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Short Paper

Comparison of three seabird bycatch avoidance methods in Hawaii-based pelagic longline fisheries

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Capture in longline fisheries is a critical threat to most albatross and large petrel species.[1–3] Black-footed *Phoebastria nigripes* and Laysan *P. immutabilis* albatrosses are the predominant seabird species incidentally caught in Hawaii longline fisheries. This study reports results of a trial in the Hawaii pelagic longline tuna and swordfish fisheries comparing four experimental treatments' seabird capture rates and commercial viability. Two research fishing trips were conducted between 1 April and 17 May 2003 on a Hawaii-based pelagic longline vessel, at traditional fishing grounds south of the Northwestern Hawaiian Islands, between 21° 41′N and 25° 08′N, 173° 58′W and 167° 43′W.

Two of the treatments employed were setting branch lines through 9 m and 6.5 m long underwater setting chutes, which release baited hooks beneath the sea surface, in an attempt to prevent diving seabirds from reaching them. The design of the underwater setting chute, illustrated in Molloy *et al.*,[4] is similar to that used in this present trial. When setting with the 9 m and 6.5 m chutes on the research vessel, 5.4 m and 2.9 m of the chute's shaft was underwater, respectively.

A third treatment, called side-setting, entailed setting from the side of the vessel, with other gear design the same as conventional approaches when setting from the stern. The crew throwing baited hooks was 8 m forward from the port-stern corner. Baited hooks were thrown forward, close to the side of the vessel's hull, to protect baits from seabirds. A bird curtain was used, 4.9 m forward from the port-stern corner, when side-setting to increase the effectiveness of this mitigation method by preventing birds from establishing a flight path along the side of the boat where baited hooks were being deployed. The hypothesis is that when side-setting, baited hooks will be set close to the side of the vessel hull where seabirds will be unable or unwilling to pursue the hooks. By the time the stern passes the hooks, the hooks will have sunk to a depth where seabirds cannot locate them or cannot dive.

A fourth treatment was blue-dyed bait. Bait was completely thawed and dyed blue by soaking in a large tub with dissolved blue food coloring (Virginia Dare FD & C Blue no. 1) powder at a concentration of 4 g/L of water for 1–4 h to achieve regulatory-required darkness. The hypothesis is that dyed bait is difficult for birds to detect because it reduces the contrast between bait and sea color.

Research on the efficacy of blue-dyed bait and underwater setting chutes for pelagic longline fisheries at reducing seabird bycatch has been conducted previously.[5,6–10] This present study is the first assessment of the effectiveness of side-setting at reducing seabird capture.

Setting occurred only during daylight to enable observations of seabird interactions with fishing gear. Both tuna and swordfish gear used 60 g swivels attached within 1 m of the hook, a weighting design selected by the Hawaii Longline Association. Gilman *et al.*[5] has provided details of the fishing gear and methods of the Hawaii longline tuna and swordfish fisheries.

A total of 40 242 hooks were set during the experiment using Hawaii longline tuna gear and 10 023 hooks using Hawaii longline swordfish gear. One replicate consisted of setting one tote containing an average of 493 hooks. However, if two or more consecutive totes employed the same treatment, these were combined and treated as a single replicate to avoid pseudo-replication.

Every 15 min throughout each set, a count of each seabird species within a 500 m by 500 m

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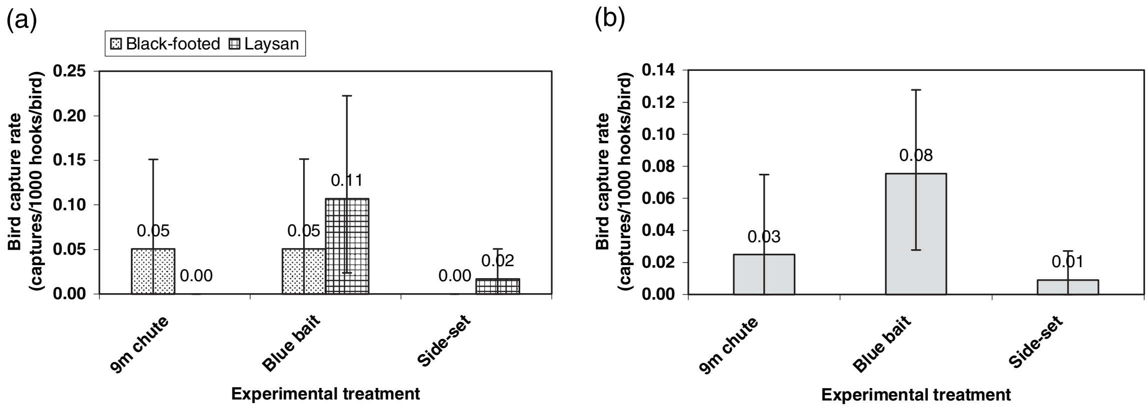

Fig. 1 (a) Laysan and black-footed albatross capture rates (captures/1000 hooks/bird) for experimental treatments used with swordfish gear. (b) Capture rates for experimental treatments used with swordfish gear for combined albatross species. Captures are based on the number of birds hauled aboard and not the number of birds observed captured during the set. Error bars are boostrapped ($n = 1000$) 95% non-parametric confidence intervals.

square area (within 250 m of port and starboard of the center of the vessel stern and within 500 m behind the vessel) astern of the vessel was recorded. Seabird captures and the species of seabirds caught during setting and hauling was recorded. A bird capture event during setting was recorded if a bird struggled persistently with outstretched flapping wings, and was finally lost to view astern as it maintained the same position of attachment to a hook. The number and species of dead seabirds hauled aboard was recorded.

Non-parametric 95% confidence intervals (95%CI) derived from percentile method bootstrapping at $n = 1000$ are reported for mean capture rates (using the number of birds hauled aboard). This is a standard resampling technique to address variability when the parametric assumptions cannot be met, when underlying distributions are poorly known because of a small sample size or other considerations such as skewed data and outliers.[11]

Seabird capture rates are reported for each experimental treatment. For instance, if seven birds were hauled aboard during an experimental treatment, 3896 hooks were set using this treatment, and the mean combined Laysan and black-footed albatross abundance during this treatment's replications was 27.8, then the mean capture rate (captures/1000 hooks/bird) is manually calculated as follows:

$$\frac{(7\ \text{captures})}{(3896\ \text{hooks}) \times (27.8\ \text{birds})} \times \frac{(1000\ \text{hooks})}{(1000\ \text{hooks})} \quad (1)$$
$$= 0.06\ \text{captures}/1000\ \text{hooks/bird}$$

Figures 1 and 2 present the mean capture rates and 95%CI using the number of birds hauled aboard. Due to the rarity of seabird captures, some CI estimates of uncertainty for capture rates may be inaccurate, especially in cases of no observed captures, which is why no CI are presented around these means.

At the end of the third set of the first research fishing trip, the 9 m chute fractured and bent at the main pipe welding joint. This prevented further use in this trip, resulting in a smaller sample size than planned. Design problems were experienced with both chutes during the second trip.

No seabird captures were observed during hauling. Based on mean seabird capture rates (for combined albatross species, based on the number of seabirds hauled aboard), side-setting was the most effective treatment for both tuna and swordfish gear resulting in seabird capture rates of 0.002 (0.00–0.01 95%CI) and 0.01 (0.00–0.03 95%CI) captures/1000 hooks/bird, respectively (Figs 1 and 2). The second most effective method was the 9 m chute when used with swordfish gear (0.03 [0.00–0.07 95%CI] captures/1000 hooks/bird). The 6.5 m chute was the second most effective seabird avoidance method when used with tuna gear (0.01 [0.00–0.03 95%CI] captures/1000 hooks/bird). Blue-dyed bait resulted in 0.03 (0.01–0.06 95%CI) and 0.08 (0.03–0.13 95%CI) seabird captures/1000 hooks/bird when used with tuna and swordfish gear, respectively. Some of the mean bird capture rates were not significantly different. Unfortunately, engineering deficiencies experienced with the two chutes prevent meaningful evaluation of their efficacy.

Of the three methods assessed, side-setting holds the highest promise when considering both effectiveness and commercial viability. In addition to being more effective at avoiding seabird capture, side-setting provides substantial operational ben-

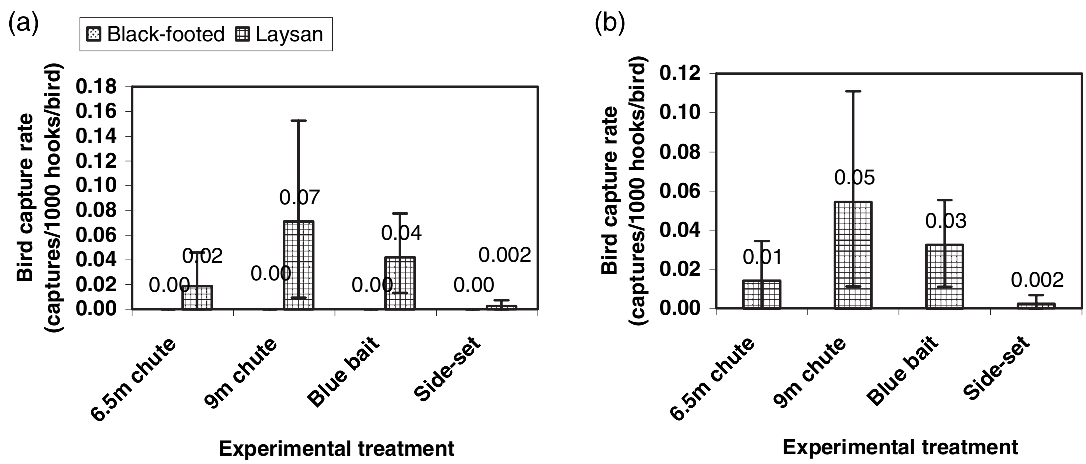

Fig. 2 (a) Laysan and black-footed albatross capture rates (captures/1000 hooks/bird) of experimental treatments used with tuna gear. (b) Capture rates of experimental treatments used with tuna gear for combined albatross species. Captures are based on the number of birds hauled aboard and not the number of birds observed captured during the set. Error bars are boostrapped ($n = 1000$) 95% non-parametric confidence intervals.

efits, such as eliminating the need to move gear and bait between two work stations, increasing available deck space by condensing the gear storage area, and having no cost to employ after the initial expense of converting the vessel deck design, which is on average less than $US1000. There were no incidences of gear being fouled in the propeller while side-setting, even when the captain turned the vessel hard to port and starboard to purposely attempt to foul the gear. Blue-dyed bait was impractical for several reasons, including the amount of time required to dye the bait, and the need to fully thaw bait, which increases bait loss from hooks and precludes retaining bait quality if a set is cut short. However, most inconveniences could be alleviated if pre-dyed bait were commercially available. The chute in its current degree of development is not expected to be acceptable to pelagic longline industries.

Side-setting, combined with adequate line weighting, holds promise to reduce seabird mortality in other pelagic as well as demersal longline fleets. Assessments in individual fisheries are needed to confirm this hypothesis. For instance, assessment of side-setting in longline fisheries with varying complexes of seabird species is needed to determine if there are species that can access baited hooks closer to the vessel hull than Laysan and black-footed albatrosses.

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