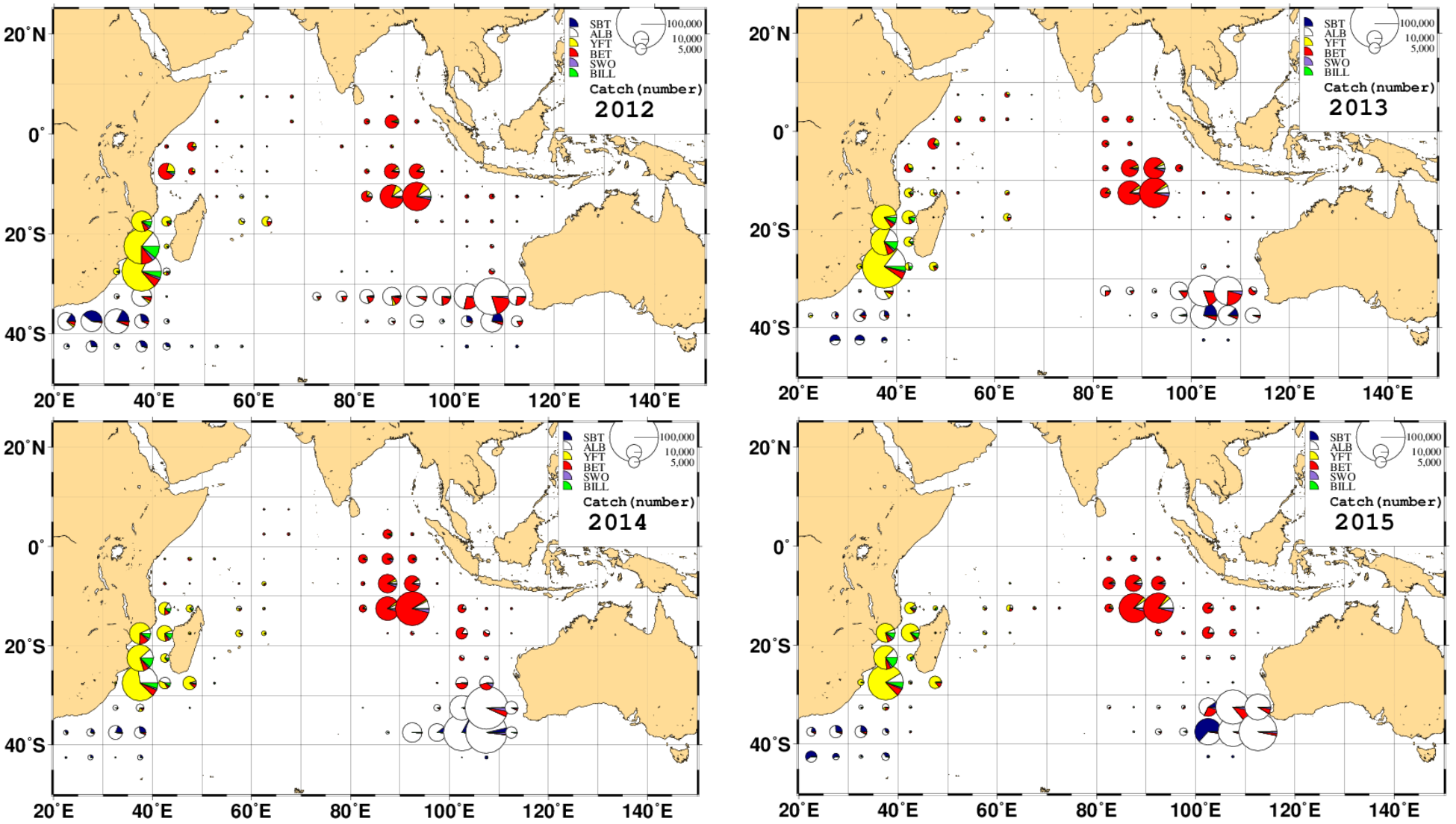

Fig. 6. Annual recent distribution of amount of catch in number by species. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (BILL).(continued)

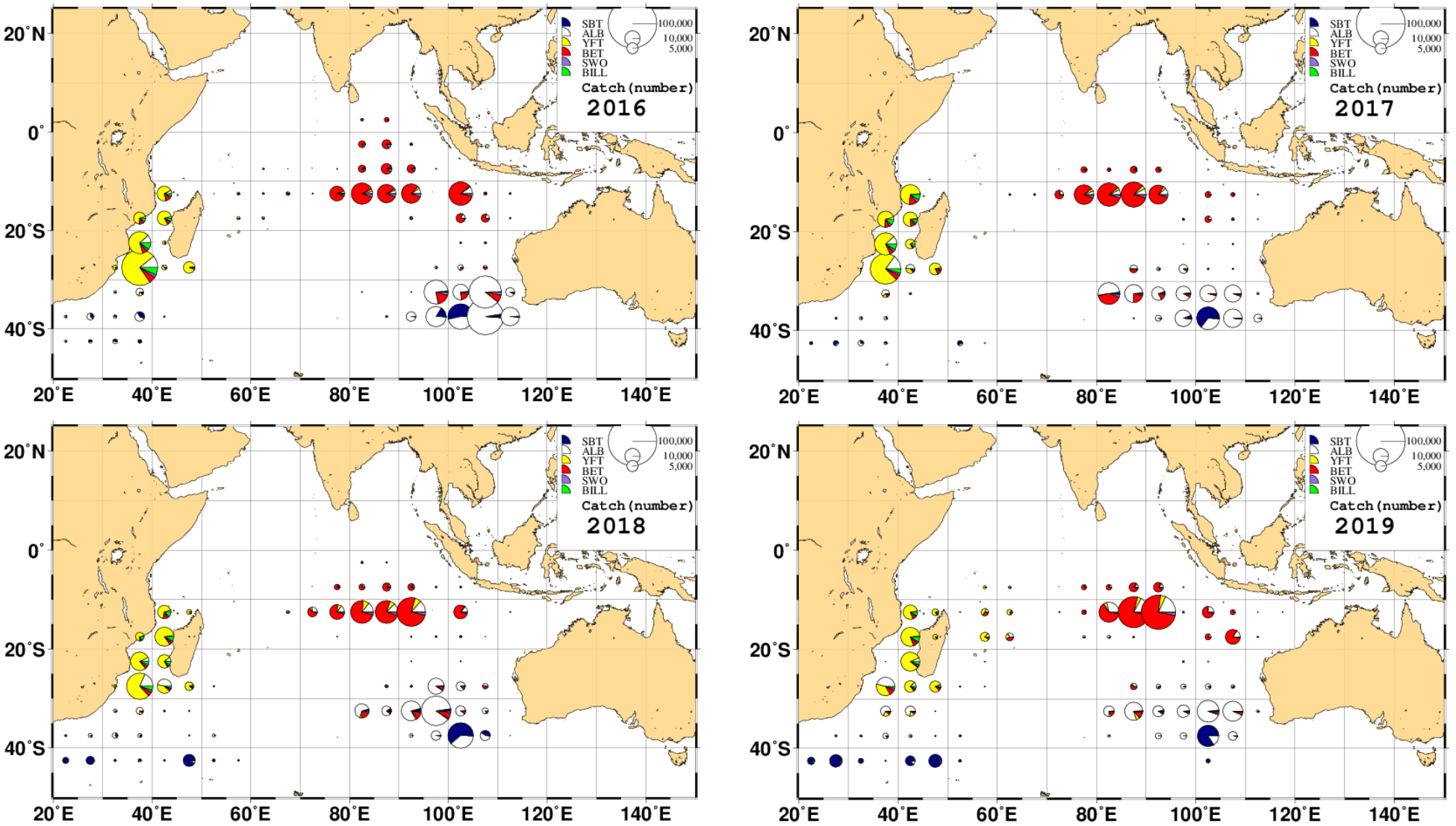

Fig. 6. Annual recent distribution of amount of catch in number by species. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (BILL).(continued)

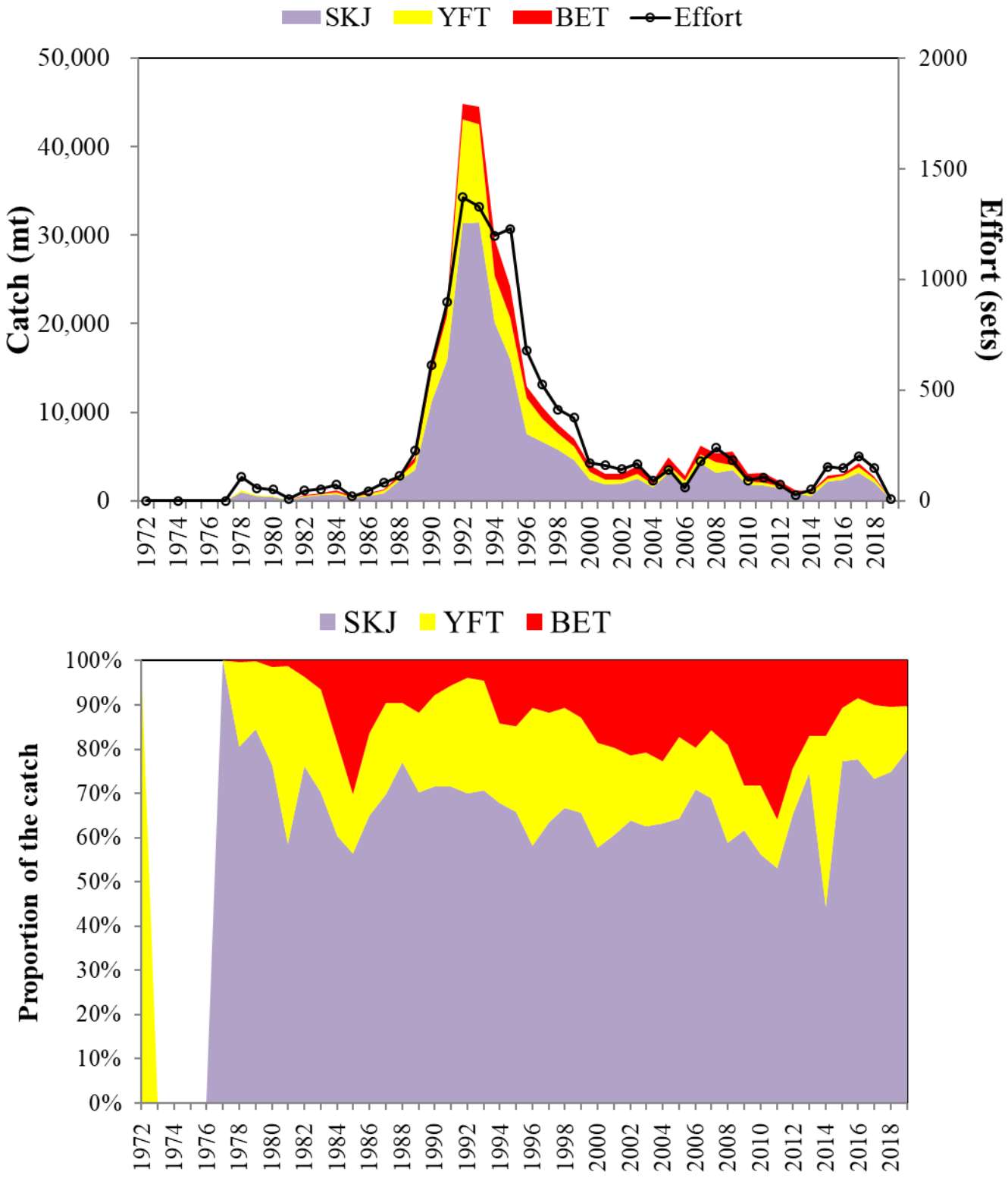

Fig. 7. The number of purse seine efforts (sets) and catch of tropical tunas (skipjack, yellowfin and bigeye tuna) (upper panel) and species composition (lower panel) caught by Japanese purse seine fishery in the Indian Ocean.

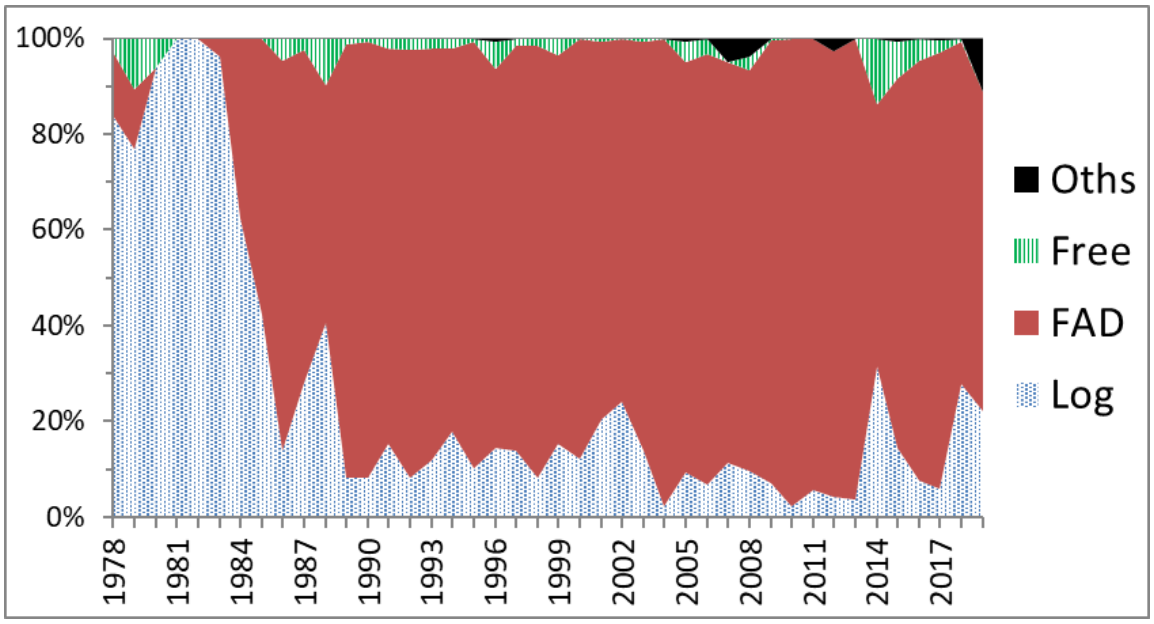

Fig. 8. The proportion of the number of set by school type for Japanese purse seine fishery in the Indian Ocean. Log: associated school with natural objects, FAD: FAD associated school, Free: free swimming school, Oths: other types of school.

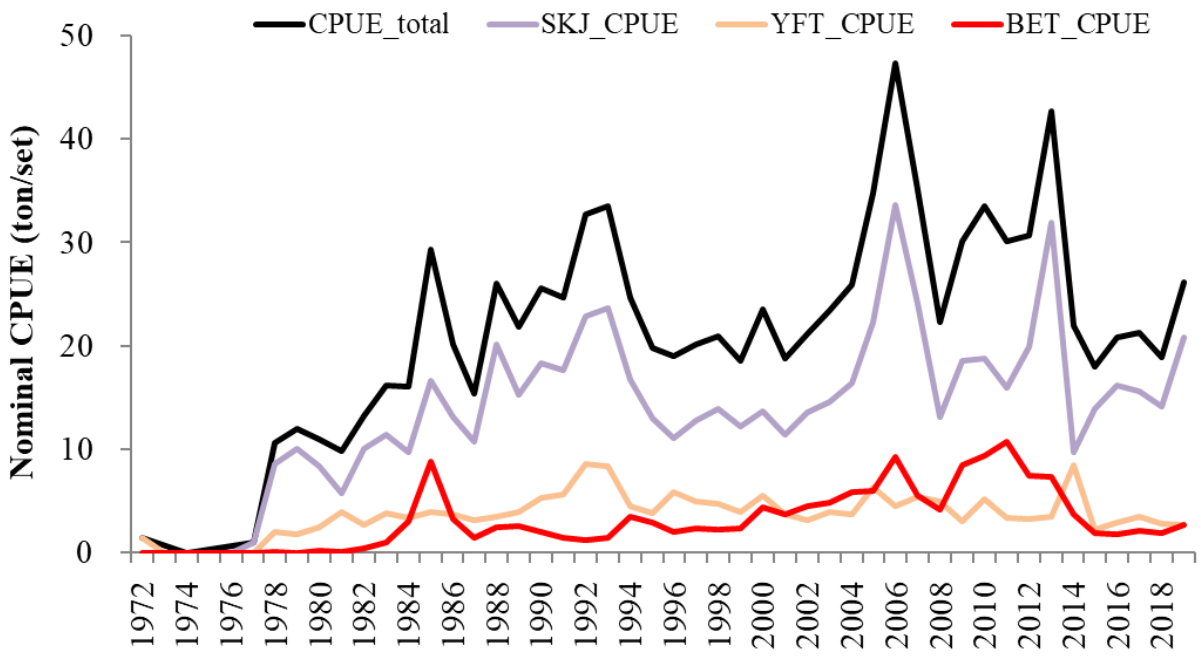

Fig. 9. The trends of nominal CPUE (catch per set) for Japanese purse seine fishery in the Indian Ocean. "CPUE_total" does not include other fish.

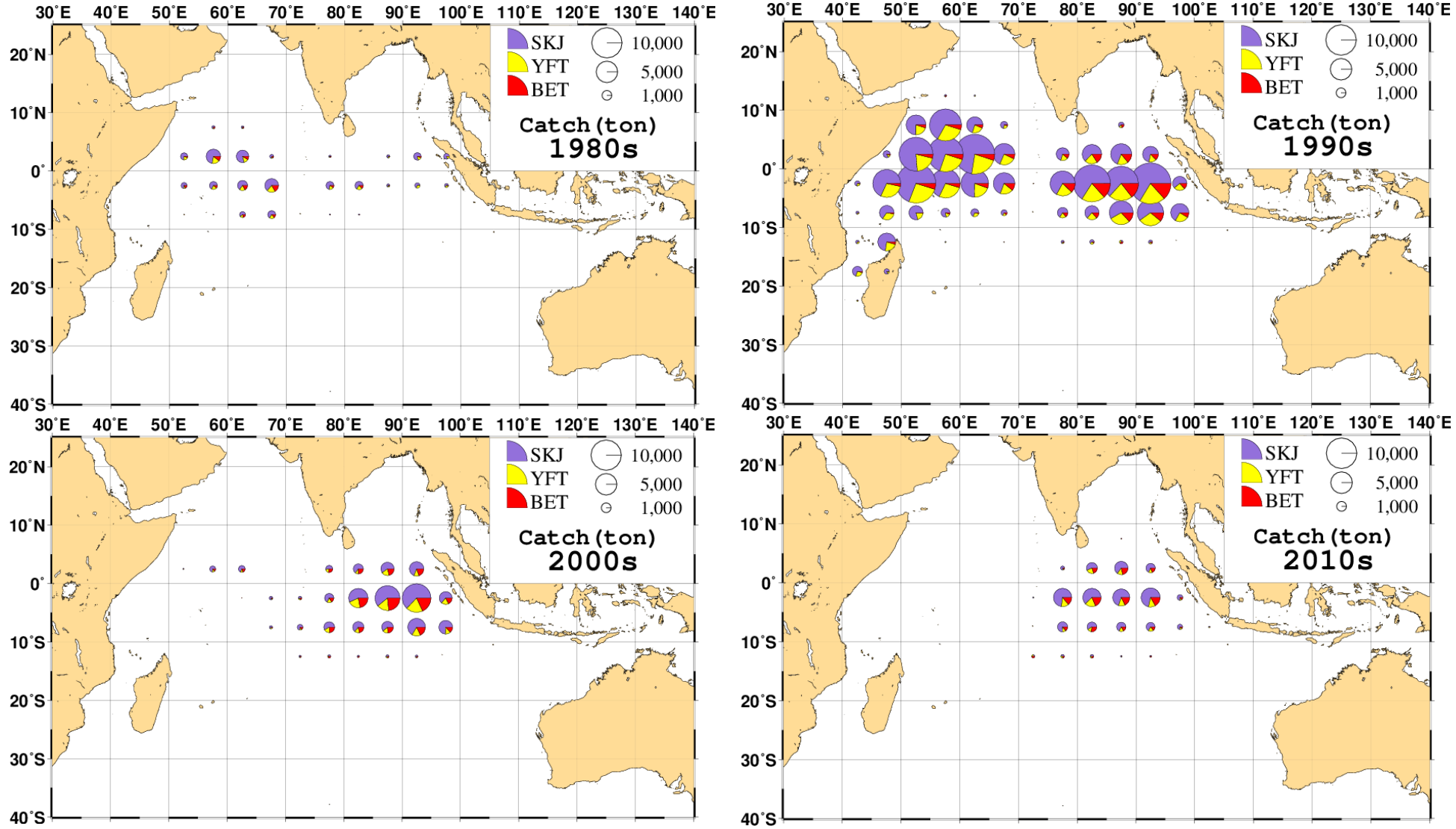

Fig. 10. The distribution of the amount of the catch in weight for the Japanese purse seine by species (SKJ; skipjack tuna, YFT; yellowfin tuna, BET; bigeye tuna) for each decade. Size of circles shows amount of total of catches (other fish are not included).

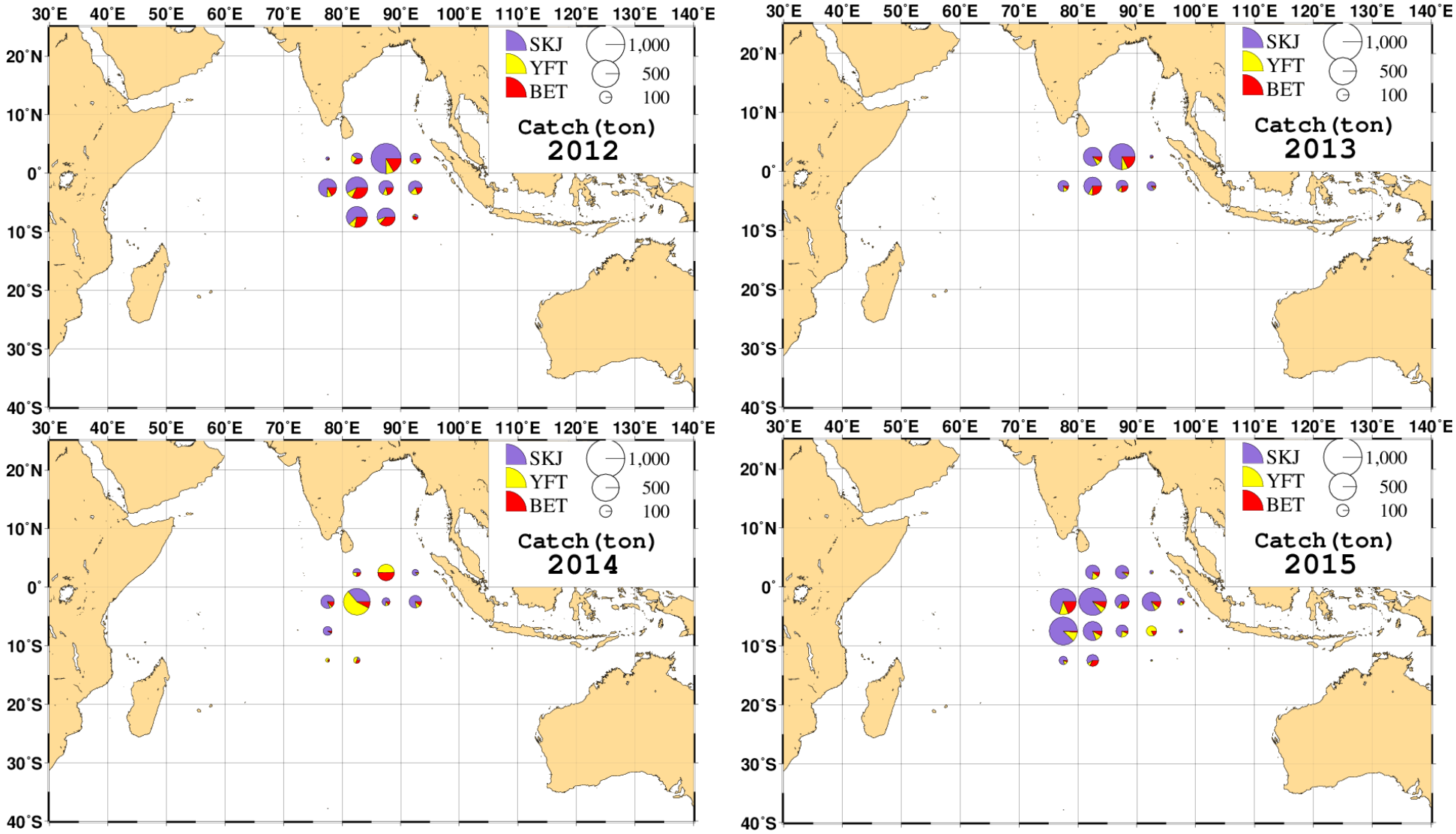

Fig. 11. Annual distribution of the amount of catch in weight for the Japanese purse seine by species (SKJ; skipjack tuna, YFT; yellowfin tuna, BET; bigeye tuna) in recent years. Size of the circles shows amount of total of catches (other fish are not included).

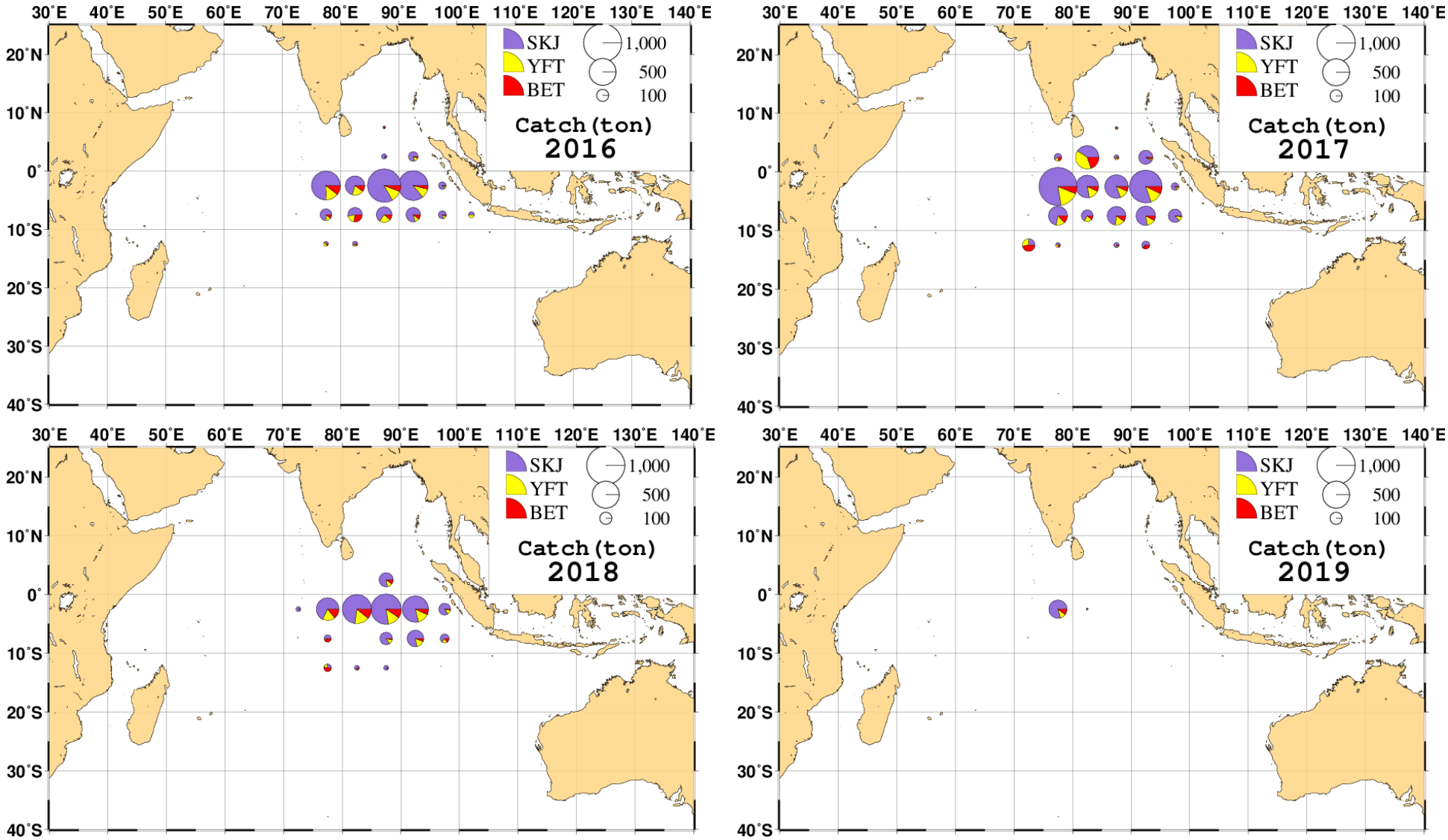

Fig. 11. Annual distribution of the amount of catch in weight for the Japanese purse seine by species (SKJ; skipjack tuna, YFT; yellowfin tuna, BET; bigeye tuna) in recent years. Size of the circles shows amount of total of catches (other fish are not included). (continued)