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Incidental catch of seabirds and sea turtles by Taiwanese longline fleets in the Pacific Ocean

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ABSTRACT

To understand the sea turtle and seabird bycatch of Taiwanese tuna longline fleets for conservation purposes, this research analyzed the data collected by onboard observers between 2008 and 2013. In total, data from 149 trips and 24.3 million hooks were analyzed, including 50 albacore large-scale tuna longline vessel (LTLVs) trips, 72 bigeye LTLVs trips, and 27 small-scale tuna longline vessel (STLVs) trips. Seabird bycatch was mostly from the albacore LTLVs. The highest bycatch rate was 0.320 bird per thousand hooks in the southwest Pacific Ocean in the first quarter, followed by the same area in the second quarter (0.046 bird per thousand hooks) by the albacore LTLVs. For seabird bycatch species, 81.7% were albatrosses, including wandering albatross (*Diomedea exulans*), Laysan albatross (*Phoebastria immutabilis*), white-capped albatross (*Thalassarche steadi*), black-footed albatross (*Phoebastria nigripes*), and black-browed albatrosses (*Diomedea melanophris*); other seabird species included white-chinned petrel (*Procellaria aequinoctialis*), flesh-footed shearwater (*Puffinus carneipes*), frigate bird and booby. Regarding sea turtles, the bycatch rate peaked in the second quarter in the western tropical Pacific Ocean by STLVs (0.034 turtle per thousand hooks), followed by albacore LTLVs (0.028 turtle per thousand hooks) during the same time period in the same region. The major bycatch species included olive ridley (*Lepidochelys olivacea*), followed by green (*Chelonia mydas*), and leatherback (*Dermochelys coriacea*). Observer training for seabird species identification and detailed information collection for mitigation measures should be implemented to ensure better data quality. This will help implement mitigation measures in areas and fisheries where a large number of birds are taken as bycatch.

1. Introduction

The Pacific Ocean is the world's largest tuna fishing ground (Majkowski, 2007). The longline fisheries catch yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in equatorial waters and albacore (*Thunnus alalunga*) at higher latitudes. The fleets are composed of large-scale longline vessels from Japan, Taiwan, mainland China, South Korea, Spain, and the United States, and small-scale longline vessels from Taiwan, Costa Rica, Panama, Japan, Ecuador, Indonesia, Mexico, and the United States, among other countries. In total, there are more than six thousand longline vessels from more than thirty countries operating in the Pacific Ocean (IATTC, 2014; WCPFC, 2014).

The populations of many sea turtle and seabird species are decreasing due to marine pollution, tourism, coastal development, degradation of habitat, plastic bags/debris, fisheries bycatch, introduced species predation, hunting, etc. (FAO, 2009). Among those populations threatened, longline fishing along with trawl, gillnet, and other fisheries have resulted in the declining abundance of some species of seabirds and sea turtles (Anderson et al., 2011; Baker and Wise, 2005; Lewison et al., 2004; Tuck et al., 2001; Wallace et al., 2010, 2013). There are three species of albatross distributed in the North Pacific Ocean and at least fifteen species in the south (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 Pacific Ocean is considered vulnerable (olive ridley, *Lepidochelys olivacea;* leatherback, *Dermochelys coriacea*), endangered (loggerhead, *Caretta;* green turtle, *Chelonia mydas*), or critically endangered (hawksbill, *Eretmochelys imbricata*) (IUCN Red List). Fisheries bycatch has been implicated in the population declines of several species of sea turtles; particularly, the bycatch rates of the loggerhead in the South Pacific Ocean and the olive ridley in the East Pacific Ocean are considered as high impact (Wallace et al., 2013). Many studies have been conducted on the distribution and bycatch rates of seabirds and sea turtles

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and have attempted to identify the degree of impact and effective conservation strategies (Anderson et al., 2011; Wallace et al., 2013).

Responding to the situation, the Food and Agriculture Organization (FAO) adopted the "International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds)" and "Guidelines to reduce sea turtle mortality in fishing operations" to encourage relevant countries to request that their vessels use mitigation measures (FAO, 1999; FAO, 2009). Furthermore, many Regional Fisheries Management Organizations (RFMOs) have adopted recommendations/resolutions to reduce incidental catch of seabirds and sea turtles, including the use of seabirds mitigation measures (e.g., bird-scaring lines, weighted branch lines, and night setting) in specific areas for seabird (WCPFC, 2007, 2012; IATTC, 2011), and data collection for sea turtle interactions (IATTC, 2007; 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, due to the difficulties of obtaining any, let alone adequate high coverage rate (Black, 2008; Lewison and Crowder, 2003; Moore et al., 2009), there is limited information related to the extent of seabird bycatch in longline fisheries, especially for the Asian pelagic longline fleets in the high seas (Anderson et al., 2011). Although more and more data have been collected in recent years, many sea turtle regional management units (RMUs) are considered as data-poor, and most analyses have been conducted in coastal areas (Wallace et al., 2013). Among the longline fishing countries in the Pacific Ocean, the tuna catch of Taiwan was ranked second only next to Japan between 2008 and 2012 in the western and central Pacific (WCPFC, 2014), which reveals Taiwan as the major tuna longline country, especially in the western and central Pacific Ocean. This study aims to analyze observer data from Taiwanese fishing vessels to explore spatial-temporal characteristics of seabird and sea turtle bycatch, and to further estimate bycatch rates to assist implementation of proper conservation measures.

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 (LTLVs) targets albacore, and bigeye tuna, and the small-scale tuna longline fleet (STLVs) target yellowfin tuna, albacore, dolphin fish, and sharks. The number of LTLVs was 84 in 2008 and decreased to 82 in 2013. The number of STLVs was 1260 in 2008 and increased slightly to 1296 in 2013. The fishing grounds, hook size, bait types, average number of hooks deployed per set, branch-line length, and fishing time are described in Table 1.

Total effort data were collected from logbooks submitted by fishermen. The logbooks recorded the position of the sets (latitude and longitude), the number of hooks, the number and weight of the catch by species, and the length of the first 30 fish. The vessels were equipped with the vessel monitoring system to automatically report their position, which was used to verify fishing positions. The logbook data were requested to be submitted to the Fisheries Agency, Taiwan and were processed by the Overseas Fisheries Development Council. The sampling efforts were extrapolated to whole fleets and summarized as the number of hooks by 5 by 5 degrees squares by month.

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, sea surface temperature (SST), 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), offal discharge (yes/no), branch-line weighted (yes/no), bait dye (yes/no), etc. The curved carapace length (CCL) of turtles brought on board was measured. The entangled hooks and line were removed prior to release when possible. The data analyzed for the LTLVs were from 2008 to 2013. For the STLVs, the observer program of Pacific Ocean started in 2012; thus, only the data from 2012 to 2013 were used in this study. The observer coverage rates were calculated as the percentage of observed number of hooks divided by total number of hooks.

2.3. Data analysis

2.3.1. Temporal and spatial stratification

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 regulations of WCPFC and IATTC (the seabirds mitigation measures are required for north of 23°N and south of 30°S) (IATTC, 2011;WCPFC, 2012), and the bycatch distribution of seabirds and fishing grounds of fishing fleets, we included the following six areas: the northwest Pacific Ocean (**PAC_NW**, north of 25°N, west of 150°W), the northeast Pacific Ocean (**PAC_NE**, north of 25°N, east of 150°W), the tropical-west Pacific Ocean (**PAC_TW**, between 25°N and 25°S, west of 150°W), the tropical-east Pacific Ocean (**PAC_TE**, between 25°N and 25°S, east of 150°W), the southeast Pacific Ocean (**PAC_SE**, south of 25°S, east of 150°W), and the southwest Pacific Ocean (**PAC_SW**, south of 25°S, west of 150°W) (Fig. 1). This stratification system yields 24 strata.

2.3.2. Estimation of bycatch rates

The rate of bycatch was computed as the number of sea turtles and seabirds caught per 1000 hooks for each stratum based on the data collected by observers (Donoso and Dutton, 2010; Minami et al., 2007; Ryan et al., 2002; Favero et al., 2013). 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; Huang and Liu, 2010). To determine potential significant differences among areas, and the seasons, a nonparametric Kruskal–Wallis test (Sidney and Castellan, 1988) was applied, as the data were not normally distributed.

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, and small albatrosses, and other seabirds. The seabird groups are listed in Table 3.

3. Results

3.1. Fishing effort

The accumulated distribution of the LTLVs in the Pacific Ocean between 2008 and 2013 is shown in Fig. 1. The PAC_TW was the major fishing ground, representing 50.0% of the total effort, followed by the PAC_TE (24.5%). As for the other areas, the efforts were