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Seabirds and sea turtles bycatch of Taiwanese tuna longline fleets in the Pacific Ocean

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Seabirds and sea turtles bycatch of Taiwanese tuna longline fleets in the Pacific Ocean

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Abstract

To understand the sea turtle and seabird bycatch of Taiwanese distant water longline fleets for conservation purposes, this research analyzed the data collected by observers onboard between 2008 and 2013. In total, the bycatch data from 149 trips and 24.3 million hooks were collected, including 50 albacore large-scale tuna longline vessels (LSTLVs) trips, 72 bigeye LSTLVs trips, and 27 small-scale longline (SSTLVs) trips. The observer coverage rates of LSTLVs varied between 4.70% and 7.95% by year. The seabird bycatch was mostly from albacore LSTLVs, followed by bigeye LSTLVs but that of the SSTLVs was very low. The highest bycatch rate was 0.318 birds per thousand hooks in the Southwest Pacific Ocean in the first quarter, followed by the same area in the second quarter (0.046 birds per thousand hooks). For seabird bycatch species, 82% were albatrosses, including wandering, black-footed albatrosses; and petrels, shearwaters, and booby. The estimated annual bycatch numbers ranged from 175 to 381 between 2008 and 2013 for LSTLVs. As for sea turtles, the bycatch rate of SSTLVs was higher than that of LSTLVs. The major bycatch species were olive Ridley turtle, followed by green and leatherback turtles. The sea turtles bycatch rate peaked in the second quarter in the western tropical Pacific Ocean (0.011 turtles per thousand hooks), followed by the fourth quarter (0.006 turtles per thousand hooks). The estimated sea turtle bycatch numbers ranged from 131 to 249 per year between 2008 and 2013 for LSTLVs.

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

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1. Introduction

Fisheries draws lots attention due to its impact on other marine ecological related species, such as cetaceans, seabirds and sea turtles (Hall et al. 2000, Lewison et al. 2004a, Moore et al. 2009a, Wallace et al. 2013). Among these fisheries, longline fisheries were considered as one major threat to seabirds (Tuck et al. 2001, Baker and Wise 2005, Anderson et al. 2011) and sea turtles (Lewison et al. 2004b, Wallace et al. 2010, Wallace et al. 2013).

Pacific Ocean is the world's largest tuna fishing ground (Majkowski 2007). The initial development of the tuna longline fishing occurred following World War II, as the Japanese fleet expanded its operation throughout the Pacific. The longline fisheries are catching yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in equatorial waters, and albacore (*Thunnus alalunga*) at higher latitudes. The fleets are comprised of large distant water vessels (Japanese, Taiwanese, China, Korea, Spain, and United States) and smaller longline vessels from Taiwan, Costa Rica, Panama, Japan, Ecuador, Indonesia, Mexico, and United States. The number of longline countries is more than thirty and the total number of large-scale and small-scale longline fishing vessels were more than six thousands (IATTC and WCPFC vessel database). However, the longline fishing technique has resulted in the decline in sustainability of some populations of albatrosses, and petrels in the North, and South Pacific Ocean (Tuck et al. 2001, Baker and Wise 2005). In tropical areas, fisheries bycatch has been implicated in population declines of several species of sea turtles worldwide (Lewison et al. 2004a).

For conservation purposes, Food and Agriculture Organization (FAO) adopted "*International Plan of Action for Reducing Incidental Catch of Seabirds in Longline fisheries(IPOA-Seabirds)*" (FAO 1999) and "*Guidelines to reduce sea turtle mortality in fishing operations*" (FAO Fisheries and Aquaculture Department 2009). Under the scientific researches and initiatives made by conservation groups and member countries, many regional fisheries management organizations (RFMOs) adopted related recommendations/resolutions to request members' vessels to take mitigation measures to reducing incidental catch of seabirds and sea turtles. Regarding the seabird conservation, Resolution 11-02 of Inter-American Tropical Tuna Commission (IATTC) asks members vessels shall take at least two mitigation measures while operating in specific areas where with high density of seabirds (IATTC 2011). the CMM 07-04 of Western and Central Pacific Fisheries Commission (WCPFC) request members shall provide seabirds interaction information, including bycatch and other details in the national report for the consideration for Scientific Committee of WCPFC (WCPFC 2007). In 2012, WCPFC CMM 12-07 is adopted to request members to implement seabirds-IPOA, ask vessels to take two specific mitigation measures to reduce seabirds bycatch, and report to WCPFC (WCPFC 2012). For sea turtles conservation, IATTC Resolution 07-03 requests members to provide sea turtle bycatch information and encourage members conducting mitigation measures research (IATTC 2007). WCPFC CMM 08-03 requests members to address their sea turtle bycatch in their national report since 2009, including the implementation of FAO technical guideline, and data collection of sea turtles interaction (WCPFC 2008).

Considering the wide distribution of marine megafauna and fisheries, it is important to evaluate the impact of fisheries across large ocean regions (Lewison et al. 2005). However, because of the difficulties to arrange observers onboard (Moore et al.

2009b), especially for those distant water fishing longline countries (Lewison and Crowder 2003, Black 2008), there was limited information relating to the scope of bycatch of tuna longline fisheries in high seas. To assess the scale of bycatch, and to identify potential conservation areas for seabirds and sea turtles, observation data collected during Taiwanese tuna fishing trips were used in this research to explore the spatial-temporal distribution of seabirds and sea turtles bycatch to Taiwanese tuna longline fleets in the Pacific Ocean and further estimate the bycatch rates and numbers for conservation purposes.

2. Materials and Methods

2.1 Fisheries and study areas

There are two Taiwanese tuna longline fishing fleets operating in the Pacific. The large scale tuna longline fleet (LSTLVs) and small scale tuna longline fleet (SSTLVs). For those targeting on bigeye (*Thunnus obesus*) tuna, the fishing fleet efforts occur in tropical waters between 15°N and 15°S. The albacore (*T. alalunga*) fleet operate at higher latitudes in either the north (north of 15°N) or the south Pacific (south of 15°S). In 2012, there were 87 LSTLVs and 1436 SSTLVs respectively.

The bigeye LSTLVs are 42-57 m in length. They use the monofilament longline system with non-off set 4-4.2' J hooks baited with squid, mackerel, sardine, milkfish or mixed. In each set, around 2700 hooks were deployed. The operation starts in early morning (0300-0600) and last for nine to eleven hours and spent approximately fifteen to seventeen hours for hauling. The average length main line is 145 km long. Secondary branch lines, which are attached to the main line, are about 48 m in length.

The albacore LSTLVs vessels are 30-50 m in length. They use the monofilament longline system with 3.2-4.2 non-off set J hooks baited with sardine, saury, mackerel, or mixed. In each set, around 3200 hooks were deployed. The operation starts at 0400-0600 and last for fourteen to sixteen hours and spent approximately thirteen to fifteen hours for hauling. The main line is around 136 km long in average. Secondary branch lines, which are attached to the main line, are about 24 m in length.

As for the SSTLVs, the fishing grounds are depending on target species. The target species include yellowfin tuna, albacore, dolphin fish, and sharks. The vessels are 21-24 m in length. They used the monofilament longline system with 2.8-4 non-off set J hooks baited with sardine, mackerel, or mixed. In each set, around 2700 hooks were deployed. The operation starts at 0500-0700 and last for five to seven hours and spent approximately ten to twelve hours for hauling. The main line is 108 km long in average. Secondary branch lines are about 18 m in length.

2.2 Data Collection

2.2.1 Observer data

Bycatch data was collected by onboard observers. Observers recorded the fishing position (latitude and longitude for starting and end of setting and hauling), number of hooks deployed, times of setting and hauling, sea water temperature (SST), bait types, catch information(species number, status, length, weight, gender), and bycatch information(number, identified by species, and status (dead/alive) and gender if possible onboard for seabirds, sea turtles, and cetaceans (Huang 2011). The curved carapace length (CCL) of turtles brought on board was measured. Hooks and line entangled will be removed prior to releasing where possible. The bycatch reason (hooked, entangled, etc) is recorded after 2010. For those turtles was not brought on board, the species, status, gender could not be identified so it would be considered as “unknown”.

2.2.2 Effort data

For estimate the total sea turtles mortality of Taiwanese longline fleets, efforts data were collected from logbooks submitted by fishermen. The logbooks recorded the position of sets (latitude and longitude), number of hooks, number and weight of the catch by species, and length of the first 30 fish. Those vessels have set up a vessel monitoring system to automatically report their position, which was used to verify the fishing position. The logbook data are requested to submit to Fisheries Agency, Taiwan and processed by Overseas Fisheries Development Council of Republic of China. The sampling efforts were extrapolate to whole fleets and summarized as hooks by 5*5 degrees by month in accordance with RFMO data requirements.

2.3 Data Analysis

2.3.1 Temporal and Spatial Stratification

For temporal factors, 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, we stratified by six fishing areas: the northwest Pacific Ocean (**PAC_ NW**, north of 20° N, west of 150° W), the northeast Pacific Ocean (**PAC_NE**, north of 20° N, east of 150° W), the tropical-west Pacific Ocean (**PAC_TW**, between 20° N and 20° S, west of 150° W), the tropical-east Pacific Ocean (**PAC_TE**, between 20° N and 20° S, east of 150° W), the southeast Pacific Ocean (**PAC_SE**, south of 20° S, east of 15° W), and the southwest Pacific Ocean (**PAC_SW**, south of 20° S, west of 150° W; Figure 1). Under the stratification system, there would be 24 strata.

2.3.2 Estimation of bycatch rates

The rate of incidental catch (bycatch per unit effort, BPUE) was computed as the number of sea turtles/seabirds caught per 1,000 hooks for each stratum (Minami et al. 2007, Donoso and Dutton 2010).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, Gilman et al. 2008). To determine potential significant differences among fleets, area, and seasons, nonparametric analysis of variance, the Kruskal-Wallis test (Sidney and Castellan 1988) were applied to test the BPUE since they were not normally distributed.

2.3.3 Estimation of incidental catch mortality

Annual numbers of the incidental catch were obtained by the following formula:

$$C_t = \sum_{i=1}^{n} c_i e_{i,t};$$

where C_t is the estimated bycatch number for year *t*, c_i is the estimated bycatch per unit effort (BPUE) in strata i, and $e_{i,t}$ is the number of thousand hooks deployed by the fleet in strata i for year *t* (Huang and Liu 2010).

3. Results

3.1 Fishing efforts and observed efforts distribution

The accumulated distribution of LSTLVs in the Pacific Ocean between 2008 and 2013 was showed in Figure 1. The PAC_TW is the major fishing grounds, composed of 50% of total efforts, following by PAC_TE (24.5% in total). The effort was distributed evenly in four quarters (25%, 23%, 24% and 27% respectively). In the other hand, the efforts in the North Pacific Ocean were around 10% and 15% in the south Pacific. The northern albacore LSTLVs operating majorly from October to March (89%) and most southern albacore LSTLVs operated from April to September (80%). The annual fishing efforts of Taiwanese LSTLVs was decreasing from 145 million hooks in 2004 to 44 million hooks in 2013(Table 1). As for the SSTLVs, the efforts distribution between 2012 and 2013 was showed in Figure 2. Most efforts were concentrated in western Pacific (west of 160 E, 30 N – 15 S). Only very limited efforts located in the east Pacific Ocean.

In total, there are 149 trips from 2008 to 2013. The observed efforts was increasing by year and the coverage rates were ranged from 4.70% to 7.95% for LSTLVs (Table 1). Among these trips, there are 50 trips for albacore LSTLVs, 72 trips for bigeye LSTLVs and 27 trips for SSTLVs (Table 2). The accumulated observed efforts were 24.3 million hooks. The first quarter of PAC_SW has highest coverage rate 31.0% due to low efforts. In tropical areas, the coverage rates ranged from 4.3% to 10.0%. As for the north area, the coverage rates were lower than 4.0% which some of the strata was 0%.

3.2 Bycatch of albacore LSTLVs

A total of 50 albacore LSTLVs observers trips were deployed in the Pacific Ocean from 2008 to 2013. The observation efforts were 9.1 million hooks as distributed in Figure 3. Majority (88%) is in the south hemisphere and only 12% from the north. Most were distributed in north of 30° N and south of 5°S.

Among these trips, 165 seabirds were incidentally caught, most in the coastal waters of Australia and few in the north of 30° N. The albatross species included wandering, white-capped, shy type albatrosses in the south and two black-footed albatross in the north. In addition, there were other seabirds including flesh-footed shearwaters, white-chinned petrels, and southern giant petrel.

Forty sea turtles were incidentally caught. The distribution were in 5°-15° S, 155°-170°W (Figure 3). Of these sea turtles caught, 31 were olive Ridley, 4 green turtles, 3 loggerhead, 1 leatherback and 1 hawksbill turtles. Eighty percent (n=33) were dead when onboard.

3.3 Bycatch of bigeye LSTLVs

A total of 72 observers trips were deployed in the Pacific Ocean from 2008 to 2013. The observation efforts were 12.3 million hooks as distributed in Figure 4. Most efforts were between 5° N and 15° S (88%) and in the western Pacific Ocean.

Although the observed efforts were higher than albacore LTSLVs, only eight seabirds were incidentally caught, including one masked booby, four frigatebirds and three other seabirds. Most bycatch were distributed in 150°-160° W and 5°-10°S.

Regarding sea turtles, 33 sea turtles were incidentally caught. The distribution were in 10°N-10°S, 145°W-155°E (Figure 4). Of these turtles, 12 were leatherbacks, followed by nine olive Ridley, seven green, three loggerhead, and two hawksbill turtles. Nine were dead onboard and the dead rate was 27.3%.

3.4 Bycatch of SSTLVs

SSTLVs observer program is started in 2012. A total of 27 observer’s trips were deployed in the Pacific Ocean between 2012 and 2013. The observation efforts were 2.9 million hooks. Observations were distributed in Figure 5. There are two major fishing grounds, one in the areas between 20°-35° N and 135°-155°E and the other was distributed in 5° N-15° S and 155°E-165°W.

Only two black-footed albatross was bycatch around 31° N, 150° E. Fifty sea turtles were incidentally caught. The distribution showed the sea turtles were bycatch in 5° N-15° S, 155°-175° E (Figure 5). Of the sea turtles caught, 38 were olive Ridley, five green, two loggerhead, three hawksbill and two leatherback turtles. Thirty six were dead and the dead % is 73.5%.

3.5 Estimated bycatch rates and numbers of seabirds

In total, 175 seabirds were caught, most from PAC_SW in January to June. There were no bycatch in PAC_NE and PAC_TE (Table 3). The major types were albatross (81.7%). In addition, some other sea birds, including shearwater (5.1%), petrels (4.0%), frigatebirds (2.3%), booby (1.7%) and giant petrel(0.6%)were recorded (Figure 6).

The seabirds bycatch rates of albacore LSTLVs is significant higher than other fleets (Kruskal-Wallis test, $H=176.25$, $p<0.001$). There was no difference among other fleets (bigeye LSTLVs, SSTLVs). For area, the bycatch rates in PAC_NW and PAC_SW are significant higher than others ($H=534.9$, $p<0.001$).

The estimated seasonal bycatch rates and 95% confidence interval of LSTLVs were showed in Table 4. The bycatch rate was highest (0.318 birds per thousand hooks) in PAC_SW from Jan-Mar, followed by 0.046 birds per thousand hooks in the second quarter in the same area. The estimated seabird bycatch were ranged between 175 and 381 from 2008 to 2013(Figure 7).

3.6 Estimated bycatch rates and numbers of sea turtles

In total, 123 sea turtles were caught, most from PAC_ TW evenly distributed in four quarters. There was no bycatch in PAC_NE, PAC_NW, PAC_SE and only 1 in PAC_SW (Table 5). The major species were olive Ridley, green turtle and leatherback (Table 6). The dead% was ranged from 0% to 80.5% by species. The olive Ridley has high mortality rate (80.8%) and the mortality rate of leatherback was only 13.3%.

The sea turtle bycatch rates of SSTLVs is significant higher than other fleets ($H=34.93$, $p<0.001$). In addition, bigeye LSTLVs is significant larger than albacore LSTLVs. For area, the bycatch rates in TW is significant higher than others ($H=48.6$, $p<0.001$).

The estimated seasonal bycatch rates for LSTLVs were listed in Table 7. The bycatch rate was highest (0.010 turtle per thousand hooks) in PAC_TW from Apr-Jun, followed by 0.006 turtle per thousand hooks in the fourth quarter in the same area. The estimated sea turtles bycatch were ranged between 131 and 249 from 2008 to 2013 (Figure 8).

4. Discussions

The sea turtles and seabirds bycatch of Taiwanese fleets were first analyzed in 2009 (Huang 2009, Huang and Yeh 2011). The major impacts on seabirds were in the North Pacific Ocean and limited sea turtles bycatch recorded. This study helps us to update the bycatch characteristics and identify hot spots for seabirds and sea turtle conservation. The results showed the fisheries impacts on seabirds were mostly came from the albacore LSTLVs and distributed in central North Pacific Ocean and southwest Pacific Ocean. As for the sea turtles bycatch, the SSTLVs have higher impacts than other fleets and bycatch distributed more in the western central Pacific Ocean.

In the Pacific Ocean, there are three species of albatross distributed in the North Pacific Ocean and at least fifteen species in the south. Based on the observer data collected between 2004 and 2007, the estimated seabird bycatch of Taiwanese fleets was decreased from 4215 to 1589 between 2004 and 2007. The seabirds bycatch rates ranged from 0.2213 in northwest and 0.025 in southwest of the Pacific Ocean (Huang and Yeh 2011). However, the data were deficiency in PAC_SE and some other strata because of low coverage rate before 2007. The update information showed PAC_SE is another important area for seabird conservation. In addition, the estimated bycatch number was decreased to 208 in 2013. The bycatch numbers were low than previous years (Huang and Yeh 2011). There are two major possible reasons. First, the total fishing efforts of Taiwanese fleets decreased grammatically because of the scrapping of large-scale tuna fishing vessels between 2005 to 2007(Huang and Chuang 2010). The other possible reason is that the use of mitigation measures. There are mandatory mitigation measures for LSTLVs operating in specific areas in accordance with RFMO’s regulations since 2007. Vessels are requested to take more mitigation measures than before. Furthermore, new standard mitigation measures were adopted in 2012 by WCPFC which come into force in 2014 (WCPFC 2012). The timely evaluation of the new mitigation measures based on observer data would be helpful to monitor the status of seabird bycatch.

For sea turtles bycatch, the bycatch rates and numbers were low, compared to some coastal areas (Petersen et al. 2009, Donoso and Dutton 2010). The bycatch species composition and mortality rates are different by fleet. The major bycatch species of albacore LSTLVs and SSTLVs fleet were olive Ridley and the bycatch species of bigeye LSTLVs was leatherback. In addition to the operating waters, the possible reason should be the fishing depth. The fishing depth was deeper for bigeye LSTLVs as well as the distribution depth of leatherback. Regarding the mortality rates of sea turtles, it's higher than other small scale longline fisheries because the operating time is longer. However, because of leatherback with larger size have stronger swimming power and diving ability, the mortality rates was lower than other species. The bycatch number of sea turtles was low, however, the bycatch number of sea turtles by SSTLVs were not calculated because of low coverage.

For data quality issue, the observation onboard small-scale longline vessels provided valuable information. In addition, with increasing experience, more education, seabirds identification materials provided, and photos taken, the identified seabird percentage is increased. Although some species were identified as other albatross, these could be further improved by education materials and training.

Due to budgets and personal limitation for observer deployment, it's important to set priority for observation hot areas. In addition, outreach and conservation measures are required. In Taiwan, posters, sheets and booklets for guidance of mitigation measures and species identification for seabirds and sea turtles were disseminated to the fishermen would helps fishermen and industries to take appropriate measures in accordance with the seabirds-NPOA. In addition, the updated Taiwan Seabirds-NPOA is published in June 2014. This could further improve the efforts to scientific research and conservation for seabirds in the Pacific Ocean.

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Table 1 Observed trips, set, efforts and coverage rates of the Pacific Ocean

Year	Observer		Whole fleet		Coverage by efforts%
	trips	Efforts (1000 hooks)	vessels	Efforts (1000 hooks)	
2008	17	3,205	84	52,668	6.09%
2009	22	4,399	75	56,806	7.77%
2010	22	3,065	90	64,889	4.70%
2011	19	3,767	95	66,018	5.74%
2012	26(13)	4,395(1,152)	87	55,279	7.95%
2013	16(14)	3,139(1,775)	82	44,331	7.08%

Note:

1. The coverage rates were estimated for LSTLVs. The figures in parentheses were the trips and efforts of SSTLVs.
2. The coverage rate of 2013 was preliminary.

Table 2 Trips and observed efforts by fleet in the Pacific Ocean from 2008-2013

	Albacore LSTLVs	Bigeye LSTLVs	SSTLVs	TOTAL	Efforts (1000 hooks)
2008	7	10		17	3,159
2009	9	13		22	3,591
2010	7	15		22	3,368
2011	7	12		19	3,767
2012	11	15	13	39	5,547
2013	9	7	14	30	4,914
Sum	50	72	27	149	24,346

Table 3 Bycatch of seabirds in the Pacific Ocean between 2008 and 2013

Area \ Season	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec	Sum
PAC_NE	0	N.A.	0	0	0
PAC_NW	13	2	N.A.	3	18
PAC_TE	0	0	0	0	0
PAC_TW	0	4	3	4	11
PAC_SE	0	0	1	2	3
PAC_SW	79	56	8	0	143
Sum	92	62	12	9	175

Table 4 Seabirds bycatch rate and 95% confidence intervals in the Pacific Ocean between 2008 and 2013 (LSTLVs only)

Area \ Season	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec
PAC_NE	0	N.A.	0	0
PAC_NW	0.019 (0.0103-0.03314)	N.A.	N.A.	0.012 (0.0024- 0.0340)
PAC_TE	0	0	0	0
PAC_TW	0	0.001 (0.0003- 0.0033)	0.001 (0.0002- 0.0022)	0.002 (0.0004-0.0040)
PAC_SE	0	0	0.002 (0.0001-0.0135)	0.007 (0.00089-0.0263)
PAC_SW	0.318 (0.2521-0.3968)	0.046 (0.0347-0.0596)	0.005 (0.0022-0.0100)	0

Table 5 Bycatch of sea turtles in the Pacific Ocean between 2008 and 2013

Season Area	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec	Sum
PAC_NE	0	N.A.	0	0	0
PAC_NW	0	0	N.A.	0	0
PAC_TE	0	1	2	3	6
PAC_TW	20	46	29	21	116
PAC_SE	0	0	0	0	0
PAC_SW	1	0	0	0	1
Sum	21	47	31	25	123

Table 6 Bycatch status of sea turtles by species in the Pacific Ocean between 2008 and 2013

Species	Alive	Dead	unknown	Sum	Dead%
Olive Ridley	15	63		78	80.8%
Green Turtle	4	11	1	16	68.8%
Leatherback	5	2	8	15	13.3%
Loggerhead	8			8	0.0%
Hawksbill	4	2		6	33.3%
Sum	36	78	9	123	63.4%

Table 7 Sea turtles bycatch rate and 95% confidence intervals in the Pacific Ocean between 2008 and 2013 (LSTLVs only)

Season Area	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec
PAC_NE	0	N.A.	0	0
PAC_NW	0	N.A.	N.A.	0
PAC_TE	0	0.001 (0.00003-0.0075)	0.002 (0.0002-0.0054)	0.002 (0.0005-0.0067)
PAC_TW	0.003 (0.0014- 0.0071)	0.011 (0.0080-0.0159)	0.002 (0.0009-0.0040)	0.006 (0.0032-0.0096)
PAC_SE	0	0	0	0
PAC_SW	0.004 (0.0001 -0.0225)	0	0	0

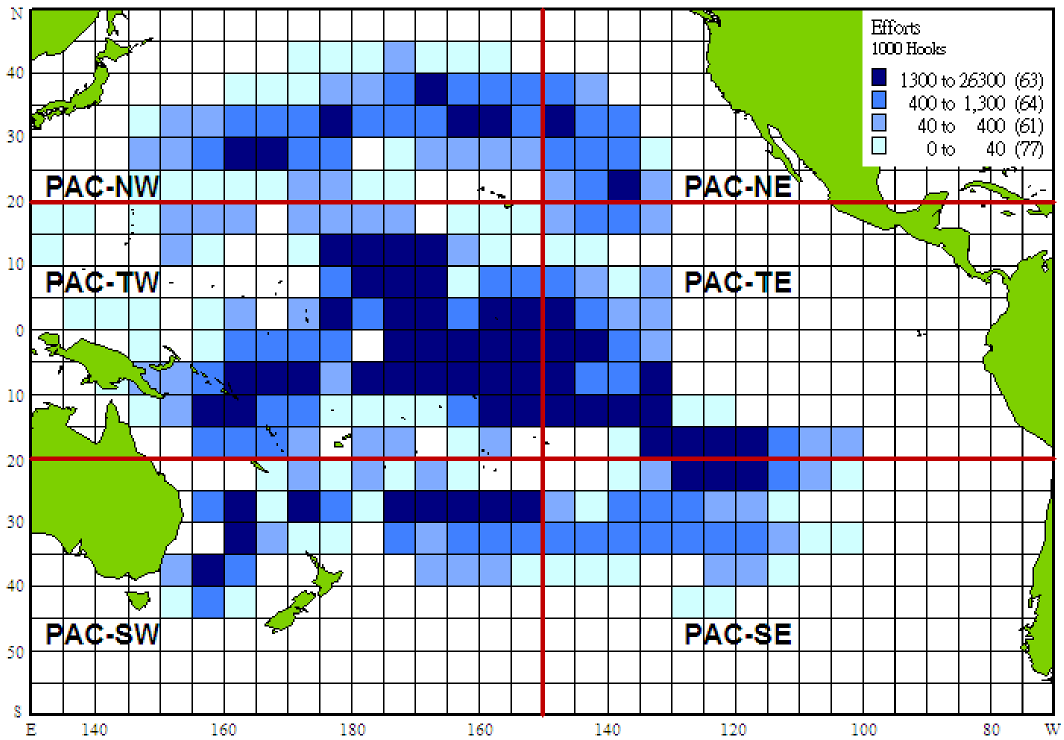

Figure 1 Distribution of fishing efforts of Taiwanese LSTLVs fleets in the Pacific Ocean between 2008 and 2013

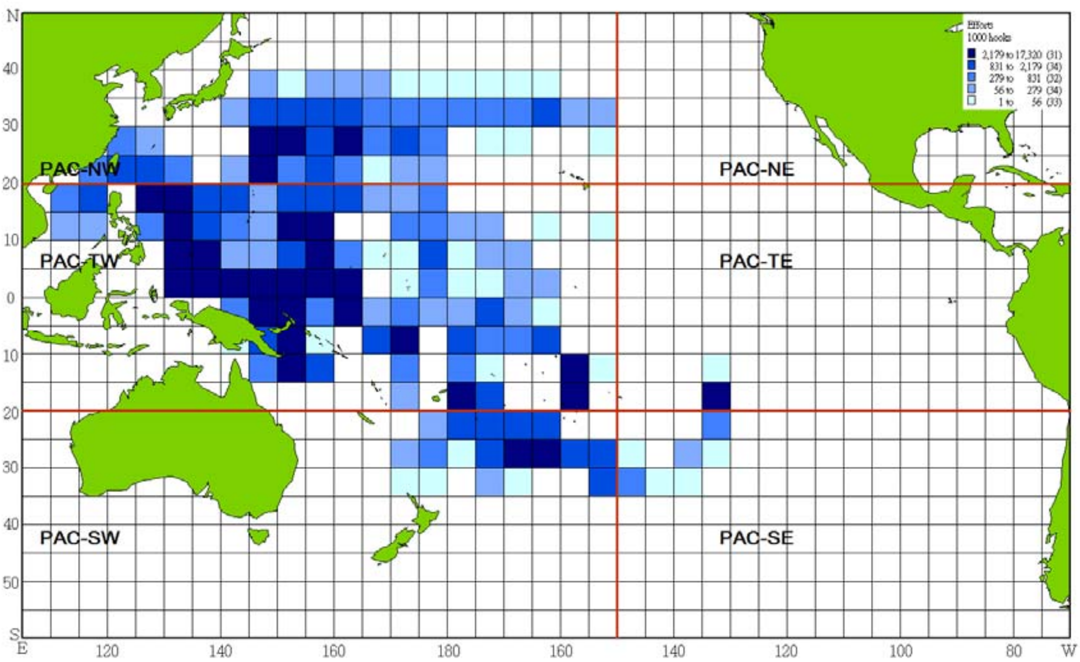

Figure 2 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan albacore SSTLVs between 2012 and 2013

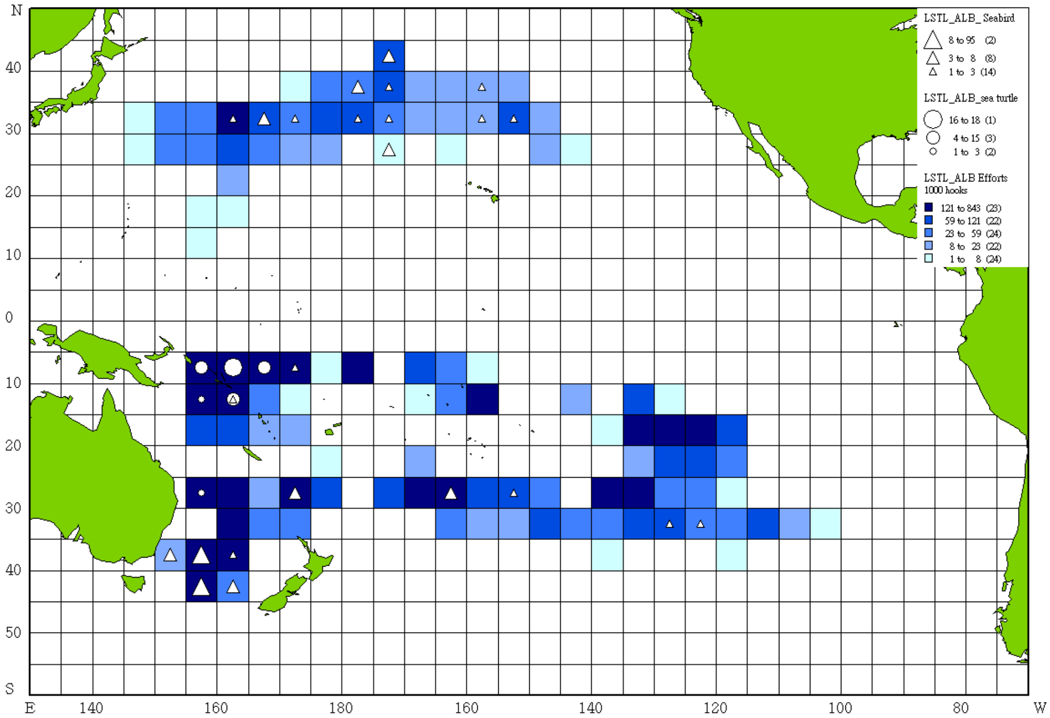

Figure 3 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan albacore LSTLVs between 2008 and 2013

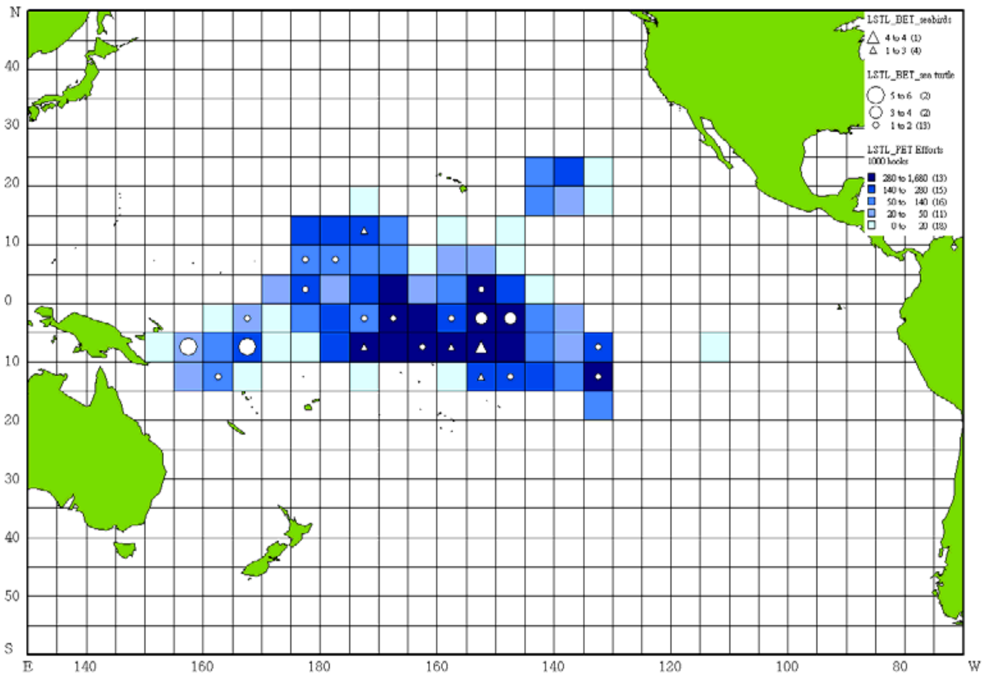

Figure 4 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan bigeye LSTLVs between 2008 and 2013

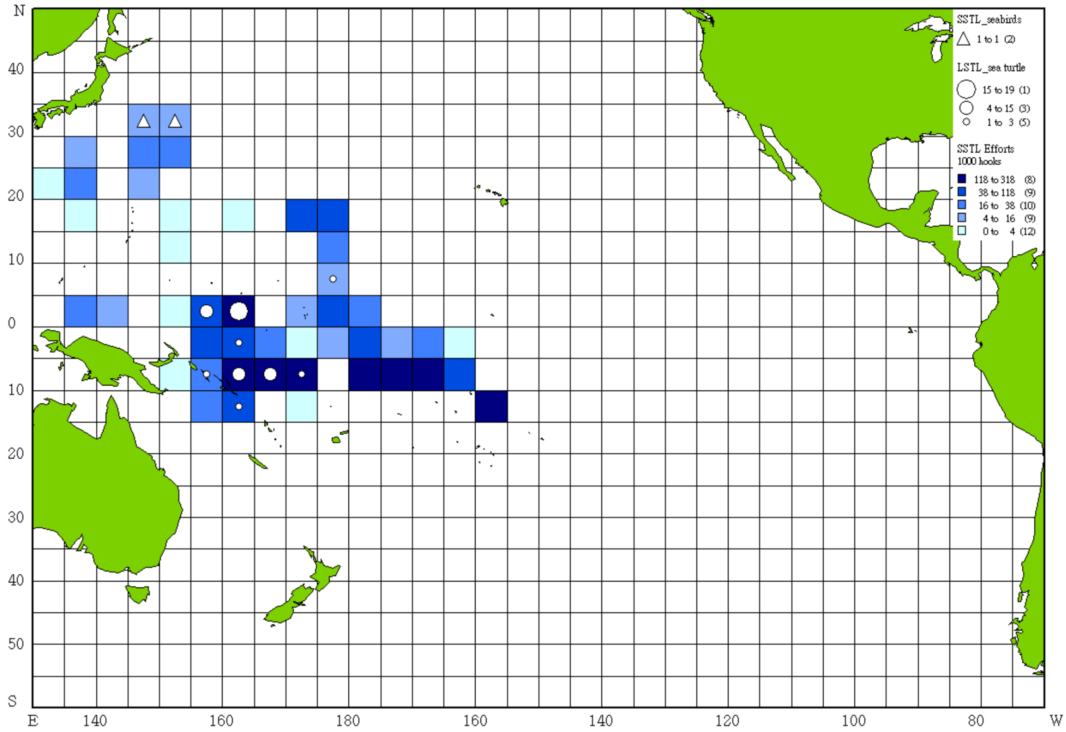

Figure 5 Distribution of observed efforts, seabirds and turtles bycatch by Taiwan SSTLVs between 2012 and 2013

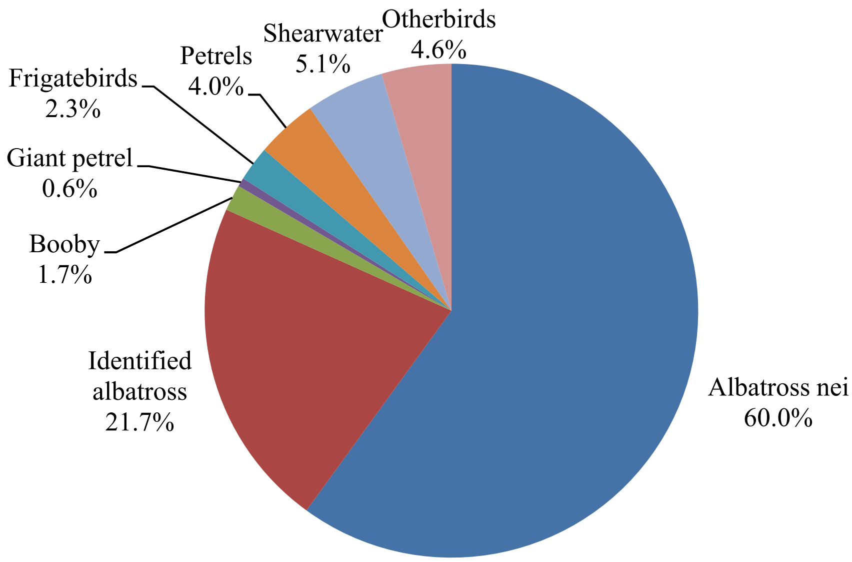

Figure 6 Bycatch seabirds species composition

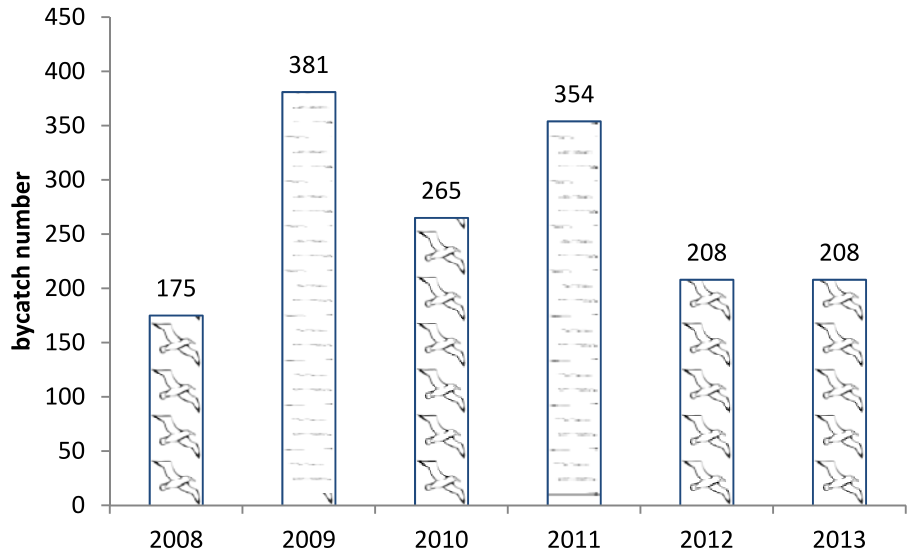

Figure 7 Estimated seabird bycatch of LSTLVs between 2008 and 2013

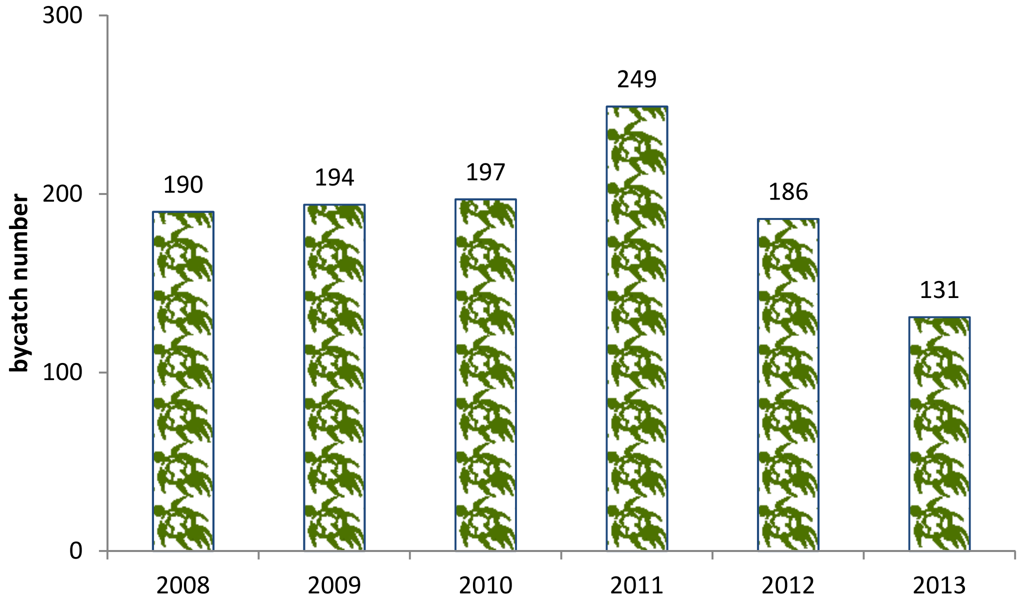

Figure 8 Estimated sea turtles bycatch of LSTLVs between 2008 and 2013