Assessment of Strategies to Reduce Seabird Bycatch Employed by Hawaii Pelagic Longline Tuna Vessels and of Observer Program Data Collection Protocols

November 2004

Prepared for the *Western Pacific Regional Fishery Management Council*

by
Eric Gilman
Blue Ocean Institute
2718 Napuaa Place
Honolulu, HI 96822 USA
ericgilman@earthlink.net

Abstract
Mortality in longline fisheries is the most critical global threat to most albatross and large petrel species. Identifying and mainstreaming seabird avoidance methods that not only have the capacity to minimize bird interactions, but are also practical and provide crew with incentives to employ them effectively, will help resolve this problem. Seabird bycatch rates for Hawaii pelagic longline tuna vessels were calculated from Hawaii longline onboard observer data collected over a 14 month period. Vessels employed one of three gear configurations: (a) side setting with untreated bait, (b) stern setting with blue-dyed bait, and (c) stern setting with untreated bait (no seabird avoidance methods). Side setting had the lowest mean seabird bycatch rate (0.0 captures/1000 hooks (0.0000 – 0.0000 95% nonparametric bootstrapped (n = 1000) confidence interval)), which was significantly lower than stern setting with untreated bait (0.0130 captures/1000 hooks (0.0026 – 0.0240)), but not significantly difference than stern setting with blue-dyed fish bait (0.0043 captures/1000 hooks (0.0000 – 0.0129)). The mean seabird bycatch rate when stern setting with blue-dyed bait was lower than when stern setting with untreated bait, but the difference was not significant. Six seabirds were captured in the observed 323 sets during the study period. Due to the rarity of occurrence of seabird captures, confidence interval estimates of uncertainty for seabird capture rates may be inaccurate. A lack of consistent, reliable information on albatross presence or absence and on albatross abundance during setting creates additional uncertainty.

Data collection protocols of the Hawaii longline onboard observer program have recently been modified enabling improved future assessments of seabird avoidance methods. Additional recommended changes are made to further standardize protocols to estimate albatross abundance during setting and to record the number of seabirds hauled aboard per tote.

Additional analysis of observer data on seabird interactions is needed to critique a regulatory requirement for employment of seabird avoidance methods by Hawaii longline tuna vessels only when fishing North of 23 degrees N. latitude. The regulatory requirement for “strategic offal discards” needs to be clarified and consideration given for its scientific basis.

1. INTRODUCTION

Mortality in longline fisheries is the most critical global threat to most albatross and large petrel species (Brothers et al. 1999; Gilman, 2001). Incidental bycatch of Laysan (*Phoebastria immutabilis)* and Black-footed (*P. nigripes*) Albatrosses in gear of the Hawaii pelagic longline tuna and swordfish fisheries, and the risk of interaction with the U.S. listed endangered Short-tailed Albatross (*P. albatrus*) are conservation and management concerns (Gilman and Freifeld, 2003; U.S. Fish and Wildlife Service, 2002 and 2004). Research and commercial demonstrations conducted from 2002-2003 assessed three methods’ effectiveness at avoiding incidental seabird capture and commercial viability in Hawaii pelagic longline fisheries (Gilman et al., 2003 and In Review). A seabird avoidance method called side-setting, setting gear from the side of the vessel instead of the stern, had the lowest mean seabird contact and capture rates of all treatments tested. Because side-setting promises to provide large operational benefits for longline vessels, including requiring only a single work area and eliminating the need to move large quantities of gear and bait between setting and hauling positions, broad industry uptake and voluntary compliance are realistic.

Since completion of the experiment on 17 May 2003, twelve Hawaii longline tuna vessels have modified their deck design to switch permanently to side setting (Sean Martin, personal communication, Hawaii Longline Association, 31 October 2004). There are 120 vessels in the Hawaii longline tuna and swordfish fleet, thus 10% of the fleet has voluntarily converted to side setting. This indicates that the industry has high expectations for operational benefits from the change and is committed to discover its full potential.

Fishery managers are now amending regulations to allow Hawaii longline tuna and swordfish vessels to employ side setting as an alternative to currently required seabird avoidance methods, and is expected to come into effect by August 2005 (U.S. Fish and Wildlife Service, 2004; U.S. Western Pacific Regional Fishery Management Council, 2004).

Side setting means setting longline gear from the side of the vessel rather than the conventional position at the stern (Fig. 1). Crew set baited hooks close to the side of the vessel hull where seabirds, such as albatrosses, are unable or unwilling to pursue them. Ideally, by the time the stern passes, the hook has sunk beyond the reach of seabirds. Guidance for vessels side setting in the Hawaii longline fleet includes:

(a) Placing 60 g weighted swivels on branch lines within 1 m of the hook;
(b) Setting as far forward as possible to maximize the time for hooks to sink beyond the reach of seabirds. This also makes it easier to deal with tote tangles and badly thrown baits. The few vessels in the Hawaii fleet that may be restricted from setting far forward need to mount their main line shooter at least 0.5 m from the stern corner to allow space for a bird curtain;
(c) Throwing baited hooks as far forward and as close to the hull as possible;
(d) Clipping branch lines to the mainline the moment that the vessel passes the baited hook. This minimizes tension in the branch line, and keeps the baited hook from being pulled towards the surface where birds can reach it; and
(e) Using a bird curtain between the setting position and the stern to prevent birds from establishing a flight path where hooks are being set (Gilman et al., In Review and 2004). The design of the bird curtain used in Hawaii trials is described in Gilman et al. (In Review) and Gilman (2004).

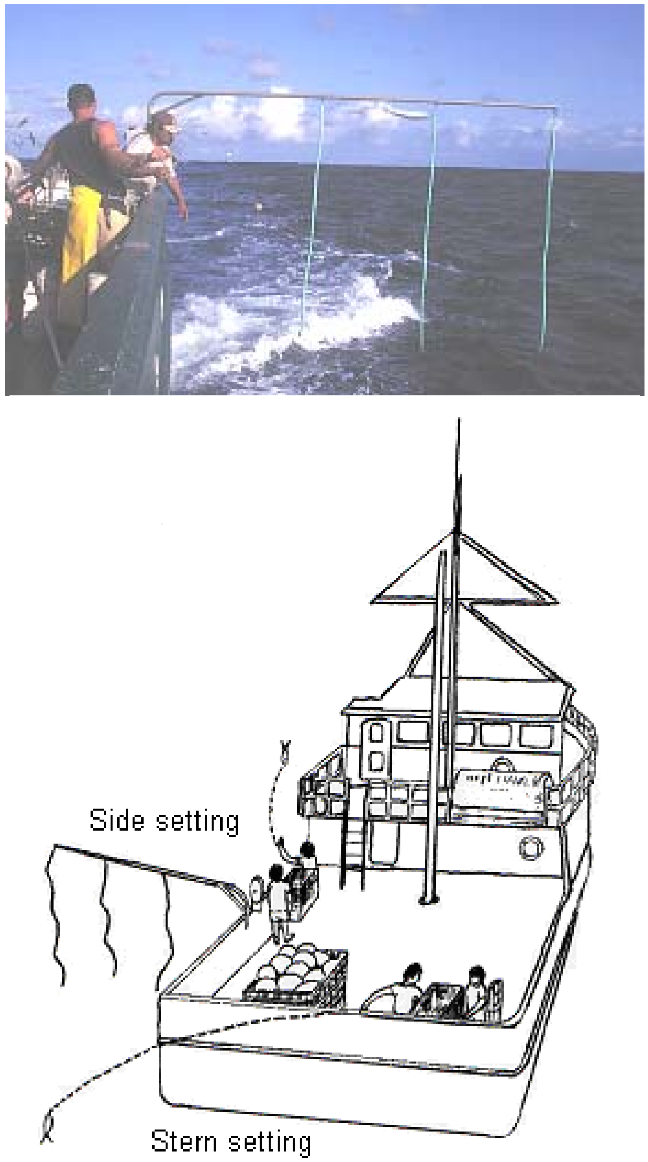

Fig. 1. Photo (top) showing a port-side forward-setting position with bird curtain and illustration showing a port side setting position with bird curtain and position of conventional stern setting.

U.S. Atlantic fishermen began experimenting with various colored baits in the mid-1970s in an attempt to increase catch-per-unit-of-effort (CPUE) (McNamara et al., 1999). Blue-dyed bait has been assessed for effectiveness as a seabird avoidance method in Hawaii and Japan's pelagic longline fisheries, and research has been initiated in Brazil (McNamara et al., 1999; Boggs, 2001; Minami and Kiyota, 2002; Gilman et al., 2003 and In Review). The hypothesis is that dyed bait is difficult for birds to detect because it reduces the contrast between the bait color and sea color. The bait is thawed, separated, and soaked in a mixture of blue food coloring and seawater. Gilman et al. (2003 and In Review) present results from these previous assessments of blue-dyed bait conducted in the North Pacific.

This paper analyzes the U.S. National Marine Fisheries Service Pacific Islands Regional Office observer program data for the Hawaii longline fleet from the date when observers first started to record the location on the deck where setting occurs (15 August 2003) through 26 October 2004 to critique the observer program data collection protocols and to calculate seabird bycatch rates for Hawaii longline vessels fishing with different methods and gear designs. Some stern-setting vessels used blue-dyed bait to reduce seabird captures, the remainder of stern-setting vessels used no strategy to avoid seabirds. Recommendations are made to modify observer data collection protocols for the Hawaii longline fleet to facilitate improved analysis of the effectiveness of strategies to reduce seabird bycatch. The Hawaii longline fleet had 20% onboard observer coverage during the study period. Hawaii longline swordfish vessels had 100% observer coverage, but only one swordfish trip was made during this period.

2. METHODS

2.1. Period

We selected the start date for analyzing the observer data of 15 August 2003 because this is when observers began to record whether vessels were setting from the stern or side of the vessel (personal communication, Tom Swenarton, U.S. National Marine Fisheries Service Pacific Islands Regional Office, 27 October 2004). On 17 May 2003, the 2003 assessment of side setting as a strategy for reducing seabird bycatch in the Hawaii longline fleet was completed (Gilman et al., In Review). Shortly after 17 May 2003 Hawaii longline vessels started to side set (personal communication, Sean Martin, President, Hawaii Longline Association). We did not include historical data on seabird bycatch rates from stern-setting vessels in the fleet because we recognize that this would introduce confounding factors as seabird behavior, species composition, and abundance can vary greatly inter-annually (e.g., Melvin et al, 2001). We selected an end date for the analysis as the most current available observer data at the time of preparing this analysis.

2.2. Replicates and Definition of Seabird Capture

This analysis uses one Hawaii longline tuna set as one replicate. Observer data identify the number and species of seabirds hauled aboard by set (versus, for instance, by each tote or by each fishing trip). Observers recorded seabird captures during setting only for small segments of some sets. Thus the number of birds hauled aboard is used to estimate the total number of seabirds captured during the set, despite evidence that this method underestimates total bird capture (Brothers, 1991; Gales et al., 1998; Gilman et al., 2003 and In Review).

2.3. Which Sets Included In the Analysis

There were 4,549 sets made by Hawaii longline tuna and swordfish vessels during the time period being assessed. Only sets made by vessels targeting tuna were included in the analysis. The vessels that have converted to side setting are all longline tuna vessels, thus seabird bycatch data for this analysis are of interest only from vessels using this same fishing gear and methods for comparing seabird bycatch rates.[1] Of these tuna sets, a subset was included in the analysis if (a) observer data showed the presence of one or more albatrosses during the set or during the day when the set was made; or (b) one or more seabirds were observed hauled aboard from that set.

If an observer recorded that there were no albatrosses present during the set or during the day that the set was made, and no seabirds were hauled aboard from that set, then it was assumed that there were no albatrosses present during the set, and the set was not included in the analysis.

2.4. Treatments

The replicates were divided into three treatments. All treatments employed Hawaii longline tuna gear, were daytime sets, and used a mainline shooter. Vessels in the Hawaii longline tuna fleet conventionally use weighted branch lines, placing swivels weighing between 45-60 g on the branch line within 1 m of the hook. In accordance with requirements for reducing seabird bycatch for the Hawaii longline fleet (U.S. Fish and Wildlife Service, 2002 and 2004), night setting is defined as when crew begin to set gear one hour after local sunset and complete deploying gear before local sunrise. Day setting is defined as when night setting did not occur. The Hawaii longline observer program defines a Hawaii longline tuna set as containing 15 or more hooks between two buoys, and a longline swordfish set as containing fewer than 15 hooks between two buoys. Observer information on the number of hooks deployed per basket was checked against the observer entry of the target species (tuna versus swordfish) to ensure the sets were correctly categorized.

The three treatments are defined as follows:

(a) **Side-setting and no additional bird avoidance measure**: Side setting with no additional measures employed to reduce seabird bycatch;
(b) **Stern-setting plus regulatory required measures**: Stern setting and using blue-dyed fish bait; and
(c) **Stern-setting and no bird avoidance measure**: Stern setting with no seabird avoidance method.

Several additional seabird avoidance methods are required of Hawaii longline tuna vessels when fishing North of 23 degrees N. latitude (U.S. National Marine Fisheries Service, 2002). Regulations require vessels fishing North of 23 degrees N. latitude to employ a minimum of 45 g weights located on branch lines within 1 m of the hook. But this weighting regime is conventionally used by all vessels in the fleet, and was employed in all but one of the 323 replicates of all three treatments. Vessels are

[1] The Hawaii longline swordfish fishery historically has had an order of magnitude higher seabird bycatch rate than the Hawaii longline tuna fishery, likely due to differences in the location of fishing grounds, fishing methods, and fishing gear (U.S. Fish and Wildlife Service, 2002 and 2004; Gilman et al., 2003 and In Review). Therefore, comparing seabird bycatch rates of Hawaii longline tuna versus swordfish vessels would not provide information to compare the efficacy of different seabird bycatch reduction methods being employed by the vessels of the two different fisheries. Only one fishing trip was made by a Hawaii longline swordfish vessel during the study period.

also required to discard fish, offal (fish parts), and spent bait during setting or hauling when fishing North of 23 degrees N. latitude, however only 18% of the replicates for vessels that were required to employ this method were in compliance, while 10% of the replicates of the other two treatments voluntarily employed this method.

There were no sets conducted during the study period by vessels side setting plus seabird avoidance methods required by U.S. National Marine Fisheries Service (2002) regulations for Hawaii longline tuna vessels fishing North of 23 degrees N. latitude.

2.5. Estimating Albatross Abundance and Normalizing Seabird Bycatch Rates for Albatross Abundance

Observers recorded seabird abundance by species within about 150 m of the vessel or around the gear at variable times during a fishing trip (sailing/running, drifting, setting, or hauling). Most observations of seabird abundance were made by the observers during the haul, which typically occur during the afternoon and at night in the Hawaii longline tuna fleet. Albatross abundance is generally lower at night than during the day. It is also very difficult to accurately estimate bird abundance around the vessel in the dark (McNamara et al., 1999). Because seabird abundance was not estimated in a standardized manner, and observations were not made during every set included in the analysis, we do not attempt to normalize seabird bycatch rates for albatross abundance, as conducted in previous studies (Gilman et al., 2003 and In Review). However, observations of albatross abundance were used to determine whether or not to include a set in the analysis. Sets were included in the analysis only if an observer recorded albatrosses being present during the day the set was made.

3. RESULTS

3.1. Summary Statistics

Table 1 presents summary statistics for combined albatross species' bycatch rates and Fig. 2 presents the mean seabird bycatch rates and nonparametric 95% confidence intervals derived from percentile method bootstrapping at N = 1000 for each treatment. 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 (Efron and Tibshirani, 1986). This approach is particularly useful for determining empirical confidence intervals that can be asymmetrical, where the error interval above the point estimate differs from the error interval below the point estimate; i.e., the error specification is flexible, and there is no assumption of symmetric error about the point estimate.

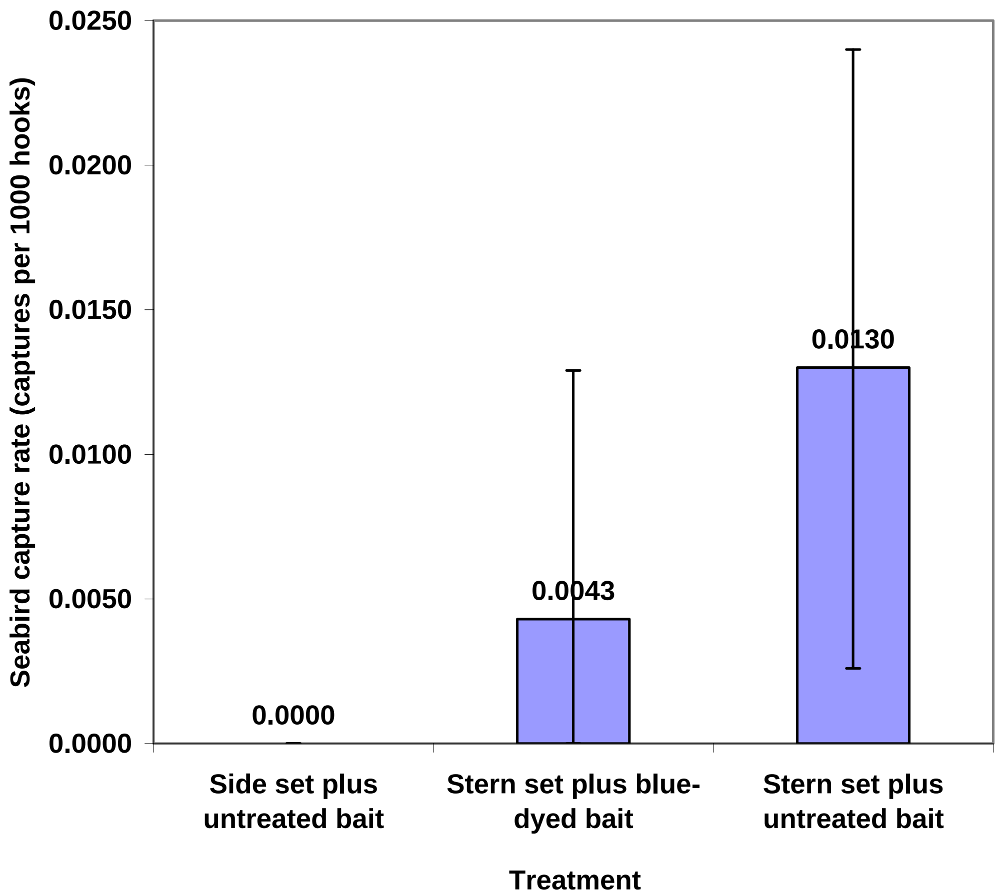

Fig. 2. Combined species seabird capture rates (captures/1000 hooks) for the three treatments observed in this study. Error bars are boostrapped (n = 1000) 95% nonparametric confidence intervals.

Due to the rarity of seabird captures, some confidence interval estimates of uncertainty for contact and capture rates are likely to be inaccurate, especially in cases of no observed contacts or captures with a confidence interval of 0.00 – 0.00. To produce accurate results using percentile method bootstrapping, 10 replications per treatment are needed when the event is common (pers. comm., Marti McCracken, U.S. National Marine Fisheries Service, August 2003). However, when the event is not common, as is the case with seabird captures in this study, more replications are needed. For instance, in the side-setting treatment, there were 21 replications but no observed albatross captures. We cannot conclude that side-setting will eliminate albatross captures, as there remains statistical uncertainty in the result of zero captures.

Table 1. Summary statistics for combined albatross species' capture rates for Hawaii longline tuna sets by vessels fishing between 15 August 2003 – 26 October 2004 where onboard observers recorded the presence of an albatross during some part of the day when the set occurred. Probable error is reported from boostrapped (n = 1000) 95% nonparametric confidence intervals.

Treatment	N (number of sets)	Total number of hooks	Number of albatrosses combined species hauled aboard	Nominal seabird catch rate[a] and confidence interval (seabird captures/1000 hooks)		Effect[b]
				Mean	95% CI	
Side-setting and no additional bird avoidance measure[c]	21	38,266	0	0.0000	0.0000 – 0.0000	100%
Stern-setting plus regulatory required measures[d]	108	234,255	1	0.0043	0.0000 – 0.0129	67%
Stern-setting and no bird avoidance measure	194	384,098	5	0.0130	0.0026 – 0.0240	0%

[a] "Nominal" means not normalized for albatross abundance.

[b] Effect is the percent reduction in albatross mean bycatch rate compared to no use of a seabird avoidance method (stern-setting and no bird avoidance method).

[c] Hawaii longline tuna vessels conventionally use weighted branch lines. Almost all vessels in the fleet use a minimum of 45 g swivels located within 1 m of the hook, which meets the weighted standard required for longline tuna vessels when fishing North of 23 degrees N. latitude (U.S. National Marine Fisheries Service, 2002).

[d] Regulatory measures required for Hawaii longline tuna vessels to reduce seabird bycatch when fishing North of 23 degrees N. latitude (U.S. National Marine Fisheries Service, 2002). The additional seabird avoidance method employed by sets of this treatment is blue-dyed fish bait, as discussed in sections 4.5-4.6.

Only six albatrosses, two Laysan and four Black-footed Albatrosses, were observed hauled aboard on Hawaii longline tuna vessels during the study period, all on stern-setting vessels. Five of these vessels were at grounds South of 23 degrees N. latitude and were not using a seabird bycatch avoidance method, and one vessel was fishing North of 23 degrees N. latitude, where it was using blue-dyed fish bait and weighted branch lines, required seabird avoidance methods when fishing at this latitude. No seabird species other than Laysan and Black-footed Albatrosses were observed hauled aboard.

3.2. Bycatch Rate Computation and Units

Seabird bycatch rates are calculated for each experimental treatment and are reported with the following units:

$$\frac{\text{Captures}}{(1000\text{ hooks})}$$

A sample calculation is provided to demonstrate how the units in reported capture rates are derived. If there were 3 observed captures out of 2000 hooks set, then the mean capture rate is manually calculated and units reported as follows:

$$\frac{(3 \text{ captures}) \times (1000 \text{ hooks})}{(2000 \text{ hooks}) \times (1000 \text{ hooks})} = 1.5 \text{ captures/1000 hooks}$$

The bootstrapping method uses replications to calculate a mean and confidence intervals, while this sample rate calculation aggregates all of the data, and the two calculation methods result in slightly different mean rates.

4. DISCUSSION AND RECOMMENDATIONS

4.1. Seabird Bycatch Rates Side Versus Stern Setting

Vessels side setting resulted in significantly lower seabird bycatch rates than vessels stern setting with untreated bait, based on non-overlapping nonparametric 95% confidence intervals derived from percentile method bootstrapping at N = 1000. There was no significant difference in seabird bycatch rates of vessels side setting and stern setting plus blue-dyed bait, or between vessels stern setting with blue-dyed bait and stern setting with untreated bait, based on overlapping nonparametric 95% confidence intervals (Table 1 and Fig. 2). No seabirds were captured by side setting vessels in 21 observed sets when albatrosses were present, while one seabird was captured by stern setting vessels using blue-dyed bait in 108 sets when albatrosses were present.

Due to the rarity of occurrence of seabird captures, confidence interval estimates of uncertainty for seabird capture rates may be inaccurate, as there were relatively few observed captures for all treatments.

The Hawaii longline observer database did not provide consistent, reliable information on albatross presence or abundance during setting. Based on this limitation of the observer database, there is little confidence that replicates of a treatment that resulted in zero albatross captures was a result of the effectiveness of any strategies being employed to avoid seabird captures versus a simple lack of albatrosses being present. Therefore, little weight should be given to the resulting seabird bycatch rates for each treatment.

4.2. Replicates

Observers should record the number of seabirds of each species hauled aboard by tote (also called snood bins or hook boxes), instead of the current practice of recording seabird bycatch for an entire set. This would substantially increase the sample size and reduce probable error of estimates of seabird bycatch rates. Observers would need to count the number of hooks in each tote deployed during each set, and count the hooks as they are being hauled back in reverse order of how they were set. Using a tote as the basis for a replicate would not result in pseudo-replicates because there are sufficient differences in environmental variables (e.g., weather, sea conditions, seabird abundance and species complex, light) when each tote is set (Gilman et al. 2003 and In Review).

4.3. Fishing Grounds Where Seabird Bycatch is Problematic

There were a total of 4,549 Hawaii longline tuna sets observed during the study period. Of these, 923 or 20.3% were at or North of 23 degrees N. latitude, and the remaining 3,826 sets were conducted at fishing grounds South of this latitude. Of the total 3,826 sets occurring South of 23 degrees N. latitude on vessels with an onboard observer during the study period, 225 or 5.8% had observations of albatrosses present during some part of the day when the set occurred. Of the total 923 sets occurring North of 23 degrees N. latitude on vessels with an onboard observer during the study period, 98 or 10.6% had observations of albatrosses present during setting. Of the 323 sets analyzed in this study, 98 or 30% were conducted North of 23 degrees N. latitude. Currently, seabird avoidance strategies are required for Hawaii longline swordfish and tuna vessels when fishing North of 23 degrees N. latitude to reduce the risk of interactions with Short-tailed Albatrosses (U.S. National Marine Fisheries Service, 2002; U.S. Fish and Wildlife Service, 2002 and 2004), but a regulatory amendment that will come into effect by August 2005 has a purpose of reducing adverse effects on all seabird species (U.S. Western Pacific Regional Fishery Management Council, 2004). Five of the six observed albatross captures during this analysis were caught South of 23 degrees N. latitude on four separate vessels during five separate sets. These four vessels were not employing a seabird avoidance method other than the conventional use of a 45-60 g weights on branch lines within 1 m of the hook. This information is not sufficient to draw conclusions on the suitability of the geographical area where seabird avoidance measures should be required, as it is a small sample size, and accurate information on albatross abundance is lacking.

4.4. Observer Estimates of Albatross Abundance

The method employed by the Hawaii longline observer program during this study period for estimating albatross abundance did not ensure that albatross abundance was recorded during each set, and was not standardized or consistent. There is low confidence that albatrosses were definitely present during all sets included in the analysis, as most observer records on the presence of albatrosses were made at times other than when the vessel was setting. Also, there is a lack of reliable information on albatross abundance during each set included in the analysis.

Gilman et al. (In Review) explain the basis for normalizing seabird bycatch rates for seabird abundance:

> Normalizing seabird interaction rates for bird abundance is an analysis approach consistent with the accepted understanding of animal abundance and the capture process (Ricker, 1958; Seber, 1973) derived from an early study on rats (Leslie and Davis, 1939). Of all the confounding factors that likely affect the level of bird interactions with longline gear per unit of effort, including weather conditions, seabird species complex, and differences in gear and fishing practices, seabird abundance is thought to be one of the most important. Gilman et al. (2003) demonstrated a highly significant linear correlation between albatross abundance and seabird interaction rates, confirming the hypothesis that seabird interaction rates should be normalized for seabird abundance. Normalizing seabird interaction rates for bird abundance allows for more accurate comparisons between results from multiple experiments.

To help explain the benefit of normalizing seabird interaction rates for bird abundance, consider the scenario where in one experiment an average of 15 albatross follow a vessel, and in another experiment 150 albatross follow a vessel, and both experiments are testing the same seabird avoidance method(s). Based on the results from Gilman et al. (2003), we expect about 10 times more captures per unit effort (e.g., per 1000 hooks) in the second experiment than in the first, assuming all other potentially confounding factors (weather conditions, seabird species complex, different type of gear, different bait, etc.) are the same for the two experiments. If we did not normalize the capture rates from the two experiments by bird abundance, a comparison of the reported capture rates (presented as captures per 1000 hooks) would imply that the capture rate in the first experiment was 10 times lower than that of the second experiment. Therefore, normalizing capture and contact rates for bird abundance is important to allow for more accurate comparisons between seabird interaction rates reported from multiple experiments. Normalizing seabird interaction rates for significant confounding factors, when possible, makes rates reported from multiple experiments more comparable. However, there are numerous additional confounding factors that may still prevent useful comparisons between results normalized for bird abundance even from experiments that are conducted in the same area.

On 2 November 2004, the Hawaii longline observer program modified protocols for observers to monitor seabird abundance. Observers are now recording seabird abundance for two five-minute intervals during all sets, once at the initiation of the set and a second time at 30 minutes into the set. Observers scan 360 degrees around the vessel with the naked eye (e.g., not using binoculars) to count all birds for which they can identify the species (personal communication, Kevin Busscher and Anik Clemens, 4 November 2004, U.S. National Marine Fisheries Service Pacific Islands Regional Office). Additional modifications can be made to further improve albatross abundance monitoring protocols to facilitate more accurate assessments of alternative strategies to reduce seabird bycatch in longline gear.

Gilman et al. (2003 and In Review) employed a standardized method to estimate mean albatross abundance during setting: Every 15 minutes throughout each set a count of each seabird species within a 500 m by 500 m 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. The Hawaii longline observer program should define a similar area around the vessel for observers to provide consistency of measurements of mean seabird abundance during sets.

Ideally, observers would record seabird abundance for entire sets whenever an albatross is present during setting. However, because observers need to observe complete hauls for every haul to record the number of seabirds captured, interactions with other protected species (sea turtles and marine mammals), handle and release any protected species brought to the vessel alive during the haul, as well as record other fundamental information, an additional requirement for an observer to also watch entire sets would leave insufficient time for sleeping and eating (personal communication, Kevin Busscher and Anik Clemens, 9 November 2004, U.S. National Marine Fisheries Service Pacific Islands Regional Office). However, it may be feasible for observers to record albatross abundance during the first and last hour of each set.

While other seabird species on rare occasions were observed to be captured in Hawaii longline fisheries, Laysan and Black-footed Albatrosses have been the only seabird species observed to frequently interact with and be captured by Hawaii longline vessels (McNamara et al., 1999; Boggs, 2001 and 2003; U.S. Fish and Wildlife Service, 2002; Gilman et al., 2003 and In Review). Furthermore, Hawaii longline vessels catch albatrosses in gear predominantly during setting versus hauling (Gilman et al., 2003 and In Review). Hence, there is a need to focus on a consistent method for estimating albatross abundance while the vessel is setting in order to accurately normalize seabird bycatch rates for seabird abundance.

4.5. Compliance with Seabird Regulations

Of the 322 sets included in this analysis, 98 were conducted North of 23 degrees N. latitude, where regulations require Hawaii longline tuna (deep-setting) vessels to employ the following methods to reduce seabird bycatch:

- Use a mainline shooter if the vessel is using a monofilament mainline;
- Attach a minimum of 45 g of weight to the branch line within 1 m of the hook;
- Use thawed bait dyed blue to a specified darkness;
- “Discharge fish, fish parts (offal), or spent bait while setting or hauling longline gear, on the opposite side of the vessel from where the longline gear is being set or hauled”; and
- Other measures, including removing hooks from fish and spent bait before discarding overboard, having a specified quantity of blue dye onboard, following a described protocol to handle captured Short-tailed Albatrosses, and attending an annual workshop (U.S. National Marine Fisheries Service, 2002).

Of the 98 sets included in this assessment that were conducted North of 23 degrees N. latitude, observers recorded that 97 sets or 99% were in compliance with dyeing bait blue, and all 98 sets or 100% were in compliance with the weighting regime. It is not clear if the bait was completely thawed (Gilman et al. (In Review) explains why this is not typically practiced by the fleet) or if the fish bait was dyed to prescribed darkness (Gilman et al. (In Review) explains that fish bait tends to not absorb blue dye well, and when handled, the scales of the fish fall off along with the dye). Of the 98 sets occurring North of 23 degrees N. latitude, 18 sets or 18% were observed to discard offal on either the set or haul. Regulations are vague on what practice is required for discarding fish, offal, and spent bait, so it is not possible to determine whether these sets were in compliance with the regulations. Clarification and outreach on required offal discard practices is needed.

However, Gilman et al. (2003) discusses how there are mixed results from research on the effectiveness of discarding offal, fish, and spent bait at reducing seabird interaction rates, and discusses how this method may exacerbate seabird bycatch. The results of research on the short-term effectiveness of strategic offal discharge in a pelagic longline fishery showed reduced seabird interactions with longline gear after offal is thrown overboard (McNamara *et al*., 1999), and results of a study of the short-term effectiveness of strategic offal discharge in a demersal longline fishery observed reduced seabird capture (Cherel *et al*., 1996). While discharging offal and fish bycatch during setting can distract birds from baited hooks (Cherel *et al*., 1996; McNamara *et* *al*., 1999), this practice is believed to have the disadvantage of attracting birds to the vessel, increasing bird abundance, searching intensity, and capture (Brothers *et al*., 1999). For instance, results from Commission for the Conservation of Antarctic Marine Living Resources studies in demersal longline fisheries have shown that vessels consistently discharging offal attract larger numbers of birds to their vessels (<http://www.ccamlr.org/pu/E/pubs/sa/abs01.pdf>), likely resulting in increased seabird bycatch rates. Brothers (1996) hypothesizes that seabirds learn to recognize by smell specific vessels that provide a source of food, implying that vessels that consistently discharge offal and fish bycatch will have higher seabird abundance and capture than vessels that do not discharge offal and fish waste. Even one discarded bait during setting can rapidly cue previously disinterested birds into an intense searching mode. If there is, for instance, a tote box tangle during setting that results in bringing a baited hook to the surface, seabirds are much more likely to detect this baited hook if offal and bait have been discarded and made the birds more vigilant in searching for discards.

Additional research is needed to test the hypothesis that the long-term practice of discarding offal, fish, and spent bait during setting reduces seabird bycatch rates compared to not discarding these materials when setting.

4.6. Voluntary Use of Seabird Avoidance Strategies

There were 225 sets included in this analysis that were conducted South of 23 degrees N. latitude and had an albatross observed present sometime during the day that the set was made. On 11 of these 225 sets, a bit below 5%, crew voluntarily used blue-dyed fish bait. Only one of these 225 sets did not use a minimum of 45 g weights on branch lines within 1 m of the hook. On 22 (10%) of the 225 sets, observers recorded discarding of offal on either the set or haul. This demonstrates that there is low voluntary use of blue-dyed fish bait, high voluntary use of a minimum of 45 g weights on branch lines within 1 m of the hook, and low voluntary discards of offal during setting or hauling. All vessels side setting were fishing South of 23 degrees N. latitude, where seabird avoidance measures are not required. This information supports the conclusion that side setting and weighted branch lines promote voluntary use, regardless of the location of fishing grounds, while blue-dyed bait, and offal discards do not promote voluntary use.

4.7. Unobserved Seabird Capture

The number of birds hauled aboard was used to estimate the total number of seabirds captured during the set. However, there is evidence that this method underestimates total bird capture as seabirds fall from the hooks before hauling, and there is unobserved discarding of incidentally caught seabirds by crew (Brothers, 1991; Gales et al., 1998; Gilman et al., 2003 and In Review). The observer program can be modified to have observers watching entire sets record seabird captures during the set in a standardized manner, such as described by Gilman et al. (2003 and In Review), to enable an estimate of drop-offs and unobserved discarding.

ACKNOWLEDGEMENTS
Funding for this study was provided by the Western Pacific Regional Fishery Management Council. Tom Swenarton, Anik Clemens, Colleen Bass, Tom Graham, Alvin Katekaru, Kevin Busscher, and Jeremy Bisson, U.S. National Marine Fisheries Service Pacific Islands Regional Office, provided adjusted observer data for the Hawaii longline fishery and insightful comments on preliminary drafts. Donald Kobayashi, U.S. National Marine Fisheries Service Pacific Islands Fisheries Science Center, performed statistical analysis.

5. REFERENCES

Boggs CH. 2001. Deterring albatrosses from contacting baits during swordfish longline sets. In: Melvin E, Parrish K, editors. Seabird bycatch: Trends, roadblocks, and solutions. AK-SG-01-01. Fairbanks, AK: University of Alaska Sea Grant, p. 79-94.

Boggs C. 2003. Annual Report on the Hawaii Longline Fishing Experiments to Reduce Sea Turtle Bycatch under ESA Section 10 Permit 1303. U.S. National Marine Fisheries Service Honolulu Laboratory, Honolulu..

Brothers NP. 1991. Albatross mortality and associated bait loss in the Japanese longline fishery in the southern ocean. *Biological Conservation* 55:255-268.

Brothers, N. 1996. *Longline Fishing Dollars and Sense*. [*Pesca de Palangreros los Dolares y el Sentido Comun*]. Australia Parks and Wildlife Service, Tasmania. 80 pp.

Brothers NP, Cooper J, Lokkeborg S. 1999. *The incidental catch of seabirds by longline fisheries: Worldwide review and technical guidelines for mitigation.* FAO Fisheries Circular No. 937. Rome: Food and Agriculture Organization of the United Nations.

Cherel, Y., H. Weimerskirch, and G. Duhamel. 1996. Interactions between longline vessels and seabirds in Kreguelen waters and a method to reduce seabird mortality. *Biological Conservation* 75: 63-70.

Efron B, Tibshirani R. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Statistical Science* 1:54-77.

Gales R, Brothers N, Reid T. 1998. Seabird mortality in the Japanese tuna longline fishery around Australia, 1988-1995. *Biological Conservation* 86(1):37-56.

Gilman E., Brothers N., Kobayashi D. In Review 2004. Assessment of methods to minimize seabird mortality in Hawaii pelagic longline fisheries.

Gilman, E. 2004. Side Setting for Hawaii Longliners. Poster. Prepared for the U.S. National Marine Fisheries Service Pacific Islands Regional Office, Honolulu, HI, USA.

Gilman, E., H. Freifeld. 2003. Seabird Mortality in North Pacific Longline Fisheries. *Endangered Species Update* 20(2): 35-46.

Gilman, E., C. Boggs, and N. Brothers. 2003. Performance assessment of an underwater setting chute to mitigate seabird bycatch in the Hawaii pelagic longline tuna fishery. *Ocean and Coastal Management* 46(11-12): 985-1010.

Gilman EL. 2001. Integrated management approach to address incidental mortality of seabirds in longline fisheries. *Aquatic Conservation: Marine and Freshwater Ecosystems* 11(5):391-414.

Leslie P, Davis D. 1939. An attempt to determine the absolute number of rats on a given area. J. An. Ec. 8:94-113.

McNamara B, Torre L, Kaaialii G. 1999. Hawaii longline seabird mortality mitigation project. Honolulu, HI, USA: Western Pacific Regional Fishery Management Council.

Melvin, E.F., J.K. Parrish, K.S. Dietrich, and O.S. Hamel. 2001. *Solutions to Seabird Bycatch in Alaska's Demersal Longline Fisheries*. Washington Sea Grant Program. WSG-AS 01-01. University of Washington, Seattle, WA, USA. 53 pp.

Minami H, Kiyota M. 2002. *Effect of Blue-dyed Bait on Reduction of Incidental Take of Seabirds*. Shizuoka, Japan: Ecologically Related Species Section, Pelagic Fish Resources Division, National Research Institute of Far Seas Fisheries, Fisheries Research Agency.

Ricker W. 1958. Handbook of Computations for Biological Statistics of Fish Populations. Bulletin No. 119. Ottawa, Canada: Fisheries Research Board of Canada.

Seber G. 1973. The Estimation of Animal Abundance and Related Parameters. New York: Hafner Press.

U.S. Fish and Wildlife Service. 2002. Revision of the U.S. Fish and Wildlife Service's November 28, 2000 Biological Opinion for the Effects of the Hawaii-based Domestic Longline Fleet on the Short-tailed Albatross (*Phoebastria albatrus*). Honolulu, HI, USA.

U.S. Fish and Wildlife Service. 2004. Biological Opinion on the Effects of the Reopened Shallow-Set Sector of the Hawaii-Based Longline Fishery on the Short-Tailed Albatross (*Phoebastria albatrus*). Honolulu, HI, USA.

U.S. National Marine Fisheries Service. 2002. Fisheries Off West Coast States and in the Western Pacific; Pelagic Fisheries; Measures to Reduce the Incidental Catch of Seabirds in the Hawaii Pelagic Longline Fishery. *Federal Register* 67(93): 34408-34413.

U.S. Western Pacific Regional Fishery Management Council. 2004. Draft. Additional Measures to Reduce the Incidental Catch of Seabirds in the Hawaii-Based Longline Fishery. A Regulatory Amendment to the Western Pacific Pelagic Fisheries Management Plan. Honolulu, HI, USA.