FINAL REPORT

Hawaii Longline Seabird

Mortality Mitigation Project

September 1999

GANDA

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FINAL REPORT

Hawaii Longline Seabird

Mortality Mitigation Project

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EXECUTIVE SUMMARY

Seabird bycatch by longline fishing vessels poses a major threat to some albatross populations, particularly some species in the southern oceans. The current world population estimate for black-footed albatrosses (*Phoebastria nigripes*) is 60,660 breeding pairs and 558,415 breeding pairs for Laysan albatrosses (*Phoebastria immutabilis*) (Cousins and Cooper, in prep.). Ninety-six percent of black-footed albatross and more than 99 percent of Laysan albatross nesting sites are in the Northwest Hawaiian Islands (Cousins and Cooper, in prep.). Data collected by the National Marine Fisheries Service (NMFS) Hawaii Longline Observer Program suggest that 1,963 (Confidence Interval 1,479–2,470) black-footed albatross and 1,479 (Confidence Interval 822–2,336) Laysan albatross were incidentally taken in interactions with Hawaii pelagic longline fishing vessels in 1998 (Kleiber 1999). The federally listed, endangered short-tailed albatross (*Phoebastria albatrus*) may also be encountered by Hawaii pelagic longline vessels.

In an effort to reduce seabird bycatch in the Hawaii longline fishery, the Western Pacific Regional Fishery Management Council (WESPAC) commissioned Garcia and Associates (GANDA) to conduct the Hawaii Longline Seabird Mortality Mitigation Project. The goals of the project were to compare the efficiency, intrusiveness, effect on catch rates, and enforceability of six mitigation measures for reducing seabird bycatch: tori lines, towed buoys, no offal discards, strategic offal discards, blue-dyed bait, and night setting.

The scope of work for the project included: a literature review, an examination of NMFS Hawaii Longline Observer Program data, development of a working research design, acquisition and construction of mitigation gear, field testing of mitigation gear, quantitative data analyses, and the preparation of recommendations to WESPAC.

A literature review was conducted to gather information on seabird longline interactions in Hawaii and other fisheries. Interviews were conducted with academicians, government agency officials, fishermen, and fishing industry representatives working on longline fishing/seabird bycatch reduction issues in Hawaii, Alaska, Australia, and New Zealand. These contacts provided information on current mitigation techniques. Seabird bycatch data from NMFS Hawaii Longline Observer Program were reviewed to characterize the Hawaii pelagic longline fishery effort.

The research design was subsequently refined to incorporate information gathered through the literature review and the examination NMFS Hawaii Longline Observer Program data. A major component of GANDA's research design was dividing the fishery into two vessel categories (Swordfish and Tuna) based on seabird interaction and mortality levels, target species, associated fishing gear, and fishing practices. Vessels targeting broadbill swordfish (*Xiphias gladius*) fishing north of the Hawaiian Islands have dramatically higher levels of seabird mortalities than vessels using fishing gear specifically designed to target bigeye tuna (*Thunnus obesus*).

Mitigation gear for the reduction of seabird bycatch was designed, purchased, and assembled. Five research trips, each lasting approximately thirty days, were conducted on Hawaii pelagic longline swordfish/tuna vessels to quantify the effectiveness of mitigation measures. Field data were recorded

on standardized forms developed for the project. Multi-varied environmental and fishing gear-related factors were also recorded.

Data were collected on the performance of mitigation methods tested relative to each other and to controls on Hawaii longline vessels, and on the specific species of seabirds these vessels encounter. Data were entered into a project database after each research trip. Quantitative data analyses were subsequently conducted. The effectiveness of the mitigation measures was evaluated by quantifying behavioral responses (attempts and interactions) and resulting mortalities of albatrosses with, and without, mitigation measures in place during setting and hauling longline fishing gear.

During gear-setting operations, blue-dyed baits were found to be the most effective mitigation strategy in reducing seabird interactions with fishing gear, followed by strategic offal discards. The tori line and the towed buoy system also proved to be effective mitigation measures during the set.

During gear-hauling operations, blue-dyed baits and the tori line were found to be equally effective mitigation strategies in reducing seabird interactions with fishing gear, followed by the towed buoy system. Analyses further indicate that the strategy of retaining offal onboard during the haul (no offal discards) led to increased attempts and interactions.

Analyses were conducted to determine the effect of the mitigation measures on catch per unit effort (CPUE) for fishery target species. Data indicate that using blue-dyed bait may actually increase CPUE. Field observations suggest that the other mitigation measures (tori lines, towed buoy system, strategic offal discard, no offal discard, and night setting) have negligible effects on CPUE other than reducing bait losses to seabirds.

Feedback from fishermen involved in this project was collected through a standardized questionnaire, which was evaluated. Responses concerned improvements to mitigation measures, safety issues, and preferred mitigation measures.

Based on the results of the literature review, the examination of NMFS Hawaii Longline Observer Program data, research trips, fishermen survey results, and data analyses, recommendations to WESPAC were developed to reduce seabird bycatch/mortalities in the Hawaii pelagic longline fishery. Data suggest that no single mitigation method will entirely eliminate mortalities of seabirds in the fishery. A combination of mitigation measures and simple modifications to common fishing practices for each fishery segment will be the most effective approach for reducing seabird bycatch in the Hawaii pelagic longline fishery. GANDA's recommendations to WESPAC have been designed for each fishery segment (swordfish and tuna) and are fully listed in Section 8.0. These recommendations are for vessels fishing above 23° north latitude or when seabirds are present. Recommendation summaries are presented below.

For tuna vessels:

- Deploy a seabird-scaring line (tori line or towed buoy system) with effective streamers throughout the towline and a terminal buoy.
- Ensure that baited hooks enter the water under the protection of the aerial portion of the seabird-scaring line.
- Dispose of all offal/discard baits on the opposite side of the vessel from where baited hooks enter/leave the water, and in such a manner as to best distract seabirds away from the vessel and fishing operations.

For swordfish vessels:

- Do not begin setting until at least one hour after sunset and complete setting at least one hour before sunrise.
- Use blue-dyed baits throughout the entire set.
- Deploy a seabird-scaring line (tori line or towed buoy system) with effective streamers throughout the towline and a terminal buoy.
- Ensure that baited hooks enter/leave the water under the protection of the aerial portion of the seabird-scaring line.
- Use strategic offal discarding to decoy seabirds away from the vessel and baited hooks.

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1.0 INTRODUCTION

In an effort to reduce seabird bycatch in the Hawaii pelagic longline fishery, the Western Pacific Regional Fishery Management Council (WESPAC) commissioned GANDA to conduct the Hawaii Pelagic Longline Seabird Mortality Mitigation Project to determine the most effective and least intrusive seabird mortality mitigation devices for use in this fishery. This study compared the efficiency, intrusiveness, effect on catch rates, and ease of compliance monitoring of five seabird bycatch mitigation methods for use in this fishery. These methods include tori lines, towed buoys, no offal discards, strategic offal discards, and blue-dyed bait. Night setting mortality data were also collected and treated separately because behavioral observations could not be made at night. Testing proposed mitigation measures during actual fishing operations, prior to mandatory implementation, should insure that the measures adopted are effective on Hawaii pelagic longline fishing vessels.

1.1 Project Background

Around the world, seabird bycatch occurs in both pelagic and demersal longline fisheries. Currently, it is likely that most albatrosses will interact with longline fishing vessels at some stage in their lives. Bycatch in some longline fisheries poses a major threat to several populations of albatrosses (family Diomedeidae) (Murray et al. 1993; Brothers 1991; BirdLife International 1995; Croxall et al. 1990; Weimerskirch et al. 1997). The current worldwide albatross bycatch rate on pelagic longlines is approximately 0.4 birds observed caught per thousand hooks set (Alexander et al.1997). Several species are endangered, such as the short-tailed albatross (Pacific Seabird Group 1997).

Foreign longline fishing fleets from Japan, Taiwan, Korea, and other nations provide approximately 90 percent of the fishing effort in the central north Pacific. The remainder is attributed to the Hawaii-based longline fleet. In 1991, federal regulations (WPRFMC 1991) were implemented to prohibit longline vessels from fishing within 50 miles of the Northwest Hawaiian Island National Wildlife Refuges and within 25–75 miles (seasonally) of the main Hawaiian Islands. The vast majority of pelagic longline fishing takes place outside the United States' 200-mile Exclusive Economic Zone (EEZ). The Food and Agriculture Organization (FAO) of the United Nations Committee on Fisheries recently adopted an International Plan of Action (IPOA) for Reducing the Incidental Catch of Seabirds in Longline Fisheries (FAO 1999).

Two species caught incidentally in the Hawaii pelagic longline fishery are the black-footed albatross (*Phoebastria nigripes*) and the Laysan albatross (*Phoebastria immutabilis*) (Plate 1). The endangered short-tailed albatross may also be encountered by Hawaii pelagic longline vessels. Laysan, black-footed, and short-tailed albatrosses are protected under the Migratory Bird Treaty Act (16 U.S.C. 703-711) (MBTA).The current world population estimate for black-footed albatrosses is 60,660 breeding pairs and 558,415 breeding pairs of Laysan albatrosses (Cousins and Cooper, in prep.). Ninety-six percent of black-footed albatross and more than 99 percent of Laysan albatross nesting sites are in the Northwest Hawaiian Islands (Cousins and Cooper, in prep.). These species have an approximate 7-foot wingspan and a lifespan of forty or more years. They become sexually mature between the ages of seven to eight years and generally mate for life (Rice and Kenyon 1962).

Plate 1a.

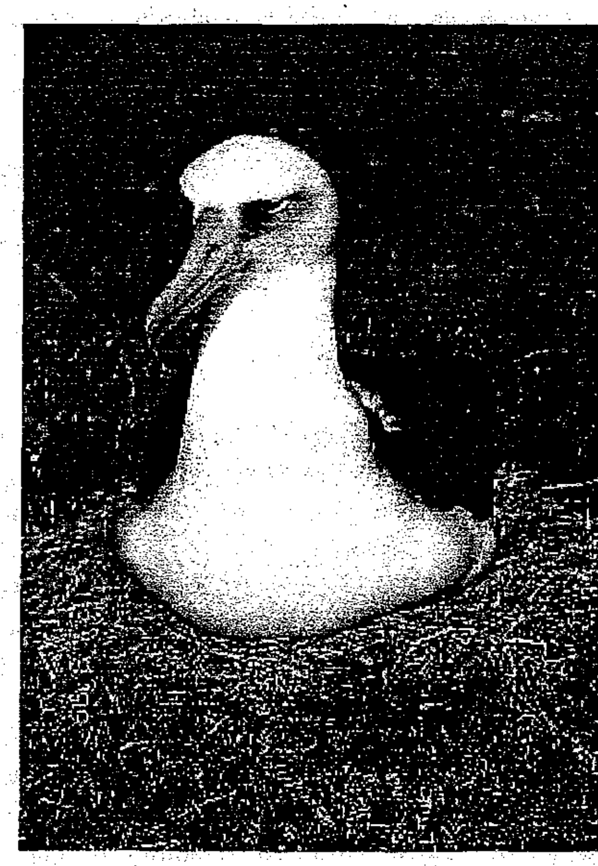

Plate 1b.

Plate 1a. Black-footed Albatross (*Phoebastria nigripes*). **Plate 1b.** Laysan Albatross (*Phoebastria immutabilis*). Both seen on a Midway Island nesting site (K. Cousins).

Breeding pairs of these species typically raise a single chick annually with gestation, and chick rearing taking five to six months. The stability of albatross populations is more sensitive to changes in the adult survivorship than to annual changes in reproductive success (Pacific Seabird Group 1997). Currently, it is not known what impacts the Hawaii pelagic longline fishery has on these two albatross populations (draft proceeding from the Hawaii Black-footed Albatross Population Biology Workshop).

Black-footed and Laysan albatrosses range widely in search of food (Anderson 1998) (Figure 1), foraging throughout the north Pacific Ocean, generally well offshore. Albatrosses forage by surface seizing or diving, with squid being a favorite prey. An albatross diet study (Harrison et al. 1985) indicated that Laysan albatrosses consumed more volume of squid (65%) than black-footed albatrosses (32%).

Albatrosses are known to follow ships, including fishing vessels, scavenging for food. Fishing vessels are particularly attractive to the albatross because bait and offal are usually found on decks, on the fishing gear, or discarded in the water. Squid are the preferred bait for the Hawaii-based longline broadbill swordfish (*Xiphias gladius*) fishery. This fishery, along with the Hawaii-based bigeye tuna (*Thunnus obesus*) fishery are both in close proximity to the breeding colonies and large concentrations of albatrosses. Most longline-related mortalities occur when albatrosses attempt to feed on baited hooks as the line is being set (Plate 2). Black-footed and Laysan albatrosses locate baited hooks and seize them with their beaks either on the surface of the water or by diving. Feeding frenzies often ensue, leading to hookings and/or entanglements. The seabirds are then drawn underwater by the sinking mainline and drown. Seabirds may also be caught when the gear is being retrieved (hauled) during daytime hauls (Huin and Croxall, in press). Seabirds caught on the haul may survive or die later from injuries associated with hookings or entanglements (Weimerskirch and Jouventin 1987).

Data collected by the National Marine Fisheries Service (NMFS) Hawaii Longline Observer Program suggests that 1,963 (Confidence Interval 1,479–2,470) black-footed albatrosses and 1,479 (Confidence Interval 822–2,336) Laysan albatrosses were incidentally killed in interactions with Hawaii pelagic longline fishing vessels in 1998 (Kleiber 1999) (Plate 3). While the long term effects of these mortality levels on the albatross populations are not currently known, it is likely that such mortalities will have a negative impact.

In addition to the impact on albatrosses, when baits are taken by seabirds, the profitability and productivity of longline fishing operations are diminished. It is in the best interest of the fishing industry and albatross conservation to reduce, and eventually eliminate, the mortality of albatrosses and other seabirds caused by interactions with longline vessels. Reduction of albatross mortality is also consistent with FAO's IPOA and NMFS's Bycatch Plan recommendations.

Collaborative research between biologists and fishing industry personnel have shown a reduction in the bycatch of seabirds by modifying gear and fishing techniques, using mitigation measures, and educating fishing personnel (Murray et al. 1993; Polacheck and Tuck 1995). Longline seabird bycatch mitigation techniques that can substantially reduce fisheries-related deaths of albatrosses are being used in several fisheries around the world, including those in New Zealand, Australia, and Alaska.

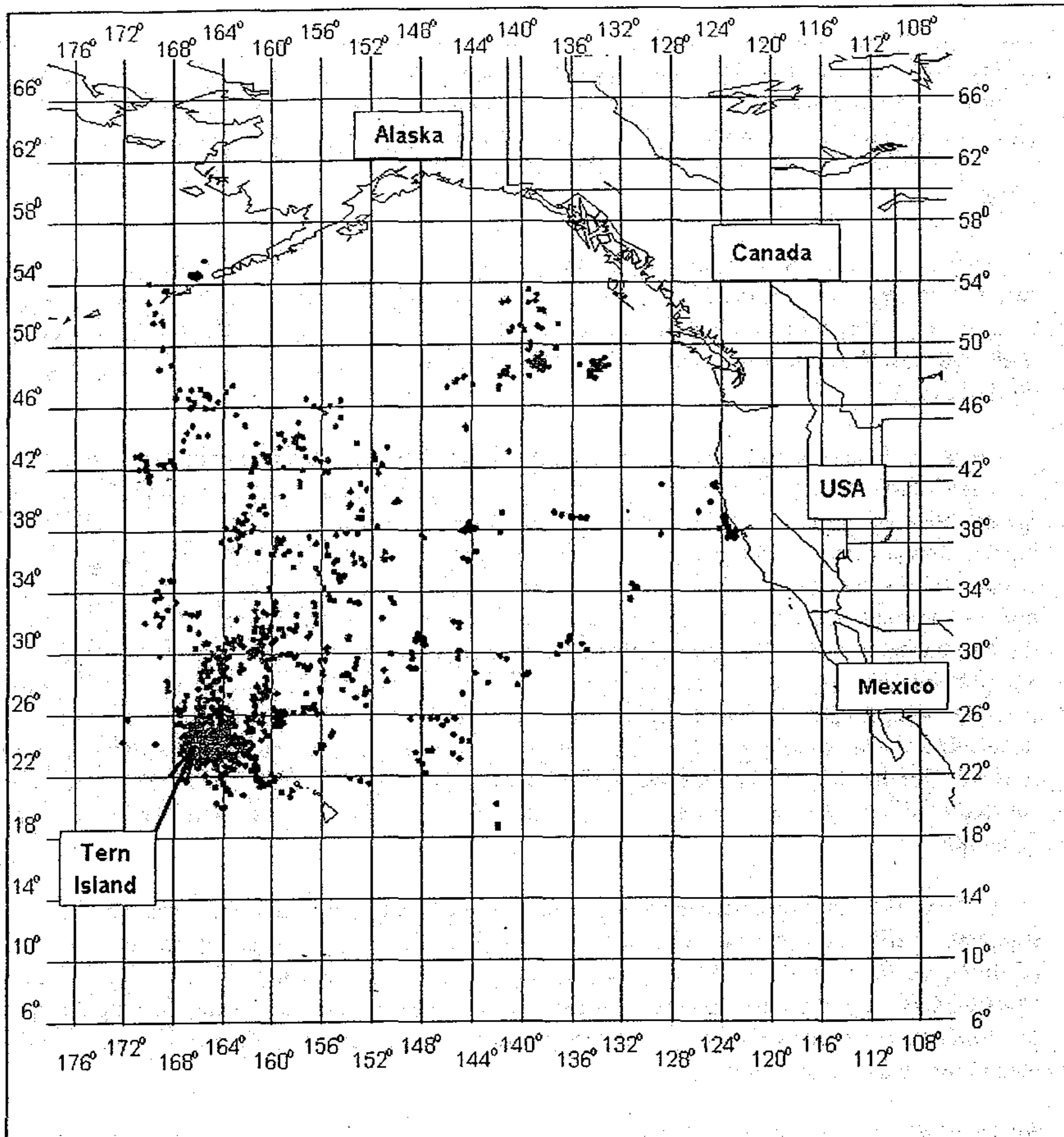

Figure 1. Flight patterns of Black-footed Albatross and Laysan Albatross from the Albatross Project: Satellite Tracking of Albatross Flight Patterns. Blue Locations are Black-footed Albatrosses and Red Locations are Laysan Albatrosses. Wake Forest University, Winston-Salem, NC.

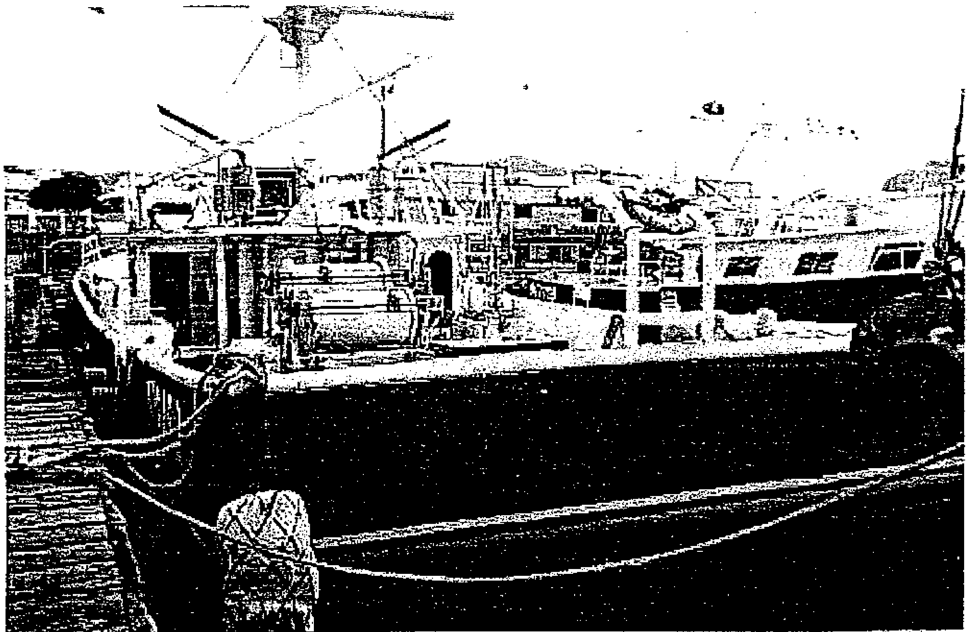

Plate 2a. Hawaii pelagic longline vessel.

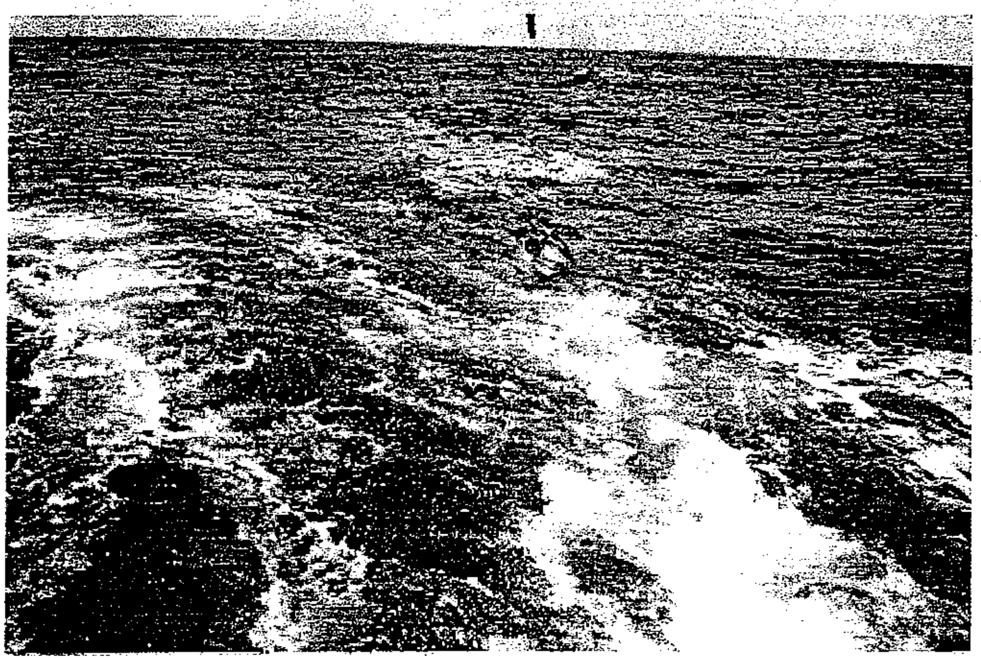

Plate 2b. Seabirds pursuing a Hawaii pelagic longline vessel.

Plate 3. Black-footed (left) and Laysan (right) Albatross mortalities resulting from an interaction with a Hawaii pelagic longline vessel.

Mitigation techniques employ three different methods to reduce mortalities:

- Setting the gear in such a way that it does not linger at the surface long enough to allow seabird interaction (increase sink rate).
- Frightening the seabirds away from the gear (seabird deterrent).
- Reducing visibility or attraction of bait (camouflage, distraction).

Mitigation techniques can be highly effective in reducing mortality. Off Tasmania, Japanese longline vessels using seabird bycatch mitigation measures reduced their bycatch by 88 percent from the previous season (Gales 1993).

1.2 Project Description

The following research tasks were completed as part of this study:

Task 1: Literature Review. A search was conducted for information and data on seabird-longline interactions in Hawaii and other fisheries. Various personnel in New Zealand, Australia, and Alaska were contacted to discuss mitigation measures in use and in production.

Task 2: NMFS Hawaii Longline Observer Program Data Review. Data were obtained from the NMFS Hawaii Longline Observer Program to optimize the effectiveness of this study. Insights were gained from this data, including geographic parameters of where the fleet was experiencing the most seabird interactions, seasonal parameters of when the most interactions were occurring, and the number of interactions per fishery segment (swordfish or tuna).

Task 3: Research Design Refinement. The research design was revised to incorporate information gathered through literature review, NMFS Hawaii Longline Observer Program data review, and characterization of longline fishing effort. Information provided by seabird bycatch experts from around the globe, U.S. Fish and Wildlife Service (USFWS) and WESPAC personnel, vessel operators, and fishermen were also incorporated into the project research design (McNamara and Torre 1998).

Task 4: Gear Acquisition. Research equipment, safety gear, and mitigation gear were purchased and assembled, taking into consideration a number of factors crucial to optimizing the effectiveness of the gear. Data collection forms and logbooks were designed to record seabird interactions with fishing gear.

Task 5: Onboard Research. Five 30-day mitigation research trips were conducted on Hawaii longline vessels. Tori lines, towed buoys, no offal discards, strategic offal discards, blue-dyed baits, and night setting were tested while seabird responses were recorded. Environmental conditions and gear specifications were recorded, and fishing crews were surveyed. All project data were recorded on project-specific data forms, which were labeled and placed in log books.

Task 6: Data Input and Quantitative Analyses. Project data were entered into a computer database and verified prior to statistical analysis. The effectiveness of mitigation measures was evaluated by quantifying behavioral responses (attempts and interactions) and resulting mortalities of seabirds with and without mitigation measures in place during setting and hauling of pelagic longline fishing gear. Behavioral data were analyzed for possible species-specific effects as the Laysan and black-footed albatrosses may behave or react to mitigation measures differently. Data tables and graphs were generated from the quantitative analyses. Data form printouts were also generated at this time and are provided in appendices.

Task 7: Qualitative Analysis/Recommendations. A qualitative analysis of each mitigation measure tested was conducted to assist fishery managers in choosing appropriate, acceptable and enforceable mitigation measures for this fishery. Based on the results of the literature review, an examination of NMFS Hawaii Longline Observer Program data, at-sea testing results, quantitative and qualitative analyses, and feedback from fishermen, recommendations to WESPAC were developed.

2.0 PROJECT OBJECTIVES

Primary objectives of the Hawaii Longline Seabird Mortality Mitigation Project included:

- Deploy, measure, and compare the effectiveness of various mitigation gear and techniques for reducing seabird bycatch on vessels in the Hawaii pelagic longline fishery.
- Conduct quantitative analyses of data gathered through at-sea testing.
- Recommend the most effective and least intrusive mitigation measures for use in the Hawaii pelagic longline fishery based on data generated through gear testing, data analyses, fishermen input, and effects of mitigation on catch of target species.

Secondary objectives included:

- Initiate a dialog with local fishermen about the seabird bycatch issue and implementation of mitigation measures.
- Gather information from seabird bycatch researchers in the North Pacific, New Zealand, and Australian longline fisheries to determine which mitigation measures were best suited to this project's goals and limitations.
- Review NMFS Hawaii Longline Observer Program seabird bycatch data collected in the Hawaii pelagic longline fishery.
- Recommend strategies for implementation of mitigation technique(s) for use in the Hawaii pelagic longline fishery.

This study has gathered new information regarding the behavioral responses of seabirds encountered by the Hawaii longline fishery to the mitigation gears and techniques tested. These data will be useful to WESPAC in planning seabird bycatch reduction strategies for this fishery. WESPAC may utilize project data to:

- Make informed management decisions regarding the most effective mitigation measures for reducing seabird bycatch in the Hawaii pelagic longline fishery.
- Implement a detailed and real-data-driven educational program for use with fishery personnel, governmental agencies, conservationists, and other concerned individuals.

3.0 PRE-FIELD ACTIVITIES

Prior to field testing mitigation gears, land-based activities included collecting information regarding seabird-longline interactions in Hawaii and in other fisheries, a review of NMFS Hawaii Longline Observer data, characterizing the Hawaii-based pelagic longline effort, securing vessel cooperation, research design refinement, design of data collection protocols and forms, and gear acquisition.

3.1 Project Commencement

Correspondence with the Seabird Bycatch Community. Research contacts included academicians, researchers, government agencies, fishermen, and industry representatives working on seabird-longline bycatch reduction issues in the states of Hawaii, Washington, and Alaska, and in Australia and New Zealand. These contacts provided up-to-date information on the most current mitigation techniques, data collection efforts, and field research on seabird bycatch in their longline fisheries. The results of these communications indicate that there is a paucity of quantifiable data on the effectiveness of the various seabird bycatch mitigation measures developed to date. Those seabird bycatch researchers who were contacted have confirmed the need to study the effects of mitigation measures in terms of reduction of seabird foraging behaviors, as well as mortalities (see Contact List in Appendix A). The current study is one of the first to measure mitigation effectiveness in terms of behavioral responses of seabirds.

Notification to Vessel Owners/Operators of Project. After consultation with WESPAC regarding the implementation of this project, GANDA and WESPAC jointly mailed a notification letter to current permit holders and/or their agents announcing the start of the project. A request was made for volunteer vessels from tuna and swordfish segments of the longline fishery to allow GANDA's researcher to conduct studies during fishing operations. Following the limited response to this request, vessel owners and operators were approached dockside and informed about the details of the project and their involvement was requested.

Vessel Cooperation Agreements. GANDA was assisted in informing fishermen about this project and securing vessel cooperation by Mr. James Cook, Captain Steve Gates, Mr. Skip Gallimore of Finest Kind Marine Distributors, Inc., Mr. Kevin Van, Mr. Dennis Hong, and Mr. Minh Dang. At the outset of the project, Mr. Cook provided the use of one of his vessels for pre-field testing of mitigation measures prior to deployment on actual research fishing trips. Vessel owners from the tuna and swordfish fisheries agreed to allow GANDA's researcher on their vessels. Mr. Gallimore offered his vessels for the project's first two research trips (Trip 1 targeted tuna and Trip 2 targeted swordfish). Mr. Khan Truong of Captain Diamond, Inc., offered his vessel for the third trip (Trip 3 targeted swordfish). Mr. Elvis Van of Ocean Diamond, Inc., offered his vessel for the fourth trip (Trip 4 targeted swordfish). Mr. Calvin Ko Huynh of Queen Diamond, Inc., offered his vessel for the fifth trip (Trip 5 targeted swordfish).

3.2 NMFS Hawaii Longline Observer Program Data Review

NMFS has established a mandatory Hawaii Longline Observer Program in the Hawaii pelagic longline fishery that records instances of marine mammal, sea turtle, and seabird interactions. Approximately 4 percent of the Hawaii longline fishing trips since 1994 have been observed. The database yielded information about interactions between the Hawaii longline fleet and albatross species (Table 1).

NMFS Observer Program data provided important information on the spatial and temporal distribution of incidental seabird takes based on NMFS classification of vessel type (swordfish, mixed, switcher, and tuna). This allowed GANDA to gain a better understanding of geographic parameters relating to where the Hawaii longline fleet was experiencing the most seabird interactions, and of the seasonal parameters relative to the time of year when most interactions were occurring.

Hawaii longline observer field experience indicated that vessels using mainline shooters nearly always target bigeye tuna and commonly use branchlines with weights in close proximity to the hooks. These vessels also have far lower seabird mortalities than vessels that do not use mainline shooters, use branchlines with weights further from the hooks, and target swordfish and other species (including bigeye tuna). Brothers (1995) found that as weights are moved closer to the hooks, sink rates will increase, thereby reducing bait losses to seabirds.

Based on these data, project staff hypothesized that vessels not using mainline shooters and the associated tackle would have higher levels of seabird mortalities. The NMFS Observer data did revealed that seabird mortalities recorded on observed trips were more than one order of magnitude higher for vessels targeting swordfish without using a mainline shooter than those using a shooter and targeting bigeye tuna (see Section 3.3 for shooter description).

The data also provided the rate of interactions per fishery segment (swordfish or tuna). Choosing vessels with high rates of seabird interactions that fish in areas with high levels of seabird concentrations was important to the mobilization of the at-sea testing phase of this project. NMFS Hawaii Longline Observer Program data helped determine which vessels were selected for testing of seabird bycatch reduction measures.

Table 1. Take estimates from NMFS Hawaii Longline Observer Program for 1994–1998*

Year	Laysan Albatross Take Estimates	95% Confidence Intervals	Black-footed Albatross Take Estimates	95% Confidence Intervals
1994	1,828	933–2,984	1,994	1,508–2,578
1995	1,457	767–2,308	1,979	1,439–2,497
1996	1,047	569–1,610	1,568	1,158–1,976
1997	1,150	599–1,875	1,653	1,243–2,102
1998	1,479	822–2,336	1,963	1,479–2,470
TOTALS	6,961	—	9,157	—

*(Kleiber 1999)

Important information affecting implementation of this study was obtained from the review of NMFS Hawaii Longline Observer Program data:

- NMFS Observer Program data indicate that overall fishing effort and recorded seabird bycatch levels are lowest during the third quarter of the year (NMFS 1998). The reduction in bycatch may be attributable to the amount and location of fishing effort (seasonality), low levels of NMFS longline observer coverage (4%), and/or under-reporting of seabird interactions in NMFS Fishermen's Logs.

- Data show that swordfish vessels (those not using mainline shooters and using fishing gear best suited for targeting swordfish) fishing north of the main Hawaiian Islands were responsible for the vast majority of seabird interactions and mortalities.

- When trip types are separated according to target species as reported in NMFS Fishermen's Logbooks (on observed trips), trips targeting tuna have lower numbers of seabird takes than those targeting swordfish (NMFS 1998). The use of a mainline shooter is a key indicator of the branchline construction and terminal tackle. Branchline construction is the single most important gear-related factor in the hook sink rate differences between swordfish and tuna vessels. Increased hook sink rates lead to reduction in seabird bycatch (Boggs 1999).

- NMFS has categorized the vessels/trip types into "swordfish," "mixed," "switchers," and "tuna" based upon NMFS Fishermen's Logbook data and fish landings. NMFS describes "Swordfish boats" as mainly landing swordfish, "Mixed boats" as landing mixed catches (swordfish and tuna), "Switchers" as mainly landing swordfish followed by landings of mostly tuna, and "Tuna boats" as landing mainly tuna. Under these classifications, the fishery has only one vessel designated as a tuna vessel (NMFS 1998). Realistically, there are many vessels dedicated to the pursuit of bigeye tuna in this fishery.

- Of all observed sets listing bigeye tuna as the target species, regardless of NMFS vessel category (swordfish, mixed, switcher, and tuna), NMFS Observer Program data show a lower number of seabird interactions and mortalities for vessels using mainline shooters and associated tuna gear. When all sets are compared by target species, swordfish versus bigeye tuna, swordfish sets incur more interactions and mortalities.

3.3 Description of Hawaii Longline Fishing Gear, Vessel Types, and Fishing Practices

Hawaii's pelagic longline fleet uses mid-water set longline gear to primarily target bigeye tuna and broadbill swordfish. Vessels range from 15–30 m (49.2–98.4 feet) in length, and set a single monofilament longline (mainline) up to 155.4 km (60 miles) in length (Figure 2). The mainline holds between 600–3,000 branchlines, each about 15–20 m (49.2–65.6 feet) long holding a single hook. Vessels in this fishery currently bait hooks by hand as the mainline is set. Hooks are usually suspended 30–200 m (98.4–656 feet) below the surface of the water. The branchlines are usually weighted with lead weights of 40–80 grams, but the proximity of the weight to the hook varies by vessel and fishery.

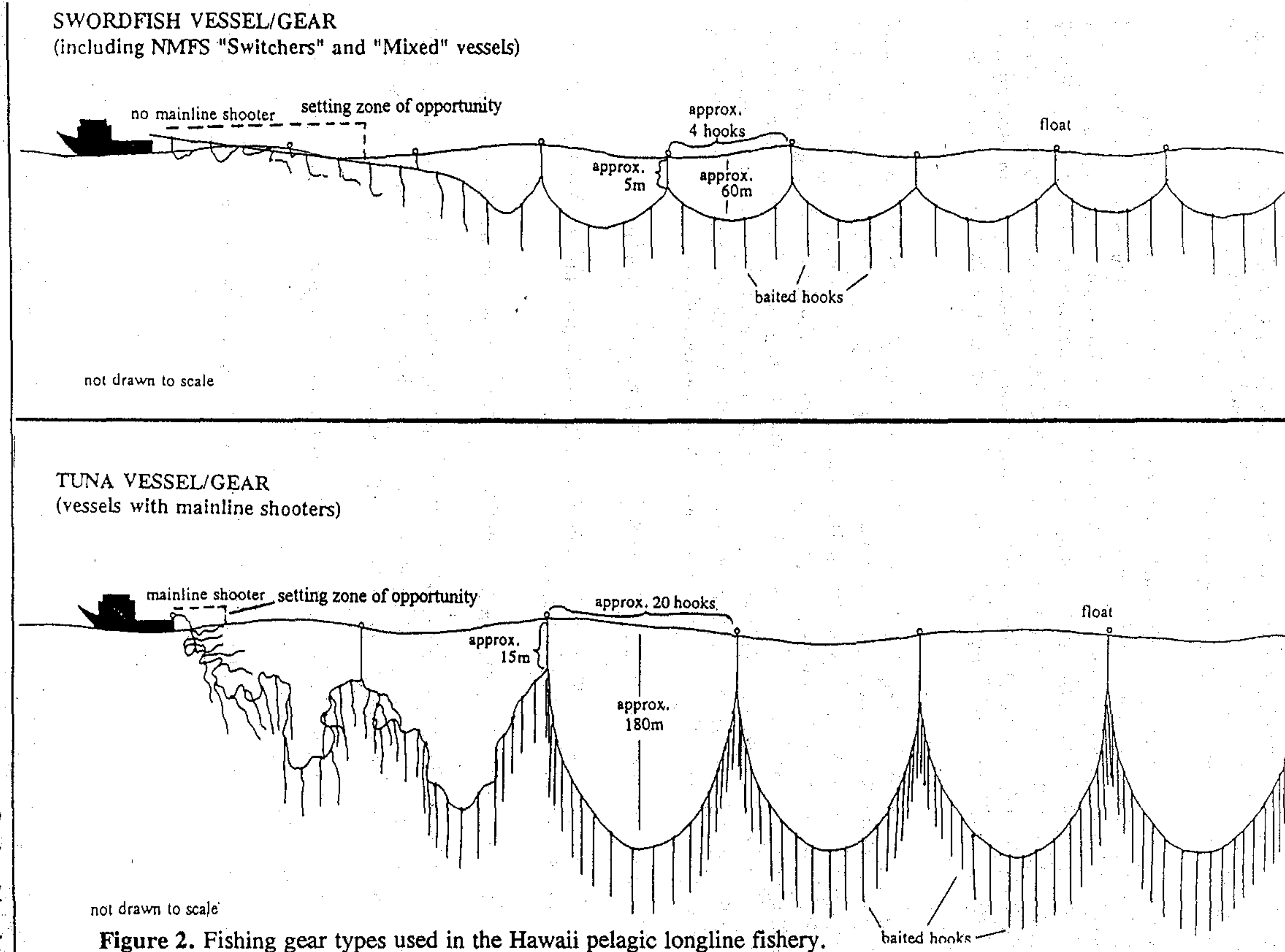

Figure 2. Fishing gear types used in the Hawaii pelagic longline fishery.

For the purposes of attributing accurate levels of seabird interactions and mortalities to the appropriate vessels, and effective implementation of this project, we have divided the Hawaii pelagic longline fishery into two distinct segments: swordfish targeting vessels versus tuna targeting vessels. These segments are based upon differences in the principal target species, associated fishing gear, fishing tactics, and areas of normal fishing effort. These differences greatly affect the numbers of seabird mortalities experienced by each type of fishing vessel (Table 2).

A key distinction between these two segments is the presence or absence of a mainline shooting device and the associated terminal tackle (Plate 4). Typically, vessels dedicated to the pursuit of bigeye tuna use a mainline shooter and the associated tackle, while vessels dedicated to the pursuit of swordfish do not. NMFS Hawaii Longline Observer experience and consultations with Hawaii pelagic longline fishermen have led to the conclusion that the presence or absence of a mainline shooting device and, importantly, the associated terminal tackle construction are significant fishing gear factors affecting incidental takes of albatrosses in the Hawaii pelagic longline fishery (Foy, pers. comm.).

3.3.1 Tuna Vessel Description. Dedicated tuna vessels use a mainline shooter to deploy the mainline at a great depth between each float. They set between 1,200–2,500 hooks, place 18–28 hooks between floats, use tuna ring hooks (Plate 5), use sanma (saury) bait (Plate 6), set the gear during the day, and start retrieving the gear in the evening or after dark. During tuna fishing operations, the largest number of seabird interactions occur during the set (Brothers 1995; NMFS Observer Program Data 1998). Tuna vessels use branchlines with a 40–80-gram weight less than 1 m from the hook to set the gear at great depth. Field observations indicate that this greatly increases the sink rate of the baited hooks which effectively reduces seabird interactions and mortalities.

The following factors affect seabird interactions during daytime tuna fishing sets:

- Setting takes place during Hawaii pelagic longline daylight hours when seabirds can better see the baits (Brothers 1995; Harrison et al. 1985).
- Dedicated tuna vessels use mainline shooters to deploy the mainline which create slack.
- Between 18 and 28 branchlines are set between floats on the mainline. Branchlines have a lead weight (40–80 grams) at a distance of 1 m or less from the hook with wire leading from sinker to hook substantially increasing the hook sink rate.
- Seabird bycatch can be higher if branchlines without weights close to the hook are used (Cook, pers. comm.).
- Often the bait is not completely thawed increasing the amount of time it takes to sink (Brothers et al. 1995).

Table 2. Key differences in fishing gear and tactics employed by Hawaii pelagic longline tuna and swordfish vessels.

Gear Types/Tactics Used	Tuna Targeting Vessels	Swordfish Targeting vessels*
Is mainline shooter used?	Yes	No
Opportunistically target other species with minimal gear changes?	No	Yes
Number of hooks set	1,200–2,500	800–1,500
Number of hooks between floats	18–28	3–5
Bait type	Samna (saury)	Squid
Begin gear set time	Morning/mid-day	Sunset/night
Begin gear haul time	Night/after dark	Early morning
Lead weight size	40–80 grams	60–80 grams
Weight proximity to the hook	20–90 cm	5–7 m
Use buoyant chemical lightsticks?	No	Yes
Vessel size	15–30 m	15–30 m
Mainline length	155.4 km	155.4 km
Length of branchlines	15–20 m	15–20 m
High levels of seabird mortalities?	No	Yes
Target depth	Deep	Shallow

*There were three trips that had sets both with and without a shooter.

- Propeller turbulence may push the baits near the surface where the seabirds can reach them by diving (Brothers 1995).
- The vessel is moving away from the hooks as they are being set; therefore, the vessel's proximity does not deter the seabird's foraging behavior (i.e., spotting, landing, diving, retrieving, and swallowing).
- Tuna vessels generally fish south of 23°latitude where albatrosses are less abundant.
- The discarding of poor quality baits attract seabirds (Brothers 1995).

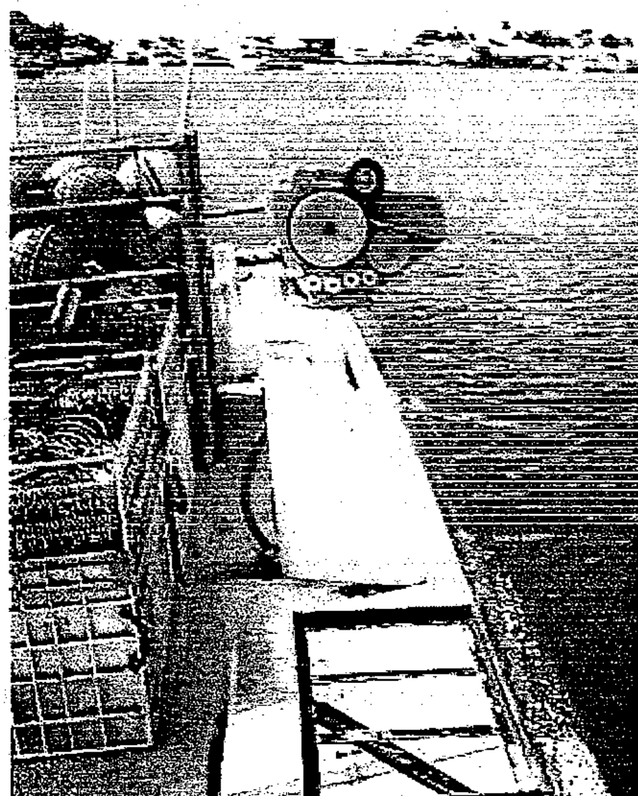

Plate 4. Mainline shooting device employed by tuna vessels.

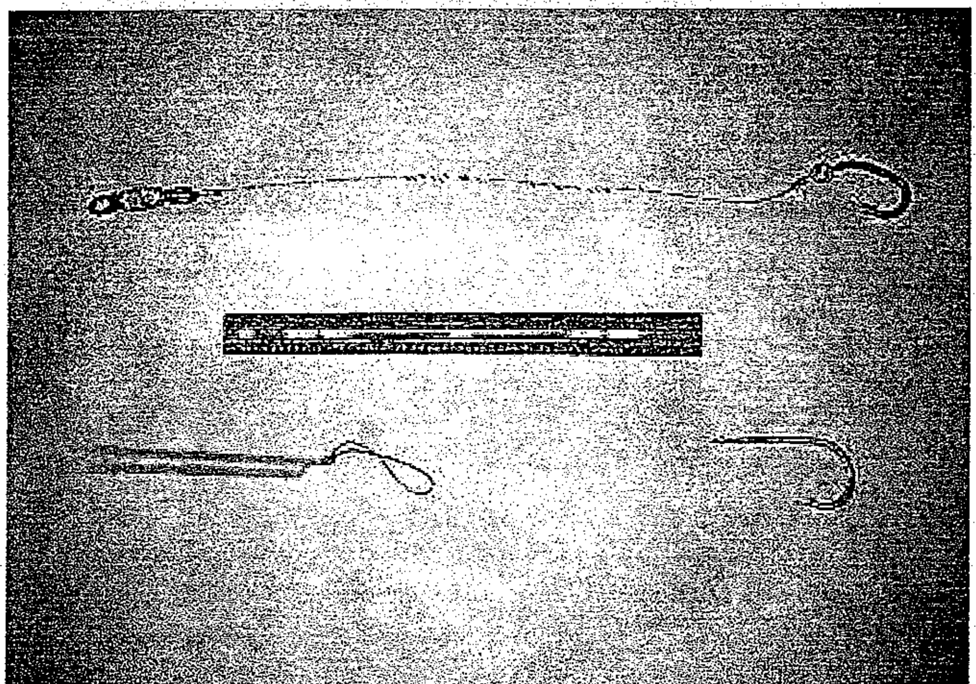

Plate 5. Terminal tackle for tuna and swordfish branchlines. Top row: tuna ring hook and wire leader from hook to 60-gram-weighted swivel. Bottom row: chemical lightstick and swordfish "j" hook. Note: 60-to-80-gram weighted swivel not shown (see Section 3.1.3.2 for description).

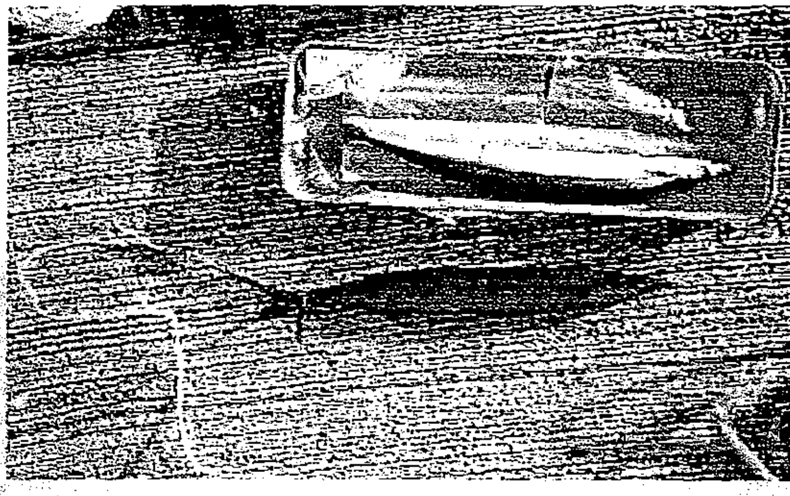

Plate 6a. Tuna vessels use sanma (saury) for bait. Note: bottom bait is dyed blue.

Plate 6b. Swordfish vessels use squid for bait.

Seabird mortalities during Hawaii pelagic longline tuna gear retrieval are nearly all attributable to interactions that took place during daytime line setting operations (NMFS 1998). This is because the gear is usually hauled beginning in the evening and continues throughout the night (reduced visibility and foraging). Another key factor is the near-vertical ascent of the mainline during retrieval. This is due to the extreme depth of the gear produced by the line shooter and the large amount of mainline between floats (Gates, pers. comm.). The steep angle of ascent causes the hauling operation to take place at slower vessel speeds than that of vessels with swordfish gear (Gates, pers. comm.). This further reduces the likelihood of baited hooks being drawn to the surface far from the vessel.

One should not infer that seabird interactions do not occur during tuna fishing hauls. Laysan albatross are somewhat adapted for nocturnal feeding (Harrison et al. 1985), and bright moonlight can increase seabird bycatch levels (Brothers 1991). The use of lazy lines to convey branchlines to crewmen working at hook baskets can result in multiple hooks being available to seabirds. The GANDA researcher's experience as a fishery observer has shown that when problems occur that force gear to be retrieved during daylight hours, the level of interactions can be similar to daytime hauling of swordfish gear.

3.3.2 Swordfish Vessel Description. This category includes vessels targeting swordfish and opportunistically targeting tuna and other species without greatly altering their gear to do so. Swordfish gear is designed to fish higher in the water column than tuna gear; therefore, a mainline shooter is not used to deploy the mainline. Swordfish vessels use open gap "J" hooks (see Plate 5) and squid for bait (see Plate 6), set between 800–1,500 hooks, deploy 3–5 hooks between floats, begin setting in the evening or after dark, and haul the gear during the day. Swordfish vessels use branchlines with weights 5–7 m from the hook and buoyant chemical lightsticks 2–3 m from the hook. The number of branchlines with lightsticks attached varies from 33–100 percent of the total branchlines on a given swordfish set. The distance of the weight from the hook, combined with placement of buoyant chemical lightsticks near the hook, greatly reduces the hook sink rate. It is hypothesized that these factors are the main gear-related causes of high levels of seabird interactions and mortalities for swordfish vessels.

Swordfish sets that begin in the afternoon or twilight hours have the highest incidence of seabird interactions and mortalities (NMFS 1998). NMFS Hawaii Longline Observer Program data show that vessels targeting swordfish and opportunistically targeting other species have a much higher number of seabird interactions and mortalities than vessels using a mainline shooter and targeting bigeye tuna (Kleiber 1999). Since the vast majority of fatal longline seabird interactions occur during the setting of gear on vessels targeting swordfish, this study primarily focuses on that segment of the fishery.

The following factors affect seabird interactions during swordfish afternoon-to-evening sets:

- Swordfish gear is set without a mainline shooter. The mainline spools off the stern at about the speed of the vessel. The drag of the gear in the water keeps the mainline taut and the line can only begin to sink once it is well astern. The baited hooks on the branchlines are kept near the surface by the taut mainline and the turbulence of the vessel's wake.

- Branchline weights (60–80 grams) are far from the hook (>5 m), and buoyant chemical lightsticks may be attached close to the baited hooks (2–3 m). These key factors combine to reduce hook sink rate and increase the time and distance behind the vessels that baited hooks may be taken by seabirds.

- Swordfish vessels use squid for bait, which has high natural buoyancy and is a preferred food of albatrosses.

- Baits are often not completely thawed, which increases the amount of time it takes them to sink (Brothers et al. 1995).

- Seabirds are able to see the baits and bright lightsticks, with the Laysan albatross having better nocturnal vision than the black-footed albatross (Harrison et al. 1985). As the sets continue into darkness, the bright buoyant lightsticks can attract seabirds and illuminate baits that are still in diving range.

- The vessel is moving away from the hooks as they are being set; therefore, the vessel's proximity does not deter the seabird's foraging behavior (i.e., spotting, landing, diving, retrieving, and swallowing).

- Swordfish vessels mainly fish north of the main Hawaiian Islands where albatrosses are much more abundant (NMFS 1998; Anderson 1998; He et al. 1997).

- During swordfish gear retrieval, interactions that become hookings or entanglements may have a lesser degree of mortalities seabirds are often brought aboard alive and therefore have a better chance of being released by the fishermen (Brothers 1995).

The following factors affect seabird interactions during the swordfish gear haul:

- The gear is hauled during the day when seabirds are most actively foraging (Harrison et al. 1985).

- Discarding baits and offal directly over trailing hooks/hauling operations serves as an attractant and increases the risk of hookings and entanglements (Brothers 1995).

- The shallow angle of ascent of the mainline, and the consequent speed of the vessel during retrieval, can bring the baited hooks to the surface at a great enough distance from the vessel that the seabirds are not deterred by its presence.

- Trailing buoyant lightsticks attract seabirds and reduce the sink rate of trailing hooks when vessels slow or stop.

- Propeller turbulence pushes baits near the surface.

- The use of a "lazy line" whereby the "roller" operator, who unclips the branchline from the mainline, attaches it to a line that allows it to slide back to the crewmen who then "coil" the lines into the baskets/totes. If the crew gets behind the pace of the roller operator, as many as four to eight baited hooks can trail 10–20 m behind the vessel. Whether the seabirds can actually strike the trailing baits depends on factors such as wind speed and direction, vessel speed, sea state, and the speed of the crew's hauling activities such as retrieving branchlines.

3.4 Research Plan Refinement

Based on the data gathered through literature review, an examination of NMFS Hawaii Longline Observer Program data, and contacts with bycatch scientists in other fisheries, the research design was refined. The initial project proposal incorporated the quantification of seabird behaviors as the main element of determining the effectiveness of various seabird bycatch mitigation gears and techniques. This key element of the project was refined into a framework that was workable in the environment of commercial longline fishing vessels. Additionally, the scope of the project was expanded to include gathering qualitative information about the effectiveness and intrusiveness into fishing operations of the mitigation measures being tested. The adaptability of effective methods used in other longline fisheries to the Hawaii pelagic longline fishery was included in order to provide WESPAC with a more comprehensive set of seabird bycatch reduction options.

3.4.1 Behaviors Per Unit Effort (BPUE). To quantify the relative effectiveness of various seabird bycatch mitigation measures, data were to be analyzed in terms of the amount of foraging behaviors per hook [behaviors per unit effort (BPUE)] that a particular measure deters. Actual interactions with longline gear are rare in comparison to the events that proceed them. It was assumed that there is a correlation between a reduction in "attempts" to take baited hooks and the "interactions" that ensue. Counting "attempts" provided a more powerful data set to quantitatively analyze the effectiveness of a particular mitigation measure.

Due to the relatively low numbers of albatross hookings, entanglements, and mortalities in relation to the higher number of attempts (chases, landings, and dives) and interactions (contact with the gear), it is difficult to make statistically valid, quantitative comparisons of the effectiveness of various seabird bycatch reduction techniques (Skillman, Molloy, Fadely, Melvin, and Scott, pers. comm.). For this project, the criteria for evaluating the effectiveness of the bycatch mitigation techniques and gear per longline fishing event (set, soak, and haul) were to be based on the behavioral responses (attempts/interactions) and mortalities of the seabirds with, and without, mitigation measures employed.

Depending on which mitigation technique or gear was being tested, different behavioral responses from the seabirds were expected. Some mitigation gear functioned to scare seabirds away from the baited hooks (tori lines, towing buoys) while other mitigation techniques functioned to reduce the attraction or visibility of baited hooks (night setting, blue-dyed baits, modified bait/offal discards). The use of these mitigation measures was expected to cause reductions in the amount of attempts, interactions, and therefore mortalities. Those measures that reduced the numbers of attempts and interactions the most in relation to control periods and the other bycatch reduction techniques would be deemed the most effective.

3.4.2 Zones of Convergence and Opportunity. In order to make quantifiable analyses of a mitigation measure's effectiveness, a zone was designated to provide a baseline count of the number of seabirds actively following the vessel. A second zone was delineated alongside and/or behind the vessel where seabirds have the opportunity to strike baited hooks (Figure 3).

- The **Zone of Convergence** is the area 300 m to port and 300 m to starboard by 300 m astern. This is the flight area where seabirds actively follow the vessel to converge on the baited hooks, bait discards, and offal discards. This is also the area where seabirds were counted for the baseline abundance measurement.

- The **Zone of Opportunity** is the area where the baited hook may be brought to the surface by the turbulence of the wake, tension on the gear created by motion of the vessel, or retrieval by the crew. Seabirds may have an opportunity to strike the bait either by diving underwater or by directly picking up the bait from the sea surface.

For example, during line setting, the maximum zone width is the length of the branchline laterally to either side of the mainline, and astern to the point where the baits are too deep to be retrieved by diving seabirds. This distance was determined by calculating the farthest distance behind the vessel that a seabird could dive for a bait. Distances were to be determined by using an optical rangefinder. During gear hauling, the Zone of Opportunity included the area abeam where a baited hook could appear at the surface or within diving range of a seabird, and to the point astern where a bait might trail at the full extent of the branchline.

3.4.3 Project Data Recording. In the field, data were to be collected by categorizing seabird behaviors into "Attempts" and "Interactions."

"**Attempts**" refers to the number of seabird attempts to pick up baited hooks. Attempts were to be counted only for pursuits of baited hooks or lightsticks attached to branchlines when they occur in the Zone of Opportunity. Attempt behaviors infer that the seabird is pursuing the baited hook were further broken down into three subgroups: chases, landings, and dives.

- **Chases:** Stalling or hovering in the air within 1 m of the visible baited hook or lightstick, or paddling/running on the surface in pursuit of baited hooks.

- **Landings:** Landing on the water within 2 m of a visible/submerged baited hook.

- **Dives:** A seabird that submerges its head or body in an attempt to retrieve a submerged baited hook (regardless if successful). Dives for discarded baits and offal will not be counted, even when they occur in the Zone of Opportunity.

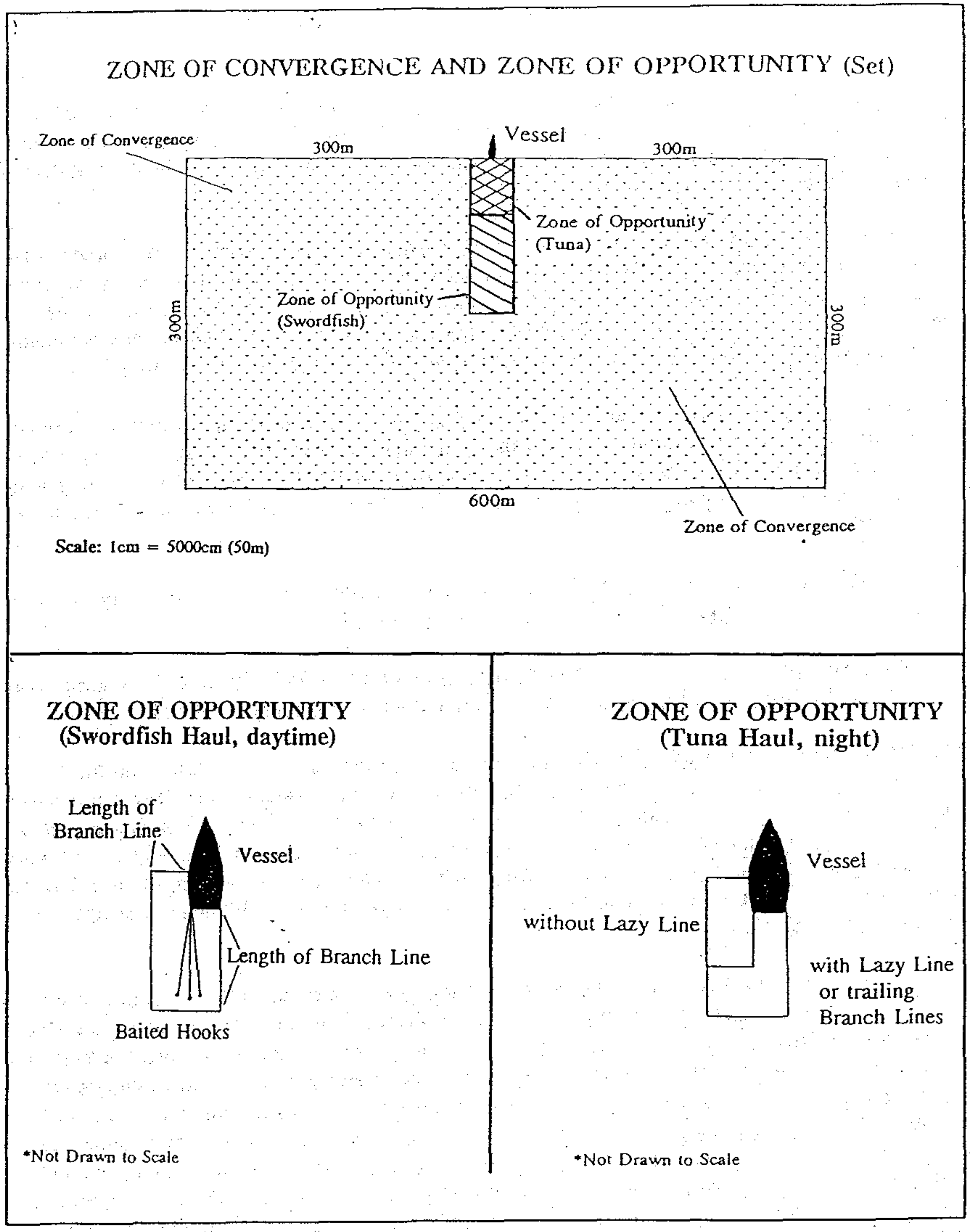

Figure 3. (a) Zone of Convergence and Zone of Opportunity for Gear Setting; (b) Zone of Opportunity for Swordfish Haul; and (c) Zone of Opportunity for Tuna Haul.

A single seabird may exhibit more than one "attempt" behavior or the same behavior multiple times. If the number of attempts became too great to subdivide, all chases, landings, and dives were to be recorded under total attempts for that observation period. Collecting seabird behavioral data was to take precedence over collection of other data elements.

"**Interactions**" refers to observed contact by individual seabirds with the gear or baited hooks. Bait on the hook is considered part of the gear. Interactions were to be subdivided whenever possible into three categories: contacts, hookings, and entanglements. If the number of interactions became too great to subdivide, all contacts, hookings, and entanglements were recorded under total interactions for that observation period. Interactions that become mortalities were also to be counted.

- **Contacts:** Any contact by the seabird with any portion of the fishing gear within the Zone of Opportunity. If a single seabird contacts the gear multiple times, each was to be recorded. Contacts include picking up a baited hook, pecking a baited hook or lightstick, flying into mainline or branchlines, and pecking floats, etc. Contact with mitigation measures were to be counted.

- **Hookings:** Any time a seabird is hooked on any part of its body for any duration. If the seabird then becomes entangled, only the hooking was to be counted.

- **Entanglements:** Any seabird that is entangled on any part of its body for any duration. An entanglement that results in a hooking was counted as an entanglement and a hooking.

"**Mortality**" was to be recorded, whenever possible, during the period of observation when the death occurred. A seabird observed interacting on the set in a hooking or entanglement and was drawn underwater was to be assumed killed and counted as a mortality at that time. A flagged clip was to be attached to the mainline to ensure that the seabird was not added to mortality counts for unobserved periods (i.e., night setting). Mortalities included seabirds found dead on the line during the haul, seabirds killed during the haul, or mortally wounded seabirds. Condition and disposition of seabirds were to be noted.

3.4.4 Other Measures. Participation by Hawaii pelagic longline vessels in this project was on a voluntary basis. The field research portion of the project was restricted to five research cruises. Due to the limited nature of this study, bait-throwing devices, spraying water at seabirds, night setting for tuna, or underwater setting were not tested. Based on preliminary research, these mitigation measures would entail great cost, re-fitting of vessels, greater resistance from fishermen, and would not be effective in meeting the goals of the current WESPAC project (Cook, Gallimore, and Gates, pers. com.). Attempts to test weighted hooks on swordfish vessels encountered strong opposition due to the fishermen's substantial safety concerns. The five mitigation measures tested are widely viewed as being effective, cost-efficient, and minimally intrusive to current fishing methods (Alexander et al. 1997).

3.5 Data Form Creation

Data collection forms were designed for the field portion of this project. All forms were printed on water-proof paper for use at sea. These forms and their specific data collection protocols can be found in Appendix B. A brief description of these forms follows:

1) *Vessel Specifications Form.* This form was used to identify the vessel, vessel owner or owner's representative, and vessel captain. Departure and arrival information and the results of the pre-boarding inspection of U.S. Coast Guard required safety equipment were also recorded on the form.

2) *Daily Operational Record.* This form was designed to be completed for every set. It includes fields for entering the date, time, and location of each set and haul. It also contains fields for the recording of bycatch mitigation technique tested, fishing gear construction, setting speeds, and hook count information for the set and haul.

3) *Pelagic Longline Seabird Interaction Record.* This form was used to record each 30-minute observation period (Figure 4). Fields for describing environmental conditions at the beginning of each period, the number of seabirds present in the Zone of Convergence, and the number of interaction behaviors exhibited by each species within the Zone of Opportunity were included. Comments about seabird behavior, injuries, mortalities, and mitigation measures' effectiveness or modifications during the current observation period were also described here.

4) *Catch Tally Sheet.* This sheet was used during the gear retrieval to record the target species, number of hooks deployed (effort), and the quantity of each species caught during the current set and haul.

3.6 Gear Acquisition

During this phase of the project, gear and equipment were purchased for use in the field including safety gear for the field researcher, research equipment and tools, and mitigation components. Mitigation gear consisted of buoys, various lines, and assorted hardware for the construction of towed seabird mitigation measures. Two tori poles and a steel base were donated to the project by the U.S. Fish and Wildlife Service (USFWS). Towed buoy systems and tori line systems were constructed, and bait dyeing tests were conducted to determine the proper soak time for baits. Mr. James Cook provided the use of one of his vessels to test gears in the near-shore waters prior to actual deployment at sea. Tori lines and towed buoys were deployed and some modifications were made to the gear based on these trials.

PELAGIC LONGLINE SEABIRD INTERACTION RECORD

PERMIT # 964927	DETERRENT tori line		PG 1 OF 3	TARGET SPECIES swordfish
TRIP # 5	SET NO. 8	WIND SPEED (KTS)	VESSEL SPEED	MOON 0 <½ >½ FULL
REC. FROM 1917	DATE 4/26/99	SEA HT. (M)	BAIT CONDITION	CLOUD COVER C PC CL F/H R
REC. TO 1947	SET HAUL	SWELL HT. (M)	LOG PAGE#	BEAUFORT SCALE 3
BFA 0|1-4|5-9|10-14|15-19|20-29|30-49|50-99| >100		LA 0|1-5|5-10|10-15|15-20|20-30|30-50|50-100| >100		ST/O 0|1-5|5-10|10-15|15-20|20-30|30-50|50-100| >100

	ATTEMPTS			INTERACTIONS			
SPECIES	CHASE	LANDING	DIVE	CONTACT	HOOKING	ENTANGLED	MORT
BFA (IN BDZ)	1	2					
(OUT BDZ)							
LA (IN BDZ)	30	90	5	32	1		1
(OUT BDZ)							
ST/O							

COMMENTS: One LA found on haul hooked through beak and throat.
At least 16 snaps put out.
@ 1932 30 LA in ZC
4 BFA

Figure 4. Hawaii Longline Seabird Mortality Mitigation Project Interaction Record.

4.0 FIELD RESEARCH

A total of five seabird bycatch mitigation research trips of approximately thirty days duration were conducted on Hawaii pelagic longline vessels. One trip was on a tuna vessel (employing a mainline shooter) targeting bigeye tuna. Four trips were on swordfish vessels (no mainline shooter) using swordfish gear to target swordfish and/or bigeye tuna. Seabird behavioral observation data were collected during daylight hours. Tori lines, towed buoy systems, modified offal discarding practices, blue-dyed baits, night setting (swordfish vessels only) and control tests were conducted during commercial longline fishing operations. Data on effects of night setting on mortalities were collected based on seabirds found dead during hauls because seabird observations could not be made at night. Multi-variate factors relating to environmental conditions and gear variation between vessels were recorded on field data forms and considered in final analyses. Research aims and objectives for each mitigation technique and gear are listed below.

4.1 Mitigation Measure Descriptions and Usage

This study tested mitigation techniques and gears that deter seabirds from interacting with the gear by either: 1) frightening seabirds away from baited hooks, or 2) reducing attraction or visibility of baited hooks. Tori lines and towed buoy systems scare seabirds away from the area where baited hooks first enter the water. Blue-dyed baits, no offal discards, strategic offal discards, and night setting serve to reduce visibility of baited hooks or attraction to the vessel.

Adaptation and modification of mitigation measures and gear were carried out on each trip to adjust to individual vessels, and to improve the effectiveness and decrease the intrusiveness of these measures on fishing operations.

4.1.1 Tori Line. Tori lines were designed for Japanese longline tuna vessels and function to deter seabirds by having streamers fluttering in the air close enough to the surface to keep the seabirds from flying under them (Brothers 1995). The tori line system tested during this project was a modified Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) version (CCAMLR 1993; see Appendix C). The tori line was attached to a sturdy fiberglass pole (tori pole) that secured near the stern of the vessel on a swiveling steel base. The base was placed atop the setting house or shelter deck on the stern of the vessel (Plate 7) approximately 2 m from the stern and 2 m inboard of the gunwale. The height of the attachment point above water ranged from 4.5–7.2 m.

The tori line varied from 140–175 m long depending on the length of the Zone of Opportunity established for the individual vessel. It was made of 1/4-inch, three-strand poly line, and had six detachable aerial streamers. The aerial streamers were made of flexible material that moved freely and unpredictably and were designed to be long enough so they dangled just above the water's surface. The portion of the tori line that trailed in the water had short (10–25 cm) plastic water streamers. The tori line incorporated a 1/2-inch hollow braid poly drogue section at the terminal end rather than a terminal buoy. The drogue reduced entanglements with fishing gear that crossed the tori line. To achieve full effectiveness, the researcher tried to assure that the tori line was positioned directly above

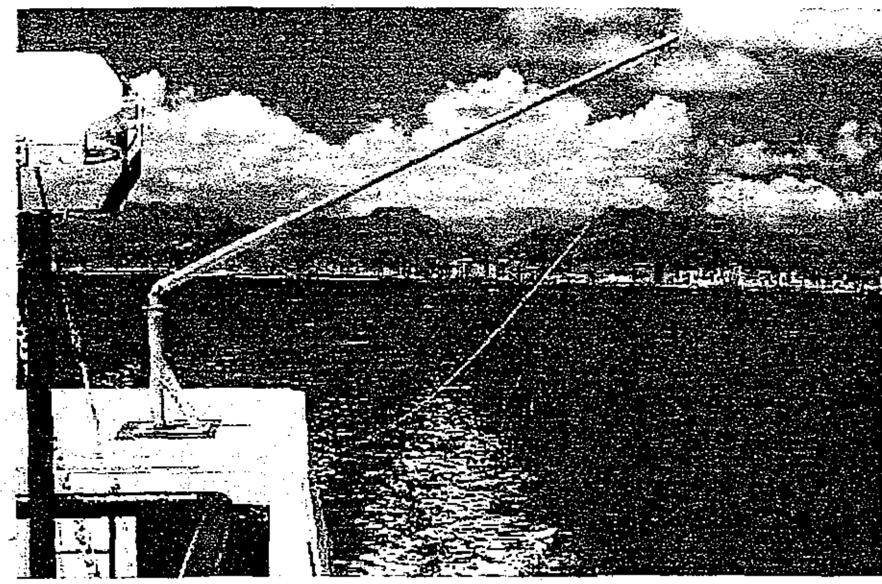

Plate 7a. Tori line and pole: the pole and swivelling steel base were mounted on top of the baitshack.

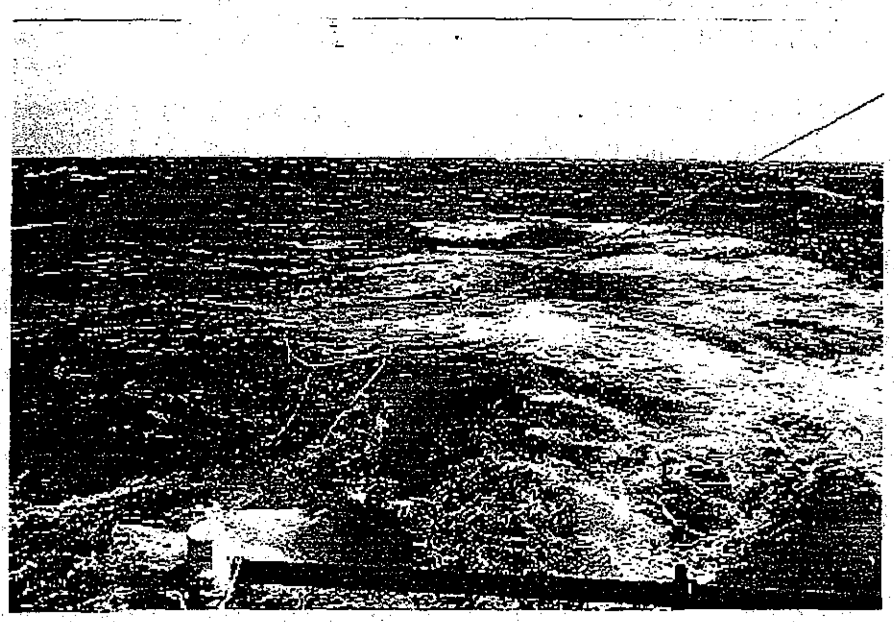

Plate 7b. Tori line deployed on the haul. Note: albatross have landed behind aerial streamer portion.

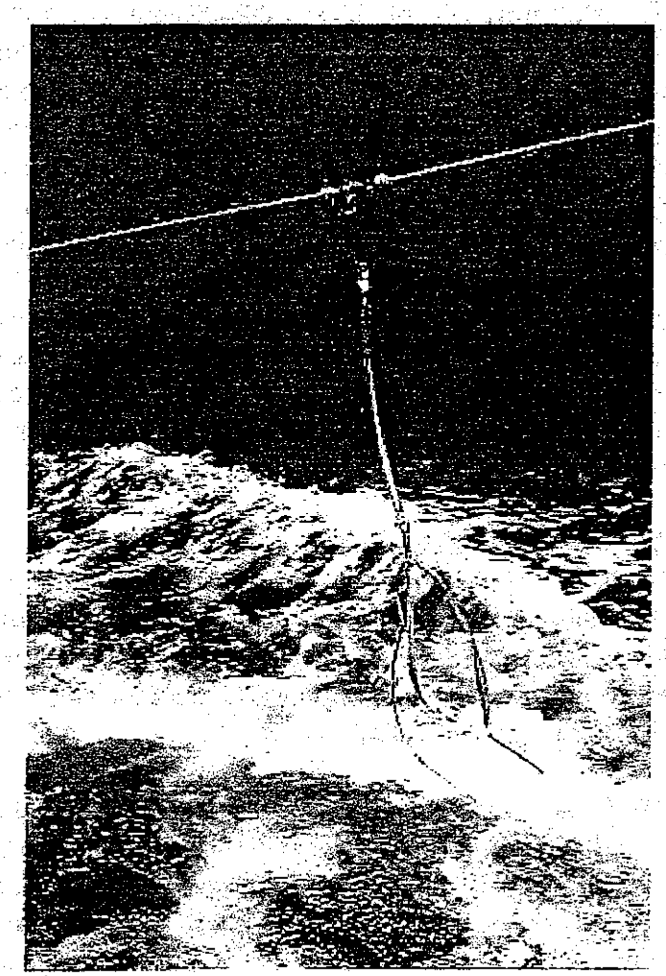

Plate 7c. Aerial streamer of graduated lengths were attached to the tori line (following page). See Appendix C for construction instructions.

the area where the baited hooks were deployed. The height of the attachment point, length of the tori line, and weight of the aerial streamers determined the distance that the aerial streamer portion remained aloft behind the vessel (see Appendix C).

Procedure for Setting. Prior to deployment of the tori line, the researcher and the captain of the vessel determined the wind direction relative to the vessel's setting course. The researcher positioned the tori pole so that the aerial portion of the tori line would best cover the area where baited hooks entered the water, while assuring that the terminal end would not cross the mainline or entangle suspender floats. The first radio buoy of the fishing gear was then deployed. Either the researcher or a crewman would then throw the tori line drogue overboard so that the tori line would then trail out behind the vessel. When the tori line was fully deployed and aerial streamers were up, the crew began setting the baited hooks. The baited hooks were thrown outside the vessel wake and under the protection of the aerial streamers. The researcher and the crew had to continually monitor the tori line for positioning, possible entanglements with fishing gear, and effects of sea state and weather.

Procedure for Hauling. During hauling operations, the tori pole was positioned so that the aerial streamers and terminal buoy best covered the area that baited hooks were brought near to or trailed on the waters surface. The position of the tori line was closely monitored because vessels slow, stop, back up, and turn repeatedly during hauls. This was found to be the best time to make adjustments to the pole positioning.

Modifications by Vessel/Target Species For Setting. Tori lines were designed for setting operations on tuna vessels with mainline shooters and associated fishing gear. The resulting increased sink rate of baited hooks means that the aerial streamer portion of the tori line on these vessels can usually cover the hooks until they sink. On swordfish vessels (without shooters), baited hooks are available near the surface well beyond the aerial portion of the tori line; therefore, the tori lines were made up to 35 m longer for use on swordfish vessels.

Modifications by Vessel/Target Species For Hauling. During hauls, the tori line was shortened to approximately 50 m, and a terminal buoy attached to create enough tension to keep the aerial streamers aloft. This was done because the Zone of Opportunity is much shorter during hauls, and the vessels stop and back up frequently. The aerial portion needs to cover only the distance the branchlines extend behind the boat (usually 20 m or less). In this study, only four shortened aerial streamers were used to cover the area where baited hooks trail on the surface during the haul.

4.1.2 Towed Buoy System. This technique works on the same principal as the tori line. It was expected that a towed streamer line with one or more buoys would be more effective than the tori line for two reasons: 1) tension on the tow line created by the buoy increases the distance that the aerial streamer portion remains aloft behind the vessel, and 2) the bouncing and splashing of the buoy distracts the seabirds. In most cases, the tow line was attached to the same base and pole used for the tori line. The tow lines tested varied from 140–175 m long. Tow lines were tested in two formats: 1) with one buoy at the terminal end; and 2) with two buoys, one at the midpoint and one at the terminal end (Plate 8). The use of a second buoy at the mid-point was abandoned after several breakdowns caused by the middle buoy submerging under swells and creating too much drag on the towing pole. Permanent 1-m-long plastic strap aerial streamers were incorporated in the buoy towing

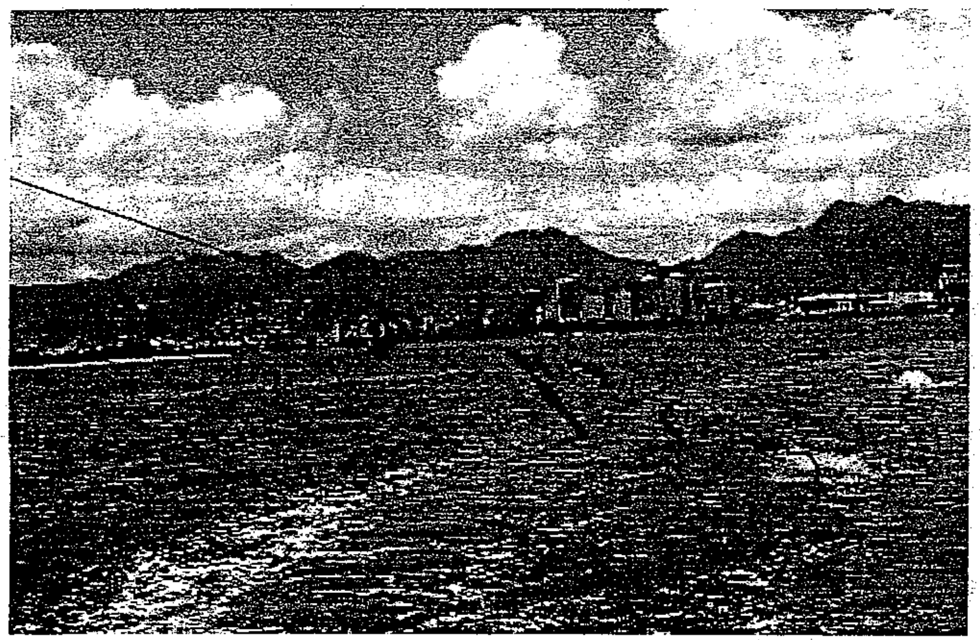

Plate 8a. Towed buoy system being deployed.

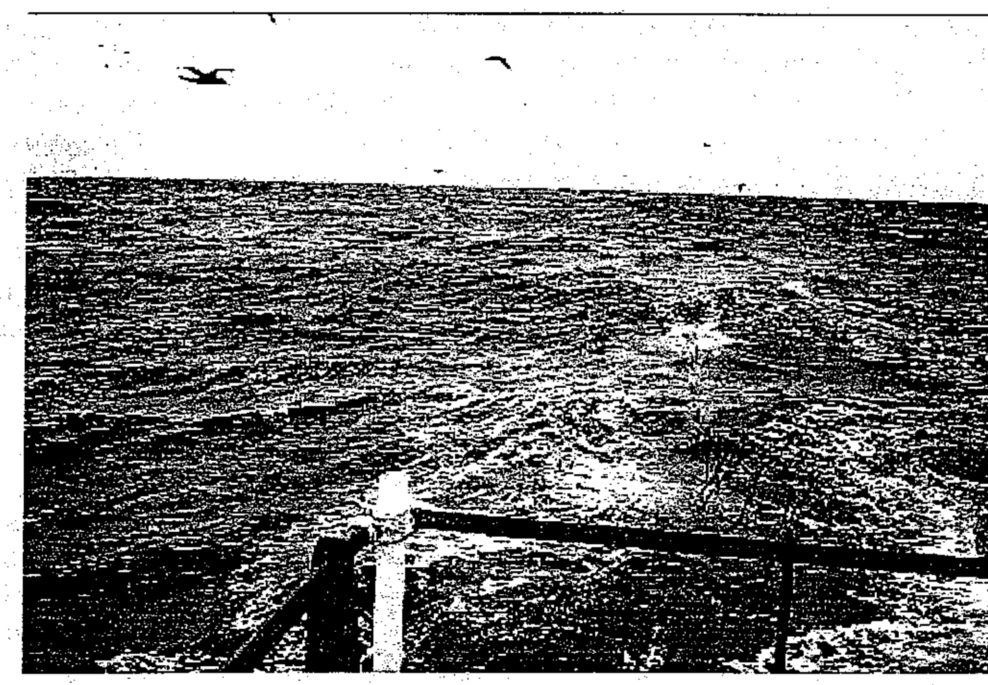

Plate 8b. Towed buoy system with one terminal buoy deployed during gear haul.

line to increase effectiveness (CCAMLR 1993; Appendix C). This system also incorporates 1/4-m-long plastic strap water streamers.

Mitigation Measure Construction. Towed buoy systems are simple to construct and use less hardware than a tori line. As with a tori line, swivels were placed every 20 m to reduce twisting in the towing line. Plastic strapping from the bait boxes was found to make excellent streamers and did not wrap around the towing line to the same extent as the longer tori line streamers. The plastic streamers were simply woven through the towing line at 1-m intervals. Attaching another buoy to the towing line was found to significantly increase the distance the aerial portion remains aloft behind the vessel and added another bouncing, splashing deterrent to frighten seabirds. This became problematic in large swells and or rough weather as the forward buoy would submerge and put too much tension on the towing pole. Materials needed for construction are essentially the same as for tori lines.

Procedure for Setting. See tori line procedure.

Procedure for Hauling. See tori line procedure.

Modifications by Vessel/Target Species. Just as the tori line was designed to best cover the Zone of Opportunity for each vessel, the towed buoy system was designed taking into account the distance behind the vessel that baited hooks are available to seabirds. The towed buoy system line was lengthened by up to 35 m to cover the extended Zone of Opportunity for swordfish vessels.

4.1.3 Night Setting. Longline sets beginning at least one hour after sunset and ending at least one hour before sunrise can be considered night sets. Baited hooks set in darkness are not easily located by seabirds (Plate 9). Turning off non-essential vessel lights can increase the effectiveness of this mitigation method (Brothers 1995). Conversely, use of buoyant chemical lightsticks may reduce the effectiveness of this technique. Fishing strategies depend heavily on the diurnal movement of target species and moon phase. Therefore, this method may compromise optimal setting operations. Although tuna vessels begin and end setting during daylight hours, the level of seabird interactions for these vessels is extremely low; therefore, this method was not tested on the one tuna trip included in this study. It was convenient to collect data about the effects of night setting on seabird mortalities because most swordfish sets begin in the evening and continue throughout the night. Collection of these data required no changes to normal setting procedures.

Procedure. There were no changes to normal fishing operations required to collect data on night setting mortalities. Night setting data were collected for hooks that were set after dark. Night setting data were collected by the researcher on sets that began before dark by marking the mainline with a colored mainline marker at the point where it became too dark to continue collecting observational data. Seabird mortalities retrieved during hauls prior to the appearance of the mainline marker, from sets that began before dark, were considered "night setting mortalities." All seabirds found dead on sets that began and ended after dark were also considered night setting mortalities.

Plate 9. Night setting: swordfish gear being deployed at night. Note: no mainline shooter and blue-dyed baits.

Modifications by Vessel/Target Species. Observations made by the researcher determined that the majority of hooks set on a swordfish set enter the water at night. It follows that swordfish vessels setting before dark are responsible for the vast majority of albatross mortalities in this fishery. Waiting until one hour after sunset to begin setting only reduces optional setting time for these vessels by a small amount. Dedicated tuna vessels begin setting in the morning and finish about five hours later. These vessels have much lower seabird mortality rates due to their use of mainline shooters combined with branchlines with weights near the hooks; therefore, night setting was not deemed appropriate for testing on the single tuna trip included in this study. It should be noted that when these weights are removed from the branchlines, tuna vessels can incur seabird interactions and mortality levels approaching those of a swordfish vessel (Cook, pers. comm).

4.1.4 Blue-dyed baits. This technique was developed by East Coast longline fishermen, but the information was not widely disseminated in the Hawaii swordfish fleet (see Section 7.7). Dyeing the baits reduces seabirds' ability to see baits. Seabirds may not recognize the odd-colored baits as food. This method reduces the contrast (visibility) of the bait's natural color to the surrounding ocean when seen from above. The bait is soaked in a mixture of blue food coloring additive and sea water until it is the same blue hue as the ocean (Plate 10). This technique had the added benefit of thawing the bait, which increases hook sink rate. Crews must take the time to thaw and separate the baits prior to dyeing them.

Procedure. Due to the voluntary nature of vessel participation in this study, strict adherence to complete bait thawing for all mitigation tests could not be required. Some fishermen prefer baits in a semi-frozen state to reduce breakage as hooks are baited. Also, keeping baits frozen gives fishermen the option of preserving bait quality should a set be cut short and baits returned to the freezer. Although bait thawing was not a mitigation measure tested during this study, the level of bait thawing was recorded for each observation period (see Figure 4).

Baits can be dyed prior to or during setting operations. The researcher dyed the baits blue by soaking them in blue food coloring mixed with sea water prior to the hooks being baited. The dye comes in a finely powdered form, and it was found to be more efficient to premix a concentrated dye solution by transferring the powder into a 1- to 2-quart container and adding warm fresh water. This concentrated solution was then portioned out for use. The researcher added approximately 15 gallons of sea water to a 40-gallon container and then added one portion of the concentrated dye solution and mixed.

The crew removed boxes of bait from the bait freezer several hours prior to dyeing. Blocks of frozen bait were sometimes soaked in sea water to speed the thawing process. When individual squids were easily freed from the blocks, they were separated and put into mesh baskets and immersed in the dye solution in the 40-gallon container. Not more than two boxes of bait (60–100 squids) were dyed at one time. The squids were stirred frequently to assure that all were coated by the dye solution. Depending on the concentration of the dye solution, 15–30 minutes was sufficient for the baits to reach a very dark blue color. When properly dyed, the squid became the same dark blue color of the ocean.

Plate 10a. Blue-dyed baits: natural colored squid baits being lowered into dye solution.

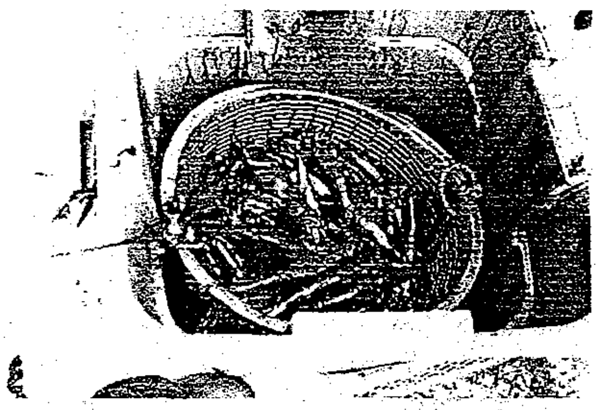

Plate 10b. Blue-dyed baits: fully dyed baits.

Plate 10c. Blue-dyed baits being deployed during a swordfish set.

During setting, the baits were thrown well outside of the turbulent propellor wash. The dyed bait was highly visible from above when it was in the white water of the propellor wash compared to when it was in clear blue water. Three or four treatments can be done by one container of dye.

Modifications by Vessel/Target Species. To date, swordfish fishermen are responsible for initiating bait dyeing efforts in the fishery. This may have a different degree of effectiveness as a seabird bycatch mitigation measure for fish baits such as sanma (saury) or mackerel. Sanma baits are already deep blue dorsally and silver ventrally from approximately the lateral line. These baits can be dyed effectively; however, the camouflaging effect may be reduced in bright sunlight. The dye fades more rapidly and to a greater degree from sanma than squid. If other mitigation measures do not prove to be effective enough for tuna vessels, further research should be conducted to determine the degree of effectiveness of blue-dyed bait for tuna vessels.

4.1.5 No Offal Discards. Dumping offal or discarding baits and bycatch while setting or hauling the fishing gear is a major cause of seabird attraction to fishing vessels. Offal discards direct seabirds towards the line setting/hauling activity and the baited hooks (Brothers 1991). Dumping offal outside the times for setting and hauling may reduce the seabirds' attraction to the fishing gear and may lessen the incentive for seabirds to follow fishing vessels in search of food (Brothers 1991). During research trips, unused baits, fish offal, and bycatch fish species were retained in buckets and barrels or on the deck (Plate 11). Retaining offal requires minimal changes to fishing practices.

Procedure. Offal from fish were put into large containers on deck by crewmen. Baits retrieved by the crew during hauling were placed into a 5-gallon bucket as the branchline was brought aboard. When buckets at the hauling stations became full, they were emptied into the larger containers used for offal and bycatch. Sharks and other large fish bycatch were piled out of the way on the deck.

Modifications by Vessel/Target Species. This strategy mainly applies to swordfish vessels as Hawaii's tuna vessels haul at night and do not normally remove the entrails from tunas at sea. Smaller vessels may find the reduction in deck space problematic.

4.1.6 Strategic Offal Discards. Some pelagic fishermen have discovered that removing the bill and sawing swordfish heads in half vertically provides a large and durable stationary floating attractant for seabirds. Swordfish and fish entrails (especially shark livers) also serve this purpose but sink faster. By periodically throwing offal overboard, large groups of seabirds were distracted away from the vessel and fishing gear (Plate 12). When the offal was consumed or sank, seabirds were well astern of the vessel and were less likely to resume pursuit. Periodic discards were made and encountered by seabirds as they resumed pursuit of the vessel. Since suitable amounts of offal are not always available, offal may be frozen for later use. Effectiveness of this method can be increased by freezing heads and offal which makes them float better and increases seabirds' consumption time. This method requires modification of offal discard practices during gear retrieval in an effort to save discards for the set. Strategic offal discards were introduced as a mitigation measure during Trip 5.

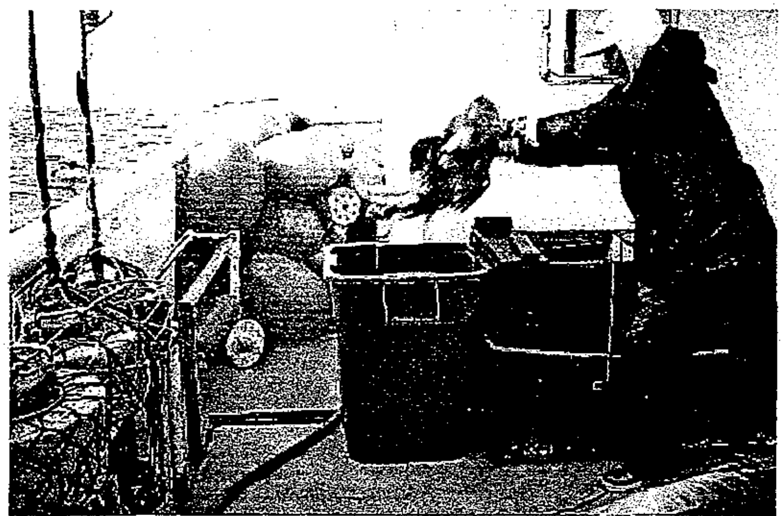

Plate 11a. No offal discards: fish entrails were retained in containers.

Plate 11b. No offal discards: swordfish heads and large bycatch species were retained in piles on the deck.

Plate 11c. No offal discards: baits remaining during hauls were retained in buckets.

Plate 12a. Strategic offal discards: swordfish heads and offal prepared for discarding.

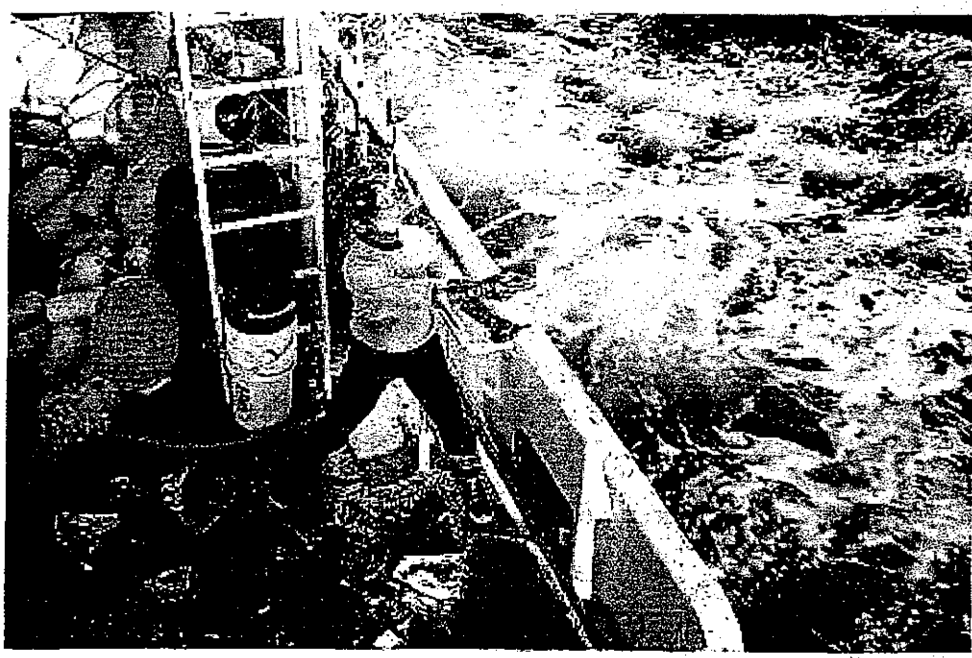

Plate 12b. Strategic offal discards were thrown to distract albatross away from baited hooks.

Procedure. Crewmen removed and retained swordfish heads as the fish were processed during hauls. The upper bills were severed at the base and discarded because they quickly sink. Heads were then sawed in half from top to bottom. Each half of a medium-sized swordfish head floats for about 5–7 minutes. Entrails (especially oil rich livers) of swordfish and sharks were also successful at distracting seabirds. A crewman simply tossed these items in plain view of the seabirds and monitored their approach. He strategically discarded more offal on the side of the vessel opposite from where baited hooks were entering the water.

Modifications by Vessel/Target Species. This method was developed by swordfish longliners. The most effective offal is swordfish heads that have been split in half or floating swordfish entrails. Smaller offal and baits can be used, however, they may allow the seabirds to quickly swallow them and resume pursuit of the vessel. Tuna vessels would have to retain offal from night hauls for day sets. This is not a significant hindrance since tuna sets generally closely follow the haul in the tuna fishery.

4.2 Field Data Collection Procedures

Seabird bycatch reduction measures were tested individually during each set and haul. Whenever possible, control periods were incorporated into each test. Vessel operational data were collected for each set/haul sequence. The catch of target species and bycatch, environmental conditions, seabird abundance, and problems with, or changes to, the mitigation measures were also recorded. The goal in designing the field data collection protocol was to maximize the number of hours (number of hooks observed) of mitigation gear data while allowing for ongoing counts of seabirds in the area, environmental summaries, and gear maintenance.

It was significant to the field data collection methodology that participation of fishing vessels in this project was voluntary. Every effort was made to incorporate tests with normal fishing operations to accurately assess each mitigation measure's effectiveness for reducing seabird mortalities and intrusiveness into current fishing procedures. To secure and maintain the cooperation of fishermen, the researcher had to accomplish testing and data collection with as little disruption of fishing operations as possible.

A total of four mitigation measures were tested on tuna vessel sets and hauls:

- tori lines
- towed buoy system
- blue-dyed bait
- no offal discards during set.

A total of five mitigation measures were tested on swordfish vessel sets and hauls:

- tori lines
- towed buoy system
- blue-dyed bait
- night setting (set only)
- strategic offal discards (set)/no offal discards (haul)

Ordering of Mitigation Tests. It is possible that a given mitigation measure may affect seabird behavior in some way (habituation) that carries over into the next test. In order to reduce any such effects, the ordering of mitigation measure testing was randomized such that the same mitigation measure was not tested on consecutive sets. Over the course of the project, more data were accumulated for some measures than others. Later testing was ordered to attempt to equalize the amount of data collected for each mitigation measure. For this reason and for operational reasons pertaining to normal fishing operations, perfect randomization of mitigation measure tests was not possible.

Control Periods. Control periods refer to the periods when seabird behavioral data were collected while no mitigation measure was employed. These periods of normal fishing operations were included within each mitigation test whenever possible. This was done to negate variations in factors influencing the effectiveness of a particular mitigation measure on any given day. Environmental conditions, level of bait thawing, availability of baited hooks, variations in seabird abundance levels, etc., can vary greatly within and between sets. By including control periods during which normal fishing gear and practices were employed baseline comparisons of seabird foraging behaviors were obtained. In some cases, control periods could not be perfectly randomized due to operational constraints, breakdowns or entanglements of mitigation measures, or other factors. Because the tori line and towed buoy system are difficult to retrieve during line setting, control periods usually occurred prior to deployment of these mitigation measures. In cases where the towed mitigation measure broke or had to be cut free, the remainder of set data were usually collected as a control.

Thirty-Minute Data Collection Periods. Standard data collection periods were 30 minutes long. Seabird abundance counts in the Zone of Convergence were collected prior to, and after, each period to provide an average abundance level for that period. The time between periods was used for gathering environmental data, mitigation gear deployment or retrieval, and fish counts. If an observation period was interrupted, the length of the interruption was noted and subtracted from the total observation time. In the case of longer interruptions, the observation period was ended and a new period started when fishing operations resumed.

Multi-variant Factors. Data were collected on environmental, operational, and technical factors that may impact the effectiveness of mitigation measures. Recordings were made for time of day, light level, moon phase, vessel speed during set/haul, vessel location, wind speed and direction, target species, gear used, bait type and condition (level of thawing), seabirds species and numbers present, and seabird behavior (attempt/interaction/mortality) during each set and haul.

Marking Changes from Mitigation Measure to Control. Changes from mitigation measure to control, and vice versa, were marked using colored mainline markers (Plate 13). Due to course changes, entanglements with fishing gear, intrusiveness into fishing operations, and other factors, mitigation measures were not always deployed throughout the night on sets. When testing of a mitigation measure was ended at night, a marker was attached to the mainline so mortalities could be attributed to the portion of the night set with, or without, a mitigation measure in place. Adherence to the mixing of control periods in each mitigation measure test was attempted as was feasible.

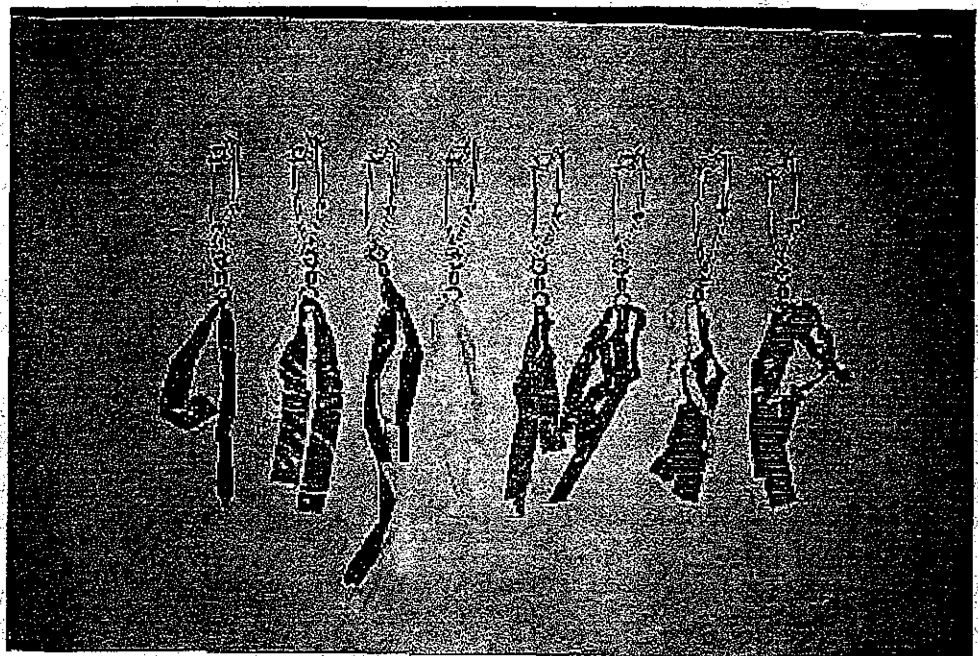

Plate 13. Colored mainline markers used to signify changes from deterrent to control, potential mortalities, and time markers.

Marking the Longline in the Event of a Possible Seabird Mortality. Actual drownings of hooked seabirds were rarely witnessed because of the great distance behind swordfish vessels where interactions can occur and because the vessel was moving away from the place where the interaction was occurring. When an albatross was observed to have brought a baited hook to the surface, a marker was placed on the mainline to mark it as a potential mortality. A hooked seabird may have been removed from the hook by sharks. The hook would only be seen as an empty hook/branchline on the haul. Empty or missing hooks found on the haul where a mortality might be expected were not counted as mortalities.

Stopping Behavioral Data Collection Due to Darkness. Data collection stopped at the time the researcher could no longer identify seabird behaviors or individual species. A marker was attached to the mainline to indicate the point where observations ceased. In a few rare cases, data were collected where species of albatrosses could not be determined. These were recorded as undifferentiated species.

Assigning Time to Mortalities. The order that mainline markers were recovered during gear hauling allowed mortalities to be entered on the data form corresponding to the period when the hooking occurred. When a mortality was not witnessed and the researcher observed a dead seabird on a hook during the haul, the mortality was assigned a time based on the marker's location on the mainline. Night mortalities were assigned times by their location on the mainline. In many cases, knowing the time a certain marker was placed on the mainline relative to the position of the mortality allowed for close approximation of the time the hooking occurred. During the last trip of the project, the number of night mortalities was higher than on all other trips combined (see Section 7.3). During night sets on this trip, mainline markers were attached to the mainline at intervals. The time the marker was attached was recorded. Approximate times of hookings could be derived by the location of the mortalities relative to the markers.

Catch Tallies. Catch Tally forms were completed during each gear haul. All target and non-target fish species, plus any seabird or sea turtle species hooked, were recorded. The catch tally form was used to test for effects of seabird mitigation methods on CPUE for all species. It also recorded whether the animal was hooked during a mitigation measure test or control period during setting operations. Seabirds that were hooked during gear hauls were recorded on the Pelagic Longline Seabird Interaction Record for the time period when it occurred. In most cases, catch was recorded as it came aboard; however, if seabird attempts and interactions were occurring, the catch was tallied after the observation period ended.

4.3 Fisherman Questionnaire

An important part of determining the most effective and least intrusive methods for reducing seabird mortalities in the Hawaii longline fishery is feedback from fishermen themselves. The collection of opinions and concerns from vessel operators and crews was an important element of this study. This information will be very useful as it pertains to adaptation, acceptance, and implementation seabird bycatch reduction mitigation measures in this fishery. A post-cruise questionnaire was designed to collect this information.

Fishermen on vessels participating in the project were asked to fill out the questionnaire to determine their opinions about the importance of reducing seabird bycatch, which mitigation measure tested was most effective, which measure was easiest to use, which measure was most difficult to use, and if mitigation measures affected CPUE. Fishermen were also asked what measures longline fishermen would voluntarily comply with. These surveys were filled out while the vessel returned to port. The results of these surveys are detailed in Section 6.0. The questionnaires are provided in Appendix D.

5.0 QUANTITATIVE ANALYSIS OF MITIGATION MEASURES

5.1 General Methods

The major quantitative goals of this study were to determine the effectiveness of each mitigation measure relative to one another and to a control in terms of seabird bycatch and CPUE. Mitigation measures tested were the tori line, towed buoy system, blue-dyed bait, no offal discards (haul only), and strategic offal discards (set only), and night setting.

In order to determine the effectiveness of each mitigation measure, seabird behaviors were recorded during sets and hauls while a single mitigation measure was in place. Behavioral data were also recorded during control periods when no mitigation measures were used. All analyses are for observation periods when seabirds were present. Night setting data were collected on all trips only in terms of seabird mortalities (i.e., behavioral data could not be collected in the dark).

Vessel preferences for bait thawing procedures were consented to during this project. Only blue-dyed bait tests incorporated completely thawed baits throughout. During most tests and controls, baits were completely or partially thawed by crews prior to being deployed.

A three-tiered behavioral data set—attempts, interactions, and mortalities—was designed for this study because it was clear from NMFS Hawaii Longline Observer Program data that the number of mortalities per "test," which for our purposes is the hook, is low. Behavioral data were recorded during all sets and hauls when light levels allowed the observer to record seabird behaviors. Behavioral data and seabird counts were recorded on "Pelagic Longline Seabird Interaction Record" data forms (see Figure 3 above).

In addition to data recorded on the Pelagic Longline Seabird Interaction Records, data describing the number of hooks and type of gear used for each set and haul; set and haul duration; trip, set and haul number; target species catch; and seabird bycatch were also used in the following analyses. To determine if mitigation measures have any effect on target species catch, the number of fish caught with, and without, a mitigation measure in place during the set was recorded.

Data collected through at-sea research were entered directly from the field forms into a computerized spreadsheet. Master data sheets were created for each discrete data collection form. Data were then entered using these master sheets as guides for each trip. Data were organized and grouped together by trip number. This procedure resulted in one large data file per trip which facilitated querying and analysis. The raw data (hard copies) collected at sea are stored in logbooks at the GANDA office. Full data printouts are presented in Appendices J through N. Electronic copies of the data files accompany the report to be delivered to WESPAC.

All data manipulations and analyses described below were performed using Corel Quattro Pro 8 spreadsheets. Raw and derived data, from which each overall result draws a conclusion, are provided as separate appendices corresponding to each analysis subsection (Appendices F through I).

5.2 Effectiveness of the Mitigation Measures on Sets

The number of albatross mortalities that occur during Hawaii pelagic longline sets is significantly greater than the number occurring during hauls (NMFS 1998); therefore, determining which mitigation measure best reduces seabird bycatch during gear setting operations was the most important goal of these analyses.

A total of 4,412 hooks were observed when seabirds were present during tuna vessel sets on Trip 1. A total of 8,023 hooks were observed when seabirds were present during swordfish vessel sets on Trips 2–5. The number of hooks observed was determined by multiplying the total number of hooks for the set by the percent of total set time represented by each observation period:

$$\text{no. hook per observation period} = \text{total no. hook} \times (\text{observation duration}/\text{total set duration})$$

The total number of hooks observed for a particular mitigation measure is the sum of all hook numbers for those observation periods when that particular mitigation measure was in place. The overall number of hooks observed is the sum of the hook numbers for all observation periods.

Five seabird mitigation measures were tested on sets: towed buoy system, blue-dyed bait, strategic offal discards (SOD), tori line, and night setting. SOD were introduced as a mitigation measure during Trip 5; therefore, the total hooks observed for SOD were less than those observed for other mitigation measures.

The best determinant of the effectiveness of mitigation measures is the number of behaviors that occurred in a given observation period with a given mitigation measure in place corrected for the number of seabirds present and divided by the number of hooks that were set in that period. This quantity, which is the rate of behavior per seabird per hook, is termed "BPUE." BPUE was calculated as follows:

$$\text{BPUE} = (\text{no. of behaviors}/\text{no. of birds present})/\text{no. of hooks observed}$$

It was necessary to correct behavioral data for the numbers of seabirds present. Without correcting the data, a given mitigation measure used in a observation period in which seabirds were abundant appeared to allow many attempts or interactions.

A low BPUE means that each observed seabird exhibited fewer behaviors per hook. Appendix F provides the data from which the BPUE was calculated.

BPUE was subdivided into attempts per unit effort (APUE) and interactions per unit effort (IPUE).

5.2.1 Attempts Per Unit Effort (APUE). APUE data is calculated as follows:

APUE = (no. of attempts/no. of seabirds present)/no. of hooks observed

The average APUE for all mitigation measures tested on both the tuna and swordfish trips was less than the observed average APUE for the respective controls.

The control on the tuna sets allowed for an average of 10.7 attempts per seabird per 1,000 hooks. The towed buoy system, blue-dyed baits, no offal discards, and tori line tested on the tuna trip had mean APUEs of 0.0, 0.0, 4.3, and 0.8 per 1,000 hooks, respectively (Table 3). Each of the mitigation measures, therefore, had lower mean APUEs than the control on tuna sets, particularly the towed buoy system and blue-dyed bait mitigation measures.

Table 3. Tuna Trip: Number of Hooks Observed and Effect of Mitigation Measures on Seabird Attempts for the Set.

Mitigation Measure	Number of Hooks Observed	Attempts per seabird per 1,000 hooks set
Towed buoy system	243	0.0
Blue-dyed bait	579	0.0
No offal discards	601	4.3
Tori line	1,463	0.8
Control	1,526	10.7

The control on the swordfish sets allowed for an average of 76.7 attempts per seabird per 1,000 hooks. The towed buoy system, blue-dyed baits, SOD, and tori line resulted in 37.1, 39.3, 29.4, and 47.1 attempts per seabird per 1,000 hooks, respectively (Table 4). These APUEs were analyzed for statistical significance using S-Plus software produced by Statsci. The frequency distribution of APUE data were generated and observed to be similar to a Poisson distribution. APUEs for all observations during the set in which seabirds were present were compared to a general linear model (GLM) for the data, assuming a Poisson distribution.

The F statistic generated from the GLM of all set data for swordfish trips was used to determine if the APUEs for mitigation measures differed from one another and/or from the control. Based on the F statistic, the probability that APUEs for mitigation measures are not different from one another and/or control is $P = 0.0038$ (see Appendix I for complete summary of F statistics). The probability that observed differences in average APUE on sets occurred solely by chance is less than 1 in 100.

Table 4. Swordfish Trips: Total Number of Hooks Observed and Effect of Mitigation Measures on Seabird Attempts and Interactions for the Set. F statistic for these data from a GLM analysis indicate that they are distinct with a probability of P = 0.0038.

Mitigation Measure	Number of Hooks Observed	APUE per 1,000 hooks set	IPUE per 1,000 hooks set
Towed buoy system	1,902	37.1	16.1
Blue-dyed bait	2,503	39.3	7.6
SOD	880	29.4	15.4
Tori line	1,526	47.1	15.7
Control	1,212	76.7	32.8

Note: Night setting data are not included in this tables because only mortalities were recorded during the haul.

The effectiveness of each mitigation measure may be expressed as the percentage by which it reduced seabird attempts. The formula for calculating percent effectiveness is:

$$\% \text{ effectiveness} = ((\text{control APUE} - \text{mitigation measure APUE})/\text{control APUE}) \times 100$$

Using this formula, a mitigation measure that is 100 percent effective results in no attempts while a mitigation measure that is 25 percent effective reduces attempts by 25 percent (and allows behaviors by 75%) when compared to the values observed with the control.

SOD reduced attempts by 62 percent, while the towed buoy system and blue-dyed bait reduced attempts by 52 percent and 49 percent, respectively (Figure 5). Since these percentages were derived from APUE data (which are statistically significant) we may consider "% effectiveness" to reflect significant differences between mitigation measures and the control as well.

5.2.2 Interactions per Unit Effort (IPUE). IPUE was calculated in exactly the same way as APUE with the single exception that interaction data were substituted into the calculation for attempt data. IPUE is calculated as follows:

$$\text{IPUE} = (\text{no. of interactions/no. of seabirds present})/\text{no. of hooks observed}$$

Because interaction data are exclusive of attempt data, IPUE is a completely independent measure of the effectiveness of mitigation measures (see Appendix F). Both APUE and IPUE data should be considered when making decisions about the overall effectiveness of each mitigation measure. APUE data are the more abundant data and provide the most statistically significant results. IPUE data are based on actual contact with fishing gear.

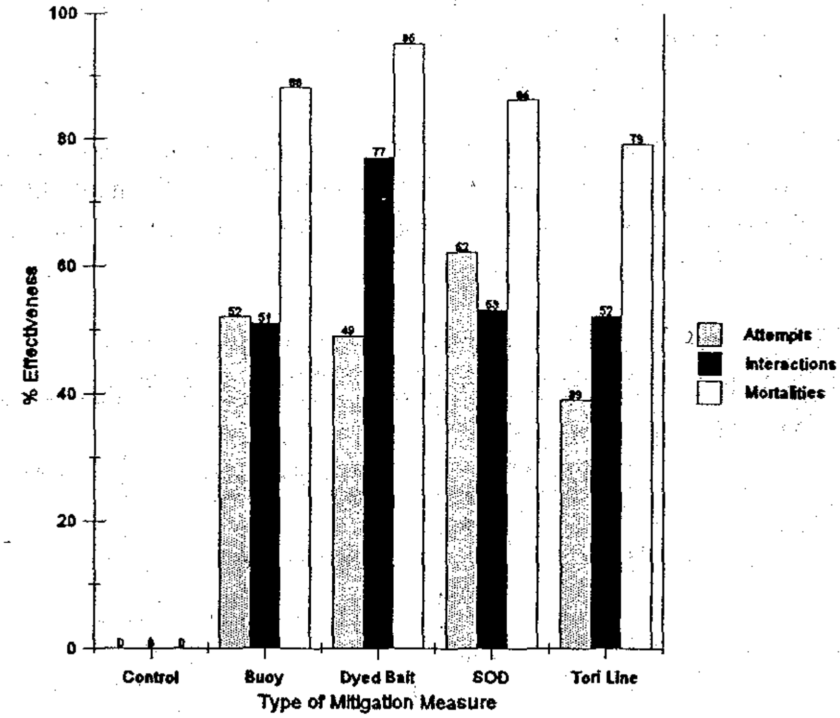

Figure 5. Effectiveness of mitigation measures in reducing attempts, interactions and mortalities on swordfish sets (Trips 2–5).

Only a single interaction occurred on the tuna trip, therefore, no quantitative analysis results of seabird interactions on tuna vessels are presented here.

The average control value for IPUE during swordfish sets is higher than IPUEs for any of the mitigation measures. Differences between IPUE averages for mitigation measures and control were found to be statistically significant via GLM with an F statistic of $P = 0.0038$ (see Appendix I). The mean IPUE for control during swordfish sets is 32.8 interactions per seabird per 1,000 hooks. The values for the towed buoy system, blue-dyed baits, strategic offal discards, and tori line are 16.1, 7.6, 15.4 and 15.7 per 1,000 hooks, respectively (see Table 4).

When data are converted into "% effectiveness" (see Figure 5), all mitigation measures reduced IPUEs by at least 50 percent. Blue-dyed bait reduced IPUEs by greater than 77 percent. The towed buoy system, SOD, and tori line reduced IPUEs by 50 percent.

5.3 Effectiveness of Mitigation Measures on Hauls

Because swordfish longline vessels typically haul during the day, they allowed for many observation periods within a single haul and, therefore, generated the largest data set. The four mitigation measures tested during the hauls were the towed buoy system, blue-dyed bait, no offal discards, and tori line.

During swordfish hauls, a total of 37,810 hooks were observed. The number of hooks observed for the towed buoy system, blue-dyed bait, no offal discards, tori line and control was 6,778, 5,521, 6,802, 7,924 and 10,785, respectively (Table 5).

5.3.1 APUE and IPUE on Hauls. APUE and IPUE were calculated for the haul in the same manner as for the set. Table 5 presents the average APUE and IPUE data on the haul. APUE and IPUE data were analyzed separately using GLM. The F statistic for both attempt and interaction data has a $P < 0.0000$ (see Appendix I).

Table 5. BPUE Summary for Swordfish Haul Data. Note that retention of offal discards (in bold) allowed the greatest number of seabird attempts and interactions to occur.

Mitigation Measure	Total Hooks Observed	APUE Per 1,000 Hooks	IPUE Per 1,000 Hooks
Towed buoy system	6,778	2.0	0.2
Blue-dyed bait	5,521	5.2	0.1
No offal discard	**6,802**	**25.5**	**1.3**
Tori line	7,924	1.2	0.1
Control	10,785	15.5	1.2

Table 5 reveals a clear pattern of the effectiveness of mitigation measures during swordfish vessel hauls. The towed buoy system, blue-dyed bait, and tori line all reduced attempt and interaction behaviors by a degree of magnitude, or greater, over the control. Interestingly, the retention of offal discards resulted in *increased* numbers of attempts and interactions at a rate greater than that observed for the control.

Figure 6 plots the "% effectiveness" of each mitigation measure on swordfish hauls. Percent effectiveness for hauls was calculated from APUE and IPUE data in the same manner as it was for sets. A negative "% effectiveness" implies that the mitigation measure resulted in a greater number of attempts or interactions than observed with the control.

The tori line, towed buoy system, and blue-dyed baits were all very effective at reducing attempts and interactions on the haul. The tori line was 92 percent effective in reducing attempts and 93 percent effective in reducing interactions. The towed buoy system was 87 percent effective in reducing attempts and 85 percent effective in reducing interactions on the haul. The blue-dyed baits were less effective than the towed buoy system or tori line at mitigating attempts but equaled the tori line in being the most effective mitigation measure in reducing interactions. The blue-dyed bait allows attempts because it offers no physical deterrent to the water above the baits.

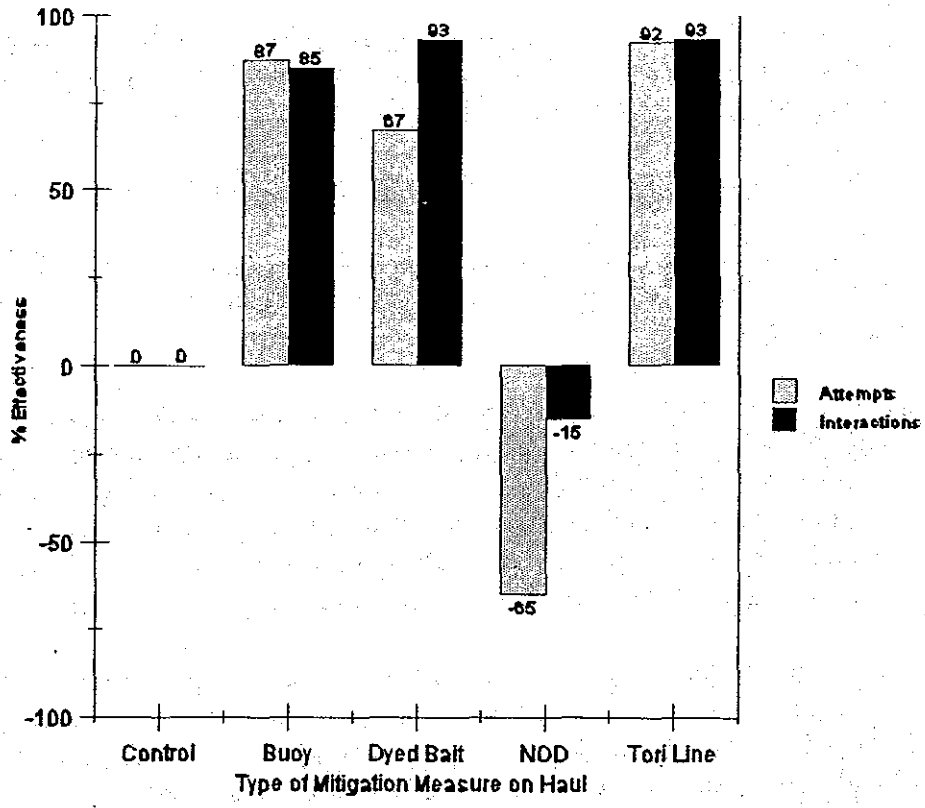

Figure 6. Effectiveness of mitigation measures in reducing attempts and interactions on the haul. BPUE data from which these "% effectiveness" values were generated were shown to be statistically significant with F statistic $P < 0.0000$.

These results suggest that blue-dyed baits may be successfully used on the haul in combination with a physical deterrent on the surface (i.e., towed buoy system or tori line) thereby increasing the effectiveness of both.

The negative "% effectiveness" of the retention of offal discards on the haul is an important result. First, as a mitigation measure, it may actually increase risks to seabirds in the short term. Prior to this study, it was expected that the control, which represents fishing without mitigation measures, was the worst-case scenario. Data gathered and analyzed through this study have proven this assumption false. Second, it allows for inferences about seabird behavior. Decreasing the presence of no-risk food sources, like offal, intensifies seabirds' efforts towards risky food sources (i.e., baited hooks). Unless a way can be devised to completely eliminate the seabirds from the Zone of Opportunity altogether, eliminating no-risk food may be an unwise choice.

The quantitative results presented here indicate that blue-dyed baits used in combination with either the tori line or towed buoy system would best mitigate seabird bycatch on the haul.

5.4 MPUE: Mortalities

5.4 MPUE: Mortalities

MPUE, or mortalities per unit effort, is a measure analogous to BPUE. Instead of quantifying the numbers of behaviors that may *lead to* mortalities, as BPUE does, MPUE quantifies the number of mortalities per seabird present per hook. MPUE is calculated as follows:

MPUE = (no. of mortalities/no. of seabirds present)/no. of hooks observed

No mortalities occurred on Trip 1. This is most likely a result of the location of the fishing effort and the low levels of interactions associated with tuna vessel fishing gear (i.e., mainline shooter and associated terminal tackle).

Seventy-eight albatross mortalities occurred during sets on swordfish trips. Of the 78 total mortalities, 54 occurred during "lighted" observation periods. The remaining 24 mortalities occurred during dark portion of the sets in which no mitigation device was in use. Since night setting mitigates mortalities (see Section 5.5), dark periods in which no mitigation measure was in place cannot be considered to be control periods and were not included as such. Mortalities that occurred in the dark have been treated separately as mortalities occurring when the mitigation measure "darkness" was in place.

Of the 54 mortalities that occurred during observed periods, 22 occurred during control periods (1,224 hooks observed), 13 mortalities occurred when the towed buoy was in place (1,902 hooks observed), 7 when dyed bait were in use (2,503 hooks observed), 2 with strategic offal discards (880 hooks observed) and 10 with the tori pole in place (1,526 hooks observed).

Although no mortalities occurred during hauls, 26 albatrosses were hooked during swordfish hauls. Had these birds been hooked on the set, many would have been pulled under the water and drowned. Birds hooked on the haul, however, are typically brought aboard and released alive but injured. Since the birds were still alive they were counted as "hookings" and not "mortalities," therefore, the data have been included in the IPUE analysis for the haul. However, all of these birds sustained injuries of varying degrees from the hook that could lead to eventual death.

Of the 26 hookings that occurred during swordfish hauls, 19 occurred during control periods (10,782 hooks observed), 5 during no offal discards (6,802 hooks observed), 1 with the towed buoy in place (6,778 hooks observed) and 1 with the tori pole in place (7,924 hooks observed). No hookings occurred as blue dyed baits were hauled (5,521 hooks observed).

Table 6 illustrates the MPUE for each mitigation measure. GLM of the MPUE data indicates that the results of the statistical analyses are significant ($P = <0.0000$). All mitigation measures resulted in a degree of magnitude fewer mortalities than that observed for the control. While the control allowed for 2.23 mortalities per 1,000 hooks set, the mitigation measures allowed for 0.12 – 0.47 mortalities per 1,000 hooks.

Percent effectiveness for mitigation measures against mortality was calculated as follows:

% effectiveness = ((control MPUE – mitigation measure MPUE)/control MPUE) × 100

Table 6. Effect of Mitigation Measures on Seabird Mortality During Swordfish Sets

Mitigation Measure	Mortalities per seabird per 1,000 hooks
Towed buoy system	0.26
Blue-dyed bait	0.12
SOD	0.32
Tori line	0.47
Night Setting	0.60
Control	2.23

All of the devices reduced mortality by 73 percent or greater. Blue-dyed bait achieved a 95 percent reduction in mortality while the towed buoy system and SOD reduced seabird bycatch mortalities by 88 percent and 86 percent, respectively (see Figure 5).

Statistical analyses of data from the swordfish vessel sets indicate that the blue-dyed baits performed best overall on the set. Blue-dyed baits have the greatest ability to mitigate against mortalities (95%) and interactions (77%), and provided a 50 percent reduction in attempt behaviors.

5.5 Effectiveness of Night Setting

Because the majority of swordfish hooks are set after dark and darkness is a facile and potentially effective mitigation measure against mortality, mortality data were analyzed for the effect of darkness utilizing MPUE.

To conduct the night setting analysis and present results as MPUE, it was necessary to estimate the total number of hooks that were set while seabirds were present during dark periods. Since it was not possible to determine if seabirds were present during dark periods, it was necessary to develop some criteria for assuming when seabirds were present and when they were absent.

It was assumed that seabirds were present during the dark portions of a set if: 1) seabirds were present during the lighted observation period immediately preceding darkness, or 2) if there was a mortality during the dark portion of the set. Seabirds were assumed to be absent from the dark portion of a set if: 1) the entire set occurred in the dark and no mortalities occurred, or 2) there were no seabirds present on the lighted portion of the set preceding darkness and no mortalities occurred.

Assuming that seabirds were present during all of the dark portions of sets would be consistent, but would lead to an overestimation of the number of hooks set when seabirds were present. This would result in a far lower MPUE for night setting, making it appear to be a better mitigation measure than it actually is. The manner in which the estimate of hooks was formulated provides for a conservative estimate of hooks that were set in the dark when seabirds were present. The value presented here represents something close to the minimum effectiveness of darkness as a deterrent.

Appendix F presents data for all sets in which seabirds were present during lighted observation periods immediately preceding darkness. It was assumed that seabirds were present during the dark portions of these sets. The total number of hooks set in the dark represented by these sets is 31,763 (total hooks set minus hooks set in lighted periods). There were nine additional sets that occurred entirely in the dark during which a mortality occurred. These sets were 4, 5 and 8 during Trip 4; and sets 4, 5, 7, 8 and 10 during Trip 5. The total number of hooks set in the dark for these sets is the sum of the hooks set, since each of these sets occurred entirely in the dark. These trips accounted for an additional 8,292 hooks set in the dark when seabirds were present. An estimated 40,055 hooks were, therefore, set in the dark when seabirds were present.

Twenty-four mortalities occurred during dark periods of the set in which no mitigation measures were in place. The MPUE of these 24 mortalities is (24 morts/40,055 hooks) or 0.60 mortalities/1,000 hooks. It is important to note that this MPUE value was not corrected for the number of seabirds present because the numbers of seabirds present during night setting was unknown. It was assumed that the number of seabirds present equals the numbers of mortalities that occurred during each night set. This is a conservative estimate that will act only to decrease the apparent effectiveness of night setting since there could only have been a number of seabirds present equal to, or greater than, the number of mortalities that occurred.

MPUEs during night setting of 0.60 per 1,000 hooks is the most conservative estimate of night setting's bycatch mitigation effectiveness. This MPUE value was much lower than that obtained for the control (2.23) and comparable to that observed for the tori line (0.47). Conversion to "% effectiveness" reveals that night setting is 73 percent effective.

5.6 Species-Specific Behavioral Responses to Mitigation Measures

5.6.1 Species-Specific Interactions. All quantitative results presented thus far group black-footed and Laysan albatrosses together. Following are the results of the statistical analyses considering the effect of the various mitigation devices on the behaviors and mortalities observed for the two albatross species treated separately.

Species-specific APUEs and IPUEs from sets and hauls for each mitigation measure were analyzed for statistical significance using GLM. The F statistic for the species-specific set and haul data were significant, with a $P < 0.05$ for interactions for both albatross species. The P-value for black-footed albatross interactions on the set was $P = 0.008$, and $P = 0.03$ for Laysan albatross. The p-value for both the black-footed albatross and Laysan albatross interactions on the haul was $P < 0.0000$.

The P-value for APUE from sets was $P < 0.05$ for the black-footed albatross ($P = 0.01$) and $P > 0.05$ for the Laysan albatross ($P = 0.8$). Because the aim of this analysis is to compare the effectiveness of each mitigation measure between the two albatross species, the APUEs for each of the species must be significant. The Laysan albatross APUE data did not meet this criterion and cannot be included in the analysis. The comparison of the effectiveness of the various mitigation measures utilizes only the IPUE data from both sets and the hauls.

Table 7 presents the IPUE for the black-footed albatross (BFA) and the Laysan albatross (LA) from the sets and hauls of Trips 2–5. Data from which these IPUEs were calculated is presented in Appendices F and G. IPUE for a single species was calculated as follows:

IPUE LA = (LA interactions / LA present)/no. of hooks observed

IPUE BFA = (BFA interactions / BFA present)/no. of hooks observed

Table 7 illustrates some important species-specific differences between Laysan and Black-footed albatrosses. Laysan albatrosses have greater IPUEs than black-footed albatrosses for every deterrent except blue-dyed bait. This implies that Laysan albatrosses were either more aggressive and interacted with the fishing gear more often, or were more "successful" at contacting fishing gear when they made the effort.

Figures 7 and 8 compare the "% effectiveness" of each mitigation measure against interactions on the set and haul. Figure 7 illustrates that three of the four mitigation measures on the set, the towed buoy system, blue-dyed bait and tori line, affected both albatross species to the same degree. Strategic offal discards, however, were much more effective in reducing black-footed albatross interactions (89%) than they were in reducing Laysan albatross interactions (46%) on the set.

Figure 8 demonstrates that all mitigation measures were effective for both species during the haul, with blue-dyed baits being more successful at mitigating Laysan albatross interactions. The towed buoy system, blue-dyed bait, and tori line all reduced black-footed albatross interactions by more than 90 percent.

Table 7. Species-specific IPUEs on sets and hauls. These differences were shown to have statistically significant ($P < 0.05$) F statistics when subjected to GLM analysis.

Mitigation Measure	IPUE on the Set Per 1,000 hooks		IPUE on the Haul Per 1,000 hooks	
	BFA	**LA**	**BFA**	**LA**
Towed buoy system	17.0	18.6	.05	0.21
Blue-dyed bait	7.0	9.6	0.09	0.04
SOD (set)/No offal (haul)	3.4	17.9	1.22	1.38
Tori line	13.0	17.0	0.02	0.15
Control	30.1	33.4	0.95	1.13

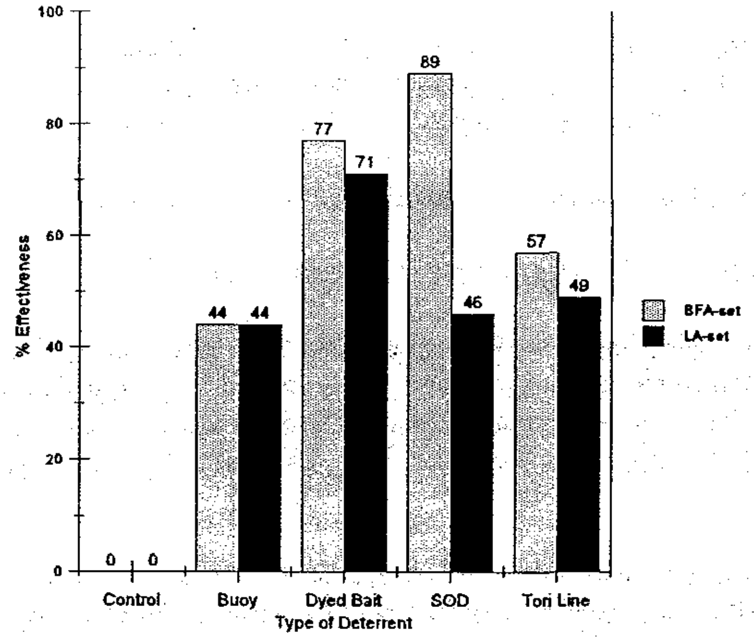

Figure 7. Species-specific effectiveness on the set.

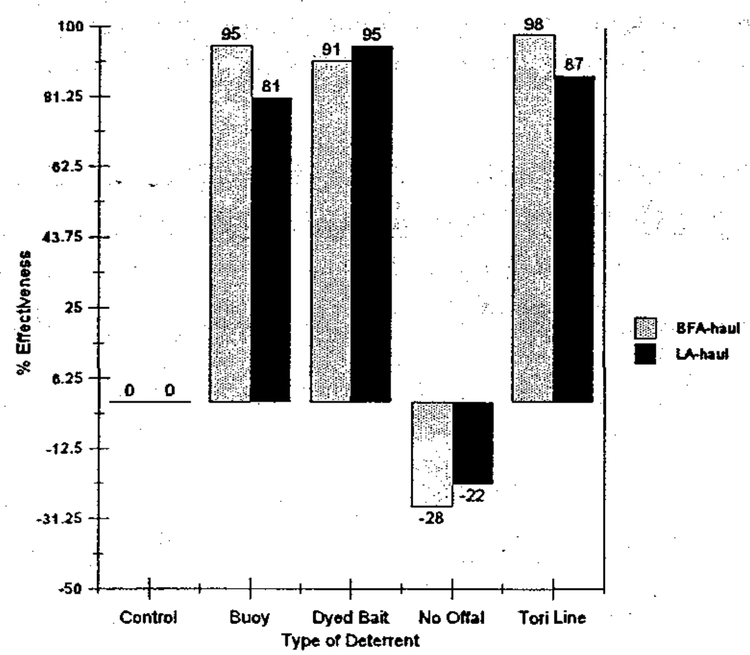

Figure 8. Species-specific effectiveness of deterrents on the haul.

5.6.2 Effectiveness Against Mortalities. MPUE data for sets on swordfish trips indicate which mitigation measures were more effective with a particular albatross species. Table 8 illustrates MPUE values for each albatross species. These values were subjected to GLM and the F statistic for both black-footed and Laysan albatrosses and were found to have a $P < 0.05$ ($P = 0.0000$ black-foot albatross data; $P = 0.04$ Laysan albatross data).

Although black-footed albatrosses interacted with fishing gear less frequently, they were more likely to be killed. MPUE for black-footed albatrosses under control conditions was 3.62 mortalities per 1,000 hooks, which is over four times the magnitude of the Laysan albatross MPUE (0.76 mortalities per 1,000 hooks). The MPUE for black-footed albatrosses is greater than, or equal to, that for Laysan albatrosses for all mitigation measures, as well.

This result runs somewhat counter to statistical analysis results for interaction data—Laysan albatrosses interacted with fishing gear much more often than black-footed albatrosses. This apparent incongruity points out an important species-specific difference between the two albatross species: Laysan albatrosses were more aggressive and more adept at taking bait without getting hooked than black-footed albatrosses. The important overall result from analyses of these data is that black-footed albatrosses are more likely to be killed.

Figure 9 illustrates the "% effectiveness" of mitigation measures used during sets at reducing mortalities for each albatross species. All mitigation measures are over 80 percent effective in reducing black-footed albatross mortalities. The blue-dyed bait and tori line are both greater than 90 percent effective with this species. Laysan albatross mortalities were best reduced using blue-dyed baits and strategic offal discards, which achieved 86 percent and 91 percent deterrent effectiveness respectively. The tori line was less successful in reducing mortalities of Laysan albatrosses achieving 66 percent effectiveness.

Table 8. Species-specific MPUEs for sets. These differences were shown to have statistically-significant ($P < 0.05$) F statistics when subjected to GLM analysis.

Mitigation Measure	Mortalities on the Set Per 1,000 Hooks	
	Black-footed Albatross	**Laysan Albatross**
Towed buoy system	0.40	0.22
Blue-dyed bait	0.23	0.11
SOD (set)/No offal (haul)	0.63	0.07
Tori line	0.26	0.26
Control	3.62	0.76

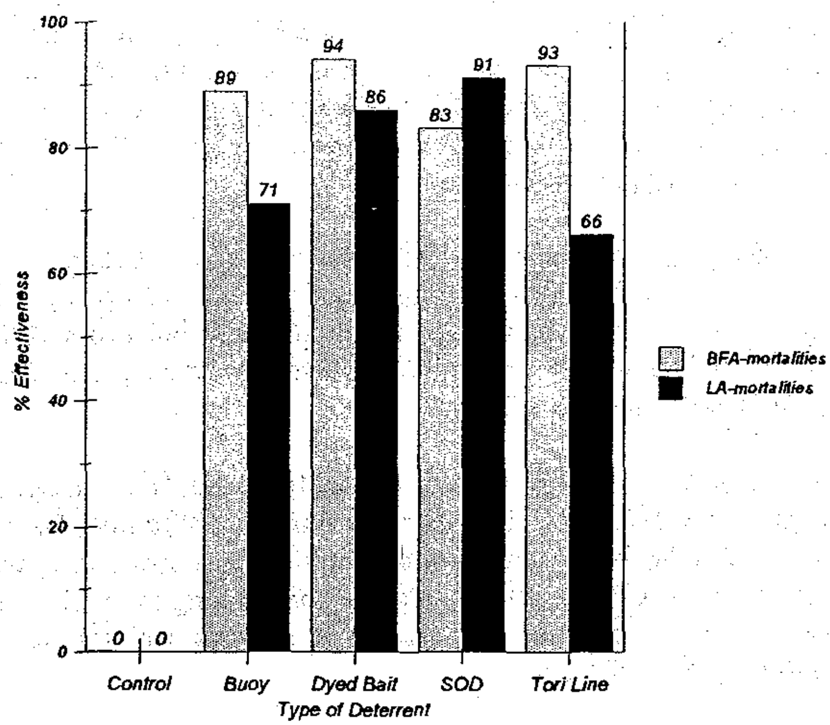

Figure 9. Species-specific effectiveness of mitigation measures in reducing mortalities.

5.7 Effect of Blue-dyed Bait on Target and Marketable Species

The mitigation measure that had the highest potential effect on CPUE was blue-dyed bait. All other mitigation measures used during sets: towed buoy system, strategic offal discards, and tori line, are in the proximity of each hook for less than 30 seconds. Any deterrent near the hooks for this short duration should have little effect on fish catch other than the reduction in bait losses to seabirds. Blue-dyed baits however are a critical part of the fishing gear itself and therefore may affect CPUE.

To remove between-set variation from the CPUE analysis of blue-dyed baits versus natural baits, control periods (natural baits) were included in all sets in which blue-dyed baits were used. CPUE data analysis was limited to sets where blue and natural baits were combined. Comparisons of CPUE could, therefore, be made within each set, as well as between overall mean CPUE's for all sets where blue and natural baits were combined (see Appendix H).

CPUE for blue-dyed bait was calculated from data as follows:

$$CPUE = \text{no. fish caught with blue bait/no. hooks with blue bait}$$

CPUE for control was calculated in the same manner.

On the tuna trip, blue-dyed baits were tested on two sets. Both sets resulted in a greater target species CPUE for blue-dyed baits than for control baits (see Appendix H). Average target species CPUE for tuna was 6.3 per 1,000 hooks with blue baits and 3.9 per 1,000 hooks with natural baits (Table 15).

For swordfish trips, 18 sets employed blue and normal baits. Blue-dyed baits had a greater CPUE on 12 of the 18 sets. The average swordfish target species CPUE was 21.8 per 1,000 hooks for blue baits and 15.9 per 1,000 hooks for natural baits. These two values, however, may not formally differ from one another as 80 percent confidence intervals around each mean target CPUE value overlap. The conclusion one draws from this is simply that there is no statistically significant difference in the ability of blue-dyed bait and natural bait to catch fish.

The effect of blue-dyed baits on marketable species looks similar to that observed for target species (Table 9). Blue-dyed baits appear to do better than natural baits on individual sets, leading to an overall higher average marketable species CPUE for blue-dyed baits on both tuna and swordfish trips. Again, however, 80 percent confidence intervals around the CPUE's for marketable species overlap indicating that both baits may simply work equally well.

Blue-dyed baits may have caught fewer blue sharks than natural baits (see Appendix H). The average blue shark catch for the tuna trip was 3.4 fish per 1,000 hooks with the natural bait, and only 2.2 fish per 1,000 hooks with blue-dyed baits (Table 9). On swordfish trips, the average blue shark catch was 32.9 per 1,000 hooks with natural baits and 29.1 per 1,000 hooks with blue-dyed baits. Once again, however, 80 percent confidence intervals around the blue shark mean CPUE's overlap, indicating that both baits may actually catch statistically equivalent numbers of blue sharks.

Figure 10 illustrates CPUE results from blue-dyed versus natural baited hooks for the target fish species, marketable fish species and blue shark catches. Overall, blue-dyed baits do not appear to have detrimentally affected CPUE for target or marketable species catch and may have actually enhanced CPUE in these two categories. The blue-dyed baits may reduce blue shark catch.

Table 9. Effect of Blue-dyed bait on Target Species, Marketable Species, and Blue Shark Catch.

Catch	Control CPUE per 1,000 hooks	Dyed CPUE per 1,000 hooks
Tuna Only	3.9	6.3
Marketable Species* (Tuna Vessel)	15.9	21.8
Swordfish Only	10.5	15.9
Marketable Species* (Swordfish Vessel)	31.3	36.6
Blue Shark (Tuna Vessel)	3.4	2.2
Blue Shark (Swordfish Vessel)	32.9	29.1

*Marketable species include all fish that may be brought back to sell, they include: all marlin species, all tuna species, swordfish, shortbill spearfish, opah, wahoo, and dolphinfish.

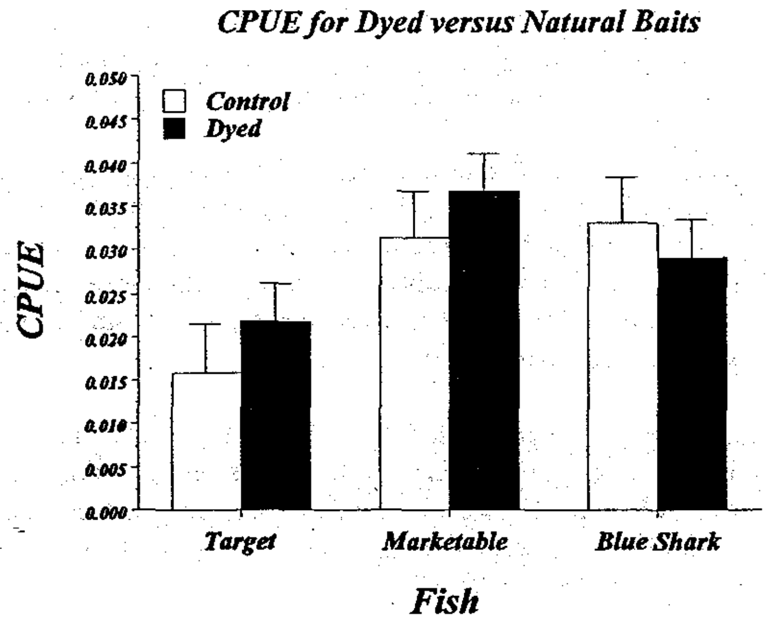

Figure 10. Comparison of CPUE data from blue-dyed versus natural baits for target fish species, marketable fish species, and blue sharks. Error bars indicate the standard error. Data are from swordfish trips only. CPUE is indicated as catch per hook.

Overall, the blue-dyed baits do not appear to have detrimentally affected CPUE for target or marketable species catch and may have actually enhanced CPUE in these two categories. The blue-dyed baits may reduce blue shark catch.

6.0 FISHERMAN QUESTIONNAIRE EVALUATION

All crew members aboard the five research trips were asked to participate in the survey by filling out a questionnaire. Questionnaires were distributed to the crew members at the end of each research trip as the vessel headed for port. Eighteen of 25 crew members completed and returned surveys. Of the 5 crew members on the tuna targeting trip (Trip 1), 4 responded. On swordfish trips (Trips 2–5), 14 of the 20 crew members responded.

A number of the fisherman questionnaires required translation from Vietnamese to English. An appropriate Vietnamese translator was located and the translations were made. Survey results were entered into the computer for analysis.

The crews of the longline vessels that participated in this study were of various ethnic groups. The ethnic breakdown of the survey respondents is as follows: nine Vietnamese, five Caucasians, two Pacific Islanders, and two African Americans. The data were analyzed along ethnic lines and by vessel type (tuna vessel crews versus swordfish vessel crews). Responses indicate that the Vietnamese tend to respond very similarly to the same questions or vote as a block. Other ethnic groups did not respond in a similar fashion to the same questions (see Section 8.3.2).

The questionnaire was designed to gather information regarding fishermen's attitudes toward, and awareness of, the seabird bycatch issue; their willingness to reduce bycatch; the degree to which mitigation measures intrude into fishing operations; and the perceived effects on CPUE. Survey topics included attitudes toward seabird bycatch reduction, ease/difficulty in the use of mitigation measures, suggestions for improvements to mitigation measures, measures that were most effective, the effects on CPUE, and the fishermen's willingness to voluntarily reduce bycatch.

When asked if they felt seabird bycatch reduction was important, 50 percent of the tuna crewmen and 64 percent of the swordfish crewmen replied affirmatively. Negative responses accounted for 25 percent of the tuna crewmen, and 29 percent of the swordfish crewmen's responses.

When asked what they thought would happen if seabird bycatch was not reduced in this fishery, 50 percent of the tuna crewmen and 36 percent of the swordfish crewmen thought that there would be restricted areas or closures implemented. In addition, 36 percent of the swordfish crewmen thought that the seabirds would become extinct if bycatch was not reduced.

When asked which mitigation measure was most difficult to use, the crewmen's responses varied significantly. Most of the tuna crewmen (75%) felt that dyed bait was the most difficult to use. Many stated that the dye was messy and was difficult to clean up. It should be noted though that these comments are based on only two sets using dyed baits. On the tuna trip, the first research trip, the fine powder dye was mixed on deck and was easily blown around by the wind. In subsequent trips, the researcher pre-mixed a concentrated dye solution. This method eliminated much of the crewmen's objections. In contrast, only 7 percent of swordfish crewmen indicated that dyed bait was the most difficult to use.

The swordfish crews' opinions of the most difficult measure were divided. Thirty-five percent thought that weighted hooks were the most difficult to use. During the latter part of this study, the researcher attempted to gather data on adding weights to the hook to increase sink rate, but there was such strong opposition to this mitigation measure that no testing was conducted. This response shows the high level of opposition to using weighted hooks, which were never deployed, but were nevertheless voted most difficult to use. Fourteen percent of the swordfish crewmen felt that the tori line was most difficult, while 14 percent felt that the towed buoy was most difficult.

When asked which mitigation measure was easiest to use, 50 percent of the tuna crewmen selected the towed buoy, followed by the tori line at 25 percent. For swordfish crewmen, 49 percent voted for blue-dyed baits (alone, or in combination with another measure), 43 percent voted for the towed buoy (alone, or in combination with another measure), and 14 percent voted for night setting.

When asked if any of the mitigation measures tested affected catch of target species, 75 percent of the tuna crewmen and 43 percent of the swordfish crewmen responded that it did not affect their catch. In addition, 43 percent of the swordfish crewmen were not sure if mitigation measures had an effect.

When asked what voluntary measures fishermen would comply with, 50 percent of the tuna crewmen and 29 percent of the swordfish crewmen left this question blank. Twenty-five percent of the tuna crewmen said they would comply with a tori line, while 36 percent of the swordfish crewmen said they would comply with a tori line (or bird-scaring line) and dyed baits (either in combination or alone).

These responses have been incorporated into our recommendations and have also been presented at public meetings during the course of this project. The survey questions and a complete breakdown of responses are provided in Appendix D.

7.0 QUALITATIVE DISCUSSION OF MITIGATION MEASURES

Variations in Hawaii pelagic longline vessels, fishing gear, tactics, weather, sea state, and seabird abundance have impacts on the effectiveness of seabird bycatch mitigation measures. Analysis of these factors is important for making recommendations about the most effective and least intrusive mitigation measures for the Hawaii pelagic longline fishery. The intrusiveness of any particular method into fishing operations will have a direct bearing on its level of implementation by the fleet. In a fishery that travels far offshore and outside the range of enforcement agencies, implementation of mandatory seabird bycatch mitigation methods will be minimal if these methods are perceived to be impractical, ineffective, unsafe, or to have negative impacts on CPUE of target species. Consequently, a qualitative discussion of each method tested during this project has been provided to assist fishery managers in choosing appropriate, acceptable, and enforceable measures for this fishery. A table summarizing this discussion can be found in Appendix E.

7.1 Tori Line

Strategy. The strategy employed by this mitigation measure is to deter seabirds away from baited hooks. Towing a line attached to a high point (pole) provides an attachment point for dangling vertical streamers, which bounce erratically, frightening seabirds away from baited hooks where they are most vulnerable as they enter the water.

Effect on Seabird Behavior During Setting. Seabirds are best able to forage on baited hooks soon after they enter the water and prior to sinking out of diving range. During field testing, it was discovered that the aerial streamer portion of the tori line was the part that effectively reduced the seabirds' ability to approach baited hooks. Attempt and interaction behaviors were thwarted by the streamers dangling from the tori line to the water's surface. Baited hooks were thrown so that they landed under this aerial portion of the tori line. This method was mainly effective on the side of the mainline where the tori line was deployed. The seabirds' flight patterns approaching the stern of the vessel were obstructed by the tori line and streamers. Seabirds that landed were distracted by the erratic movements of the streamers. If the bait was on or near the surface in close proximity to the seabirds, they occasionally ignored the streamers. This was especially true when seabird abundance was high, as this increased competition for available baits.

As the tori line trailed back behind the boat, it eventually entered the water. The portion of the line trailing through the water had only the limited effectiveness afforded by short plastic water streamers woven through the tori line. These splashed as they were dragged through the water. In some cases, seabirds would land and inspect or peck at them. The tori line used a drogue section at the terminal end rather than a buoy. Without a terminal buoy bouncing and splashing towards them, the seabirds could dive for baits or compete with other seabirds for baited hooks along the water streamer portion of the tori line.

Effect on Seabird Behavior During Hauling. During hauling operations the tori line was shortened and used a terminal buoy to keep the aerial streamers aloft. The bouncing action of the buoy also increased the erratic motion of the streamers, more effectively deterring seabirds from chasing baited hooks. Seabirds that did land on the water's surface were more effectively distracted from diving for baited hooks. When the vessel slowed or stopped to haul in fish, the aerial streamers dropped to the water and the seabirds quickly landed on trailing baited hooks.

Intrusiveness During Setting. The tori line had to be positioned in such a manner as to provide maximum coverage of the baited hooks and yet not be in such close proximity to the fishing gear that it became entangled. Captain and crew had to continuously monitor and maintain this desired proximity during fishing operations. Since the tori line's aerial streamers reach to the water's surface, care had to be taken to assure that baited hooks did not become entangled with them. Baits that were not completely thawed floated, and increased this risk. Towing a 150-to-175-meter-long tori line compromised vessel maneuverability. Even small changes in vessel heading sometimes caused the tori line to entangle with longline gear. Safety concerns and monitoring the mitigation measure can distract the crew from fishing operations. This was more problematic for swordfish vessels since the majority of a set occurs in darkness. The tori line required more attention during the haul as the vessel stopped, backed up, and turned more to land fish. When the vessel stopped, a crewman had to be ready to retrieve the tori line and redeploy it once the haul resumed.

Intrusiveness During Hauling. The addition of a terminal buoy on the shortened tori line used during hauls increased its effectiveness to levels comparable to the towed buoy system. The tori line had to be hauled in and redeployed repeatedly during hauling operations.

Crew Safety. In good weather conditions, safety concerns were minimal; however, if the tori line became entangled with the gear, extreme stresses occasionally resulted in broken tori poles, back-spooling of mainline onto the deck, broken mainlines, and associated dangers. These conditions were more serious at night when entanglements might not be seen until something broke.

Effects on CPUE. The tori line had minimal effects on CPUE (see Sections 5.7 and 7.7).

Cost. The approximate cost for the pole, swivelling base, and tori line used in this project were as follows: base $600.00, fiberglass pole $500.00, and tori line with streamers $65.00. The fiberglass tori pole was manufactured in Fujieda, Japan, by Kotake and Company.

Advantages.

- Protects baited hooks while hooks are accessible to seabirds at water surface.
- Forces seabirds to forage further behind boat, giving baits a chance to sink.
- Highly visible when deployed; presence on vessels can be verified visually for compliance monitoring.
- Aerial streamers reach to the water surface and give more vertical protection of baited hooks.
- Using a drogue instead of terminal buoy decreases entanglements.
- Tori lines can use a terminal buoy, which increases the distance behind the vessel the aerial portion remains aloft and increases the erratic movements of streamers.
- May increase CPUE of target species by reducing bait loss to seabirds.

- Components can be purchased locally, and literature on construction and deployment in other fisheries is available.

Disadvantages.

- Only covers one side of mainline.
- Only aerial portion of streamer line has maximum effectiveness (which is critical in covering Zone of Opportunity).
- Aerial portion covers less than half of the Zone of Opportunity for vessels without mainline shooters.
- Tori line must be close to mainline to cover area where baited hooks enter water.
- During night setting, entanglements with fishing gear may not be quickly discovered.
- Seabirds can carry branchlines over the tori line leading to entanglements/breakdowns.
- Multiple poles and pre-constructed tori lines MUST be available to be rapidly redeployed when an entanglement results in a pole breaking or a tori line being cut free.
- Variations in vessel design in the Hawaii longline fleet will require vessel-specific tori line/pole construction and mounting.
- Tori pole requires a swiveling base to be fully effective in all circumstances.
- Rough seas and high winds reduce effectiveness and increase risk of entanglement.
- Extreme length of tori line reduces vessel course change options.
- Seabirds can become habituated to tori line and streamers.
- Tori line is difficult to retrieve while underway.
- Tori lines that use a drogue rather than a terminal buoy do not have a seabird-scaring device to distract seabirds beyond the aerial portion of the tori line.
- When the vessel stops during hauls, the hardware of the aerial streamers causes the tori line to sink, increasing the risk of entanglement with the gear or propeller.

Compliance Monitoring. While the presence of a tori pole and tori line can be monitored at the dock, actual use at sea will be difficult to monitor without aerial monitoring or at-sea monitoring by onboard observers or the U.S. Coast Guard (USCG).

7.2 Towed Buoy System

Strategy. The strategy employed by this mitigation measure is to deter seabirds away from baited hooks. This method works on the same principle as a tori line. A buoy towing line with streamers is towed behind the boat to frighten the seabirds away from the area where the baited hooks enter the water, allowing the baits to sink untouched. One or more buoys bounce and splash behind the vessel, scaring seabirds that may have landed on the water.

Effect on Seabird Behavior During Setting. Like the tori line, this method relies on aerial streamers to keep seabirds away from baited hooks as they were set. Flight patterns were disrupted as seabirds approached the baited hooks, giving them time to sink out of diving range. This method also required a pole and swivelling base to assure its effectiveness in all weather conditions. The towing line also incorporated a water streamer section to distract seabirds (see Appendix C). The bouncing and splashing objects distract seabirds from pursuing baits. The aerial streamers were shorter than those of the tori line but still remained effective in distracting seabirds. Seabirds that had spotted or landed near available baits would occasionally ignore the aerial streamers, however, the presence of the buoy(s) splashing towards them would distract seabirds from taking the bait. The buoy(s) provide greater tension on the towing line, which kept the aerial (most effective) portion aloft further behind the vessel.

Effect on Seabird Behavior During Hauling. The buoy towing line was shortened during hauls. The bouncing terminal buoy is closer to the vessel and trailing baited hooks. Seabirds that landed on the water and prepared to dive or contact gear were dispersed by the buoy's approach. The aerial streamers' actions were also made more erratic. When the vessel slowed or stopped to haul in fish, the aerial streamers dropped to the water and the seabirds quickly landed on whatever baited hooks were trailing.

Intrusiveness. As with the tori line, this towed deterrent had to be constantly monitored particularly because the buoy(s) were more likely to entangle with mainline suspender floats. The towed buoy caused the same intrusions on fishing operations that were described for the tori line.

Crew Safety. In good weather conditions, safety concerns were minimal; however, if the towed buoy system became entangled with the gear, extreme stresses result in broken attachment poles, back-spooling of mainline onto the deck, broken mainlines, and associated dangers. These conditions were more serious at night when entanglements might not be seen until something broke.

Effects on CPUE. The towed buoy system has minimal effects on CPUE (see Section 7.7).

Cost. The cost of the towed buoy system were as follows: swiveling base $600.00, fiberglass pole $500.00, towing line $30.00, buoy $35.00, and plastic strapping from bait boxes (streamers) $0.

Advantages.

- Protects baited hooks while accessible to seabirds at water surface.
- Highly visible when deployed; presence on vessel can be verified visually for compliance monitoring.
- Bouncing buoy has greater seabird-scaring capacity than tori line drogue.
- Bouncing buoy reduces seabird habituation.
- Towed buoys add tension, which keeps the aerial portion up farther behind the vessel and keeps the towing line from crossing the mainline.
- Shorter aerial streamers are less likely to entangle branchlines.
- Less chance of entanglement between branchlines and aerial streamers.
- Terminal buoy is useful as a visual indicator of where the end of the towing line is.
- Components can easily be purchased from local suppliers, and literature on construction and deployment in other fisheries is available.

Disadvantages.

- Towed buoy system only covers one side of mainline.
- Only aerial portion of streamer line has maximum effectiveness, which is critical in covering Zone of Opportunity.
- Buoy line must be close to mainline to cover area where baited hooks enter water.
- Pole requires swiveling base to be fully effective in all weather conditions.
- Variation in vessel design in Hawaii longline fleet will require vessel-specific buoy line mounting.
- Rough seas and high winds reduce effectiveness and increase risk of entanglement.
- Multiple poles and pre-constructed buoy lines MUST be available to be rapidly redeployed when an entanglement results in a pole breaking or a buoy line being cut free.
- Seabirds can carry branchlines over buoy line, resulting in entanglements/breakdown.
- More than one buoy is problematic during rough weather or large swells.
- Terminal buoy is prone to entanglement with fishing gear.
- Cannot be retrieved without slowing or stopping vessel.

Compliance Monitoring. While the presence of an attachment pole and towed buoy system can be monitored at the dock, actual use at sea will be difficult to monitor without aerial monitoring or at-sea monitoring by onboard observers or the USCG.

7.3 Night Setting

Strategy. The strategy employed by this mitigation measure is to reduce the visibility of baited hooks. Setting fishing gear in the dark reduces the ability of seabirds to locate baited hooks. Reducing the vessel's aft-facing deck lights is an important factor in this strategy.

Effect on Seabird Behavior. Albatrosses cannot easily locate baited hooks set in the dark, particularly when vessel lighting is reduced. Seabird foraging behavior appears to be reduced at night (Anderson 1998). One working hypothesis was that night setting would result in lower seabird mortalities. While quantitative observations of seabird behaviors in the dark could not be collected during night setting operations, it was found that mortalities per unit effort (MPUE) during night portions of setting operations during this study were far lower than during daylight portions of sets (see Section 5.4). Albatrosses were seen landing in close proximity to the bright, buoyant chemical lightsticks attached to branchlines during night portions of swordfish sets. These lightsticks slow the sink rate of baited hooks and illuminate the baits, increasing the risk of seabird interactions. Seabirds taking up lightsticks can bring baited hooks to the surface or within diving range.

It has been noted that Laysan albatrosses have somewhat better night vision than black-footed albatrosses. A comparison of optical density units (D) of rhodopsin in the eyes of these species indicates that Laysan albatrosses are much better adapted for nocturnal vision than black-footed albatrosses, the former having 16 D/gram and the latter having 4 D/gram (Harrison et al. 1985). The majority of night mortalities during this project were Laysan albatrosses. On one trip, hooks set at night with no mitigation method in use (occurring within the U.S. EEZ in proximity to Midway

Island), resulted in 15 Laysan albatross mortalities, compared to 3 black-footed albatross mortalities. Laysan albatross night feeding behaviors in close proximity to breeding colonies should be an issue of great concern.

Intrusiveness. This technique reduces available setting options with regard to time and moon phase (see Section 7.7).

Crew Safety. Safety concerns associated with night setting are minimal since the major portion of most swordfish sets currently occur in the dark. If towed deterrents are used during night setting, entanglements with fishing gear, which occur far behind the vessel, may not be recognized until something breaks. Using blue-dyed baits during night setting may reduce the need for a towed deterrent.

Effects on CPUE. Night Setting may have an effect on CPUE related to optimal fishing times (see Section 7.7).

Cost. There are no costs associated with this measure.

Advantages.

- Swordfish vessels commonly set at night; therefore, this technique may have more intrinsic acceptance by fishermen.
- Weather and sea condition are not a factor in the effectiveness of this mitigation method.
- No additional costs incurred by vessels.
- Requires no additional crew duties.
- Minimal safety concerns.
- Can be monitored for compliance by Vessel Monitoring Systems (VMS) technology.

Disadvantages.

- Requires modification of existing VMS program to monitor time of gear deployment.
- Area-specific setting times will have to be devised based upon latitude and longitude.
- VMS is not currently mandatory for vessels not leaving from, or landing fish in, Hawaii ports.
- Some fishermen feel this will reduce the amount of sleep time available (see Section 6.0).

Compliance Monitoring. This strategy has the highest compliance monitoring potential as all Hawaii longline vessels currently have mandatory electronic VMS aboard. If this technology is modified, it may allow monitoring of the beginning and ending times for setting.

7.4 Blue-Dyed Bait

Strategy. The strategy employed by this mitigation measure is to camouflage baited hooks. Dyeing baits blue to match the color of the surrounding ocean reduces bait visibility when seen from above.

Effect on Seabird Behavior During Setting. Squid baits that have been dyed a deep azure blue have remarkable effects on seabird foraging behaviors. It is not known whether seabirds do not see blue well; the matching blue of the ocean and dyed bait acts as camouflage (reduced contrast); or, the seabirds no longer consider the dyed squid as food. In many cases, seabirds that were actively pursuing natural-colored baits would completely ignore dyed baits that were obviously within view and range of the seabirds. Their foraging behavior towards dyed baits were greatly reduced during both setting and hauling operations. Seabirds that landed close to these blue baits were less likely to dive for them. If a seabird did pick up a blue-dyed bait, the other seabirds were not as likely to try to take it away. This was especially the case when there were few seabirds in the area.

It should be noted that on some occasions, Laysan albatrosses were considerably more aggressive in their pursuits of blue baits than black-footed albatrosses in the same area. Further study is required to determine whether this is attributable to the Laysan albatrosses' natural aggressiveness in foraging closer to vessels where baits are near the surface.

Effect on Seabird Behavior During Hauling. After many hours in the water, the blue color of the bait fades somewhat, but the seabirds still did not pursue the trailing blue baited hooks or discarded blue baits with the same vigor as natural baits or discarded offal (see Section 5.3). Seabirds would occasionally chase or land in close proximity to the dyed bait, and sometimes even duck their heads under water to look at it, but rarely dove or competed for it in the aggressive manner exhibited toward natural baits. Seabirds that were actively chasing a baited hook splashing along behind the boat were less likely to pick up the blue-dyed bait if the boat slowed or the bait was discarded in plain view of the seabird. If a seabird picked up a blue bait, it was often seen to hold, peck, or toy with it for longer than they would a natural bait. In some instances seabirds have discarded the dyed baits.

During observed gear hauls, blue-dyed baits reduced attempts by 67 percent, whereas tori lines and towed buoys reduced attempts by 93 percent and 87 percent, respectively (see Section 5.3). The seabird-scaring lines provide a visible physical barrier to seabirds attempting to approach the baited hook. It is notable that dyed baits reduced interactions (contacts with fishing gear) during the haul by 93 percent, which was equal to the effectiveness of the tori line and greater than the towed buoy system (see Section 5.3.1).

Intrusiveness. The process of dyeing bait required some preliminary preparation of the dye solution, and thawing and separating individual baits prior to immersion in the blue food coloring solution. This should be of minimal concern, as the sink rate of thawed baits is increased and reduces bait loss to seabirds. Vessel personnel handling the dye and baits were supplied with leak-proof gloves. Additional clean-up time is required, but the dye is water-soluble and is easily removed. Bait dyeing is intrusive in that it affects every bait, and fishermen will be concerned with its effect on CPUE.

Crew Safety. Crew safety was not affected by the use of dyed bait. It is a non-toxic food coloring. The only precaution suggested is that powdered dye be mixed with water in a place where the wind will not blow the fine powder into one's eyes. This concentrated solution can then be added to ordinary seawater in a barrel on deck. This method did not effect vessel maneuverability and was safe and effective even under adverse weather conditions.

Effects on CPUE. Project data indicate that blue-dyed baits may increase CPUE (see Sections 5.7 and 7.7).

Cost. Current retail price for one container of Virginia Dare FDC No. 1 Blue Food Additive is \$53.20. This will dye approximately four sets of 1,000 baits. The price per container should be less if dye is purchased by the case. A 40-gallon bucket that serves as the dye container should cost about \$35.00, and a mesh basket that fits inside the 40-gallon bucket should cost about \$7.00.

Advantages.

- Blue-dyed baits' effectiveness as a mitigation measure is not affected by adverse weather conditions.
- This measure works throughout the Zone of Opportunity. In fact, the farther behind the boat the baited hook gets, the deeper it will be and the greater the camouflage effect of the surrounding water.
- The use of these baits does not affect vessel maneuverability in any way.
- Baits that are unprotected by towed deterrents (due to propeller turbulence, when the towed deterrent breaks or becomes entangled, or when the bait passes beyond the aerial streamer portion) still retain a degree of protection.
- There are no safety issues associated with dyed baits.
- If the bait is dyed just prior to use, thawing of the baits will be assured, thereby increasing the sink rate.
- There are no changes to current fishing gear or practices other than the bait dyeing process.
- CPUE does not appear to be adversely affected.
- Dyed baits remain effective for reducing attempts and interactions during hauling operations, but at a lower level than during sets.
- Blue-dyed baits have been used to reduce bait losses to seabirds and increase swordfish CPUE in this fishery in the past (Gallimore, pers. comm.).
- Fishermen surveyed during this project felt that this was a measure they were willing to use (see Section 6.0).
- Bait loss to seabirds should be reduced, leaving more baited hooks to catch fish.

Disadvantages.

- Dyeing the baits is intrusive in that it affects each bait.
- Bait dyeing requires some preparation.
- Bait must be monitored to assure that it remains in the dye solution long enough to become thoroughly darkened for maximum effectiveness.
- May require some extra clean-up time.

Compliance Monitoring. Monitoring the use of dyed baits will be difficult. There is no way to assure that baits are being dyed without an observer on board or via at-sea inspection. In the future, bait suppliers may find incentive to provide the fishery with pre-dyed bait. Until that time, its use will depend entirely on education and acceptance by vessel operators.

7.5 No Offal Discards

Strategy. This mitigation measure was tested to determine its effectiveness in reducing attraction to baited hooks by reducing attraction to vessel and fishing gear. This is most relevant during the haul because there are few baits and little or no offal being discarded during setting operations (see Section 4.1.5).

Effect on Seabird Behavior. By not feeding seabirds while hooks are present in the water, the seabirds' behavior of following the fishing vessel is expected to be reduced (Brothers 1995). Additionally, seabirds should not mistake baited hooks as safe forage, such as discarded offal; however, data collected through this project show significant increases in attempts and interactions. When this method was employed, seabirds followed closer to the vessel and attempted to forage on the only food available, i.e., baited hooks.

Intrusiveness. Retention of sharks and other fish bycatch can result in large quantities of fish stored on the deck over the course of the haul, which can lead to possible safety concerns. Some extra effort is required to retain, move, and store offal and bycatch. Smell from retained offal can become offensive.

Crew safety. Crew safety concerns are minimal. Rough weather can make retaining offal and bycatch on board more hazardous. Retained sharks can bite the unwary, and billfish bills can pose a safety hazard.

Effects on CPUE. No offal discards have minimal effects on CPUE (see Sections 5.7 and 7.7).

Cost. Five-gallon buckets are readily available on vessels from engine oil changes. Three large garbage containers at less than $50.00 each.

Advantages.

- Requires simple modification of fishing practices.

Disadvantages.

- Retaining offal significantly increases the rate of attempts and interactions.
- Applicable mainly to hauls, as few baits and no offal are discarded during sets.
- Discarded baits and offal may constitute a major source of food for seabirds.
- Piles of bycatch and containers of offal reduce the amount of available deck space.
- Fishing crews may be unwilling to retain large amounts of bycatch and offal.
- Smell from offal can become offensive.
- Fishermen prefer a technique of jerking the branchline such that most or all of the bait comes off in the water making it easier to haul in and not requiring the bait to be removed by hand.

Compliance Monitoring. Compliance monitoring will be difficult without aerial monitoring or at-sea monitoring by onboard observers or the USCG.

7.6 Strategic Offal Discards (SOD)

Strategy. Strategic offal discards distract seabirds away from baited hooks. By periodically discarding large stationary floating offal, such as split swordfish heads, on the opposite side of the vessel from where baits enter the water, seabirds were decoyed away from the baited hooks. The vessel then moved away from the seabirds as they sit on the water feeding. As seabirds resumed pursuit of the vessel, more offal was strategically discarded in plain view of the seabirds.

Effect on Seabird Behavior. This method employs seabirds' natural foraging behaviors to distract them away from the vessel and baited hooks. Seabirds often land on the water next to other seabirds that appear to be feeding. This "mobbing" behavior attracts other seabirds. Large groups of seabirds land at a single halved swordfish head or other piece of offal. After the mobbing ends, the seabirds will often sit together "rafting" (resting and preening) on the water's surface rather than immediately resuming pursuit of the vessel. During this time, the vessel has moved away from the seabirds at approximately 8 knots. If the seabirds choose to pursue the vessel, they come upon other groups of seabirds feeding on consecutive strategic offal discards and often land there as well. In general, seabirds appeared to expend the least possible energy to assure a meal. They are social feeders and this method effectively takes advantage of this behavioral trait. Seabirds may become sated and stop following the vessel.

Intrusiveness. This method required retention and preparation of offal from hauls for use on sets. It also required a crewman to monitor the approaching seabirds and discard the offal at the appropriate time to distract the seabirds away from the baited hooks. Depending on the size of the crew, this can reduce the manpower available for fishing activities.

Crew safety. Crew safety is not affected by this method.

Effects on CPUE. Strategic offal discards has minimal effects on CPUE (see Sections 5.7 and 7.7).

Cost. Five-gallon buckets are readily available on vessels from engine oil changes; and three large garbage containers at less than $50.00 each.

Advantages.

- This method was developed by pelagic longline fishermen and may have more intrinsic acceptance by fishermen.
- Temporarily reduces seabird abundance around the fishing vessel.
- Distracts seabirds away from baited hooks.
- No cost to fishermen.
- Works in all weather conditions.
- No safety concerns for crews.
- When catch rates are high or seabirds are not present, offal may be frozen for future use.
- Frozen offal floats better and is harder for seabirds to pick apart.
- Some fishermen enjoy feeding the seabirds.

Disadvantages.

- Requires full attention of at least one crewman to be done effectively.
- Requires modification of fishing practices and monitoring of seabird abundance levels by crew.
- Requires storage and preparation of offal prior to setting operations.
- When fish catch rate is low, offal may not be available.
- Mainly applicable to vessels setting or hauling during the day.
- Retaining offal during hauls has been shown to increase attempts and interactions with fishing gear. Note: baits may be discarded strategically during the haul to reduce interactions while larger offal is retained for sets.
- Fishermen prefer a technique of jerking the branchline such that most or all of the bait comes off in the water, making it easier to haul in and not requiring the bait to be removed by hand.
- While temporarily reducing seabird abundance in close proximity to baited hooks, offal discards provide long term positive reinforcement for following fishing vessels.

Compliance Monitoring. Monitoring will be difficult without aerial surveillance or at-sea monitoring by onboard observers or the USCG.

7.7 Effects of Mitigation Measures on CPUE

Maintaining acceptable levels of CPUE is a crucial component to acceptance of seabird bycatch reduction measures.

A wide range of factors affect the CPUE for pelagic longline fishing gear. Longline vessels deploy as much as 55 miles of gear in a single set. Currents, water temperature, bait quality, bait loss to small fish and squid, the amount of time the bait is in the water (soak time), presence or absence of chemical lightsticks, and hook size can vary along the mainline within a single set. Great variation in CPUE can occur between sets over the same area on consecutive days. It should be stressed that, with the exception of no offal discards, all mitigation measures reduced seabird interactions and in turn reduced bait loss to seabirds. In order to determine the effectiveness of mitigation measures being tested in relation to each other and control periods, measures were not tested in combination. Combining these measures during fishing operations, may result in greater reductions in bait loss to seabirds (Brothers 1995).

Tori Lines and Towed Buoys. Tori lines and towed buoy systems were effective at reducing seabird interactions with fishing gear. The effectiveness of these towed deterrents to reduce bait losses to seabirds, and thereby increase CPUE potential, is dependent upon deterrent construction, deployment, seabird abundance, species, fishing gear type, bait thawing, weather, and sea state. Towed buoy systems proved to be somewhat better at deterring seabirds away from baited hooks (see Section 5.2.2); therefore, CPUE potential should be higher for towed buoy systems. It was recognized from the outset of this study that tori lines and towed buoy systems would have little or no negative effect on CPUE. These deterrents are fixed to the vessel and trail on the surface as the fishing gear is set and hauled. The hooks are close to the deterrent for less than 30 seconds during line setting. Any negative effects are attributable to loss of course change options once the deterrent is deployed or to entanglements with fishing gear. Usually, if an entanglement occurred, the deterrent was immediately cut free from the vessel and retrieved during the haul.

Night Setting. Swordfish feed near the surface at night. Most swordfish hooks are set in darkness, even when sets begin in the evening. Some swordfish fishermen prefer to begin setting shortly before dark and begin hauling at first light to have the gear in place so that hooks are encountered by the fish on their upward diurnal migration and again as they return to deeper water in the morning. Others determine optimal setting times based upon the moon phase. There may be some reduction in CPUE if sets do not begin before dark. Potential bait loss to small fish, squid, and seabirds also affect CPUE and setting time decisions. CPUE potential based on the these factors is countered by the intensity of seabird foraging (bait loss) just prior to dark.

Blue-dyed Baits. The evolution of bait dyeing in American pelagic longline fishing has not been documented. It is known that some fishermen on the East Coast (Atlantic Ocean) began experimenting with various colored baits as early as the mid-1970s (Gates, pers. comm.). The goal at that time was to increase CPUE of target species. It is not clear when it was discovered that blue-dyed baits resulted in reductions in bait losses to seabirds. At some point, American pelagic longline fishermen found that a variety of different colored squid baits were effective for targeting swordfish (Plate 14). A key difference was that seabirds did not take blue-dyed baits as often as red, green, or natural colored ones (Gallimore, pers. comm.; Gates, pers. comm.).

CPUE data for analysis were collected on sets where both blue-dyed and natural (control) baits were combined. Although blue-dyed baits' placement along the mainline was not perfectly randomized during this study, the total number of dyed and natural baits was relatively equal. Seabird bait-taking behaviors towards blue-dyed squid were greatly reduced on sets during this project.

Many sets had higher CPUE in dyed sections that were set well after dark or when no seabirds were present. Swordfish sets combining dyed and natural baits during this study resulted in a higher overall swordfish CPUE (see Section 5.7). It is noteworthy that overall CPUE for blue sharks (*Prionace glauca*) on sets where blue-dyed and natural baits were combined shows a lower catch rate for these sharks by blue-dyed baits.

Dyeing of samna (saury) baits was tested on two sets during the tuna trip. While not a statistically large sample, CPUE for bigeye tuna was higher for blue-dyed baits on both sets (see Section 5.7).

CPUE data and positive feedback from fishermen during this study indicate that blue-dyed baits effectiveness at reducing bycatch of seabirds may outweigh concerns that bait color have a negative effects on CPUE.

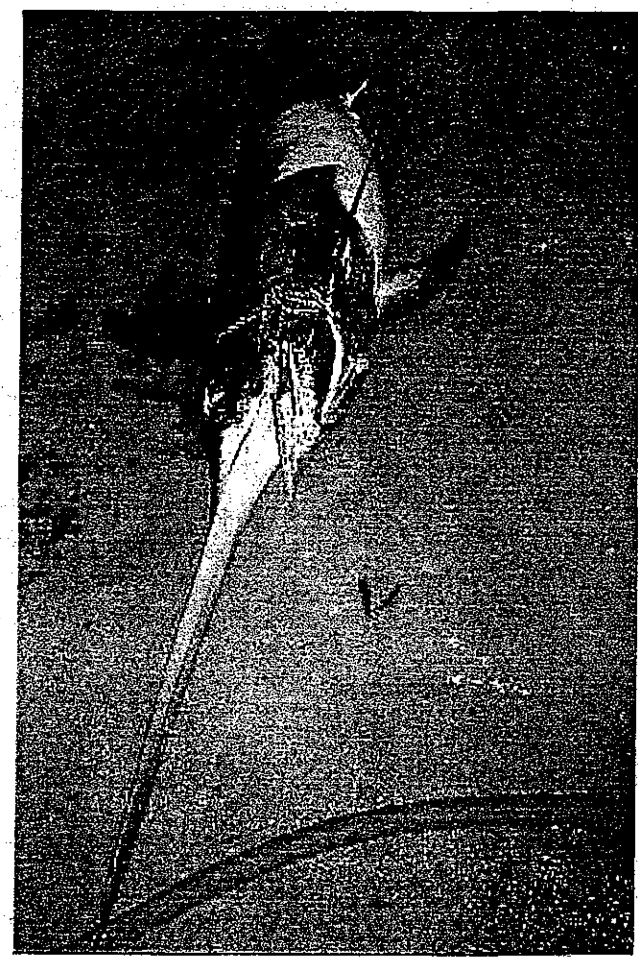

Plate 14. Blue-dyed bait were effective for catching target species.

No Offal Discards. The practice of retaining offal to reduce seabird longline interactions during setting operations was found to be of minimal testable value in terms of CPUE as it was restricted to its effectiveness for reducing interactions while gear was being retrieved during daylight hours. Discarding offal at any time may draw fish to the vessel and fishing gear and increase CPUE. This is known as "chumming." Chumming is a known method for attracting sharks. Sharks may damage saleable fish and take baits that were intended for target species. Chumming is not the intended purpose of offal discarded in this fishery. Offal and bycatch are discarded at sea as caught because of the length of trips and lack of suitable space for retention.

Strategic Offal Discards. The effects of SOD on CPUE will have effects similar to those mentioned above. SOD was developed by fishermen to reduce bait loss to albatrosses and thereby increase CPUE. If this practice did not increase CPUE, fishermen would probably have not continued to use it. Most swordfish sets begin at sunset or evening. The baits that enter the water at the beginning of sets have the longest soak time and the highest potential CPUE. Strategic offal discards are most effective at reducing bait loss during this time. The greater portion of swordfish sets continue into darkness when seabird foraging and visibility of the strategic offal discards are reduced.

Summary of Effects of CPUE. All of the methods listed above can increase CPUE by reducing bait loss to seabirds. Tori lines and towed buoy systems are above water and have no intrinsic effect on CPUE. No offal discards and strategic offal discards may affect CPUE to a minimal degree based on "chumming." Night setting may adversely affect CPUE depending on target species, vessel gear type, and current setting practices. During this project, using blue-dyed baits resulted in increases in overall CPUE over natural baits. Of all mitigation methods tested during this project, bait dying and night setting have the highest potential effects on CPUE and also the highest potential for reducing mortalities of seabirds.

7.8 Qualitative Discussion Summary

The purpose of the qualitative discussion section was to examine the factors that determined the effectiveness of the seabird bycatch mitigation methods being tested, their intrusiveness on fishing operations, and their implementation should use of these measures become mandatory.

Some key findings of the qualitative analysis are that blue-dyed baits (camouflage), strategic offal discards (distraction), and night setting (reduced visibility) were very effective methods for reducing seabird longline interactions and mortalities on swordfish sets. These methods have the major benefit of not being influenced by weather or sea conditions. These methods were also the least intrusive into fishing operations and had the fewest cost and safety issues. Night setting is both effective against mortalities and may be monitored for compliance with some modifications to the VMS system.

Strategic offal discarding and blue-dyed baits are techniques that have been used effectively by some fishermen in this fishery for many years. Integration of these techniques into normal swordfish fishing practices may be more readily accepted by fishermen. The towed buoy system (deterrent) and tori line (deterrent) were also effective during line setting and hauls. These deterrents were more intrusive in fishing operations because they reduce vessel course change options and required monitoring to avoid entanglements with fishing gear. The effectiveness of these mitigation methods can be greatly reduced in rough weather.

8.0 RECOMMENDATIONS

The following recommendations are provided to WESPAC as a framework for actions that may be initiated to reduce the mortalities of albatrosses in the Hawaii pelagic longline fishery. These recommendations are based on qualitative and quantitative findings from the Hawaii Longline Seabird Mortality Mitigation Project, review of seabird bycatch mitigation methods used in other fisheries, NMFS Hawaii Longline Observer Program data, and feedback from fishermen. Recommendations were developed with an understanding that there is a major division in this fishery (swordfish vessels and tuna vessels) based upon vessel fishing gear configuration, fishing practices, and principal target species. The levels of seabird mortalities incurred by each segment are not equal. For this reason, different recommendations have been made for tuna vessels as opposed to swordfish vessels. It is known that swordfish vessels fishing north of the Hawaiian Islands are responsible for the vast majority of seabird mortalities in this fishery (NMFS 1998). A more comprehensive suite of mitigation methods has been provided for these vessels.

Data collected during this study indicate that all mitigation methods tested, with the exception of no offal discarding, significantly reduced the number of seabird interactions during pelagic longline fishing operations. The data also show that none of these measures alone will completely eliminate bycatch of albatrosses by the Hawaii pelagic longline fishery. This conclusion has previously been reached in pelagic longline fisheries in the southern oceans (Brothers 1995; Alexander et al. 1997). Brothers states that "No solution on its own is totally effective but combinations of solutions can almost completely prevent bait loss and the death of birds" (Brothers 1995:6).

The authors believe that implementation of a combination of mechanical and non-mechanical mitigation methods (i.e., bird-scaring devices with bait camouflage, distraction, and bait visibility reduction strategies) and simple changes to common fishing practices will produce the greatest reduction in seabird interactions for the Hawaii pelagic longline fishery as well. Using a combination of mitigation methods may provide continued protection if seabirds become habituated to a given mitigation method, weather conditions reduce its effectiveness, or breakdowns occur.

Night setting, blue-dyed baits, and strategic offal discarding are simple and effective methods that serve to reduce the visibility of bait or distract birds away from fishing operations. They are non-mechanical methods; their effectiveness is not adversely affected by high winds or rough seas.

The towed buoy system and tori line are bird-scaring devices. They provide a physical, visible barrier that effectively reduce the seabirds' ability to approach baited hooks. Their effectiveness can be reduced by high winds and rough seas. When these conditions cause breakdowns, baited hooks will be unprotected until the deterrent is repaired, unless one of the non-mechanical mitigation methods is also in use.

The findings and recommendations of this study are based on current Hawaii pelagic longline swordfish and tuna vessel gear configurations. The effectiveness of seabird bycatch mitigation measures are highly dependent on fishing gear construction and deployment. If changes are made to current fishing gear or practices, alterations to these recommendations may be required.

As noted above, Hawaii pelagic longline vessels targeting swordfish are responsible for the majority of albatross mortalities experienced by the Hawaii pelagic longline fleet. Additionally, NMFS Observer Program data shows that little swordfishing effort takes place below 25° north latitude (WPRFMC 1999). In order to protect seabird colonies on French Frigate Shoals in the Northwest Hawaiian Islands, the recommendations that follow incorporate a demarcation at 23° north latitude. Research also shows that four-fifths of the Hawaii pelagic longline tuna targeting fishing trips occur south of 23° north latitude (He et al. 1997). Therefore, the recommendations take into consideration the far lower numbers of seabird takes experienced by this segment of the fleet. All vessels in the Hawaii pelagic longline fishery would still be required to employ seabird bycatch mitigation measures below 23° north latitude when seabirds are present.

The authors wish to direct attention to promising new underwater setting technology currently undergoing field testing on pelagic longline vessels by the New Zealand Department of Conservation. This stern mounted bait setting funnel is used to deploy baited hooks below the water's surface, effectively reducing seabirds' ability to interact with baited hooks (Molloy, pers. comm.). This device may prove highly effective for the seabird species encountered by the Hawaii pelagic longline fishery.

8.1 Recommendations for Tuna Vessels

Tuna vessels are defined as vessels targeting bigeye tuna, using a mainline shooter, 18–28 branchlines between suspender floats, using weights 45–80 grams within 1 m of the hook, using sanma (saury) for bait, and not using chemical light sticks.

8.1.1 Tuna Setting: Daytime Setting Allowed. The following recommendations are for all vessels fishing above 23° north and for vessels fishing below 23° north when seabirds are present.

- Deploy a seabird-scaring line (tori line or towed buoy system) with effective streamers throughout the towline and a terminal buoy.

- Employ aerial streamers that are a minimum of 1 m in length and that remain aloft 50 m behind the vessel or beyond the point where baited hooks sink below the diving range of the seabirds.

- Use and adjust pole or attachment point for the seabird-scaring line to ensure that the aerial portion covers the area where seabirds can take baited hooks throughout the set, regardless of wind direction and sea condition.

- Ensure that baited hooks enter the water under the protection of the aerial portion of the seabird-scaring line.

- Dispose of all offal/discard baits on the opposite side of the vessel from where baited hooks enter the water, and in such a manner as to best distract seabirds away from the vessel and fishing operations.

GANDA recommends that WESPAC consider these additional measures:

- Continue to use sinkers/weights of at least 45 grams on branchlines.

- Continue placing sinkers/weights within 1 m of the hook and attach to the hook by a wire leader.

- Continue current use of tuna/ring hooks.

- Completely thaw baits and deflate swim bladders.

- If seabirds are taking baits with a mitigation measure in place, cease the set until one hour after dark.

- Determine the maximum allowable number seabird takes for the fishery and enact area restrictions when it is reached.

- Consider an extension of protected zones (currently 50 miles nautical miles) around colonies due to the high density of seabirds in these areas.

- Require the completion of a mandatory seabird bycatch reduction education program in order to receive a commercial fishing license.

8.1.2 Tuna Hauling. The following recommendations are for all vessels fishing above 23° north and for vessels fishing below 23° north when seabirds are present.

- If seabirds are present, or hauling occurs during daylight hours, tow a seabird-scaring line with streamers and a terminal buoy. The length of the streamer line should be sufficient to keep the aerial portion of the line aloft beyond trailing branchlines.

- Retain baits and offal for use as strategic offal discards or discard on the opposite side of the vessel from baited hooks.

GANDA recommends that WESPAC consider these additional measures:

- Minimize deck lighting during the haul, especially in the area where baited hooks may trail behind the boat.

- Stop vessel when seabirds are hooked or entangled during hauls, or encountered still alive from the set, and back up to the seabird rather than hauling the seabird to the boat by the branchline.

- Have bolt cutters and pliers available on deck to facilitate safe removal of hooks from injured seabirds.

8.2 Recommendations for Swordfish/Mixed/Switcher Vessels

Vessels included in this category are all vessels, whether using a mainline shooter (other than those meeting the fishing gear parameters listed above), targeting swordfish or other species, deploying less than 18 branchlines between suspender floats, attaching weights to branchlines more than 1 m from the hook, using "J"-shaped open gap hooks, using squid for bait, and using any number of chemical light sticks.

8.2.1 Swordfish Setting: No Daylight Setting Allowed. The following recommendations are for all vessels fishing above 23° north and for vessels fishing below 23° north when seabirds are present.

- Do not begin setting until at least one hour after sunset and complete setting at least one hour before sunrise.
- Use baits that are dyed dark blue throughout the entire set.
- Deploy a seabird-scaring line (tori line or towed buoy system) at least 150 m long, with effective streamers throughout the towline and a terminal buoy.
- Employ aerial streamers that are a minimum of 1 m long and that remain aloft at least 50 m behind the vessel.
- Use and adjust pole or attachment point for the seabird-scaring line to ensure that the aerial portion covers the area where seabirds can take baited hooks throughout the set, regardless of wind direction and sea condition.
- Ensure that baited hooks enter the water under the protection of the aerial portion of the seabird-scaring line.
- Use strategic offal discarding to decoy seabirds away from the vessel and baited hooks.

GANDA recommends that WESPAC consider these additional measures:

- Completely thaw baits.
- Continue using sinkers/weights of at least 60 grams (preferably 80 grams) on branchlines.
- Place chemical light sticks, attached to branchlines, between the mainline snap and the branchline weight.
- Minimize vessel lighting for the entire set, particularly lights that shine aft.
- Determine the maximum allowable number of seabird takes for the fishery and enact area restrictions when it is reached.

- Consider an extension of protected zones (currently 50 nautical miles) around colonies due to the high density of seabirds in these areas.

- Consider monitoring night setting electronically via VMS. (Note: this will require modification to VMS technology.)

- Require the completion of a mandatory seabird bycatch reduction education program in order to receive a commercial fishing license.

8.2.2 Swordfish Hauling. The following recommendations are for all vessels fishing above 23° north and for vessels fishing below 23° north when seabirds are present.

- Baits will remain dyed blue from the set.

- Use a seabird-scaring line with streamers and a terminal buoy.

- Ensure that the aerial portion of the seabird-scaring line remains aloft beyond the trailing hooks.

- Adjust the seabird-scaring line throughout the haul to best cover the area where baited hooks are available to seabirds, depending on wind direction and vessel course.

- Do not discard bait or offal on the hauling side of the vessel. Dispose all offal/discard baits on the opposite side of the vessel from where baited hooks leave the water and in such a manner as to best distract seabirds away from the vessel and fishing operations.

GANDA recommends that WESPAC consider these additional measures:

- Stop vessel when seabirds are hooked or entangled during hauls, or encountered still alive from the set, and back up to the seabird rather than hauling the seabird to the boat by the branchline.

- Have bolt cutters and pliers available on deck to facilitate safe removal of hooks from injured seabirds.

8.3 Strategies to Implement and Ensure Compliance with Regulations

The following recommendations are based on a review of seabird bycatch reduction efforts in other fisheries, experience in the Hawaii pelagic longline fishery, consultations with fishery managers and Hawaii longline fishermen, and representatives from compliance monitoring agencies. It should be understood by all concerned parties that the Hawaii-based pelagic longline vessels are some of the farthest-ranging fishing vessels in the world. Thousands of miles can be covered in the course of a single trip. Depending on vessel size, refrigeration capacity, target species, catch rates, and season, trips may last from ten to fifty days. Vessels may leave Hawaii and land fish in other states. Vessels may leave other states and land fish in Hawaii. Compliance monitoring of mandatory seabird mortality mitigation measures will be problematic, costly, and require ongoing commitment of time, effort, and resources. Compliance by fishermen will be based on costs, benefits, and perceptions of the ability and commitment of enforcement agencies to prosecute violators.

While these problems are not insurmountable, previous attempts to initiate voluntary use of seabird bycatch mitigation methods in this and other fisheries have met with limited success. Mandatory measures have only been marginally more effective. New approaches are needed to ensure compliance with regulations and effective use of seabird bycatch reduction methods by Hawaii pelagic longline vessels. Educating fishermen about the need for these measures is crucial. Providing instructions to fishermen regarding construction and use of measures adapted for this fishery is equally important. Commitment of compliance monitoring resources and effective punishment for violations will determine whether regulations are obeyed. Increased scientific monitoring of the fishery will be needed to determine if seabird mortalities are being reduced. A close working relationship between fishery managers, fishing industry personnel, and enforcement agencies will provide the open communication and flexibility needed to ensure that what works is retained and what does not is changed or eliminated.

8.3.1 Fishing Industry Initiatives

Rewards for Compliance or Innovation. Avoiding seabird bycatch is the responsibility of fishermen and they should be encouraged to solve the problem themselves. Commercial fishermen are the most appropriate source of new mitigation methods. To promote innovation, fishermen who devise methods to increase the sink rate of baited hooks or find other methods to reduce bycatch to near zero levels should be rewarded in some way. For example, the New Zealand government on behalf of New Zealand fishing companies requested CCAMLR to grant an exemption from the night setting requirement in high latitudes due to lack of darkness during night-time hours. CCAMLR considered the request in 1998, and agreed to grant the exemption only south of 65° south, for the two New Zealand flagged and permitted vessels, so long as a line sink rate of 0.3m/sec were met. The two vessels used time depth recorders to prove that they could achieve this sink rate, by weighting the line. They were subsequently given a permit under New Zealand legislation (the Antarctic Marine Living Resources Act 1981).

Scientific Charters. Industry and fishery managers should work together to increase scientific study of bycatch mitigation measures through charters of commercial pelagic longline vessels for scientific purposes. Data collected will better reflect actual fishing realities. Additional research should be conducted on current hook sink rates based on the presence or absence of mainline shooters and branchline construction (i.e., placement of weights, buoyant chemical lightsticks, and hook types), effects of blue-dyed baits on target species CPUE, and the effects of night setting on CPUE for tuna vessels. Underwater setting devices currently being tested in pelagic longline fisheries in the Southern Oceans should be tested in the Hawaii pelagic longline fishery as soon as they are available. Information gained should be shared with fishermen who will benefit from the information and feel they are being included in the fishery management process. Information about benefits of an innovation will then be quickly spread throughout the fleet. Fishery managers and scientists will also gain accurate data and insights about Hawaii longline fishing efforts and seabird bycatch reduction methods.

Industry Leaders and Highliners. Fishery managers should initiate contact with respected fishery leaders and top producing fishermen (a.k.a. highliners). Information disseminated through respected individuals within the fishery will have greater acceptance by fishermen. Special efforts should be made to identify and educate these individuals about the benefits of adoption of bycatch reduction measures. Fishermen are more likely to adopt ideas that have been accepted and implemented by their peers.

Fishermen Associations. Fishermen should be encouraged to form associations so that their interests are looked after by a group rather than individually. Many Hawaii longline fishermen have little understanding of the seriousness of bycatch issues and the effect it can have on their fishery. The need for information is even greater for ethnic groups who may feel disenfranchised by the fishery management system. Vessel owners, operators, and permit holders in the Hawaii longline fishery fall into three main ethnic groups: Vietnamese, Koreans, and Caucasians. There is little communication between these groups, hindering the flow of information on important fishery issues and innovations. For example, the effectiveness of blue-dyed baits for deterring seabirds was not transmitted from Caucasian-manned swordfish vessels to Vietnamese-manned swordfish vessels. The three groups that comprise this fishery should be encouraged to come together and solve their mutual problems. By having fishermen associations dedicated to informing them of regulations and other imperatives that may affect their livelihoods, fishermen will have a forum where they can agree to do something by consensus.

Suppliers, Buyers, and Processors. Shore-side service providers such as marine suppliers, fish buyers, and fish processors have a stake in the preservation of the Hawaii longline fishery. They should be encouraged to take an active role in longline bycatch reduction issues. They have access to fishery management meetings, newspapers, and public opinion that fishermen at sea do not. These businesses have the most contact with fishermen when they are in port. Cooperation between these businesses and fishery managers can increase the flow of information to fishermen.

Value-Added Promotions. The Hawaii longline fishery should be encouraged to immediately and voluntarily initiate use of seabird bycatch reduction measures, thereby reducing negative public perceptions that the fishery is waiting to be "forced" to take action. The industry should then begin marketing its product as caught in a "BIRD SAFE" manner. Competition is fierce from other U.S. fisheries and abroad. Negative public opinion recently resulted in a boycott of swordfish caught by the East Coast longline fishery. The boycott caused ex-vessel prices in Hawaii to fall. The Hawaii longline fishery should act quickly to reduce seabird bycatch, promote positive public opinion, and increase the value of its product by marketing it as "BIRD SAFE."

8.3.2 Educational and Research Initiatives

Bycatch Reduction Certificates. Annually renewable seabird bycatch reduction certificates should be required for longline permit holders, captains, and crewmen. There should be quarterly workshops where educational videos on protected species bycatch issues are shown, hands-on training in construction and use of mitigation measures is provided, and safe seabird release procedures are taught. These should be conducted with Vietnamese and Korean interpreters, as needed. Longline vessels should be required to have one or more certified crewmen aboard while fishing. Two-way information exchange should be promoted during these training sessions so that fishermen will have an opportunity to relate improvements to existing methods or innovative new bycatch reduction techniques.

International Working Groups/Cross Fishery Seminars. Hawaii fishery managers should support, promote, and attend international seabird symposiums to acquire and transmit up-to-date information about seabird bycatch reduction efforts and technologies. Hawaii longline fishery representatives should be among those sponsored to attend. Experienced fishermen from fisheries that have already successfully adopted seabird bycatch mitigation measures should be encouraged to provide training or informational seminars for fishermen and fishery managers in Hawaii concerning design, construction, and usage of successful mitigation gear and techniques.

NMFS Hawaii Longline Observers. NMFS currently has a mandatory observer program in place for Hawaii longline vessels. Observers' main duties are associated with bycatch of sea turtles. Fish morphometric data, biological samples, and seabird information are also collected. NMFS policy is that observers are not to perform compliance monitoring functions. However, observer data collection priorities should be shifted to increase data collection on the effectiveness of seabird bycatch reduction measures. Observers should receive training in construction and usage of seabird bycatch reduction techniques in order to provide a valuable source of experience and information to fishermen. Observer field experiences should be used by fishery managers to evaluate the effectiveness of seabird bycatch reduction regulations. The NMFS Hawaii Longline Observer Program is the most promising source of two-way information about seabird bycatch reduction available.

NMFS Observer Data on Seabird Interactions and Mortalities. The NMFS Hawaii Longline Observer Program database contains information on hundreds of incidental albatross mortalities that have occurred on Hawaii pelagic longline vessels (see Section 3.1.2, Tables 1 and 2). New analyses of this data based on fishing gear parameters will provide valuable information on albatross longline interactions and mortalities. Effects of mainline setting methods (shooter, no-shooter), terminal tackle (weight size, placement, hook type), and lightsticks on mortality rates could also be analyzed. The database could also be used to determine time of interactions/mortalities (daylight/darkness). This information, combined with analysis already completed, can be used by fishery managers and fishermen to focus implementation of seabird bycatch reduction efforts appropriately.

Cross-cultural Education. Fishery managers should be encouraged to initiate and attend a cross-cultural training seminar. Greater awareness of the cultural norms of the three groups in this fishery will provide insight into the most effective strategies for gaining compliance with mandatory mitigation regulations. For example, Hawaii's Vietnamese American longliners cultural norms cause them to avoid self-promotion. This tendency to avoid giving or receiving criticism has resulted in information about seabird bycatch reduction not being transmitted within the group. Few fishermen wish to come forth and perhaps be seen as attempting to control others. Loss of "face" is so important that many fisherman who would like to do more to reduce seabird bycatch feel constrained to remain silent and avoid possible confrontations or ill feelings. Understanding culture-specific norms, values, and strategies for gaining compliance with innovations will create positive and effective communication between fishery managers and the constituents of the fishery.

8.3.3 Compliance Monitoring Options

Electronic Monitoring. Electronic and/or video monitoring are the only compliance monitoring options that can ensure compliance by all vessels. Effective and consistent monitoring is a key element in compliance monitoring of any seabird bycatch reduction regulation. The feasibility of using video monitoring to verify compliance with the mandatory requirement to use bird scaring lines on tuna boats is being investigated in New Zealand (Molloy, pers. com.). Hawaii longline vessels are currently monitored by VMS, which, if modified, has the capacity to determine when and where a vessel is setting gear. Technology exists that can more effectively determine if the mainline reel is turning (SAIC 1999).

Utilizing electronic monitoring methods to ensure compliance with mandatory night setting should be considered. VMS would have to be substantially modified for use in monitoring compliance; however, VMS is the only electronic measure that is currently in place aboard Hawaii longline vessels that has the potential to ensure that all vessels are monitored equally and effectively. Fishermen and vessel owners in the Hawaii longline fishery have stated that they would comply with regulations that are enforced effectively and consistently among all vessels.

Aerial Monitoring. Due to the wide geographic range of fishing effort in this fishery, aerial surveillance may be impractical and economically prohibitive as a compliance monitoring tool. Areas around the Northwest Hawaiian Island seabird colonies have both high levels of seabird abundance and swordfish fishing effort. Periodic aerial fly-overs in these areas by the USCG should be considered.

At-sea Monitoring. Periodic deployment of USCG vessels to areas of high seabird abundance and fishing effort should be considered. This would allow USCG personnel to conduct surveillance and vessel boardings to ascertain if seabird bycatch reduction regulations are being followed. Only USCG vessels have the range and capacity to enforce fishery regulations at sea.

Dockside Inspections. The most feasible monitoring will likely be dockside inspections by USCG or NMFS compliance monitoring officers. The presence of tori lines or towed buoy systems, functional towing poles, bait dye and buckets, or electronic monitoring equipment may be confirmed before and after trips. While these inspections cannot ensure that these methods will be used at sea, they can determine if they are present on vessels.

Rewards. NMFS Enforcement Branch should consider initiating an anonymous reward system to encourage video documentation of vessels fishing without mandatory mitigation measures in place when fishing with seabirds present. This anonymous reward system gives fishermen complying with regulations the opportunity to report violators.

9.0 BIBLIOGRAPHY

Alexander, K., G. Robertson, and R. Gales
1997. The Incidental Mortality of Albatrosses in Longline Fisheries. First International Conference on the Biology and Conservation of Albatrosses, Hobart, Tasmania.

Anderson, David
1998. The Albatross Project: Satellite Tracking of Albatross Flight Patterns. Wake Forest University, Winston-Salem, NC (from web page:www.wfu.edu/albatross).

Audubon
1997. Longline fishing, short-lived birds (a fatalities causes by longline fishing). *Audubon* (99) No. 3:24(1).

Australian Fisheries Management Authority (AFMA)
1996. Australian Fishing Zone (AFZ) Observer Program: Observer Vessel Cruise Log.

BirdLife International
1995. Global Impacts of Fisheries on Seabirds. Paper Prepared by BirdLife International for the London Workshop on Environmental Science, Comprehensive and Consistency in Global Decisions on Ocean Issues. 30 Nov.–2 Dec. 1995. BirdLife International, Cambridge, UK.

Boggs, C.
1999. Deterring Albatross from Taking Baits During Longline Swordfish Sets. In preparation.

Boggs, C., M. Musyl, and R. Brill
1998. Results from archival tagged bigeye tuna. *Hawaii Fishing News* 24(8):5. September 1998.

Brothers, Nigel
1991. Albatross mortality and associated bait loss in the Japanese longline fishery in the southern ocean. *Biol. Conserv.* 55:255–268.

1994. Catching Fish Not Birds. A Guide to Improving Your Longline Fishing Efficiency. Commission for the Conservation of Antarctic Marine Living Resources. 9/20.

1994. Principles of Birdline Construction and Use to Reduce Bait Loss and Bird Deaths During Longline Setting. Commission for the Conservation of Antarctic Marine Living Resources.

1995. Catching Fish Not Birds. Australian Longline Version. Parks and Wildlife Service, Tasmania, Australia.

Brothers, N., and A. Foster
1994. Influence of Bait Quality on Seabird Mortality and Economic Losses in Longline Fishing: An Experimental Approach. Commission for the Conservation of Antarctic Marine Living Resources. 94/24.

1997. Seabird catch rates: an assessment of causes and solutions in Australia's tuna longline fishery. Submitted to *Marine Ornithology*.

Brothers, N., A. Foster, and G. Robertson
1995. The influence of bait quality on the sink rate of bait used in the Japanese longline tuna fishing industry: an experimental approach. *CCAMLR Science* 2:123–129.

Chapman, Lindsay
1995. Introduction of New Fisheries Regulation: Use of Tori Poles and Bird Line to Reduce the Incidental Take of Seabirds During Tuna Longline Operations.

Cook, James
1998. Personal communication. Pacific Ocean Producers, Honolulu, HI.

Commission for the Conservation of Antarctic Marine Living Resource (CCAMLR)
1993. Observations on CCAMLR Specifications for Streamer Lines to Reduce Longline Bycatch of Seabirds.

1994a. Report of the Ad Hoc Working Group on Incidental Mortality Arising from Longline Fishing. *SCCAMLR* XIII Annex 8, 405–440.

1994b. Extract from the Rep. of the Thirteenth Meeting of the Scientific Committee. Hobart, Australia. 24–28 Oct. 1994, 59–74.

1995. An Investigation into the Causes of Seabird Mortality and Solutions to This in the Spanish System of Demersal Longline Fishing for Patagonian Toothfish (*Dissostichus eleginoides*) in the South Atlantic Ocean. Commission for the Conservation of Antarctic Marine Living Resources Fish Stock Assessment Working Group 95/58.

1996a. Scientific Observers Manual. System of International Scientific Observation. Unpaginated Document, CCAMLR, Hobart, Tasmania.

1996b. Fish the Sea Not the Sky. CCAMLR, Hobart, Tasmania.

Cooper, J.
1993. Records of Fishing Hooks Associated with Albatrosses at Bird Island, South Georgia 1992/93. *SCCAMLR* XII/BG/7.

1994. Seabird Mortality from Longline Fisheries: Evidence from Marion and Gough Islands. Commission for the Conservation of Antarctic Marine Living Resources. 94/18.

(in press). Records of fishing hooks associated with albatrosses at Bird Island, South Georgia 1992/93. *Marine Ornithol.*

Cousins, K. and J. Cooper (eds.)
(in prep.). The Population Biology of the Black-footed Albatross in Relation to Mortality Caused by Longline Fishing. Report of a Workshop held in Honolulu, Hawaii. October 8–10, 1998.

Crawley, M.J.
1993. GLIM for Ecologists, p. 379. Oxford, Blackwell Scientific Publications.

Croxall, J.P., P. Rothery, S.P.C. Pickering, and P.A. Prince
1990. Reproductive performance, recruitment, and survival of wandering albatross (*Diamedea exulans)* at Bird Island, South Georgia. *Journal of Animal Ecology* 59:775–796.

de Fries, A
1998. Observer Coverage of the Japanese Longline Fishery Targeting Southern Bluefin Tuna in the Australian Fishing Zone with Emphasis on Recording the Incidental Take of Seabirds. Case Study for the NMFS Workshop on Statistical Methods for Estimating Incidental Takes of Sea Turtles and Seabirds in Longline Fisheries.

Dunn, E
1995. Global Impacts of Fisheries on Seabirds. The London Workshop on Environmental Science, Comprehensiveness and Consistency in Global Decisions on Oceans, London.

Fadely, Brian
1998. Personal communication. NMFS Protected Resources Division, Juneau, Alaska.

Fadely, J, K. Rivera, M. Sigler, J. Karinen, and J. Fujioka
1998. Test Plan to Evaluate Effectiveness of Seabird Avoidance Measures Required in Alaska's Hook-and-Line Groundfish and Halibut Fisheries. National Marine Fisheries Service.

Fisher, H.A
1975. Mortality and survival in the Laysan albatross (*Diomedea immutabilis*). *Pacific Science* 29:279–300.

Flint, Elizabeth
1998. Personal communication. United States Fish and Wildlife Service, Honolulu, HI.

Food and Agricultural Organization of the United Nations (FAO)
1999. Consultation on the Management of Fishing Capacity, Shark Fisheries, and Incidental Catch of Seabirds in Longline Fisheries. Rome, 26–30 1998. International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries.

Foster, A
1994. The wandering albatross: saving a southern seas icon. *Australian Fisheries* 53(11):16–17.

Foy, Mike
1998. Personal communication. Vessel owner, Hawaii pelagic longline fishery.

Furness, R.W.
1981. Estimating the Food Requirements of Seabirds and Seal Populations and Their Interactions with Commercial Fisheries and Fish Stocks. Symposium on Birds of the Sea and Shore, Cape Town.

1982. Competition between fisheries and seabird communities. *Advances in Marine Biology* 30:225–307.

Gallimore, Skip
1998. Personal communication. Vessel owner, Hawaii pelagic longline fishery.

Gales, Rosemary
1993. Cooperative Mechanisms for the Conservation of Albatross. Australian Nature Conservation Agency, Tasmanian Government Printer, Hobart.

(in press). Albatross Populations: Status and Threats. Proceedings of the First International Conference on the Biology and Conservation of Albatrosses, Hobart 1995.

Gates, Steven
1998. Personal communication. Vessel captain, Hawaii pelagic longline fishery.

Gould, P.J., and R. Hobbs
1993. Population dynamics of the Laysan and other albatrosses in the North Pacific. *International North Pacific Fisheries Commission Bulletin* 53:485–487.

Gould, P.J., et al.
1995. Black-footed and Laysan Albatrosses: Tropic Dynamics and Fisheries Interactions. Abstract. First International Albatross Conference, CSIRO, Hobart, Tasmania.

Harrison, C.S., T.S. Hida, and M. Seki
1985. Hawaiian seabird feeding ecology. *Wildl. Monogr.* 85:1–71.

He, Xi, K.A. Bigelow, and C.H. Boggs
1997. Cluster Analysis of longline sets and fishing strategies within the Hawaii-based fishery. *Fisheries Research*. 31:147–158.

Honolulu Advertiser
1998. Tern Island's Albatrosses Rack Up Frequent-Flier Miles. March 28, 1998.

Huin, N., and J.P. Croxall
(in press). Fishing gear, oil and marine debris associated with seabirds at Bird Island, South Georgia, 1993/94. *Marine Ornithol.*

IUCN (World Conservation Union)
1996. Resolutions and Recommendations: Incidental Mortality in Longline Fisheries. Montreal, IUCN.

Johnson, D.H., et al.
1993. Incidental Catch of Marine Birds in the Birds in the North Pacific High Seas.

Kalmer, A.K., R. Fujita, and C. Wurster
1996. Seabird bycatch in longline fisheries. *Pacific Seabirds.* 23(2):3.

Klaer, Neil and Tom Polacheck
1998. The influence of environmental factors and mitigation measures on by-catch rates of seabirds by Japanese longline fishing vessels in the Australian region. *Emu* (1):1–17.

1997. By-catch of albatrosses and other seabirds by Japanese longline fishing vessels in the Australian fishing zone from April 1992 to March 1995. *Emu* (97):150–167.

1995. Japanese Longline Seabird Bycatch in the Australian Fishing Zone April 1991 to March

Kleiber, Pierre
1999. NMFS Honolulu Laboratory Provisional Estimates of Albatross Interactions in the Hawaii-based Domestic Longline Fishery. Presented at 1999 Western Regional Fisheries Management Council Meetings.

Lokkeborg, S
1996. Seabird Bycatch and Bait Loss in Longlining Using Different Setting Methods. Commission for the Conservation of Antarctic Marine Living Resources.

McNamara, Brian, Gail L.G. Kaaialii, and Laura Torre
1998. Research Design for Hawaii Longline Seabird Mortality Mitigation Project.

Melvin, Edward
1998. Personal Communication. University of Washington Sea Grant Program, Washington.

Melvin, E. F., L.L. Conquest, and J. K. Parrish
1997. Seabird by-catch reduction: New Tools for Puget Sound Drift Gillnet Salmon Fisheries. 1996 Sockeye and 1995 Chum Salmon Test Fisheries Final Report. University of Washington Sea Grant Program.

Mendenhall, Vivian
1998. Personal communication. United States Fish and Wildlife Service, Anchorage, Alaska.

Mendenhall, V. and J. Fadely
1997. Update on seabird bycatch issues in the North Pacific. *Pacific Seabirds* 24(1): 6–7.

Mendenhall, V. and C.S. Harrison
1997. Seabirds in Relation to Ecosystem Management of Fisheries. Testimony to the Ecosystem Advisory Panel. 10 Sept. 1997.

Molloy, Janice
1998. Personal communication. Director, Protected Species Office, Dept. of Conservation, Wellington, New Zealand.

Murray, T.E., J.A. Bartle, S.R. Kalish, and P.R. Taylor
1993. Incidental capture of seabirds by Japanese southern bluefin tuna longline vessels in New Zealand Waters 1988–1992. *Bird Conserv. Int.* 3:181–210.

National Marine Fisheries Service (NMFS)
1998. Data on Hawaii pelagic longline seabird interactions and NMFS longline observer data. Honolulu, HI.

O'Toole, Declan
1998. Personal communication. Researcher, Emerald Fisheries Science, Inc. Wellington, New Zealand.

Pacific Seabird Group
1997. Interactions between albatrosses and pelagic longline fisheries in the North Central Pacific. *'Elepaio* 57(6):119–121.

Paul, L.
1997. Albatross bycatch conservation measures. *'Elepaio* 57(6):122.

Polacheck, T., and G. Tuck
1995. Trends in Tuna Longline Fisheries in the Southern Oceans and Implications for Seabird By-catch. CSIRO Marine Laboratories, Hobart, Tasmania.

Robertson, G. (ed.)
1995. First International Conference on the Biology and Conservation of Albatrosses. Hosted by the Australian Antarctic Division and National Parks and Wildlife Service (Tasmania). Abstracts. Hobart, Australia.

Rice, D.W., and K.W. Kenyon
1962. Breeding distribution, history, and populations of North Pacific Albatrosses. Auk 79: 365–386.

Science Applications International Corporation (SAIC)
1999. Automated Fishing Surveillance System Literature. Correspondence to Dr. Don Schug of WESPAC. June 4, 1999.

Scott, Martin
1998. Personal communication. Senior Observer, Australia Fishing Zone Observer Program, A.F.M.A., Canberra, Australia.

Skillman, Robert
1998. Personal communication. Fisheries Biologist, NMFS, Honolulu, HI.

Weimerskirch, H, N. Brothers, and P. Jouventin.
1997. Population dynamics of wandering albatross (*Diamedea exulans)* and Amsterdam albatross *(D. amsterdamensis)* in the Indian Ocean and their relationship with longline fisheries: conservation implications. *Biological Conservation* 79:257–270.

Weimerskirch, H., and P. Jouventin
1987. Population dynamics of the wandering albatross (*Diomedea exulans*) of the Crozet Island: causes and consequences of the population decline. *Oikos* 49:315–322.

Western Pacific Regional Fisheries Management Council (WPRFMC)
1991. Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region, Amendment Three.