Incidental catch of seabirds and sea turtles by Taiwanese longline fleets in the Indian Ocean between 2009 and 2015

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Abstract

Observers data collected from 149 Taiwanese tuna longline vessel trips, including 14 albacore large-scale tuna longline vessel (LTLV) trips, 41 bigeye LTLVs trips, 57 trips of southern bluefin tuna(SBF) LTLV, 2 trips for part-time-SBF LTLV, and 35 small-scale tuna longline vessel (STLV) trips between 2009 and 2015 were analyzed. Four hundred and forty-four seabirds and 55 sea turtles were incidental caught. Most seabird bycatch was from the SBF LTLVs (64.6%) and 30.4% from albacore LTLVs. There were limited seabird bycatch in the north of 30 S. The highest rate was 0.201 bird per thousand hooks in the south of 30 S Indian Ocean in the first quarter by albacore LSLVs, followed by the same area, last quarter by SBF LTLVs (0.087 bird per thousand hooks). For bycatch species, 64.4% were albatrosses, including yellow-nosed, wandering, sooty, and shy-type, northern royal, white-capped, light-mantle, black-browed, and grey-headed albatrosses. Other seabird included white-chinned petrel, giant petrel and others. Regarding sea turtles, the high bycatch areas were between 10° N ~15° S, 60° ~90° E. The bycatch rate peaked in the third quarter by STLVs (0.0108 turtle per thousand hooks), followed by same fleet in the first quarter (0.0099 turtle per thousand hooks). The major bycatch species was olive ridley (71.0%). The numbers of other species are very limited.

Keywords: observer, seabirds, sea turtles, tuna longline fisheries

1. Introduction

The Indian Ocean is the most important fishing ground for Taiwanese distant water tuna longline fleets. The target species included albacore (*Thunnus alalunga*), bigeye tuna (*T. obesus*), yellowfin tuna (*T. albacares*), and southern bluefin tuna (*Thunnus maccoyii*) (Fisheries Agency and Overseas Fisheries Development Council of the Republic of China 2015). During the operation of longline fishing, sea turtle and seabird might be incidental catch and increased the fishing mortality for those species (Anderson et al. 2011; Wallace et al. 2013; Wallace et al. 2010). There are many species

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of albatross distributed in the Southern Indian Ocean (Birdlife International 2004). Most of these species are identified as vulnerable, near threatened, critically endangered, or endangered (IUCN Red List). In addition, the status of five species of turtles in the Indian Ocean is considered vulnerable (olive ridley, *Lepidochelys olivacea;* leatherback, *Dermochelys coriacea*), endangered (loggerhead, *Caretta caretta;* green turtle, *Chelonia mydas*), or critically endangered (hawksbill, *Eretmochelys imbricata*) (IUCN Red List).

For conservation of those incidental species, the IOTC adopted recommendations to request members to take actions. *Resolution 12/06 on Reducing the Incidental Bycatch of Seabirds in Longline Fisheries* request members to record bycatch data by species and take mitigation measures (IOTC 2012b). *Resolution 12/04 on the Conservation of Marine Turtles* request members shall collect related information and report to the Scientific Committee(IOTC 2012a). Among the longline fishing countries in the Indian Ocean, the tuna catch of Taiwan was ranked the first one since 1986, especially in the western Indian Ocean(IOTC 2016). Considering the wide distribution of marine megafauna and fisheries, it is important to evaluate the impact of fisheries on those incidental catch species across large ocean regions. This study aims to analyze observer data from Taiwanese fishing vessels to explore spatial-temporal characteristics of seabird and sea turtle incidental catch, and to further estimate bycatch rates to provide conservation suggestions.

2. Materials and methods

2.1 Fisheries and study areas

In accordance to the target species and fishing characteristics, there are four Taiwanese tuna longline fishing fleets operating in the Indian Ocean. The large-scale tuna longline fleet (LTLV) targets albacore (ALB), bigeye tuna (BET), southern bluefin tuna (SBF), and the small-scale tuna longline fleet (STLV) target yellowfin tuna, albacore, dolphin fish, and sharks. The number of LTLVs was 281 in 2010 and decreased to 120 in 2015. The number of STLVs was 261 in 2010 and increased slightly to 290 in 2015(Fisheries Agency and Overseas Fisheries Development Council of the Republic of China 2015).

2.2 Observer Data Collection

Bycatch data were collected by onboard observers. Onboard observers recorded

the fishing position (latitude and longitude for the start and end of setting and hauling), the number of hooks deployed, the times of setting and hauling, bait type, catch information (species, number, status, length, weight, sex), and bycatch information (number, species, status (dead/alive), and the gender, if possible) for seabirds, sea turtles, and cetaceans (Huang 2011). If the bycatch species was not able to be identified, photographs were taken for further identification by experts when observers come back to Taiwan. The seabirds mitigation measures, if used, are recorded, such as bird-scaring line (yes/no, number), branch-line weighted (yes/no), etc. The curved carapace length (CCL) of turtles brought on board was measured. The data analyzed for the LTLVs were from 2009 to 2015. For the STLVs, the observer program of Indian Ocean started in 2012; thus, only the data from 2012 to 2015 were used in this study.

2.3 Data Analysis

The rate of bycatch was computed as the number of sea turtles and seabirds caught per 1,000 hooks for each stratum based on the data collected by observers (Donoso and Dutton 2010; Ryan et al. 2002). The bycatch rate and variation was estimated for each strata by the binomial estimator with Clopper-Pearson confidence intervals using the R program (Agresti 2002; Huang and Liu 2010).

Considering that bycatch rates are important for each species, we estimated bycatch rates for sea turtles by species. The seabird species is more diverse and some species could not be identified by observers. Thus, seabirds are separated into four groups, including large, medium, small albatrosses, and other seabirds.

For temporal stratification, we separated the time into 4 quarters: 1st quarter (January~ March), 2nd quarter (April~ June), 3rd quarter (July~ September), and 4th quarter (October~ December).

For spatial stratification, in response to the bycatch distribution of seabirds and fishing grounds of fishing fleets, we included the following four areas: the north Indian Ocean (IND_ N, north of 5° N), the tropical-west Pacific Ocean (IND_Trop, between 5° N and 15° S), the temperature Indian Ocean (IND_Temp, between 15° S and 30° S), the south Indian Ocean (IND_S, south of 30° S) (Figure 1).

3. Results

3.1 Fishing effort

The accumulated distribution of the LTLVs in the Indian Ocean between 2010 and

2014 is shown in Figure 1. The IND_Trop was the major fishing ground, representing 61.7% of the total effort, followed by the IND_S (26.2%). The efforts were 9.8% and 2.2% in the north and temperate Indian Ocean, respectively.

As for the STLVs, the effort distribution between 2010 and 2014 is shown in Figure 2. Most efforts were distributed in the tropical Ocean (36.9%) The efforts of and south Indian (27.0%) and temperate Indian Ocean (25.8%) were followed, and the efforts in temperate was limited to only 10.3%.

For observed efforts distribution, there were 149 observer trips and 23016 thousand hooks from 2009 to 2015, including 14 trips for the ALB LTLVs, 41 trips for the BET LTLVs, 57 trips for SBF fleet, 2 trips for the part-time SBF LTLVs, and 35 trips of STLVs. The observed efforts were low during 2011 and 2012 due to pirate, and the data of 2009 and 2015 was only partial of that year (Table 1).

The characteristics, including the target species, length and gross tonnage, hook size, bait types, number of hooks per set, length of mainline, branch-line, set starts time, span of each fleet and haul last time were listed in Table 2. The BET LTLVs have larger vessels operating in tropical areas. Some equipped with 4.2" circle hooks. The length branch-line was almost double than other fleets. Although the set time were all ranged from 5~ 8 for four fleets, it will take more time for BET LTLVs for hauling. However, the number of hooks per set was highest for SBF, followed by ALB, BET, and STLVs.

The distribution of observed efforts by fleet was showed in Figure 3-6. It is clearly that ALB LTLVs operating in western IND_temp and IND_S; BET LTLVs were operating in IND_Trop; SBF fleet operating in IND_S and the STLVs operating in wider ranged due to different targets.

Although the coverage rates were low in some year for some fleets, it could cover most of the Indian Ocean after combined all the observed efforts during 2009 to 2015.

3.2 Seabirds bycatch

In total, 444 seabirds were caught (Table 3), the major species were white-chinned petrel, yellow-nose albatross, wandering albatross, sooty albatross, and shy albatross. Mostly were from the IND_S between 30° ~40° S. There was no bycatch in the IND_N and only five from IND_Trop and IND_Temp (Figure 7).

The seabird bycatch rate of the ALB LTLVs and SBF were higher than other fleets. The estimated bycatch rates by group and quarter are shown in Table 4. In summary, the highest rate was 0.201 bird per thousand hooks in the south of 30 S Indian Ocean

in the first quarter by ALB LSLVs, followed by SBF LTLVs in last quarter (0.087 bird per thousand hooks). The bycatch of the other two fleets were almost zero.

Bycatch of ALB LTLVs

Among these trips, 135 seabirds were incidentally caught, 133 of which were in south of 35° S (Figure 2). The collection of species was diverse. The major bycatch species were white-chinned petrel (77, 57.0%), followed by 10 wandering albatross (*Diomedea exulans*), 3 white-capped albatross, southern giant petrel (2) and others (Table 3). There were 42 albatross could not be identified.

The bycatch rate was highest for other seabirds bycatch from ALB LTLVs in first quarter (0.122 bird per thousand hooks), followed for those albatross_other in the fourth quarter (0.035 bird per thousand hooks).

Bycatch of southern bluefin tuna LTLVs

Two hundred and eighty-seven seabirds were caught by southern SBF LTLV (Table 3 and Figure 5). The species was most diverse, included yellowfin-nosed albatross, white-chinned petrel, sooty albatross, shy albatross, wandering albatross, black-browed albatross, grey-headed albatross, light-mantled albatross, and northern giant petrel, other petrel and other seabirds (Table 3). However, there were 90 albatross could not be identified.

For SBF fleet, the bycatch rate were higher for other albatross from October to December (0.370 bird per thousand hooks), followed by the bycatch rates of other seabirds were around 0.034 from October to March (Table 4). It showed the bycatch rates in fourth quarter were highest.

3.3 Sea turtles bycatch

In total, 55 sea turtles were caught. Most were olive ridley turtle (70.9%), followed by green (10.9%) and loggerhead (10.9%). Most (92.7%) caught by bigeye fleet and SLTV (Table 5). More than 90% are distributed in the north of 15° S (Figure 8).

The sea turtle bycatch rate of the STLVs and BET LTLVs were higher than other fleets. The estimated bycatch rates by group and quarter are shown in Table 6. In summary, the highest rate was 0.0108 turtle per thousand hooks in the third quarter by STLVs, followed by the fleet in the first quarter (0.099 bird per thousand hooks). The bycatch of the other two fleets were almost zero for four quarters.

Bycatch of BET LTLVs

Twenty sea turtles were incidentally caught by BET LTLVs (Table 5). The distribution was between 5° N-15° S (Figure 4). Of these turtles, 14 were olive ridley. The mortality rate was 35.7% for this species and 100% for other species. Among those measured for CCL, the average length was 57.0± 1.41 cm for olive ridley, 43.0± 13.4 cm for green turtle, and 36.0 cm for loggerhead turtle. The percentage of identified females varied by species was 45%. Majority of those species were hooked (Table 5).

The sea turtle bycatch rate for bigeye fleet was different from season. The estimated bycatch rate was 0.007 for olive ridley and 0.001 turtle per thousand hooks for loggerhead in the first season (Table 6). Other seasons has very low or zero bycatch.

Bycatch of STLVs

Thirty-one sea turtles were caught by STLV. It is distributed widely from 10° N to 35° S (Figure 6). The major species were the olive ridley (Table 5). The mortality rate ranged from 96% to 100% by species. Among those measured for CCL, the average length was 51.1±7.12 cm for olive ridley. The female identified percentage for olive ridley was 64.0%. All sea turtles were hooked (Table 5).

For STLVs, the olive ridley bycatch was higher in the third quarter (0.0108 turtle/1000 hooks), followed by first quarter (0.0082 turtle/1000 hooks). The bycatch rates for all other species were lower than 0.002 turtle per thousand hooks (Table 6).

4. Discussion

The sea turtle and seabird bycatch of the Taiwanese fleets were previous analyzed in 2010 (Huang and Liu 2010). It is identified the southern Indian Ocean was high bycatch for albatross and tropical area for sea turtles bycatch. Due to more data collected thereafter, especially from albacore and small scale longline vessels, this research further identified specific bycatch hotspots for seabirds and sea turtles. The analysis showed that the fisheries impacts on seabirds were not only from SBF LTLVs, but also from the ALB LTLVs operating in the coastal areas of South Africa. Regarding the sea turtle bycatch, this is the first analysis of the STLVs and showed that the fishing grounds of STLVs are boarder with higher impacts on sea turtles than other fleets.

4.1 Seabird bycatch distribution

Regarding the trend of seabird bycatch in the Indian Ocean, southern Indian Ocean remains the major hot spots for seabirds bycatch (0.201 bird per thousand hooks), specially between 70° - 95° W(Huang and Liu 2010). This research further identified the coastal area of South Africa (20° - 45° W) where the bycatch rate was high.

In addition to yellow-nosed, wandering, and sooty albatrosses, more species of seabirds were identified as bycatch in this study, including northern royal, shy-type, white-capped, light mantled, black-browed, grey-headed were identified. The identification rates were increased.

With more updated research on the effectiveness of the mitigation measures (Melvin et al. 2013), the new standard mitigation measures were adopted by the IOTC and came into force in July 2014 (IOTC 2012b). The timely evaluation of the new mitigation measures based on observer data would be helpful to monitor the status of seabird bycatch. However, observers did not record details of mitigation measures during 2008 to 2013, only start to collect detailed information since 2014 in response to new best practice. Those new information would be helpful for detail analysis in the future. In these data collected for this research, the major seabirds mitigation measures were tori-line, most of the vessels operating in the south of 25° S applied this measures, and night setting. Because of the high bycatch rates in the IND_S by SBF and ALB LTLVs, it is recommended the seabird mitigation measures shall be strengthened and detail recorded and photos by observers.

4.2 Sea turtle bycatch distribution

In the Indian Ocean, the olive ridley was the most abundance turtles (Shanker and Pilcher 2003). Like previous study, the catch of olive ridley was the major bycatch. Furthermore, it is found the incidental catch of SLTVs was higher than other fleets.

In this study, the bycatch rates of 0.0014 to 0.0108 turtle per thousand hooks were similar to last time and was low compared to the weighted median bycatch per unit effort for coastal longlines fisheries (Donoso and Dutton 2010; Petersen et al. 2009; Wallace et al. 2013). The reason for low bycatch rate and high mortality rate were because the depth of Taiwanese BET LTLVs was deeper with longer operation time. However, for STLVs, the depth was shallower; it’s the possible reason for higher bycatch rates than other fleets.

Studies have suggested that the use of whole finfish as opposed to squid bait may have resulted in fewer sea turtles captured (Santos et al. 2012; Watson et al. 2005). In Taiwanese fleets, squid would be used by BET and STLVs fleet (Table 2), it was might be another reason for sea turtle bycatch.

Regarding the conservation measures for sea turtles, although circle hooks have proven to be useful to reduce the bycatch rates in some fisheries (Gilman and Moth-Poulsen 2007; Sales et al. 2010), the use of circle hooks has not yet been adopted as a mandatory measure. Previous research on Taiwanese deep-set fleet also showed there is no significant effect of circle hooks on reducing sea turtle bycatch (Huang et al. 2016). Nevertheless, some Taiwanese fishing vessels have been used circle hooks. It might be beneficial for them to increase the catch of target species. Considering the previous research is conducted in the Atlantic Ocean where the leatherback is higher. For the Indian Ocean, the olive ridley is more than leatherback. It is worth to further study the effect of circle hooks.

4.3 Data improvement

Taiwanese observer program has been conducted for 10 years. The seabird species identification rates were increased. It could be further improved through photo collection and capacity building.

It would be appropriate to increase the observer coverage rate to decrease uncertainty. However, due to the budget limitation and the difficulties to deploy observers on STLVs, the electronic-observer should be considered. In addition, under the current coverage rate, to increase the coverage during hot season in hot spots would be another approach to decrease uncertainty.

The results showed the distribution of STLVs was broader than other fleets. It's possible these STLVs were targeted on different species and different fishing gear design. It's suggested to explore the target species and separate STLVs to more specific fleets for analysis.

5. Conclusions

This research updated the incidental catches of seabirds and sea turtles by the Taiwanese large-scale and small-scale longline fisheries in the Indian Ocean by analyzing onboard observer data gathered from 2009 to 2015. In addition to the hotspots (30° – 40° S and 70° 95° W) identified by (Huang and Liu 2010), this study further

identified seabird bycatch hotspot areas south of 30°~40° S, 20° - 40° W. The olive ridley turtle bycatch was mostly caught by the STLVs in tropical areas. Continuous data collection and de-hooker education, test of circle hooks for the STLVs would be necessary and helpful. Continuing to conduct monitoring and data collection at the national and international levels is necessary to ensure conservation.

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Table 1 Observed trips, set, efforts and coverage rates of the Indian Ocean from 2009-2015

Year	ALB	BET	Part	SBF	SMLL	trips	Efforts (1000 hooks)
2009	3	5		2		10	1258
2010	9	13	1	13		36	6269
2011		16		2		18	1956
2012		6		9	4	19	2819
2013	2			10	10	22	4149
2014			1	10	11	22	4031
2015		1		11	10	22	2533
Sum	14	41	2	57	35	149	23016

Table 2 Fishing Characteristic of Taiwanese tuna vessels in the Indian Ocean

Fleet	ALB LTLV	BET LTLV	SBF	STLV
Target species	albacore	bigeye tuna	Southern bluefin tuna	yellowfin tuna, albacore, bigeye tuna
Number	39	105	100 (seasonal)	290
Length of vessel	37-51 m 178~500 GRT	45-57 m 473~740 GRT	32.9~57.6 m 160~778 GRT	23.9~28 m 96-98 GRT
Hook size	3.2-4.2’ non-offset tuna hooks, some with 4.2’ circle hooks	3.8-4.2’ tuna hooks, and some with 4’ circle hooks	3.2-4.2’ non-offset tuna hooks,	3.2, 3.6, 4, 4.2 tuna hook, and some with 4’ circle hook
Bait types	sardine, mackerel, herring	mackerel, sardine, squid	sardine, jacks, mackerel, scads	sardine, mackerel, squid
Number of hooks per set (mean±SD)	3475±653	3052±540	3576±498	2467±584
Length of branch-line(m)	25	41	24	22
Set starts time	0400-0500/1400-1600	0300-0500	0100-0700/1400-1700	0200-0600
Set lasts time span	5-7 hours	5-8 hours	5-8 hours	5-8 hours
Hauls lasts	12-16 hours	13-17 hours	12-17 hours	9-14 hours

Table 3 Bycatch characteristics of seabird in the Indian Ocean.

Type/Species	ALB		BET	SBF		Part		SMA		Sum	
	Alive	Dead	Dead	Alive	Dead	Alive	Dead	Dead	Alive	Dead	Sum
Albatross_large		***10***	***1***	***1***	***16***	***1***		***2***	***2***	***29***	***31***
Wandering Albatross		10	1	1	16	1			2	27	29
Northern royal Albatross								2		2	2
Albatross_medium		***3***		***3***	***49***			***2***	***3***	***54***	***57***
Sooty Albatross				1	25			2	1	27	28
Shy Albatross				2	22				2	22	24
White Capped Albatross		3								3	3
Light-Mantled Albatross					2					2	2
Albatross_small				***9***	***50***				***9***	***50***	***59***
Yellow-Nosed Albatross				6	39				6	39	45
Black-Browed Albatross				2	9				2	9	11
Grey Headed Albatross				1	2				1	2	3
Albatross net	***2***	***40***	***1***	***23***	***67***		***6***		***25***	***114***	***139***
Seabird	***3***	***77***	***2***	***13***	***56***		***2***	***5***	***16***	***142***	***158***
White-chinned Petrel	3	74	2	2	32		1	2	5	111	116
Northern Giant Petrel					2					2	2
Southern Giant Petrel		2								2	2
Giant Petrels nei					2					2	2
Shearwaters nei							1			1	1
Petrel nei		1		7	13				7	14	21
Other Seabird				4	7			3	4	10	14
Sum	***5***	***130***	***4***	***49***	***238***	***1***	***8***	***9***	***55***	***389***	***444***

Table 4 Seabirds bycatch rate and 95% confidence intervals in the Southern Indian Ocean between 2009-2015

Fleet	Quarter	Albatross -large	Albatross -medium	Albatross small	Albatross _other	Seabird _other	Seabirds	95% confidence Interval
ALB LTLVs	1	0.015	0.006	-	0.006	**0.122**	**0.201**	0.0957-0.1525
	2	-	-	-	-	0.007	0.016	0.0013- 0.0194
	3	-	-	-	0.002	0.004	0.004	0.0005- 0.0153
	4	0.004	-	-	0.035	-	0.009	0.000- 0.01608
SBF LTLVs	1	0.010	0.012	0.011	0.018	0.027	0.066	0.0186- 0.0389
	2	0.001	0.007	0.003	0.015	0.004	0.019	0.0023- 0.0067
	3	-	0.002	0.005	0.001	0.002	0.019	0.0008- 0.0033
	4	0.011	0.003	0.020	**0.370**	**0.034**	**0.087**	0.0173- 0.0588

Table 5 Bycatch characteristics of sea turtles in the Indian Ocean.

	Fleet/species	n	CCL	±SD	Mortality%	Female%	Hooked%
	BIGEYE FLEET	20			55.0%	45.0%	95.0%
	LKV	14	57.0	1.41	35.7%	57.1%	100.0%
	TTL	2	36.0		100.0%	0.0%	100.0%
	TUG	4	43.0	13.44	100.0%	25.0%	75.0%
STLV		31			96.8%	61.3%	100.0%
	DKK	2			100.0%	0.0%	100.0%
	LKV	25	51.1	7.12	96.0%	64.0%	100.0%
	TTH	1			100.0%	100.0%	100.0%
	TTL	1	65.0		100.0%	0.0%	100.0%
	TUG	2	45.0		100.0%	100.0%	100.0%
	Albacore Fleet	2			50.0%	50.0%	50.0%
	TTL	2	41.0		50.0%	50.0%	50.0%
	Southern bluefin fleet	2			0.0%	0.0%	50.0%
	DKK	1			0.0%	0.0%	100.0%
	TTL	1	75.0		0.0%	0.0%	0.0%
	Sum/average	55.00			76.4%	52.7%	94.5%

Note: DKK, Leatherback Turtle; LKV, Olive ridley Turtle; TTH, Hawksbill ; turtle; TTL, Loggerhead Turtle; TTX, Unidentified Turtle; TUG, Green Turtle.

Table 6 Sea turtles bycatch rate and 95% confidence intervals in the Indian Ocean between 2009 and 2015

Fleet	Quarter	Olive Ridley	Green Turtle	Leatherback	Loggerhead	Hawksbill	Turtles	95% confidence Interval
BET fleet	1	0.0070	0.0005		0.0010		0.0085	0.005- 0.0135
	2							0.0000-0.0090
	3							0.0000-0.0041
	4		0.0014				0.0014	0.0003-0.0039
STLVs	1	0.0082	0.0008		0.0008		**0.0099**	0.0051-0.0172
	2	0.0024					0.0024	0.0001-0.0131
	3	0.0108					**0.0108**	0.0040-0.0235
	4	0.0056	0.0007	0.0014		0.0007	0.0084	0.0044-0.0147

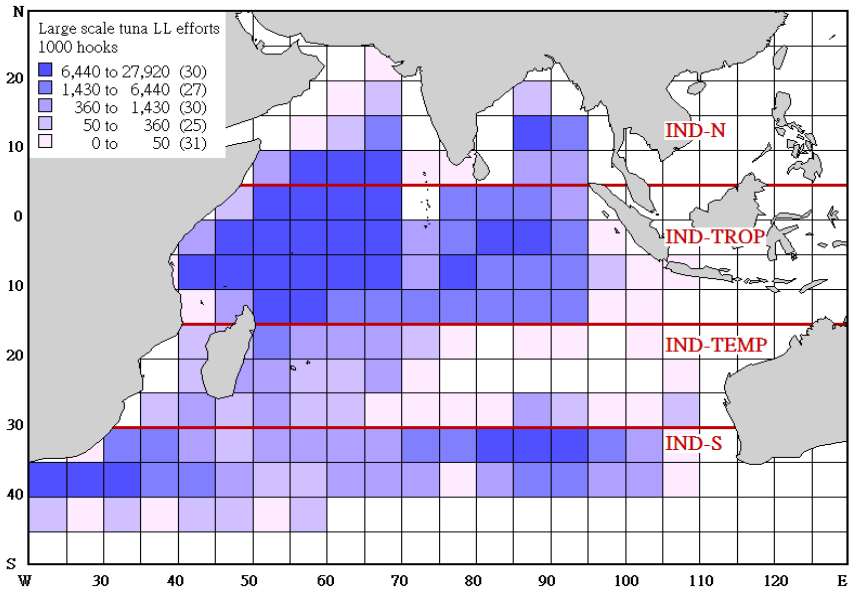

Figure 1 Distribution of fishing efforts of Taiwanese LTLVs in the Indian Ocean

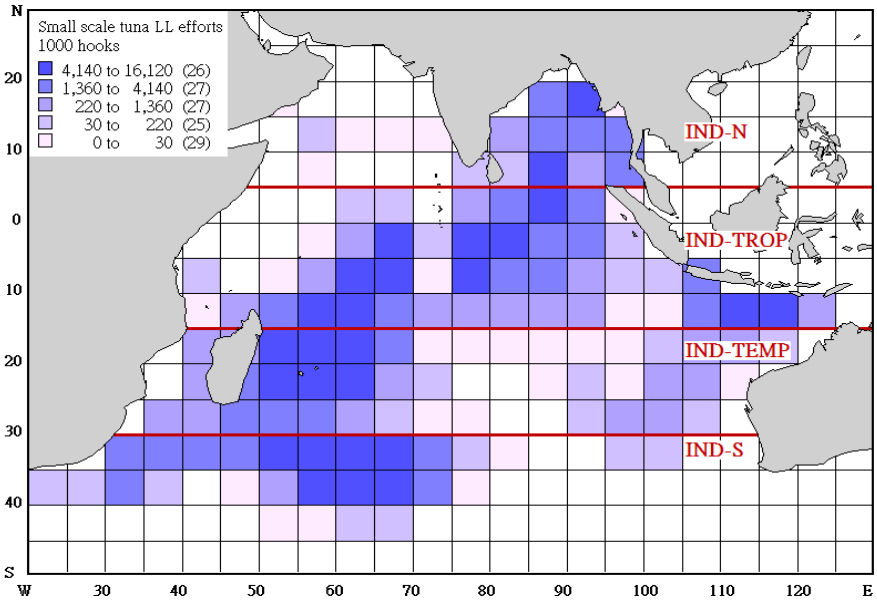

Figure 2 Distribution of fishing efforts of Taiwanese STLVs in the Indian Ocean

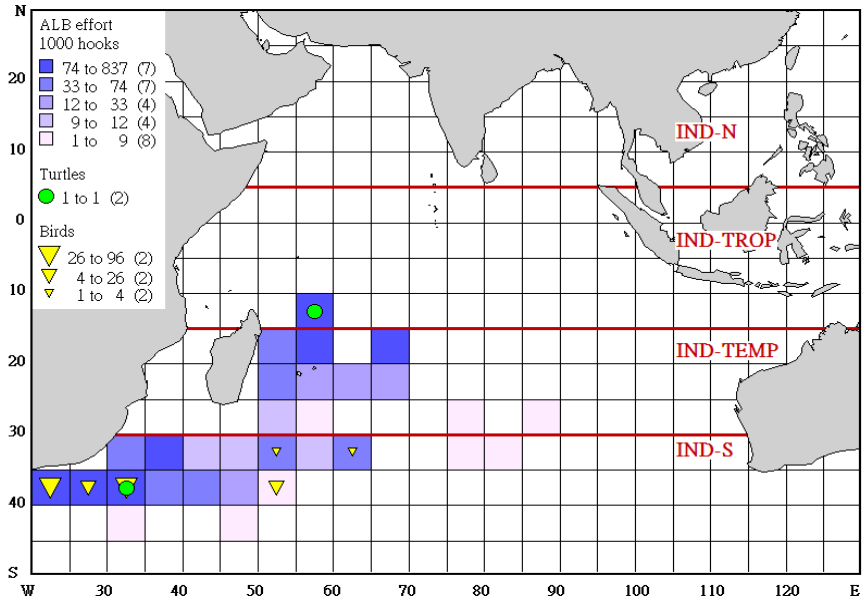

Figure 3 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan albacore LSTLVs in the Indian Ocean between 2009 and 2015

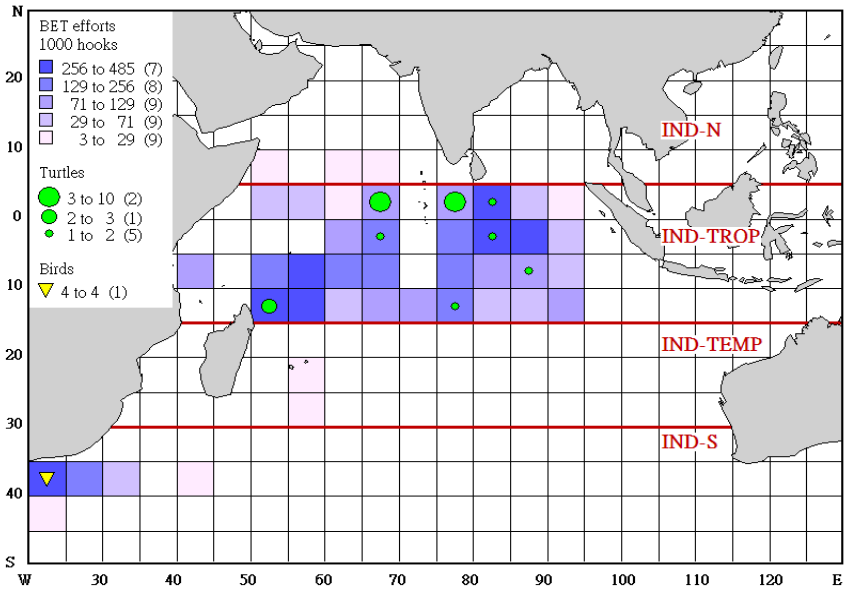

Figure 4 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan bigeye fishing vessels in the Indian Ocean between 2009 and 2015

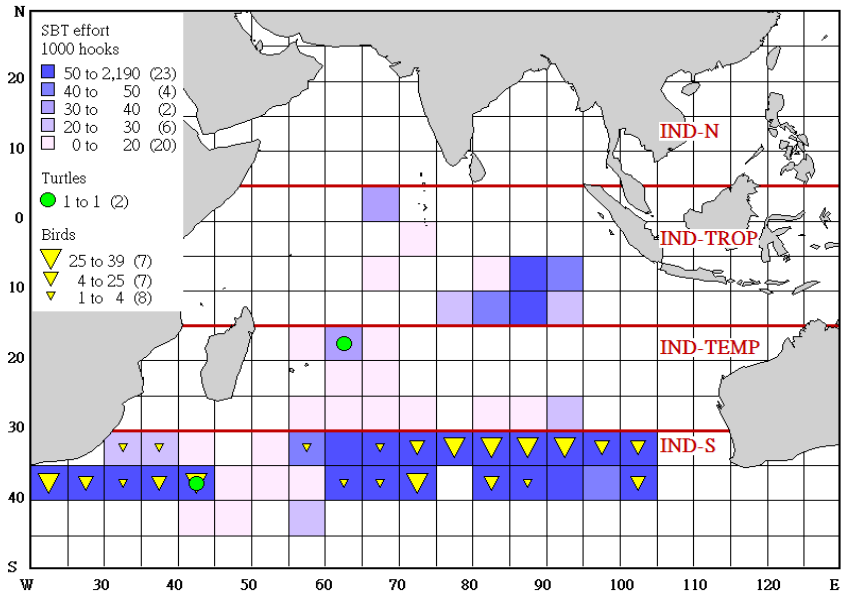

Figure 5 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan SBF fishing vessels in the Indian Ocean between 2009 and 2015

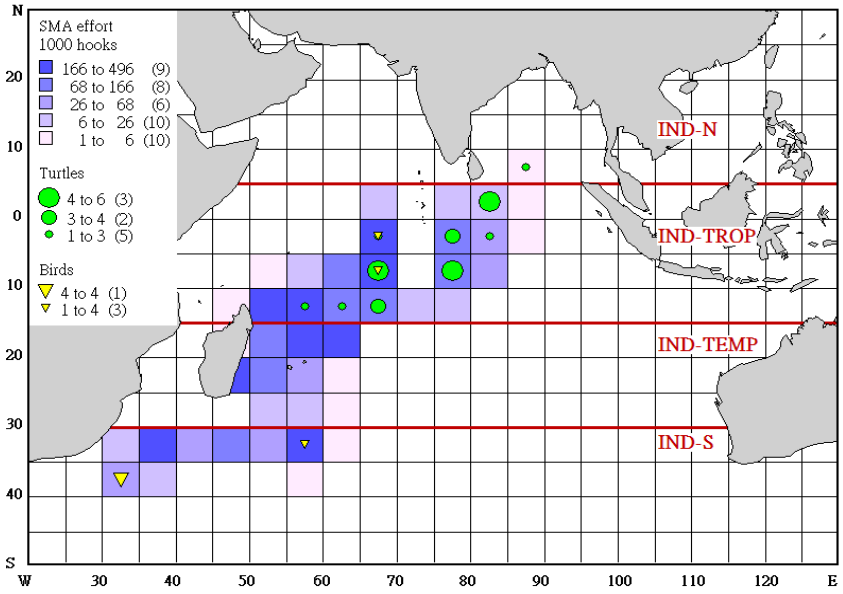

Figure 6 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan SSTLVs in the Indian Ocean between 2009 and 2015

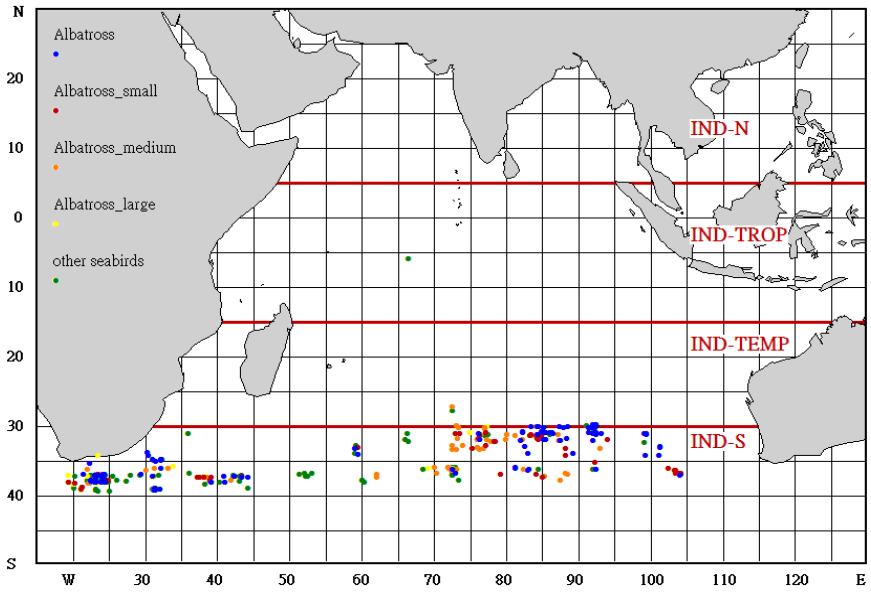

Figure 7 Distribution of seabirds bycatch by group in the Indian Ocean between 2009 and 2015

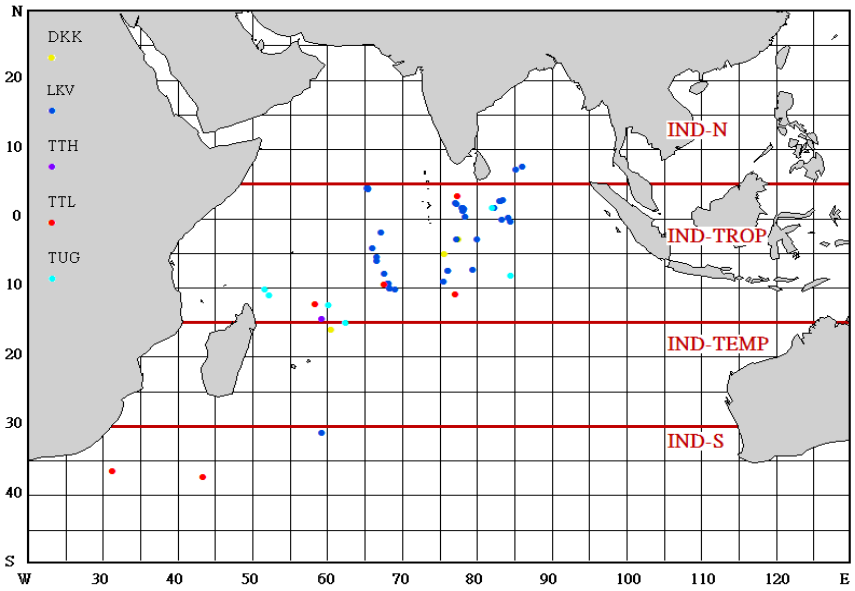

Figure 8 Distribution of sea turtles bycatch by group in the Indian Ocean between 2009 and 2015