Solutions to Seabird Bycatch in Alaska's Demersal Longline Fisheries

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Cover Photo. Left to right, northern fulmars, black-footed albatross, Laysan albatross, and short-tailed albatross feeding on discarded offal.

Executive Summary

The incidental mortality of seabirds in longline fisheries is a serious conservation issue worldwide. In Alaska 10,000 to 27,000 seabirds are hooked each year. Most (75% of total number) are northern fulmars and gulls. However, regulatory and conservation attention is focused on bycatch of the endangered short-tailed albatross. Under the U.S. Fish and Wildlife Service's Biological Opinion, takes exceeding 6 short-tailed albatross within a 2-year period (4 in the groundfish fishery and 2 in the Pacific halibut fishery) would trigger an Endangered Species Act (ESA) Section 7 consultation and could interrupt or close Alaska's $300 million (ex-vessel value) demersal longline fishery. The Biological Opinion requires that mitigation devices be used in the fishery and that research be conducted to test their effectiveness. Our research program stems from this imperative.

This research program compared seabird bycatch mitigation strategies over 2 years (1999 and 2000) in 2 major Alaska demersal longline fisheries: the Gulf of Alaska / Aleutian Island Individual Fishing Quota (IFQ) fishery for sablefish and halibut (referred to as the sablefish fishery) and the Bering Sea catcher-processor longline fishery for Pacific cod (referred to as the cod fishery). We conducted tests over two years to account for inter-annual variation and allow for improvement and innovation. A key feature of this program was an industry-agency-academic collaboration to identify possible deterrents and test them on active fishing vessels under typical fishing conditions. We report the results of experimentally rigorous tests of seabird bycatch deterrents on the local abundance, attack rate, and hooking rate of seabirds in both fisheries. Based on our results, we recommend a suite of bycatch mitigation measures.

Our goal was to identify mitigation devices that significantly reduced seabird bycatch with no loss of target catch or increase in the bycatch of other organisms. Control sets with no deterrent established a baseline and allowed exploration of seabird interaction with longline gear as a function of temporal and spatial variation, physical factors such as wind and sea state, and fishery practices.

Deterrents tested were identified by fishers in an ad-hoc committee process and included a mix of bird scaring strategies and techniques designed to minimize the time baited hooks are at or near the surface. See table "Deterrents by Year".

Participating vessels were recruited in cooperation with the Fishing Vessel Owners Association and the North Pacific Longline Association. Data were collected by specially trained National Marine Fisheries Service (NMFS) certified observers.

Deterrents by Year

	1999	2000
Sablefish Fishery	Added weight (0.5 lb/11 m)	Single streamer line
	Paired streamer lines	Paired streamer lines
		Paired streamer lines with weight
Cod Fishery	Added weight (10 lb/90 m)	Paired streamer lines
	Mustad line shooter	Single streamer line
	Mustad lining tube	Paired streamer lines with weight

In the sablefish fishery, effort was focused along the shelf break at 500 to 800 meters in the central and western Gulf of Alaska and in the Aleutian Islands, in NMFS Management Areas 630-620, 610, and 541-542. In 1999, we fished on 3 vessels from May 14 to June 6 and set over 400,000 hooks in 121 sets. We caught 348 metric tons of fish and 90 seabirds. In 2000, we fished on 5 vessels from April 18 to July 10, nearly doubling the effort to 800,000 hooks (226 sets). We caught 606 metric tons of fish but only 23 seabirds. In both years, seabird bycatch consisted of northern fulmars (1999: 80% of total; 2000: 30% of total), Laysan albatross (18%; 61%) and gulls (2%; 9%).

In the cod fishery, most effort was focused along the 100-meter isobath southeast of the Pribilof Islands in NMFS Management Areas 509, 513, and 517. In 2000, we extended effort farther north into areas 523 and 531 in an attempt to increase interactions with albatrosses. Research was conducted on 2 fishing vessels each year. In 1999, we set almost 2 million hooks (156 sets) in August and caught over 1,500 metric tons of fish and 403 seabirds. In 2000, effort more than doubled to nearly 4.5 million hooks (334 sets) through August and September; we caught 2,800 metric tons of fish but only 27 seabirds. The primary seabirds hooked in both years were northern fulmars (1999: 87% of total; 2000: 70% of total) and short-tailed shearwaters (12%; 26%).

Between years, target fish catch per unit effort (CPUE) remained constant (sablefish fishery) or declined slightly (13% cod fishery in 2000). However, changes in seabird abundance, attack rate, and bycatch as a function of both time (year and time of day) and fishing region (for the sablefish fishery) were dramatic. All measures of seabird interaction with the fisheries were two to three times higher in 1999 relative to 2000. Thus, despite a doubling of sampling effort between years, our absolute seabird catch dropped by 74% (sablefish fishery) and 93% (cod fishery), and sets that captured birds became very rare - 15% in control sets and 5% overall in 2000 (for both fisheries). Extreme inter-annual variation in rare event phenomena such as seabird bycatch has important implications for fisheries management. Specifically, we emphasize that adequate evaluation of seabird bycatch deterrents via observer programs will require multi-year data sets.

There were also dramatic differences in seabird bycatch rates within days. Seabird bycatch was significantly higher (10x) at night and sunrise relative to day and sunset. These differences were driven by interactions with northern fulmar – the dominant species caught in this fishery and the only species caught at night. In the sablefish fishery, one Laysan albatross was caught at night in each year. In regions such as Alaska, where night-active seabird species occur, fishing at night is not an effective seabird bycatch deterrent strategy. We conclude that in the North Pacific, the regulation that allows night fishing alone as a deterrent should be eliminated.

In the sablefish fishery, regional differences were apparent. In both years, seabird bycatch was highest in the Aleutian Islands (10x the Central Gulf of Alaska in 1999) and, in general, appeared to increase as fishing moved west. We caution that our study covered only a subset (3 weeks to 3 months) of the 8-month season and that we deliberately selected times and areas for high seabird interactions. Because comprehensive technical solutions (i.e., paired

streamer lines) were effective across regions, management action calling for regional closures are unnecessary and are not recommended.

Among all deterrents tested, paired streamer lines proved to be the most comprehensive solution. Paired streamer lines successfully reduced seabird bycatch in all years, regions, and fleets (88% to 100% relative to controls with no deterrent), despite the fact that we saw orders of magnitude variation in bycatch across years and in the case of the sablefish fishery, among regions. Paired streamer lines were robust in a wide range of wind conditions and required little adjustment as physical conditions changed. Functionally, paired streamer lines created a moving fence that precluded seabird attacks. Most significantly, this success came with no consequence to catch rates of target-fish or the rate of capture of other bycatch species, thus satisfying our primary goal.

In 2000, paired streamer lines virtually eliminated both Laysan albatross and northern fulmar attacks on baited hooks and completely eliminated albatross and northern fulmar bycatch. In 1999, paired streamer lines were slightly less effective, a difference we attributed to the dramatically higher attack rates in that year, as well as to evolving performance standards. Although short-tailed shearwater attacks were displaced astern with the use of paired streamer lines, these diving birds were able to attack the groundline beyond the effective range of the streamer lines, and bycatch and attack rates of this species were unchanged relative to controls.

Single streamer lines were slightly less effective than paired streamer lines, reducing seabird bycatch by 96 percent and 71 percent in the sablefish and cod fisheries, respectively. Behavioral evidence and qualitative observations support this conclusion. When single streamers were used, Laysan albatross attack rates were five times that of paired streamer deployments. This suggests that the risk of hooking albatrosses, including the short-tailed albatross, remains when single streamer lines are used.

In both fisheries, weighting gear had no negative effect on target catch; however, the effect on seabird bycatch was variable. In 1999, adding weight to the gear in both fisheries significantly reduced seabird bycatch relative to a control of no deterrent (37% for the sablefish fishery, 76% for the cod fishery), although the effect was not as pronounced as for paired streamer lines. In 2000, the addition of weight to the groundline in both fisheries provided no improvement in the already high bycatch reduction of paired streamer lines. Although adding weight to groundlines caused gear to sink faster, differences in vessel speed and vessel characteristics proved much more important. In the cod fishery, the attachment of additional weight to the groundline posed a safety hazard during both deployment and retrieval. For weighting to be a practical seabird bycatch deterrent, the weight should be integrated into the line. Adding weight may be beneficial in some cases - e.g., if seabird interactions are intense, gear is to be set into the updraft of the propeller wash, or is set gear at higher speeds.

The Mustad line shooter tested in the 1999 cod fishery was the only deterrent that significantly increased the rate of seabird bycatch and is, therefore, not recommended. The Mustad lining tube tested in the 1999 cod fishery significantly reduced bycatch to levels comparable to adding weight to the groundline. Because performance was variable and limited by a number of factors, and because the device is costly and inappropriate for some vessels, the Mustad lining tube alone is not a recommended seabird bycatch solution for the Alaska fleet. However, an improved setting funnel that sets gear well below the influence of propeller turbulence and, hence, beyond the diving capability of most seabirds, is likely to provide an efficient and reliable method of seabird avoidance for many fisheries throughout the world.

Several additional measures are discussed, including directed discharge while setting gear and the need for report card and peer-review systems, as well as the need for national and international action.

Paired streamer lines create a moving fence that precludes seabird attacks.

Recommendations

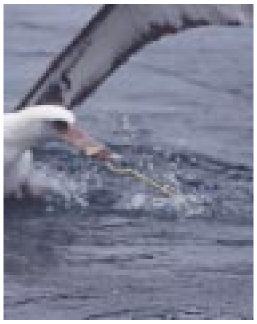
I. REGULATORY ACTION

A. Gear

Based on the results of the research program, we recommend that existing requirements for seabird bycatch reduction (50 CFR Part 679.24(e)(3) Gear Limitations) be replaced with the following requirements.

1. Paired Streamer Lines: All Alaska longline vessels must deploy a minimum of two streamer lines while setting longline gear. If both streamer lines cannot be deployed prior to the first hook, at least one streamer line must be deployed before the first hook and both streamer lines must be fully deployed within 90 seconds. In conditions of wind speeds exceeding 30 knots (near gale or Beaufort 7 conditions), it is acceptable to fly a single streamer line from the windward side of the vessel. In winds exceeding 45 knots (strong gale or Beaufort 9 conditions), the safety of crew supersedes deployment of streamer lines.

2. Performance Standard: Streamer lines must be deployed in such a way that streamers are in the air for a minimum of 40 meters aft of the stern for vessels under 30.5 meters (100 feet) and 60 meters aft of the stern for vessels 30.5 meters or over. The performance standard can be achieved in several ways: by increasing the height off the water at the stern (recommended minimum is 20 feet), minimizing the weight of



Laysan albatross attacking a baited longline hook.

streamer line components, and/or increasing drag at the far end of the streamer line with combinations of drogues, weights, and buoys.

3. Materials Standard: Minimum streamer line specifications include:
Length: 300 feet (~90 meters)
Spacing of streamers: Every 5 meters until performance standard is achieved.
Streamer material: Brightly colored, UV-protected plastic tubing or 3/8 inch polyester line or material of an equivalent density. An individual streamer must hang from the mainline to 0.25 meters of the water in the absence of wind.
Line material: Discretionary
Terminal end: Discretionary
Breakaways: Discretionary, but highly recommended.

B. Operations

We recommend that existing requirements for seabird bycatch reduction (50 CFR Part 679.24(e)(2)(ii) Requirements) be amended to include the following:

1. Directed discharge during the set: All Alaska longline vessels must eliminate directed discharge (through chutes, pipes, etc.) of residual bait or offal from the stern of the vessel while setting gear. Baits falling off the hook or offal discharges from other locations that parallel the gear and subsequently drift into the wake zone well aft of the vessel are not included. Vessels deploying gear amidships must eliminate directed discharge of residual bait or offal over sinking longlines during deployment.

II. Optional Non-Regulatory Actions

Based on qualitative observations, we recommend that the following actions be taken to minimize seabird interactions with longline gear, promote stewardship within the fishing fleet, and address bycatch at national and international levels:

A. Gear

1. Hand-Bait Chutes: Develop methods to deploy weights in a way that prevents longlines from going taut while setting gear. Actions might include a modification to the chute by adding a setting shelf that would prevent the need to lift weights from the deck up the full height of the chute thereby minimizing tension to deployed gear.

2. Auto-Bait Systems: Encourage companies that manufacture and sell auto-bait systems to refine designs to minimize hook foulings.

B. Education and Outreach

1. Report Card: Institute a system to annually inform the owners and operators of longline fishing vessels of their seabird bycatch numbers and rates (per 1,000 hooks) relative to their fleet based on NORPAC data. Fleets include IFQ sablefish, Pacific cod, and Greenland turbot. The Pacific halibut fleet should be included if observer data become available.

2. Peer System: Develop an industry-based peer system to reward vessels that successfully avoid seabird bycatch. Encourage dialogue among fishers to share information and methods to minimize the incidental capture of seabirds.

3. Fleet Education: Develop and deliver an education program targeting vessel owners, operators, and crew, illustrating the proper deployment and use of streamer lines, as well as the need for seabird conservation and related regulations.

4. National Action: Encourage other U.S. fishery management councils, including the Pacific Fishery Management Council and the NMFS Northwest Region, to extend recommended regulatory measures to demersal longline fleets in their jurisdiction. Extend recommended regulatory actions to Pacific halibut fisheries.

5. International Action: At a minimum, all demersal fisheries should use properly deployed paired streamer lines and eliminate directed discharge of residual bait and/or offal over sinking longlines. In the longterm, longlining nations in the Pacific Rim should be encouraged to develop, test and ultimately require seabird bycatch deterrents in their demersal and pelagic longline fisheries which virtually eliminate all seabird bycatch under all fishing conditions without the need for oversight and enforcement.

III. Future Research

Research programs testing seabird deterrent strategies are limited by existing technologies. Continued innovation and technology development are required in Alaska fisheries and worldwide to minimize seabird bycatch in longline fisheries. Accordingly, we recommend the following:

A. Fleet Innovation

Encourage continued development of seabird bycatch avoidance measures by the Alaska fleet.

B. Novel Technologies

Encourage the development of designs and technologies that eliminate the need to fly streamer lines. These include:

1. Underwater Setting. Technologies that deploy longlines below the surface beyond the reach of seabirds (tubes and chutes or novel hull designs).

2. Line Weighting. Fishing line that sinks quickly below the surface but also maintains the handling qualities valued by fishers.

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Introduction

The incidental capture, or bycatch, of marine organisms in fisheries poses serious conservation concern worldwide (Alverson *et al.* 1994, Hall 1996). In particular, bycatch of mammals, turtles, and seabirds has proven problematic due to the sensitivity of these species to even slight increases in adult mortality and the belief of the general public that these charismatic animals must be protected (Hall 1996).

The fact that seabird bycatch events are rare complicates perceptions regarding the need for conservation. For each seabird incidentally taken, hundreds to thousands of target fish will be captured. In many fisheries, the majority of sets are made with no seabird take (Melvin *et al.* 1999; Melvin and Parrish 2001). At the same time, tens to thousands of seabirds feeding on discards typically surround fishing vessels (Furness *et al.* 1988, Hudson and Furness 1988, Garthe and Hüppop 1994, Weimerskirch *et al.* 2000, Skov and Durick 2001). In longline fisheries, the number of birds surrounding the vessel is several orders of magnitude higher than the number caught (Weimerskirch *et al.* 2000). Because birds are abundant on the fishing grounds but rarely caught, individual fishers perceive seabird bycatch as insignificant (Robertson 1998). Only when the cumulative bycatch is considered at the fleet scale (tens to thousands of vessels, depending on fishery) do the numbers grow large. This perceptual paradox prevents fishers and fishery managers from accepting that the incidental capture of seabirds in fisheries can threaten seabird populations and is a serious conservation issue.

Seabirds are long-lived species with delayed maturity and limited reproductive capability. For example, albatross can live 60 to 70 years, do not reproduce until they are age 5 or older, only raise one chick per reproductive attempt, and commonly reproduce every other year (Robertson and Gales 1998). Because of these life-history traits, seabirds are vulnerable to population decline when subject to small increases in adult mortality (Croxall *et al.* 1990, Weimerskirch *et al.* 1997). Humans have directly exploited seabirds by hunting them for feathers, eggs, and meat and have indirectly threatened them by habitat destruction and fisheries bycatch (Nettleship *et al.* 1994, Tasker *et al.* 2000). Although most direct exploitation has declined markedly as conservation awareness has increased, many seabird populations worldwide are in decline (Bergin 1997; Gales 1998).

Whereas world attention was first focused on seabird bycatch in high seas and coastal drift gillnets (DeGange and Day 1991), more recent work in the Southern Ocean has implicated longline fisheries in seabird population declines. For the period 1981-1986, Brothers (1991) estimated that approximately 44,000 albatross were killed each year (0.41 albatross per 1,000 hooks) in the Japanese tuna (*Thunnus* spp.) longline fishery in the Southern Ocean. Subsequently, both pelagic and demersal longline fisheries have been documented taking an unsustainable proportion of seabirds, especially albatross, in the Southern Ocean (Murray *et al.* 1993, Weimerskirch *et al.* 1997, Tasker *et al.* 2000). In the case of wandering albatross (*Diomedea exulans*), an the International Union for the Conservation of Nature (IUCN) internationally endangered species and the initial focus of the Southern Ocean seabird bycatch issue, Croxall *et al.* (1990) estimated that the pelagic longline fishery for southern bluefin tuna (*T. maccoyii*) may be responsible for as much as 2 to 3 percent of annual adult mortality and 14 to 16 percent of subadult mortality. Seabird mortality occurs in longline fisheries when seabirds attack baited hooks at the surface during gear deployment, become hooked and drown. Seabirds can also be hooked as the line is retrieved, but often birds can be released before drowning (Brothers *et al.* 1999a).

The rate at which seabirds are hooked in longline fisheries is highly variable worldwide. Bycatch rates are influenced by the type of fishing gear used (e.g., pelagic or demersal), the seabird species present, as well as temporal (year, season, time of day), spatial, and physical factors (Brothers *et al.* 1999b). In general, seabird bycatch rates or catch per unit effort (CPUE) are reported to be higher in pelagic longline fisheries (0.03 – 5.03 birds per 1,000 hooks) than in demersal fisheries (0.19 – 0.67 birds per 1,000 hooks; Alexander *et al.* 1997), but this trend may change with more recent data. In the Kerguelen Island fishery for toothfish, bycatch rates were highly variable and ranged from 1.08 birds per 1,000 hooks when streamer lines were successfully deployed, to 2.42 birds per 1,000 hooks when streamer line deployment failed (Weimerskirch *et al.* 2000). Because demersal fisheries set many more hooks than pelagic fisheries, the total number of birds caught in demersal fisheries can be high despite lower or similar bycatch rates.

Although concern over the effects of seabird bycatch originated in the southern hemisphere, documentation of seabird bycatch rates from northern latitudes is increasing. In demersal longline fisheries for torsk (*Brosme brosme*) and ling (*Molva molva*) in the North Atlantic, bycatch rates range from 0.4 birds to 1.75 birds per 1,000 hooks and virtually all birds caught have been northern fulmars (*Fulmarus glacialis*; Løkkeborg 1998, 2001, Dunn and Steel 2001). Although northern fulmar populations do not appear to be at risk, and are actually increasing in both range and size (Hatch and Nettleship 1998; Tasker *et al.* 2000), total effort in the Norwegian fleet is large (e.g., 476 million hooks in 1996; Tasker *et al.* 2000). Annual northern fulmar bycatch in the combined Norwegian, Icelandic, and Faeroese longline fleets is estimated conservatively at 50,000 to 100,000, but may be much higher depending on the use of mitigation measures (Dunn and Steel 2001). For the Mediterranean, Belda and Sanchez (2001) reported rates of 0.16 to 0.69 and 0.25 birds per 1,000 hooks for demersal and pelagic longline fisheries, respectively. The principal seabird species caught in both fisheries was Cory's shearwater (*Calonectris diomedea*). Breeding population mortality due to longlining was estimated at 4 percent to 6 percent annually, coinciding with an observed 45 percent decline in local shearwater breeding population size. In the Hawaii-based pelagic longline fishery for tuna and swordfish (*Xiphias gladius*), 1,130 Laysan albatross (*Phoebastria immutabilis*) and 1,743 black-footed albatross (*P. nigripes*) were caught annually between 1994 and 1999 at rates ranging from 0.053 to 0.172 per 1,000 hooks for Laysan and 0.068 to 0.153 per 1,000 hooks for black-footed albatross (Cousins *et al.* 2000, NMFS 2001b).

Longline Fisheries in Alaska

The Alaska demersal longline fishery is an aggregate of over 2,000 vessels, ranging in size from skiffs to ships, targeting groundfish and Pacific halibut (*Hippoglossus stenolepis*) throughout the Gulf of Alaska, the Bering Sea, and the Aleutian Islands. Seabird bycatch in the groundfish fishery (not including halibut) from 1993 to 1999 averaged 17,000 seabirds per year (0.089 birds/1,000 hooks) and ranged from a low of 10,725 seabirds in 1996 (0.061 birds/1,000 hooks) to a high of 27,140 seabirds in 1998 (0.133 birds/1,000 hooks; Figure 1 and Appendix I; NMFS 2001a). Most of the seabirds taken are northern fulmars (59%) and gulls (*Larus* spp.; 16%). Albatross (9%) and shearwaters (*Puffinis* spp.; 4%) are also caught. The remaining 13 percent are mostly unidentified seabirds and small numbers of other species. Most albatross taken are Laysan albatross (5.6%) and black-footed albatross (2%). On average, NMFS estimates two short-tailed albatross (*P. albatrus*) are taken each year (NMFS 2001a). None were observed taken in 1999 or 2000 (NMFS Observer Program, unpublished data).

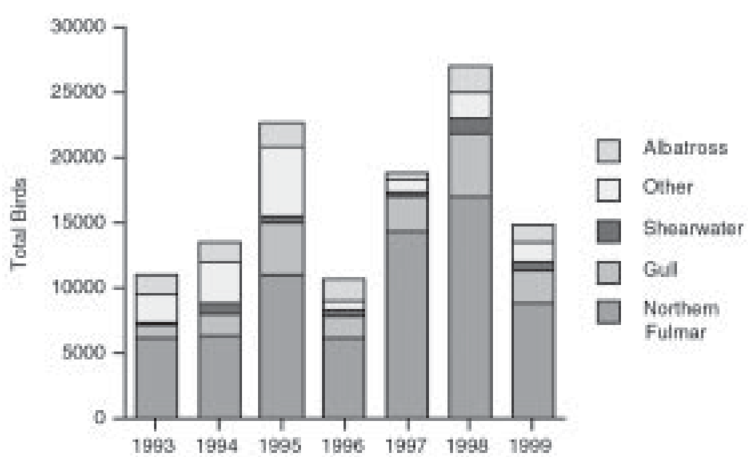

Figure 1. Estimated total seabird mortality by species in Alaskan longline fisheries. **Appendix I includes specific values by geographic area, 1993 to 1999 (NMFS 2001a).**

Short-tailed albatross are the fulcrum of the conservation challenge to the Alaska longline fisheries because of their endangered status. Short-tailed albatross are the only endangered seabird in Alaska offshore waters (Mendenhall and Fadely 1997). The current world population of short-tailed albatross is approximately 1,500 birds (H. Hasegawa, pers. comm. 2001), principally confined to a single colony in the Japanese archipelago, Torishima (1,300 birds), with a minor contingent in the Senkaku Islands (200 birds). Although the population is increasing, low incidence of additional (i.e., human-induced) mortality can be critical to population recovery.

Under the U.S. Endangered Species Act (ESA), agencies whose actions (or actions authorized by that agency) may effect a listed species must consult with the relevant federal stewardship agency, in this case the U.S. Fish and Wildlife Service (USFWS). Consultation by the National Marine Fisheries Service (NMFS) concerning take of short-tailed albatross in the Alaska longline fisheries resulted in the issuance of a Biological Opinion stating that no more than 6 birds could be captured within each two-year period: 3 in the groundfish fishery (USFWS 1999) and two in the Pacific halibut fishery (USFWS 1998). Additional requirements included reporting of all short-tailed albatross bycatch, salvage of dead short-tailed albatross, education of fishers on bycatch avoidance, the use of seabird avoidance measures, and NMFS undertake a study to evaluate the effectiveness of bycatch deterrents (USFWS 1997). Take in excess of these levels would trigger an ESA Section 7 consultation and could interrupt or close a $300 million (ex-vessel value) fishery (NPFMC 2000).

In 1996, IUCN called on all nations to "eliminat[e] seabird bycatch within longline fisheries" (Mendenhall and Fadely 1997). The United Nation's Food and Agriculture Organization has since published an International Plan of Action for Seabirds (IPOA-Seabirds, FAO 1999) with an objective of "reduc[ing] the incidental catch of seabirds in longline fisheries where this occurs." In a comprehensive review of seabird bycatch in longline fisheries, Brothers *et al.* (1999a) identified 61 seabird species incidentally captured, of which 39 percent have been listed as threatened.

Fishers' concerns that seabirds remove baits from hooks with a consequent negative effect on fish catch rates, as well as conservation concerns over seabird bycatch, have motivated experimentation to develop strategies to reduce seabird interactions with longlines (Brothers 1991, Løkkeborg 1998, 2001). In general, bycatch mitigation strategies fall into 3 basic categories (Brothers *et al.* 1999a):

Subsurface Technologies: Various strategies to eliminate or minimize the time baits at or near the surface have been utilized: underwater setting using chutes; tubes or capsules; manipulating vessel speed; adding weight to the groundline or in close proximity to the hook (gangion, snood, or branchline); using line throwers; and reducing bait buoyancy (thawing bait or puncturing swim bladders of bait fish).

Surface Scaring or Deception: Scaring is any technique that scares birds away from the area where hooks are deployed. Scaring includes towing a line or lines parallel to or above sinking baited hooks that prevent birds from accessing sinking hooks (streamer lines -also called tori or bird scaring lines, buoys, boards or sticks), shooting water over sinking baits (water jets), or using concussive sound (gun shots, cracker shells, acoustic cannons). Deception includes coloring baits to make them less visible (Boggs 2001), using artificial lures (pelagic only), or strategically discharging fish waste (offal) to lure birds away from baits and hooks as they sink (Cherel *et al.*1996).

Temporal Manipulation: These strategies include setting gear at night to avoid diurnally active seabird species or modifying fishing seasons to avoid seabird breeding seasons.

High rates of albatross mortality in longline fisheries coupled with the concomitant decline of albatross populations at several breeding colonies in the Southern Ocean (Weimerskirch and Jouventin 1987, Weimerskirch *et al.* 1987, 1989, de la Mare and Kerry 1994) led the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) to adopt seabird bycatch mitigation measures for its 23 member countries in 1992. Soon thereafter, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) required use of bird-scaring lines in member fleets in 1995 (FAO 1999). Several nations (Australia, New Zealand, South Africa, and the U.S.) have implemented regulations requiring the use of specific deterrent strategies to reduce seabird bycatch. The use of streamer lines (single), night fishing, and control of offal discharge during hauling and setting are common to most regulatory packages (Appendix II).

Regulations directed at demersal domestic longline fleets operating in their immediate Exclusive Economic Zone (EEZ) are relatively new, beginning with the Alaska groundfish fishery in 1997. Under the leadership of the North Pacific Longline Association (NPLA), the Alaska groundfish longline industry proposed regulations based on the CCAMLR conservation measures developed in the southern hemisphere fisheries. The regulations were effective on 29 May 1997 (62 FR 23176) and extended to the halibut fishery effective on 6 April 1998 (63 FR 11161). These regulations are similar to CCAMLR measures, but provide more flexibility by allowing the choice of using one or more bycatch reduction measures from an approved list. The list includes setting the gear subsurface through a lining tube, fishing at night, towing streamer lines, and using a towed buoy, board, stick, or other device. In addition to choosing one or more of these measures, vessel operators must use baited hooks that sink as soon as they enter the water and discharge offal in a manner that distracts seabirds (Appendix II).

To date, seabird bycatch avoidance measures in longline fisheries, such as those adopted by CCAMLR, have been developed primarily from post-hoc analyses of observer data (Murray *et al.*1993, Klaer and Polacheck 1995, Duckworth 1995, Gales *et al.* 1998, Brothers *et al.* 1999b) or anecdotal evidence (Brothers 1991). With a few exceptions (Løkkeborg and Bjordal 1992, Cherel *et al.* 1996, Løkkeborg 1996, Agnew *et al*. 2000, Løkkeborg 2000), relatively few studies have been devoted *a priori* to testing specific mitigation measures using an experimental design and controls.

This research project resulted from the requirement within the USFWS Biological Opinion that NMFS evaluate the effectiveness of bycatch deterrents (USFWS 1997) and is the first comprehensive test of deterrent effectiveness in an active demersal longline fishery. Our study was a collaboration of industry, NMFS, USFWS, and the University of Washington. The scope of this report includes results of research conducted over 2 years (1999 and 2000) in 2 unique fisheries: the Gulf of Alaska/Aleutian Island Individual Fishing Quota (IFQ) longline fishery for sablefish (*Anoplopoma fimbria*) and halibut, and the Bering Sea catcher-processor longline fishery for Pacific cod (*Gadus macrocephalus*). We report the results of experimentally rigorous tests of seabird bycatch deterrents on the behavior, attack rate, and hooking rate of seabirds in both fisheries. Finally, based on results, a suite of bycatch mitigation measures for each fishery are recommended.

METHODS

FISHERY DESCRIPTION

In general, demersal longlining is a method of fishing where baited hooks are affixed via a short length (less than 50 cm; 1.6 ft) of line (gangion or snood) to a continuous line (groundline) that is laid on the seafloor for less than 24 hours (Figure 2). The groundline is composed of a series of sub-units, called skates. Anchors are affixed to each end of the groundline. Lines run from the anchors to a flagged buoy at the surface. Multiple gear deployments (sets) and retrievals (hauls) may be made each day. Gear is set as the vessel is underway at speeds from 3 to 10 knots. In a typical set, the buoy and flag are cast into the water, followed by the anchor, and the groundline is pulled off the deck or from racks into the water as the vessel steams away from the anchor. During gear retrieval, the groundline is hauled to the surface with a hydraulic wheel (gurdy) and in some cases a drum. The hooks come up one after the other across a roller, and target fish are gaffed onto the vessel, while non-target fish and remaining baits are cleared from the hook and discarded. Both sablefish and cod longline fishing share these same basic steps. However, they vary in scale, intensity, vessel size, area fished and gear systems (Table 1).

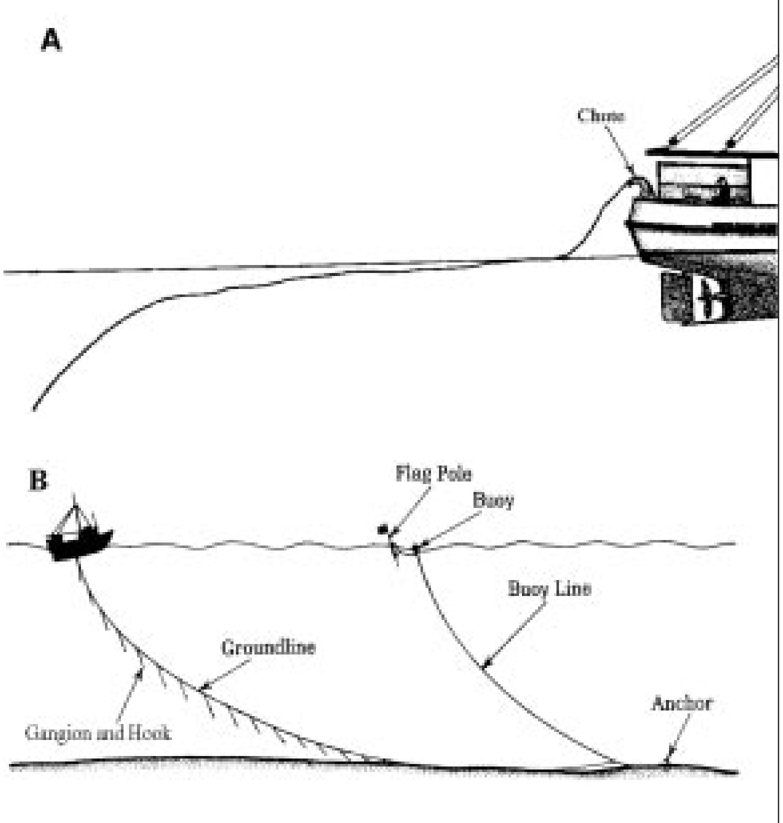

Figure 2. Schematic of hand-bait longline gear.
(A) A view of gear deployment (setting). (B) A view of gear retrieval (hauling). Reprinted from Geernaert *et al.* (2001) with permission.

Sablefish	Pacific Cod
Owner-operated	Corporate-owned
Catcher boats	Catcher/processor
IFQ fishery	Open access
10m - 25 m vessels	12m - 55m vessels
Gulf of Alaska	Bering Sea
Spring	Winter/Fall
Hand bait	Autobait

Table 1. Fleet characteristics by fishery.
See Appendix III for more detail.

SABLEFISH/PACIFIC HALIBUT

In 1999, approximately 444 vessels landed 12,000 metric tons of sablefish valued at $71 million (Hiatt and Terry, 2000). The sablefish fleet operates primarily in the Gulf of Alaska, Aleutian Islands, and, to a lesser extent, in the Bering Sea at the continental shelf break in water deeper than 500 meters (273.4 fm). Most effort (75%) is focused in the central and eastern management areas of the Gulf of Alaska. The season extends from 15 March to 15 November, but the majority of fishing occurs prior to July. Pacific halibut and sablefish fixed gear fisheries are managed under the Individual Fishing Quota (IFQ) program; as well as under the Community Development Quota (CDQ) program. In the IFQ program, each quota share holder is annually allocated a percentage of an area's total allowable catch (TAC) in accordance with the percentage of the quota share pool they hold for that area. Small vessels less than 18.3 meters (60 ft) which land sablefish make up 64 percent of fleet and are not required to carry fishery observers. Vessels 18.3 meters (60 ft) but less than 38.1 meters (125 ft; ~90 vessels) have required observer coverage for 30 percent of their fishing days per calendar quarter. Vessels 38.1 meters (125 ft) and over have required observer coverage for 100 of their fishing days. Crew size varies with vessel size and ranges from 1 to 2 persons on smaller vessel to 5 to 8 on larger vessels.

The Pacific halibut fleet is larger (1,800 vessels) than the sablefish fleet although many halibut vessels also fish sablefish (Geernaert *et al.* 2001). Halibut is typically fished on the continental shelf at depths less than 600 meters (328 fm). Annual landings in 1998 totaled 24,200 metric tons (53.4 million lbs.), valued at $74.8 million (Geernaert *et al.* 2001). As with the sablefish fishery, most vessels (55%) are less than 18.3 meters (60 ft) and 11 percent of these are less than 10.7 meters (35 ft). The Pacific halibut fishery is managed by the International Pacific Halibut Commission. The IFQ system for the Pacific halibut fishery off Alaska is managed and monitored by NMFS. Fisheries observers are not required.

In general, most sablefish and halibut operations bait hooks by hand, which dictates the methods of gear handling on the vessel (for further details by fleet, see Appendix III). As individual skates come aboard, they are bundled ("skate bottom" gear), coiled into tubs, or rolled onto a hydraulic drum. With typical skate bottom and tub gear, hooks are permanently attached to the line via gangions. When drums are used, each gangion and hook is clipped (using halibut snaps) to and removed from the groundline for each set. Gear goes out smoothly through a wide metal chute and rarely tangles. Hook spacing is target species-specific. Typically one-meter (3.3 ft) spacing is used, but spacing can be up to 5 meters (16.4 ft) when targeting halibut (Geermaert *et al.* 2001). A typical sablefish set is 3 to 4 kilometers in length (1.6 to 2.2 nautical miles; 3,500 hooks), and the larger vessels usually make 3 sets each day. Because fishers ice their catches, trips rarely exceed 6 days. Since sablefish and halibut are high-valued species, quota owners have more at stake than those who have not made this investment. Vessels tend to be owner-operated, and crew fidelity is high. Many crews stay intact for decades.

Pacific Cod Fishery

In 1999, Pacific cod landings by longline vessels totaled 101,000 metric tons valued at $72 million (Hiatt and Terry 2000). Most longline-harvested Pacific cod (80%) is fished by 40 catcher-processors (freezer-longliners) primarily in the Bering Sea at depths from 70 to 120 meters (38 to 66 fm), although fishing also extends to the Gulf of Alaska and the Aleutian Islands. Unlike sablefish and halibut, the fishery is not regulated by an individual quota system and consequently, vessels compete for optimal fishing grounds until a fleet allocation for cod is reached or until limits of Pacific halibut bycatch are reached. Most fishing takes place in two distinct seasons: January to May and September to October or November. Some cod (7.5% of TAC) is fished under community development quotas, mostly during the summer. Freezer-longliners also harvest sablefish/rockfish (13% of total harvest volume), Greenland turbot (*Reinhardtius hippoglossoides*; 5%) and walleye pollock (*Theragra chalcogramma*; 3%; NMFS 2001a) in addition to cod. Almost all of the vessels engaged in the fishery are corporate-owned.

Ninety percent of cod freezer-longliners use auto-bait systems and all freeze their catch. Freezer-longliners are large vessels with large crews that fish 24 hours per day and stay at sea for extended periods (up to 30 days). As a result, they set many more hooks (up to 55,000 per day) and catch many more fish than sablefish/halibut hand-bait vessels. Most auto-bait systems use swivel gear. Gangions are tied to swivels clamped onto the groundline with metal stops on either side to prevent swivels from sliding along the groundline. As the gear comes aboard it continues to be pulled via hydraulics to the setting area, typically at the stern, where the hooks are loaded onto racks (magazines) with the groundline coiled below. During the setting process, racks are aligned so that hooks are pulled from the racks through the baiting machine at three to four hooks per second. A major responsibility of the crew is to make sure that hooks do not cross and foul each other as they enter the baiter. If serious fouling occurs, hooks become lodged in the baiter, gear deployment stops, the groundline becomes taut, and the deployed groundline is lifted to the surface or even out of the water. To clear fouled hooks, the vessel must stop and reverse direction (backdown) to create enough slack to clear the auto-baiter. An experienced crew is essential for smooth operations.

Because the cod season is long and the work is arduous, crew turnover, including captain and mate, can be high. High crew turnover coupled with corporate ownership make consistent attention to seabird protection a difficult challenge for cod fleets compared with the halibut and sablefish fleets. In our experience on vessels that are owner-operated, crews perceive that they have much more at stake - their investment in the quota and vessel and legacy for their families - from the negative consequences of hooking a prohibited species. In addition to being highly motivated to eliminate seabird bycatch, smaller, low-turnover crews are better equipped to adopt and maintain consistent seabird bycatch mitigation measures.

Approach Philosophy

The goal of this research was to identify and test seabird bycatch deterrent strategies that significantly reduce the incidental mortality of seabirds in the Alaska demersal longline fishery, but with two important conditions: a given deterrent must not decrease the catch of the target species or increase the bycatch of other organisms. In order to fully achieve this goal, we established an experimental design, testing deterrents against a control of no deterrent. Control sets with no deterrent were incorporated to allow exploration of how seabirds interact with longline gear as a function of temporal and spatial variation, physical factors such as wind and sea state, and fishery practices (offal discards, vessel speed, etc.). Because gear deployments in which seabirds are caught are rare, hooking rates had the potential to yield inconclusive (i.e., not statistically powerful) results. To minimize this risk, we maximized the number of hooks deployed in the study and developed measures to characterize seabird behavior in addition to collecting hooking rate data. Because behavioral interactions occur at a rate several orders of magnitude higher than hookings, these measures increased the likelihood of discerning statistically significant differences. Moreover, we explored links between behavioral data and hooking rate data to determine if behavior is a useful predictor of bycatch.

Our objectives were fivefold, to:

- Test devices in 2 target fisheries that have unique characteristics and distinct geographic ranges;
- Conduct tests over 2 years to account for inter-annual variation and allow for improvements and innovation;
- Test deterrents individually and in combination;
- Conduct tests under worst case conditions in areas with high bird abundance and interaction; and,
- Conduct tests on multiple, active fishing vessels under typical fishing conditions.

The Collaboration

Equally important to the success of the experimental approach was the process by which it was reached. This research activity was an industry/university/agency collaboration to test seabird bycatch deterrent strategies identified by the fishing industry. The North Pacific Longline Association (NPLA) and the Fishing Vessels Owners Association (FVOA) assisted in establishing an Ad-Hoc Industry Advisory Committee. This committee was tasked with identifying potentially effective and practical deterrents for testing with a clear focus on improved and practical regulations. Eventually, it evolved into two committees - one for each fishery - due to differences in fishing seasons. Committees met to identify initial deterrents, to review the results of the first year of work and refine deterrents for the second year, and to review the completed work and comment on proposed recommendations stemming from the research results. NPLA represents freezer-longliner vessels that harvest Pacific cod, sablefish, and Greenland turbot in waters off Alaska and that process their catch at sea. FVOA represents approximately 80 catcher longline vessels that harvest sablefish and halibut in waters off Alaska and that deliver their catch to shore-based processing facilities.

In order to conduct the research on active fishing vessels, incentives were provided to cooperators. In the sablefish fishery, observer coverage was provided at no cost to the vessel. In the Pacific cod fishery, we were able to obtain additional fishing time via an Exempted Fishing Permit from NMFS with support of the North Pacific Fishery Management Council. Both NMFS and USFWS played key roles by participating in the ad-hoc committee process and by providing funding and necessary permits. The NMFS North Pacific Groundfish Observer Program (NPGOP) provided staff, who we specially trained to help us collect data at sea. NPGOP staff also assisted in developing the data collection protocols.

This collaborative approach allows for proof at two levels. Because industry is fully involved in every stage - from design to development of proposed regulations – fishers and fishing organizations develop confidence that the outcome will be practical and effective. By conducting the research under rigorous scientific protocols, the work will be credible to the management agencies, the scientific community, and to the public.

A wide range of possible seabird deterrent strategies were discussed in the ad-hoc committee process. Our objective was to identify strategies that were most likely to achieve project goals and be applicable and practical to the entire fleet. Strategies considered but rejected were: towed buoys (“bird bags”), water jets, strategic offal discharge, dying bait, and loud sounds. There was strong consensus that towed buoys were less effective than streamer lines and should not be tested.

Deterrents Tested

Sablefish Fishery

In both years, skippers agreed to deploy 20 skates (~3,400 hooks) of gear in each set and target sablefish. Four deterrents were tested (Table 2). In 1999, groundlines with added weight and paired streamer lines were each compared to a control of no deterrent. The baseline gear in all sets (control and deterrents) included a weight (3 to 5 kg; 6.6 to 11 lb.) tied at the junction of each skate. The added-weight deterrent included replacing every 10th hook (~ 11 m; 36.3 ft) with two 3-ounce (0.23 kg) lead weights. Paired streamer lines consisted of flying streamer lines from both the port and starboard side of the vessel.

	Control	SS	PS	WT	PS+W	Shoot	Tube
Sablefish	1999, 2000	2000	1999, 2000	1999	2000	---	---
Pacific cod	1999, 2000	2000	2000	1999	2000	1999	1999

Table 2. Deterrents tested by year and fleet.

SS = Single streamer lines; PS = paired streamer lines; WT = weighted gear; PS+W = Paired streamer lines in combination with weight treatment; Shoot = Mustad line shooter; and Tube = Mustad lining tube.

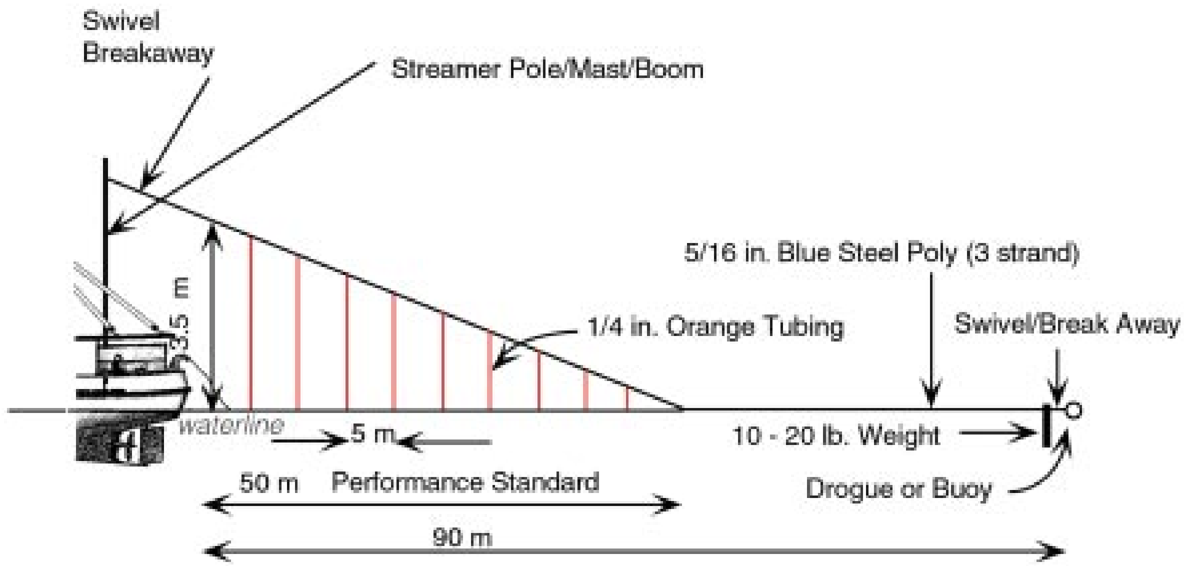

Figure 3. Streamer line schematic.

Our streamer lines consisted of a 90 meter (295 ft) line (5/6 inch or 21 mm; Blue Steel 3-strand polyester) with streamers attached at 5-meter (16.4 ft) intervals (Figure 3). The 5 meter spacing was taken from CCAMLR (1996) and Løkkeborg (1998) recommendations. An object (drogue, buoy, and/or weight) was attached to the far end of the line to create drag as the vessel was underway. Streamers were made of 6.4 mm (1/4 inch) Kraton UV-protected thermoplastic orange tubing, which extended to within a foot of the water in the absence of wind. We doubled each streamer and wove them through the twist in the streamer line; streamers were knotted or taped together for added durability. The streamers function to prevent birds from reaching the sinking hooks. To minimize safety hazards should fouling occur, breakaways (weak-links) were added to the design by individual vessel crews, usually at the buoy and at the attachment point to the vessel. When streamer lines are paired, a moving fence is created that bounds the sinking gear and functionally precludes seabirds from attacking baits. In the 1999 sablefish fishery, we maximized streamer line performance based on our observations and interaction with crew on individual vessels. Our year 2000 performance standard required that the streamer line be affixed to the vessel (to a boom, mast, or pole) so that the line was a minimum of 6.1 meters (20 ft) above the water at the stern and the streamer lines did not touch the water until 50 meters (164 ft) beyond the stern. The 50-meter requirement was relaxed in the sablefish fleet to a minimum of 40 meters (131 ft) in 2000, after some vessels had difficulty achieving this standard.

In 2000, deterrents included paired streamer lines, paired streamer lines in combination with added weight to the groundline (as described in the 1999 added-weight treatment) and a single streamer line flown on the windward side of the vessel. In both years skippers were provided with vessel-specific schedules based on a randomized block design such that the order of fishing deterrents and the control within each day and across days within a trip were randomly distributed.

Pacific Cod Fishery

Skippers agreed to make sets with 10,000 to 15,000 hooks per set in 1999 and 12,000 hooks or more in 2000. Six deterrents were tested over 2 years (Table 2). In 1999, deterrents focused on technologies that might minimize the time baits are at the surface. These included setting gear with a line shooter, setting gear subsurface using a lining tube, and adding weight to the groundline. Swivel gear with no added weight (i.e., no weights added at the skate junctions) was the baseline (control) gear. The line shooter was manufactured by Mustad and consisted of a pair of hydraulically operated wheels that pulled the line through the auto-baiter, delivering the line slack into the water. The line shooter was operated by the ship's engineer, who manually compensated for the pitch and yaw of the vessel by maintaining the proper speed of the line shooter wheels to keep the line slack. Gear set with line shooter does not necessarily sink faster; however, line set slack might begin to sink closer to the vessel. The lining tube, also made by Mustad, is a large metal funnel attached to the stern that delivers the line into the water up to 1 meter below the surface. The weighting treatment consisted of clipping (with halibut snaps) 4.5 kilogram (10 lb.) lead cannonballs every 90 meters (295 ft) to the groundline as it was deployed. When the gear was retrieved, weights were detached and carried to the stern for future deployments.

In 2000, deterrents focused on surface scaring technologies and included paired streamer lines, paired streamer lines plus weight (as described for cod in 1999), and a single streamer line flown from the windward side of the vessel. Performance standards and streamer line materials were identical to those described for the sablefish fishery.

In both years, skippers were provided with vessel-specific schedules, based on a randomized block design such that the order of fishing deterrents and the control within each day and across days within a trip were randomly distributed. In 2000, the single streamer deterrent was not formally integrated into the experimental design because single streamer lines were considered by the ad-hoc committee to be less efficient than paired streamer lines and limited sample sizes were reserved for the most promising deterrents. Instead, skippers agreed to fly a single streamer if they made a fourth set in any given day to collect anecdotal evidence of their efficiency compared to paired streamer lines.

Plan for Short-tailed Albatross Avoidance

Although we were allowed a take one short-tailed albatross in the course of our research without consequence to the fleet incidental take limit (ESA permit, USFWS), we developed a protocol to minimize the likelihood of a short-tailed albatross hooking. In the event a short-tailed albatross was sighted at any time during gear deployment, the captain was notified immediately by the crew or the observer. If a short-tailed albatross approached the groundline, two streamer lines were immediately deployed, or gear deployment was aborted. The decision to abort was made by the captain and lead scientist, based on the bird's behavior. If the set continued, the observer abandoned other duties and recorded the position and behavior of the short-tailed albatross. This protocol was implemented 4 times in two years.

Data Collection Method

Data were collected by specially trained observers. With the exception of the principal investigator, all were highly experienced NMFS-certified groundfish observers (minimum 335 days at sea) or Observer Program staff. Special training included North Pacific seabird identification and quantification of seabird abundance and behavior with respect to the gear. New personnel were accompanied by a senior, experienced observer and trained at-sea. Multiple observers were used on each vessel, with the exception of the sablefish fishery in 2000, when a single observer was deployed on each vessel. In cases of multiple observers, data were collected independently, without comparison during sets.

Catch

All sets were sampled for species composition according to the NMFS NPGOP longline sampling protocol (NMFS AFSC 2001). All organisms including fish, birds, and invertebrates were counted (tallied) and identified to species or lowest taxonomic level as the gear was retrieved, regardless of whether the catch was landed. If not brought on board, the best possible identification was made and a weight estimated. Fish were sub-sampled for weight according to the protocol. Data on length-frequency, age structures, and halibut viability (i.e., standard observer duties) were optional and not collected unless time permitted. In the sablefish fishery, we tallied all hooks deployed in 1999 and averaged 50 percent of the hooks in 2000. In the cod fishery, we monitored 66 percent of all hooks in 1999 and 75 percent in 2000. These sampling rates far exceed the typical fishery where observers effectively monitor at 8 percent to 10 percent for sablefish and at 24 percent for cod. Five of 837 gear deployments were not sampled according to NPGOP protocol, due to unavoidable problems with deterrent devices, interactions with killer whales, or when sets did not adhere to protocols.

Crew were requested to land all hooked seabirds regardless of whether the observer was present, and the location of the hook in the carcass was recorded. In the sablefish fishery, because the observer was on deck throughout the entire haul, we assumed that all birds were landed for the portion of the haul not monitored by an observer. In the cod fishery, the number of birds recorded during a tally was extrapolated for the unmonitored portion of a haul.

Bird Behavior

We developed protocols to count seabirds in areas astern of vessels and to quantify the rates at which they attack sinking baits. These observations were limited to daylight hours. An "attack" was defined as any attempt to take bait off a hook within 1 meter of the groundline. Attacks were operationally identified by surface plunging or aerial diving directly over baits. Attacks on loose baits or uncertain attacks were not recorded. Methods differ somewhat among years, particularly in the 1999 sablefish fishery - our first season (Table 3). In 1999, all seabird counts in both fisheries were limited to a distance at which seabirds could be identified to species without binoculars. Binoculars were only used to verify identification and to search for short-tailed albatross. In 2000, all counts were limited to within a distance of 100 meters (328 ft) from the vessel (Figure 4).

For the sablefish fishery in 1999, we counted the number of seabirds by species just prior to the first hook being set in a hemisphere aft of the vessel and in the wake zone (bounded by the width of the vessel or streamer lines) just after the last hook was set (Figure 4). The number of attacks was estimated for the duration of the entire set - about 20 to 40 minutes - to the greatest possible distance - about 80 to 100 meters (262 to 328 ft). Counts were recorded on audio tape.

In 2000, seabird counts in the aft hemisphere and the wake zone were recorded immediately after the first hook was deployed and again after a 10-minute attack-rate sample, while hooks were still being deployed. Attacks were recorded by species and by distance from the stern. Distances were estimated by referencing a 100-meter (328 ft) measuring line marked at 10-meter (3.28-ft) intervals and deployed at the far edge of the wake zone farthest from the groundline.

In the Pacific cod fishery, all counts were made during gear deployment. In both years, counts and attacks were broken into 2 sampling periods during each daylight gear deployment. For each sample period, counts were made before and after each attack-rate sample. In 1999, counts were made of birds occupying the aft hemisphere only. In 2000, observers counted birds in the aft hemisphere and the wake zone. Attack-rate samples were 15 minutes in 1999 and 10 minutes in 2000. In both years attack rates were by species and by distance. Distances were estimated by referencing a 100-meter (328-ft) measuring line, or in 2000, by referencing the distance between streamers during streamer line sets.

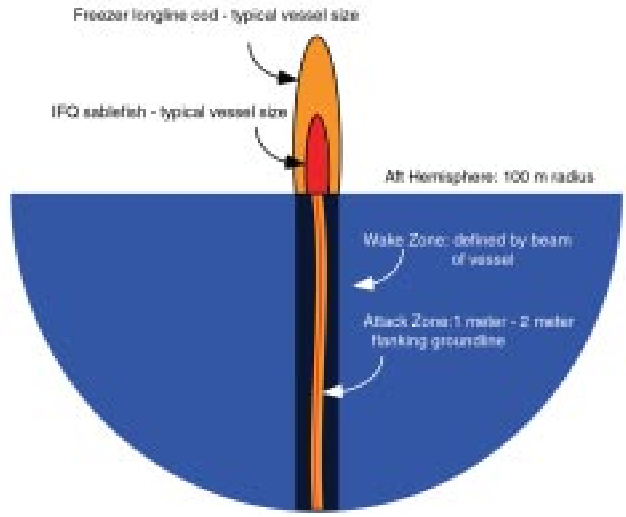

Figure 4. Seabird behavior observation areas.
Abundance by species was estimated in the aft hemisphere and wake zone. Seabird attacks on baited hooks were estimated in the attack zone during daytime sets.

Physical Variables

In addition to the abundance, behavior and seabird/fish CPUE, several physical variables were recorded for each set. These included wind speed and direction, Beaufort sea state, swell height, moon phase, visibility, cloud cover, time of first and last hook in deployments, bait type and condition, and extent of deck lighting (Appendix IV). Wind meters were used to collect wind speed in 1999 but were upgraded to electronic anemometers in 2000. Barometric pressure was recorded from the vessel barometer. Vessel captains provided average set speeds, positions, distances from last haul and numbers of other vessels in the area.

Time of Day

We required sablefish vessels to restrict gear deployments to daylight hours so as to maximize interactions with albatross and to make behavioral observations. However, one sablefish vessel was a catcher-processor and fished continuously. In this case, we asked that they avoid crepuscular hours (defined as an hour before and after sunrise or sunset). Less than 18 percent of total sets were crepuscular or night fishing. In the cod fishery, we required vessels to make half their sets during the day and half their sets at night within a trip using pre-established times for day or night. Day was defined by the beginning and end of civil twilight (i.e., when the center of the sun is geometrically 6 degrees below the horizon). We decided post-hoc to examine crepuscular effects. For this analysis, we defined crepuscular sets as those which came to

	Sablefish 1999	Sablefish 2000	Pacific cod 1999	Pacific cod 2000
Aft Hemisphere (to species)	1 / pre	n/a	n/a	n/a
Aft Hemisphere (100 m)	n/a	2 / during	3 / during	2-4 / during
Wake Zone	2 / pre & post	2 / during	n/a	2-4 / during
Attack Rate	1 / all	1 / 10	1-2 / 15	2 / 10

Table 3. Seabird behavior sampling protocol.
Abundance variables reported as frequency per set and prior (pre) to first hook, after (post) last hook, and during hook deployment. Attack rate is reported as number of samples per set and duration of each observation. See Figure 4 for observation areas.

within 48 minutes (either before or after) of sunrise or sunset. Using this criterion, 26 percent of all sets were either sunrise (84 sets) or sunset (43 sets).

Analysis

Because behavioral data collected were potentially subjective and prone to variation among observers, differences in abundance and attack rates were examined by comparing sets observed by more than one observer using multiple regression. In 1999, consistent observer differences were not apparent for the sablefish or cod fishery. All sets were monitored by a single observer in the 2000 sablefish fishery.

In the 2000 cod fishery, 70 percent (abundance) and 77 percent (attack rate) of sets were observed by more than one observer. For observers whose estimates were consistently different (either higher or lower), data collected by the junior observer (defined as the less experienced of the pair) were standardized to the senior observer (the more experienced) via linear regression. In these cases, data collected by the junior observer were standardized to those of senior observers in 48 percent (abundance) and 23 percent (attacks) of sets. In a few instances (3 abundance observations and 7 attack rate observations), extreme outliers by junior observers were excluded from analyses.

In both years, measures of seabird abundance in both fisheries varied slightly, making direct inter-annual and inter-fishery comparisons difficult. In the sablefish fishery, wake-zone abundance was the most comparable measure of abundance between years and is reported here. In cases of sets observed by more than one observer, (standardized) data were averaged within sets to produce a single value. For the cod fishery, we report only aft hemisphere abundance because it was common to both years. Aft hemisphere abundance data were collapsed into a single value per set by averaging individual observations within each sample, samples within each period, and periods within set. If there was only one period instead of two, data were averaged within period and considered representative of that set.

Attack rate data were similarly averaged between observers for each sample period and then across periods to produce a single representative value. Fish catch data and seabird bycatch data are presented as catch per unit effort (CPUE - that is, total kilograms of fish or total numbers of seabirds per 1,000 hooks per set).

Statistical methods were chosen to compensate for the rarity or frequency of events and to relate fish catch, seabird bycatch, seabird abundance and seabird attack rates to deterrent use and spatial, temporal, physical, and fishery-specific factors. Weighted multiple linear regressions were used to relate fish bycatch, seabird abundance and the logarithm of attack rate +0.1 (to avoid log(0)) to deterrent use and the above factors.

Seabird bycatch rates were not normally distributed (over 88% zeros in the sablefish fishery, over 83% zeros in the cod fishery), even after transformation. Therefore, we explored the relationships between seabird bycatch and a range of spatial, temporal, physical, fishery-specific, and behavioral factors using generalized linear models with a log-link, Poisson error term. This class of models allows for ANOVA and regression analyses using non-normal errors. The effect of these variables on seabird bycatch rate was explored for control sets only - without the confounding effect of bycatch deterrents. CPUE data were weighted to account for different effort levels per set. Any unidentified birds were included in total bird CPUE for all analyses.

Initially, all variables (Appendix IV) were included in all multivariate analyses, with a model inclusion cutoff of $p < 0.05$. This reduced the number of variables to year, vessel, region, date, time of day and wind direction. Because the variable "vessel" necessarily incorporated many different factors, including region fished, seasonal timing, and a range of weather variables, we chose not to include vessel in the final model, even though it was usually highly significant. Rather, we chose to incorporate the underlying factors, so that differences in seabird attack and bycatch rates might be more appropriately explained. In the cod fishery, region was not included in the model process, as the majority of sets were within a single region. Final factors used in the analysis included year, region, date, time of day, wind direction, and attack rate for the sablefish fishery, and year, time of day, wind direction, and attack rate for the cod fishery. The effect of these factors on seabird attack rate was similarly explored. Finally, the addition of deterrents on both seabird attack and bycatch rates was examined. In this case, "deterrent" was loaded as an additional factor. For each final model, we report the percent of deviation within the transformed parameter space for all significant factors and for the total model. Comparisons within significant factors were further explored for all regressions using Bonferroni-corrected post-hoc contrasts.

Results

IFQ Sablefish

Effort and Catch

In both years we fished areas typical of the sablefish fleet in the Gulf of Alaska and the Aleutian Islands (Figure 5). Most effort was focused along the continental shelf break at 500 to 800 meters in the central and western Gulf and the Aleutian Islands in NMFS Management Areas 630-620, 610, and 541-542, respectively.

In 1999, 3 vessels set over 400,000 hooks in 121 sets. Fishing took place from May 14 to June 6. We caught 348 metric tons of fish and 90 seabirds (Table 4). Fish catch consisted of sablefish (37%), Pacific halibut (37%), and assorted bycatch (26%). Fish bycatch species included grenadier (Macrouridae;16%), arrowtooth and Kamchatka flounders (*Reinhardtius* spp.; 5%), thornyheads (*Sebastolobus* spp.; 3%), skates (Rajidae; 1%) and rockfishes (*Sebastes* spp.; 1%). Seabird bycatch consisted of northern fulmars (80%), Laysan albatross (18%), and gulls (2%).

In 2000, 5 vessels set 800,000 hooks (226 sets) nearly doubling effort from 1999. Fishing took place over a longer period - April 18 to July 10 - as well as over a greater distance; effort was extended east to Yakutat (Area 640) and increased in the Aleutian Islands. We caught 606 metric tons of fish but only 23 seabirds (Table 4). As in 1999, fish catch was composed of sablefish (39%), Pacific halibut (25%), and bycatch (36%). Fish bycatch species included grenadier (16%), Greenland turbot (5%), arrowtooth and Kamchatka flounders (4%), thornyheads (3%), rockfishes (2%), and skates (1%). The primary seabird bycatch species were the same as in 1999; however, Laysan albatross (61% of the catch), replaced northern fulmars (30%) as the primary species. The remainder were gulls (9%). In both years, 60 percent of the seabirds were foul-hooked (i.e., hooked in the body including neck or wing) as opposed to hooked in the beak.

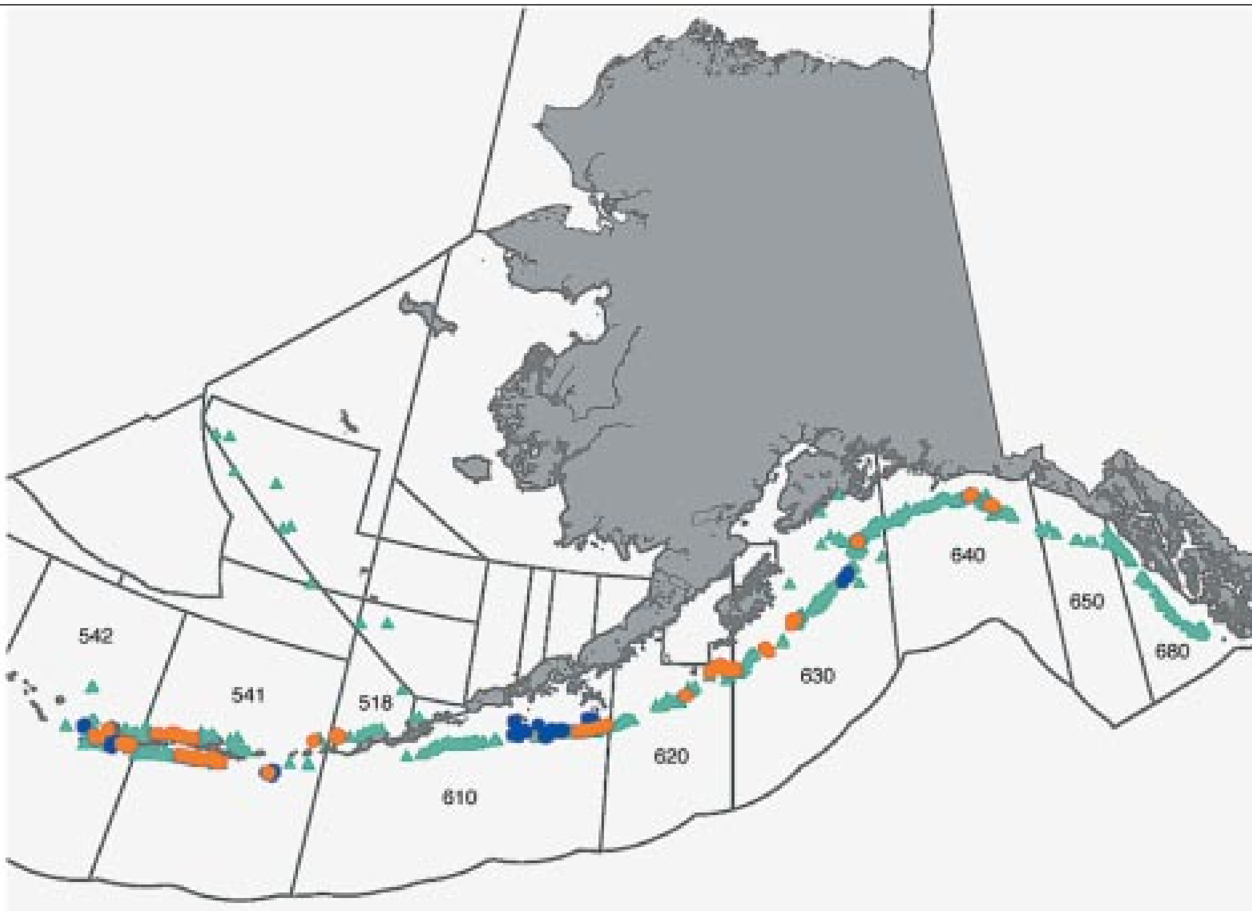

Figure 5. Sablefish: Fishing effort by location.

Distribution of sablefish fleet effort (gear deployments or sets) in 2000 (triangles; NMFS Observer Program data) and research effort in 1999 (blue circles) and 2000 (orange circles). Aleutian Islands includes areas 541 and 542. Area 610 is the western Gulf of Alaska, areas 620 and 630 are the central Gulf of Alaska and area 640 is the Yakutat area.

	Sablefish		Pacific Cod	
	1999	2000	1999	2000
Effort				
Hooks	416,046	799,770	1,904,071	4,418,072
Sets	121	226	156	334
Hooks Sampled (%)	100%	52%	75%	66%
Bird Mortalities/Events				
Northern Fulmars	72	7	352	19
Shearwater Spp.	0	0	48	7
Gull, Unid.	2	2	0	1
Seabird, Unid.	0	0	3	0
Laysan Albatross	16	14	0	0
Total	90	23	403	27
Sets w/ Mortalities	22%	5%	38%	6%
Control sets w/ Mortalities	34%	17%	31%	15%
Body Hooked (neck & wing included)	60%	61%	79%	80%
Sets w/ Birds	27	12	60	20
Sets >1 Bird	18	7	48	4
Largest Event (Number of Birds)	23	5	114	4
Total Fish (MT)*	348.1	606.4	1,572.7	2,854.4
Total Sablefish	129.6	234.5		
Total Halibut	127.4	152.1		
Total Bycatch	91.1	219.8	344.1	789.8
Total Pacific Cod			1,130.2	1,941.1
Total Pollock			98.4	123.5

*Sablefish fishery includes halibut sets

Table 4. Summary of effort and seabird and fish catch by year and fishery.

Target Species

There was little difference in fish CPUE between years (Figure 6). Total fish (541 kg versus 547 kg/ 1,000 hooks; p = 0.47, t = 0.09), sablefish (305 kg versus 304 kg/1,000 hooks; p = 0.99, t = 0.01) bycatch (187 kg versus 219 kg/1,000 hooks; p = 0.136, t = 1.10), and Pacific halibut (50 kg versus 23 kg/1,000 hooks; p = 0.078, t = 1.42) CPUE were nearly identical.

Fish CPUE in sets targeting sablefish varied significantly by region (Figure 7C; p = 0.000, $F_{3,259}$ = 10.78). Total catch rates were highest in the central Gulf (755 kg/1,000 hooks) relative to both the western Gulf (476/1,000 hooks; p = 0.003, t = 3.20) and the Aleutian Islands (471 kg/1,000 hooks; p = 0.002, t = 3.25). Sablefish catch rates paralleled total catch. Catch was similar in Yakutat (551kg/1,000) and the central Gulf (534 kg/1,000) and over two times that of the western Gulf (229 kg/1,000) and the Aleutian Islands (202 kg/1,000). Fish bycatch increased from east to west, from a low of 82 kg per 1,000 hooks to a high of 244 kg per 1,000 hooks. With the exception of a few sets made in the Yakutat area with no halibut, the proportion of halibut in the catch was relatively constant (5% to 8%).

Because the CPUE of all fish groupings did not vary between years, data were pooled across years when examining the effects of seabird bycatch deterrents. In general, mean fish CPUE in sets targeting sablefish (sablefish CPUE > Pacific halibut CPUE) was greater in sets made with deterrents compared to the control sets. However, only total fish catch was significantly greater with deterrents (p = 0.015, $F_{4,253}$ = 3.132; Figure 8). Total fish, sablefish, and fish bycatch rates were lowest in controls (544, 305 and 207 kg/1,000 hooks, respectively) and greatest in sets made with the paired streamer deterrent (702, 351, and 305 kg/1,000 hooks, respectively). Pacific halibut CPUE was least in control (33 kg/1,000 hooks) and single streamer sets (32 kg/1,000 hooks) and greatest in sets with added weight (74 kg/1,000 hooks). Because sets targeting Pacific halibut (halibut CPUE > sablefish CPUE) were few (78 of 347 sets) and irregularly dispersed among deterrents, these data were not compared.

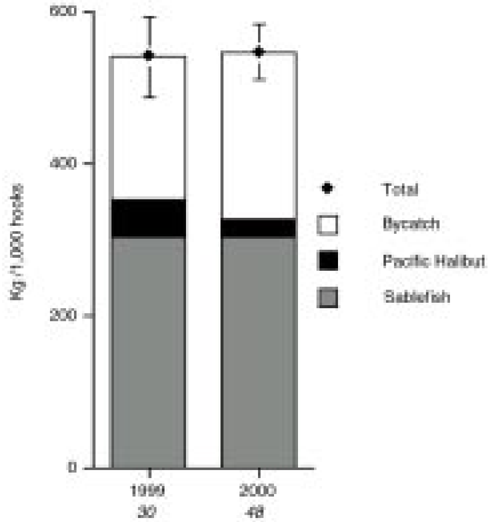

Figure 6. Sablefish: Inter-annual comparison of mean fish CPUE by species.

Control sets (no seabird deterrent) only. Bycatch includes all other species of fish and invertebrates. Error bars are standard errors.

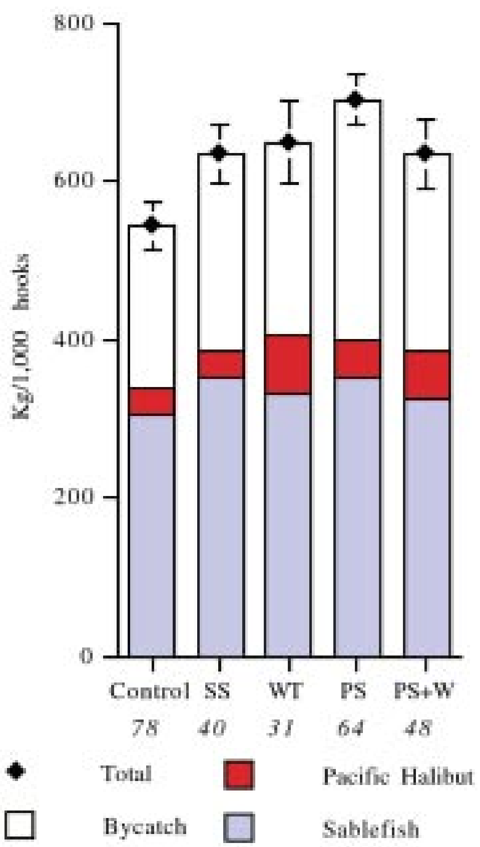

Figure 8. Sablefish: Mean fish CPUE by deterrent.

Control and paired streamer data are pooled for 1999-2000. Control = no deterrent , SS = single streamer, WT = weight added to groundline (.23 kg per 11 m), PS = paired streamer, PS+W = paired streamer lines with added weight (.23 kg per 11 m). Error bars are standard errors.

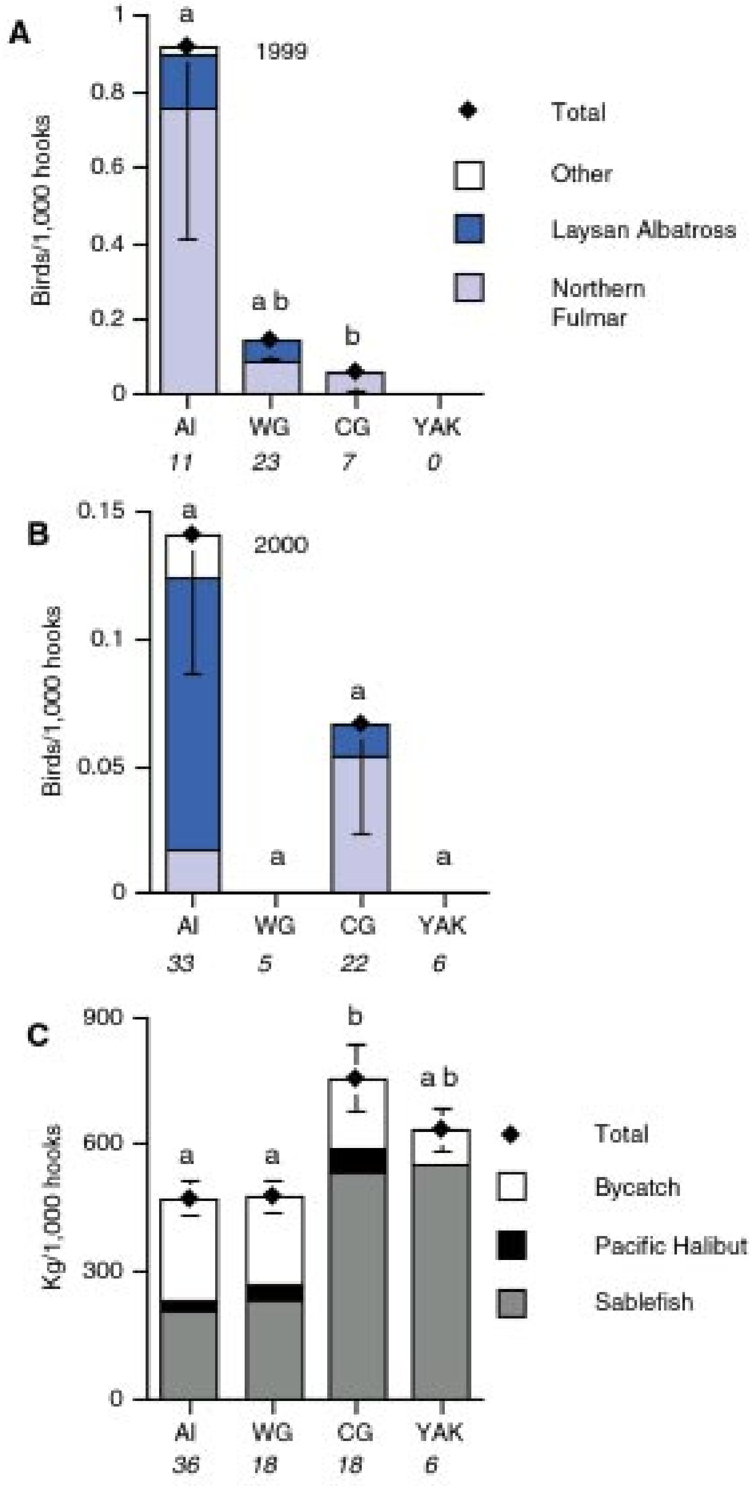

Figure 7. Sablefish: Mean fish CPUE by region.

(A) 1999 seabirds, (B) 2000 seabirds, and (C) 1999-2000 (combined) fish. AI = Aleutian Islands area; WG = Western Gulf of Alaska; CG = Central Gulf of Alaska; Yak = Yakutat. Sample size per region (number of sets) is italicized. Significant post hoc groupings (at least p< 0.05) are indicated by lowercase letters. Error bars are standard errors; only negative error bars are shown in panels A and B. Scale obscures some error bars.

Seabirds

Multivariate Effects

Multivariate modeling was used to identify those factors – physical and biological – that, when taken together, structured seabird interactions with the gear, including attack rate (linear model with the log of attack rate) and bycatch rate (generalized linear model with log-link, Poisson error term). We first examined only control sets (i.e., without the mitigating influence of deterrents), and then analyzed the entire data set, with deterrent as an additional explanatory factor. The identification of significance led to a more comprehensive analysis within the relevant factors using post-hoc contrasts. We report model results for each overall comparison, followed by post-hoc analyses in subsequent sections.

Both seabird attack and bycatch rates were significantly affected by inter-annual differences. Using only data from control sets, the factor "year" explained the greatest amount of variation in attack rate (21% of the deviation) and was the second most important factor explaining bycatch rate (11% of the deviation). "Region" explained an additional 11 percent of the deviation in attack rate and was the most significant variable explaining bycatch rate (17% of the deviation). However, with respect to bycatch rate, the factor "date" (actually, a quadratic function, with the highest attack rate in the middle of the season) explained an equal amount of deviation. When "date" was loaded into the model before "region", the latter was not significant. We chose to include "region" in the final model for seabird bycatch, rather than "date", as it was significant in both years, and we fished over a small portion (less than 20%) of the entire sablefish season.

When years are considered separately, both "region" and "wind direction" had significant impacts on seabird bycatch in 1999 (59% and 9% of total deviation, respectively). In 2000, the influence of "region" dropped, but was still significant (11% of total deviation). "Wind direction" was also significant (10% of total deviation), where crosswinds increased attack rate. To examine the influence of annual and regional impacts on both attack and bycatch rates in more depth, we report post-hoc comparisons within each relevant factor, as well as species-specific effects. "Wind direction" is not examined "post-hoc", as this variable did not range over a wide set of values within our study.

Inter-annual Differences (Control data only)

In both years, seabird bycatch was rare. In sets made without deterrents, only 34 percent in 1999 and 17 percent in 2000 caught seabirds (Table 4). The maximum number of birds caught in a single set, and the number of sets with more than one bird caught were also dramatically higher in 1999—23 birds versus 5 birds and 18 sets versus 7 sets (Table 4). Inter-annual differences in seabird bycatch were reflected in all other measures of seabird interaction with fishing vessels (Figure 9). Because measures of seabird abundance were not identical in both years, we cannot be certain that our data accurately reflect absolute change in seabird abundance between years. We are, however, confident that our data depict relative trends in abundance, as well as species composition within year (Figure 9A). Northern fulmars and Laysan albatross were the dominant species in both years, comprising 91 percent and 92 percent of all seabirds sighted, respectively. The remaining 8 percent to 9 percent included gulls, black-footed albatross, shearwaters, and kittiwakes (*Rissa* spp.).

Total seabird attack rate, expressed as the average number of attacks per minute, was significantly lower in 2000 as compared to 1999 ($p < 0.001$; $F_{1,73} = 23.3$), dropping threefold from 27.3 to 9.1 attacks per minute (Figure 9B). Because species-specific data were not recorded in 1999, comparison of species-specific attack rates between years is not possible. In 2000, northern fulmars (39%) and Laysan albatross (47%) accounted for almost all attacks, which matched anecdotal observations in 1999. Other species attacking baited hooks included gulls, shearwaters, black-footed albatross, and kittiwakes.

Fewer attacks yielded a fourfold reduction in seabird bycatch in 2000 as compared to 1999 (0.094 versus 0.371 per 1,000 hooks; $p = 0.000$, $c^2 = 31.9$, $df = 1$). Species-specific differences were dramatic and accounted for this difference. Northern fulmar mortality decreased by an order of magnitude in 2000 (0.026 versus 0.285 per 1,000 hooks, $p = 0.000$, $c^2 = 48.5$, df=1) . By contrast, Laysan albatross and gull bycatch rates did not differ between the years (albatross, 0.078 versus 0.060 per 1,000 hooks; $p = 0.51$, $c^2 = 0.44$, $df = 1$; gulls, 0.007 versus 0.009 per 1,000 hooks; $p = 0.88$, $c^2 = 0.02$, $df = 1$).

Regional Differences (Control Data Only)

Seabird abundance was not significantly different among regions ($p = 0.262$, $F_{3,75} = 1.36$). However, attack rate ($p = 0.011$, $F_{3,75} = 3.99$) and seabird bycatch ($p = 0.000$, $c^2 = 51.5$, $df = 3$) did vary. As with fish bycatch, seabird interactions increased from east to west. In 1999, seabird bycatch varied significantly among regions (Figure 7A,B; $p = 0.000$, $c^2 = 75.5$, $df = 2$); it was higher in the Aleutian Islands (0.920/1,000 hooks) compared to the central Gulf (0.060/1,000 hook ($p = 0.0004$, $t = 3.57$). The Western Gulf was intermediate and not significantly different from either. Regional differences were less pronounced in 2000 ($p = 0.025$, $c^2 = 9.3$, $df = 3$), in part because fishing was less balanced across region.

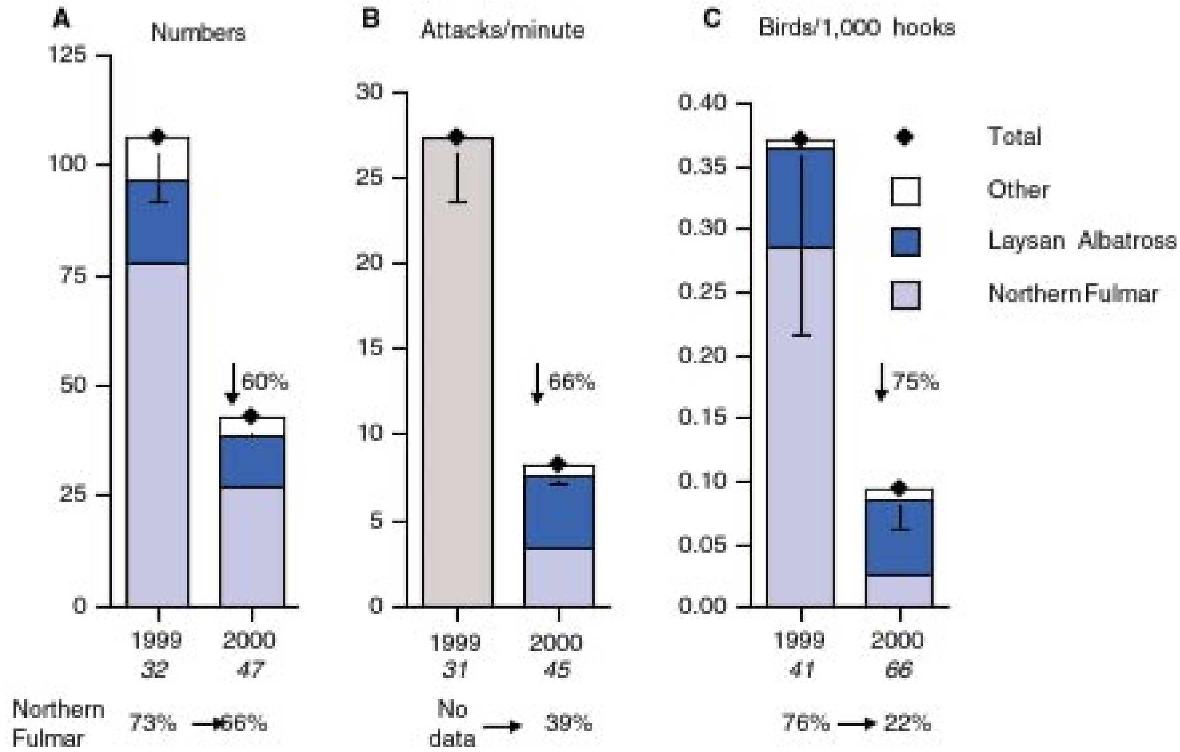

Figure 9. Sablefish: Inter-annual comparisons of seabird interactions.

Control sets (no seabird deterrent) only. (A) Mean abundance in the wake zone. (B) Mean attacks per minute. Species-specific attacks were not collected in 1999. (C) Mean seabird bycatch per 1,000 hooks by year and species. Percent northern fulmar within year shown per variable. Only negative standard error bars are displayed.

Regional effects appeared to be driven largely by species-specific differences. In 2000, northern fulmars virtually disappeared from the catch in the Aleutian Islands (0.755 versus 0.017 birds/1,000 hooks), while Laysan albatross catch rates remained near-constant (0.142 versus 0.108 birds/1,000 hooks). These data strongly suggest a fundamental shift in northern fulmar foraging behavior in the Aleutian Islands between years.

Deterrent Comparisons

To assess the importance of deterrents in relation to all other physical factors as sources of variation in both seabird attack and bycatch rates, we used multivariate models on the entire data set, including control sets, with the additional explanatory factor "deterrent." We considered years separately, because the deterrents tested varied from year to year, making direct annual comparisons less useful. In 1999, "deterrent" was the only factor to significantly influence seabird attack rates on the gear (29% of the deviation). The effect of "deterrent" on bycatch rates was similarly clear. In 1999, "deterrent" explained 22 percent of the deviation in the model data. "Region" was also highly significant (28% of the deviation), followed by "time of day" (8%).

In 1999, seabird abundance ($p = 0.003$, $F_{2,95} = 6.153$), attack rates ($p = 0.000$, $F_{2,93} = 19.39$), and CPUE ($p = 0.000$, $c^2 = 41.1$) varied significantly among deterrents (Figure 10 and Appendix 5). Compared to controls of no deterrent (0.371 birds/1,000 hooks), paired streamer lines reduced bird bycatch by 88 percent (0.044 birds/1,000 hooks; $p = 0.000$, $t = -6.374$) whereas added weight reduced bycatch rates by 37 percent (0.234 birds/1,000 hooks; $p = 0.000$, $t = -4.487$). The dramatic reduction in seabird bycatch in paired streamer sets was matched by significant declines in wake zone abundance after sets (43%; $p = 0.009$, $t = -2.43$) and attack rate (73%; $p = 0.000$, $t = -5.19$) relative to controls (106.5 birds and 27.3 attacks per minute). Although weighted gear significantly reduced seabird bycatch relative to controls, there was no corresponding decrease in either seabird abundance (increased 16%) or attack rate (decreased 2%). In fact, when the set with the largest seabird bycatch (23 birds in a single control set) was removed from the analysis, added weight no longer appeared to significantly reduce seabird bycatch ($p = 0.13$, $t = -1.14$). Northern fulmars and Laysan albatross combined dominated seabird numbers, attacks, and catch in all deterrents.

In 2000, when we expanded our coverage, "deterrent" was the overwhelmingly influential factor in our multivariate models, explaining 51 percent of the deviation in seabird attack rate. The factor "region" was weakly, albeit significantly, important (3% of the deviation). When examining bycatch rates in 2000, "deterrent" was the only significant factor (33% of the deviation).

All streamer line deterrents dramatically reduced seabird abundance ($p = 0.000$, , $F_{3,178} = 12.99$), bait attacks ($p = 0.000$, $F_{3,173} = 62.7$), and bycatch ($p = 0.000$, $c^2 = 72.6$) relative to controls (Figure 11). Both paired streamer lines and paired streamer lines with weight completely eliminated the bycatch of all seabirds. Single streamer lines reduced seabird bycatch by 96 percent (a single northern fulmar was caught) relative to controls (0.094 birds/1,000 hooks; $p = 0.003$, $t = -2.76$). The rate for a single streamer (0.006 birds/1,000 hooks) was not significantly greater than paired streamer lines (0.000/1,000 hooks; $p = 0.137$, $x2 = 2.21$, $df = 1$).

All streamer line deterrents reduced seabird numbers (50% to 62%) and bait attacks (87% to 95%) relative to controls (42.7 birds in the wake zone and 9.1 attacks per minute). Single streamer lines were slightly less effective, accounting for the lower range of these percents. Attack rates during paired streamer sets were half that (0.5 attacks per minute; $p = 0.002$, $t = -3.15$) of single streamer sets (1.2 attacks per minute). Paired streamer deterrents were 5 times more effective at reducing Laysan attacks (0.1 attacks per minute) and twice as effective at reducing northern fulmar attacks (0.3 attacks per minute) compared to single streamer deterrents (0.5 attacks per minute and 0.6 attacks per minute, respectively).

In the sablefish fishery, Laysan albatross and northern fulmars demonstrated an opposing interaction with fishing gear (Figure 11). Although Laysan albatross were less abundant (26%) than northern fulmars (64%) during control sets, they made relatively more attacks (47% versus 39%), and an even greater proportion were hooked (70%

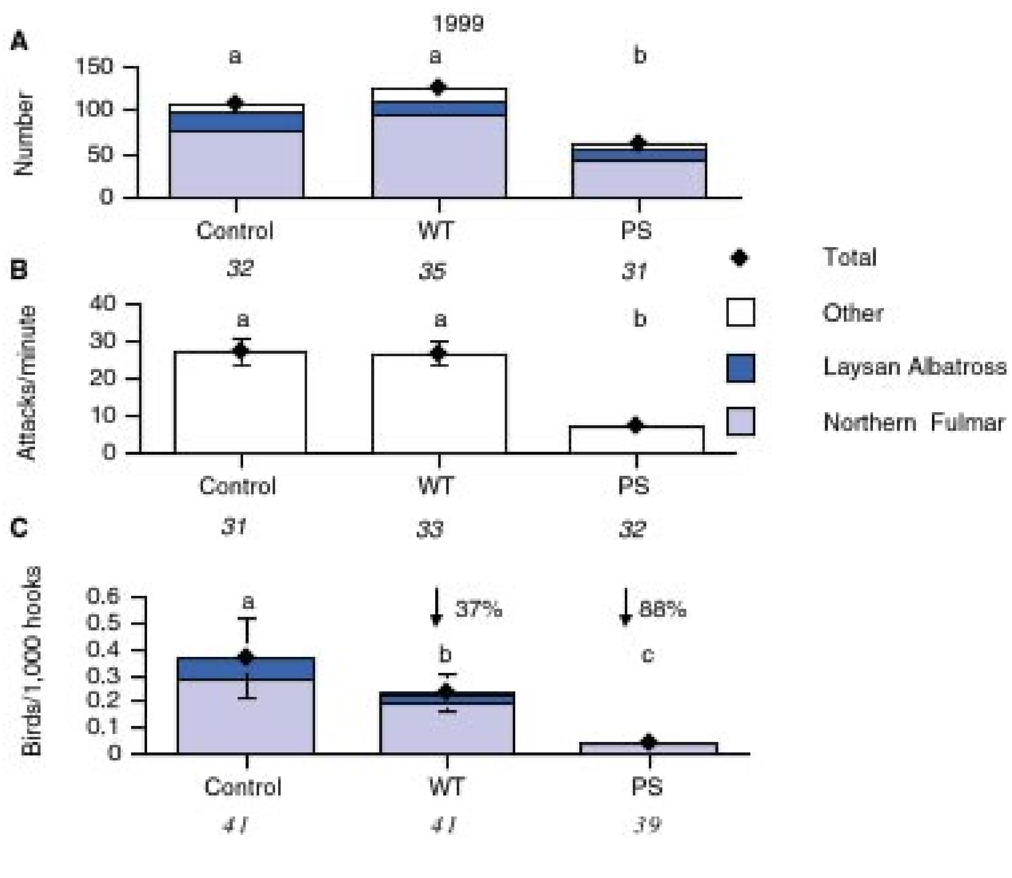

Figure 10. Sablefish 1999: Seabird interactions by deterrent.

(A) Mean abundance (wake zone) by deterrent and species, (B) mean total attacks per minute, and (C) mean bycatch per 1,000 hooks by deterrent and species. Control = no deterrent , WT = added weight to the groundline (.23 kg per 11 m), PS = paired streamer lines. Significant post hoc groupings (at least p< 0.05) are indicated by lowercase letters. Error bars are standard errors. Scale obscures some error bars.

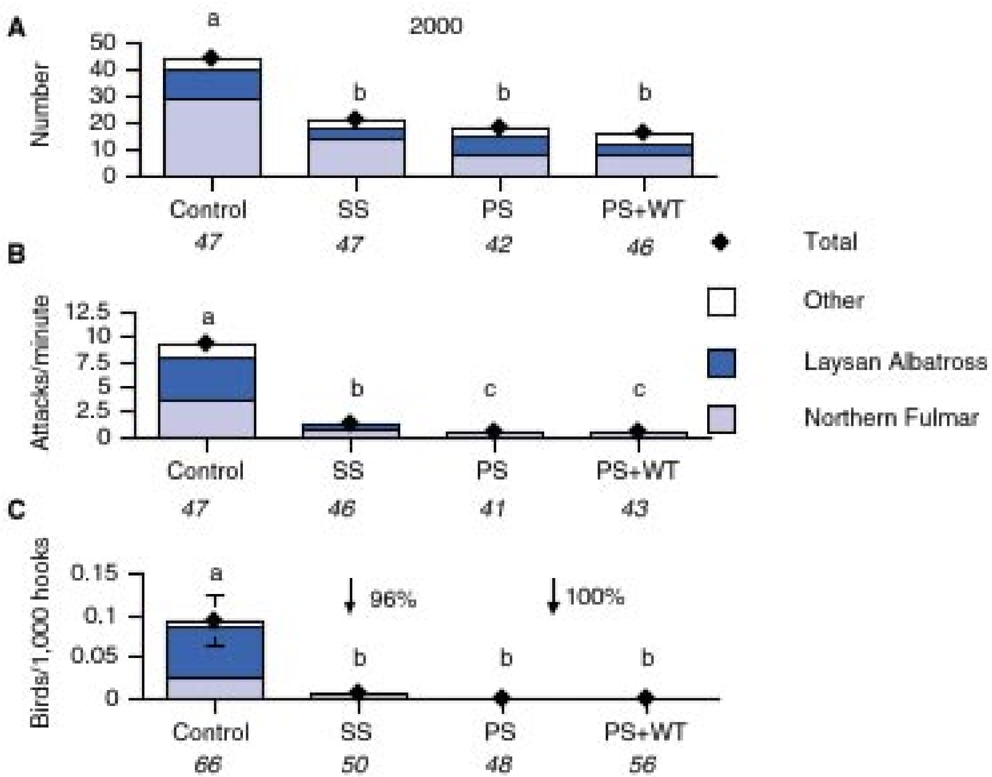

Figure 11. Sablefish 2000: Seabird interactions by deterrent.

(A) Mean seabird abundance (wake zone) by deterrent and species. (B) Mean attacks per minute by deterrent and species. (C) Mean seabird bycatch per 1,000 hooks by deterrent and species. Control = no deterrent , SS = single streamer, PS = paired streamer, PS+W = paired streamer lines with added weight (.23 kg per 11 m). Significant post hoc groupings (at least $p< 0.05$) are indicated by lowercase letters. Error bars are standard errors. Scale obscures some error bars.

versus 22%; Figure 11). These data clearly illustrate that species-specific abundance alone is not a reliable predictor of attacks or bycatch.

Attack Rate by Distance Astern

By-distance analyses focus on data collected in 2000, as species-specific data were not collected in 1999. Seabird attacks on baited hooks in sets made with no deterrent occurred throughout the 100-meter area surveyed, but over 98 percent of all attacks occurred within 10 meters to 50 meters of the stern (Figure 12A). The distribution and intensity of attacks over sinking longlines varied by species. Laysan albatross were most prevalent from 10 meters to 50 meters astern (99% of Laysan attacks) and peaking at 10 meters to 20 meters (Figure 12A). No Laysan attacks were recorded beyond 70 meters. Northern fulmars occupied an area slightly aft of Laysan albatross and peaked at 20 meters to 30 meters. No northern fulmar attacks were recorded beyond 90 meters. Attacks by black-footed albatross and gulls were few.

All deterrents reduced the number of attacks at all distances and shifted the peak of attack distance away from the stern, as compared to control sets (Figure 12). Among deterrents, paired streamer lines virtually excluded albatross attacks throughout the 100-meter area. Single steamers displaced albatross aft, but were less effective than paired streamer lines (Figure 12B). Single streamer lines also displaced northern fulmars aft although to a lesser degree (Figure 12C).

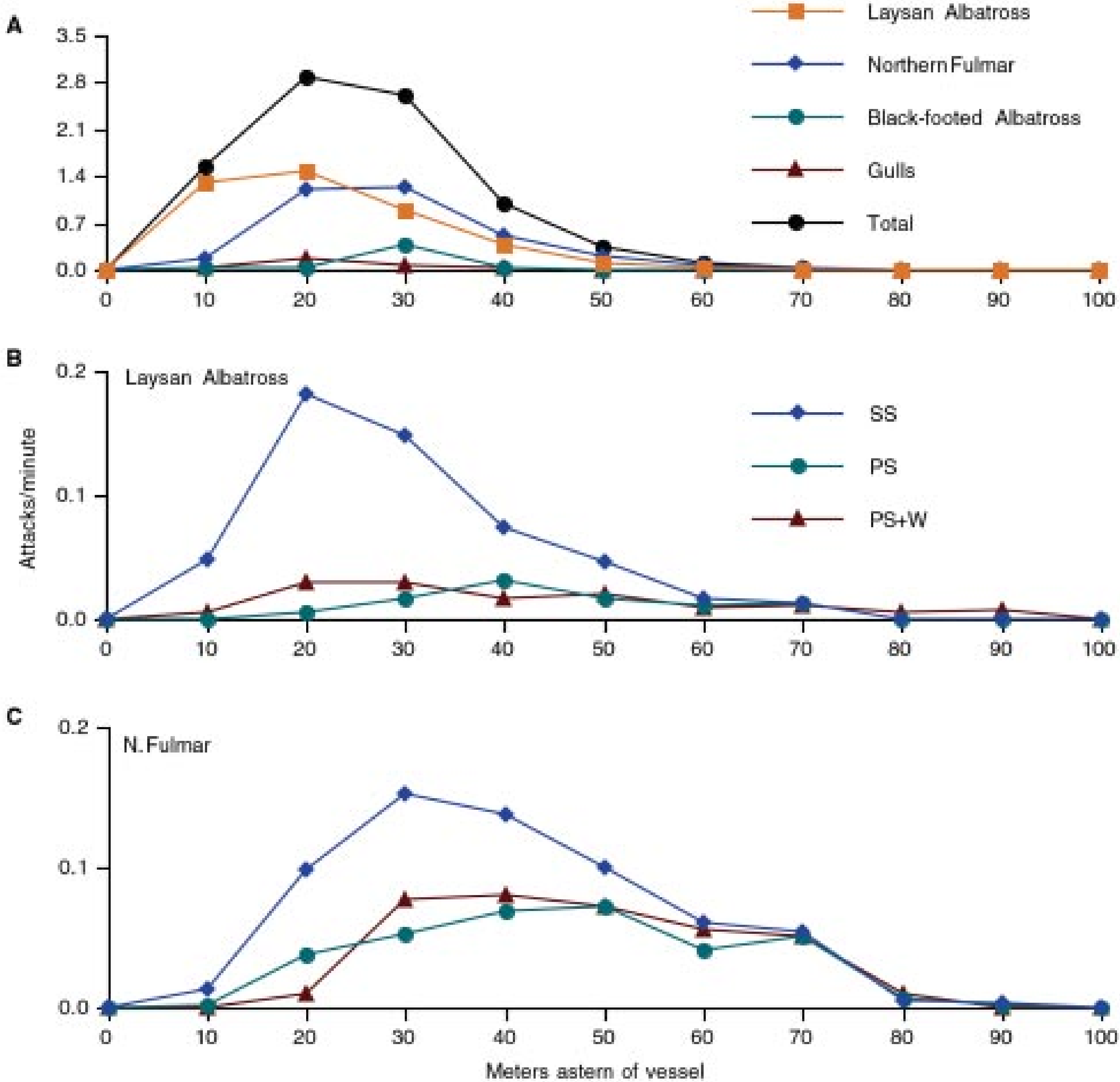

Figure 12. Sablefish 2000: Distribution of seabird attack rates astern. (A) Mean attack rates by distance (in meters astern) and species for control sets. (B) Laysan albatross attack rates by deterrent. (C) Northern fulmar attack rates by deterrent. Control = no deterrent , SS = single streamer, PS = paired streamer, PS+W = paired streamer lines with added weight

Freezer Longline/ Pacific Cod

Effort and Catch

In both years, we fished areas typical of the cod catcher-processor fleet in the Bering Sea (Figure 13). Most effort was focused along the 100 meter isobath southeast of the Pribilof Islands in NMFS Management Areas 509, 513 and 517. In 2000, we extended effort farther north into areas 523 and 531 in an attempt to increase interactions with albatrosses. Research was conducted on 2 fishing vessels in each year.

In 1999, we set almost 2 million hooks (156 sets) and caught over 1500 metric tons of fish and 403 seabirds (Table 4). Fishing took place from July 31 to September 6. Catch included Pacific cod (72%), walleye pollock (6%), and bycatch (22%). Primary bycatch were skates (10%), Pacific halibut (7%), arrowtooth/Kamchatka flounder (2%), and a mix of miscellaneous species (3%). Seabird bycatch consisted of northern fulmars (87%), shearwaters (12%; mostly short-tailed shearwaters, *Puffinus tenuirostris*), and 3 unidentified seabirds (1%).

In 2000, effort more than doubled to nearly 4.5 million hooks (334 sets; Table 4). Fishing took place in August (as in 1999) as well as in September (30 July to 26 September). We caught over 2,800 metric tons of fish but only 27 seabirds. Composition of the fish catch was similar to 1999: cod (68%), pollock (4%), and bycatch (28%). Bycatch species composition was consistent with 1999. Skates made up the majority (12%), followed by Pacific halibut (11%), arrowtooth/Kamchatka flounder (2%), and a mix of miscellaneous species (3%). Seabird species included northern fulmars (70%), shearwaters (26%), and a single gull.

Seabird bycatch was rare in both years. No albatross were hooked and few were observed in either year. In both years, most birds (~80%) were hooked in the body (neck or wing) rather than in the beak.

Target Species

Fish catch varied annually. The CPUE of most fishes was significantly lower in 2000 than in 1999 (Figure 14). Total fish caught (769 versus 668 kg/1,000 hooks; p = 0.003, t = 2.83), cod (558 kg/1,000 hooks

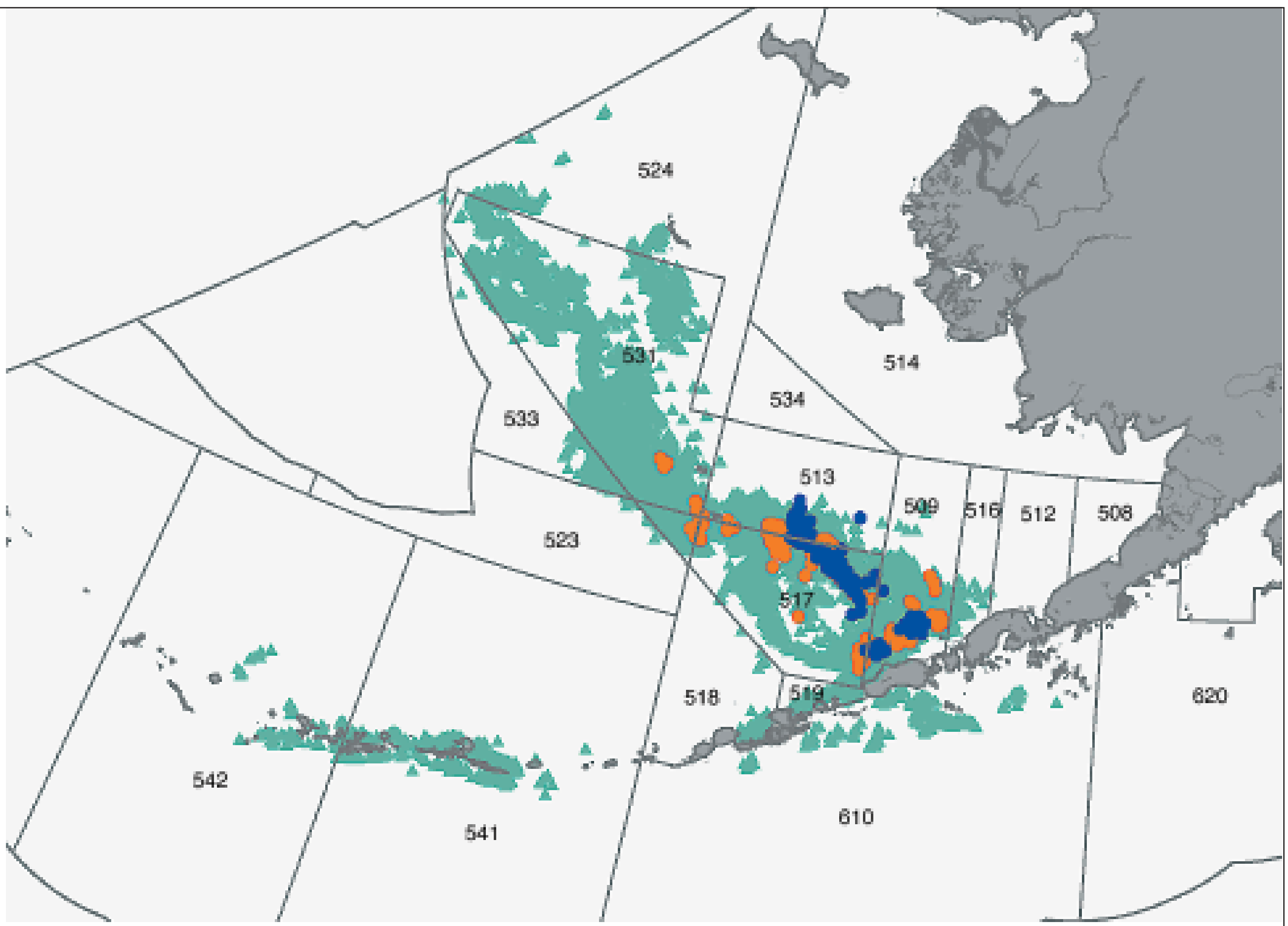

Figure 13. Pacific Cod fishing effort by location. Distribution of Pacific cod freezer longline effort (gear deployments or sets) in 2000 (triangles; NMFS Observer Program data) and research effort in 1999 (blue circles) and 2000 (orange circles).

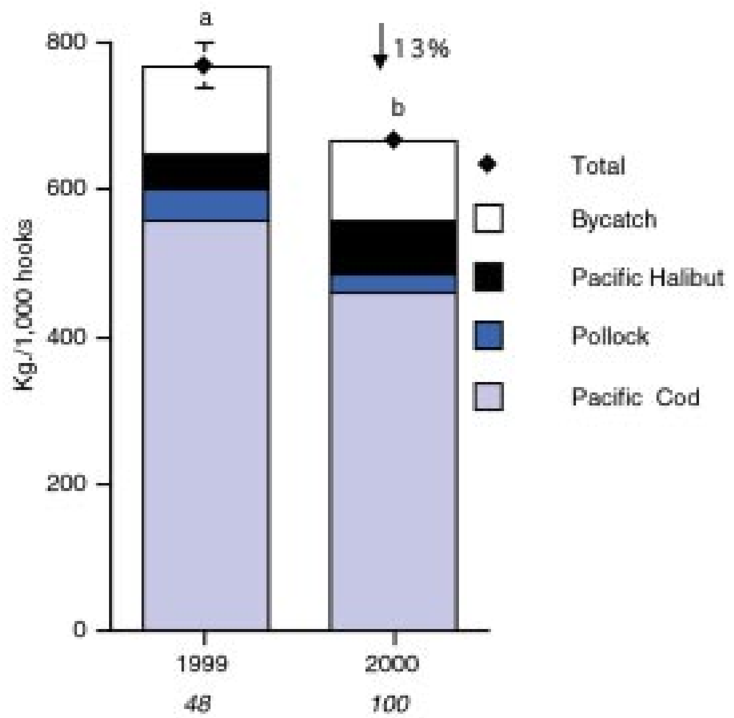

Figure 14. Pacific Cod: Inter-annual comparisons of mean fish CPUE by species. Control sets (no seabird deterrent) only. Error bars are standard errors. Scale obscures some error bars.

versus 460 kg/1,000 hooks; p = 0.001, t = 3.05); pollock (45 kg versus 26 kg/1,000 hooks (p = 0.000, t = 4.15), and fish bycatch (not including halibut; 117 kg/1,000 hooks to110 kg/1,000 hooks; p = 0.21, t = 0.82) all decreased in 2000. Only catches of Pacific halibut increased (45 kg/1,000 hooks to 72 kg/1,000 hooks; p = 0.001, t = 3.33). However, within each year, total fish CPUE did not vary among the 3 time of day categories (p = 0.0684, $F_{3,479}$ =2.386), nor were there species-specific differences (Figure 15A). Although it appears that fewer fish were caught in hours surrounding sunset, this difference was not statistically significant (p = 0.07 , t = 1.48).

Clearly and importantly, the use of seabird bycatch deterrents in both years had no detectable effect on fish catch (Figure 16). Fish CPUE did not vary significantly among seabird bycatch deterrents and controls (1999: p = 0.242 $F_{3,146}$=1.41; 2000: p = 0.103, $F_{3,322}$= 2.08), nor were there species-specific effects.

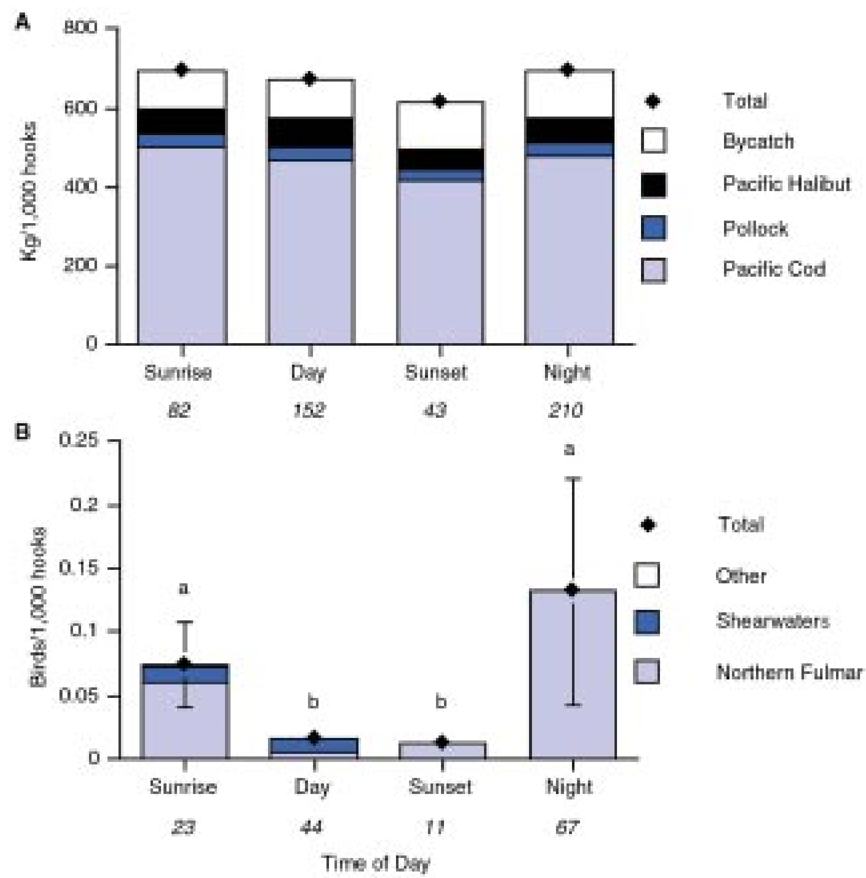

Figure 15. Pacific Cod: Diel variation in fish and bird catch by time-of-day. (A) Mean fish per 1,000 hooks and (B) mean seabird bycatch per 1,000 hooks by species (control sets only). Significant post hoc groupings (at least p< 0.05) are indicated by lowercase letters. Error bars are standard errors. Scale obscures some error bars.

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Seabirds

Multivariate Effects

As in the sablefish fishery, multivariate models were used to identify physical factors significantly influencing seabird interaction with gear. Using only control sets, the factor year explained a significant amount of the deviation in both attack (9%) and bycatch (23%) rates. Time of day also had a significant influence on bycatch (11%), but not on attacks.

Inter-annual Differences (Control Data Only)

As in the sablefish fishery in both years, seabird bycatch was rare. In sets made without deterrents, 31% (1999) and 15% (2000) caught at least one bird (Table 4). The maximum number of birds caught in a single set (114 birds in 1999 versus 4 birds in 2000) and the number of sets with more than one bird (48 sets in 1999 versus 4 sets in 2000) were also dramatically greater in 1999 (Table 4). All measures of seabird interaction with fishing vessels decreased dramatically in 2000 (Figure 17). Local abundance, measured as the number of seabirds within a 100-meter radius of the stern as longlines were deployed, decreased almost 3-fold from 259 to 94 ($p = .0002$, $t = 3.73$). Although seabird counts were made to a distance of 100 meters in 2000 and to a distance where birds could be identified to species in 1999, we believe this difference in collection methodology to be minor. Because both shearwaters and northern fulmars, especially when mixed and numerous, are difficult to identify beyond 100 meters, observations in 1999 were indirectly limited to 100 meters. Attack rates were also lower in 2000 (4.5 attacks/min.) as compared to 1999 (9.1 attacks/min; $p = 0.016$, $t = 2.47$), although this difference is not as great (52% decline). Nevertheless, fewer birds and fewer attacks resulted in an order of magnitude decrease in seabird bycatch in 2000 (0.016 birds/1,000 hooks) as compared to 1999 (0.218 birds/1,000 hooks; $p < 0.001$, $c^2 = 210.3$, df =1).

Northern fulmars were the dominant species in both years. They were most abundant and attacked and were caught at the highest rates. Although there were proportionately fewer northern fulmars (80% to 65%) making fewer attacks in 2000 (74% to 51%), the proportion of the bycatch rate for northern fulmars was similarly high (94 to 88%) between years. Shearwaters were the next most abundant species (11%), making 19% of all attacks in 1999, but were eclipsed in both abundance (28%) and attacks (27%) in 2000 by the Larids (mostly kittiwakes and some gulls) in 2000. Despite this shift in relative abundance and behavior in 2000, shearwaters were the second most frequently caught seabird in both years (6%). In 2 years, one gull was the only other seabird species caught.

These data clearly demonstrate that, on a gross (e.g., annual) scale, fewer birds result in fewer attacks and lower rates of seabird bycatch. However, seabird abundance and attack rate are poor predictors of bycatch at finer scales (e.g., species-specific within day, trip and year), both in terms of the species caught and the magnitude of that catch.

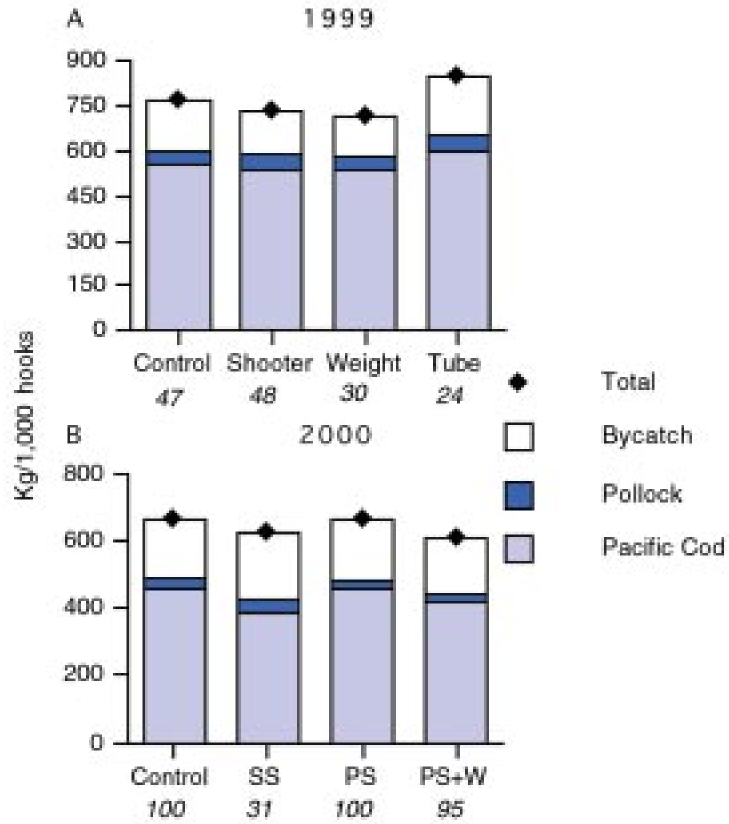

Figure 16. Pacific Cod: Mean fish CPUE by deterrent. (A) 1999 and (B) 2000. Control = no deterrent , Shooter = line shooter, Weight = groundline with added weight (4.5 kg every 90 m), Tube = lining tube, SS = single streamer, PS = paired streamer, PS+W = paired streamer lines with added weight (4.5 kg per 90 m). Error bars are standard errors. Scale obscures some error bars

Time of Day Differences (Control Data Only)

Because sets with bycatch in controls were few in 2000 (15 sets), we pooled data across years to compare bycatch rates among 3 time of day categories. In contrast to fish, time of day had a profound effect on seabird bycatch, both in overall magnitude and by species (Figure 15B). The rate at which seabirds were caught varied significantly across time of day categories ($p = 0.000$, $c^2 = 97.9$, df = 3) and was driven by northern fulmar bycatch. Hooking rates were significantly higher during nighttime hours (0.132 birds/1,000 hooks) and sunrise hours (0.074 birds/1,000 hooks) as compared to both day and sunset (0.016 birds/1,000 hooks and 0.012 birds/1,000 hooks respectively; $p= 0.000$, $t =6.62$). These differences remained robust when 2 outliers from 1999 were removed from the analysis. Northern fulmars dominated the catch in

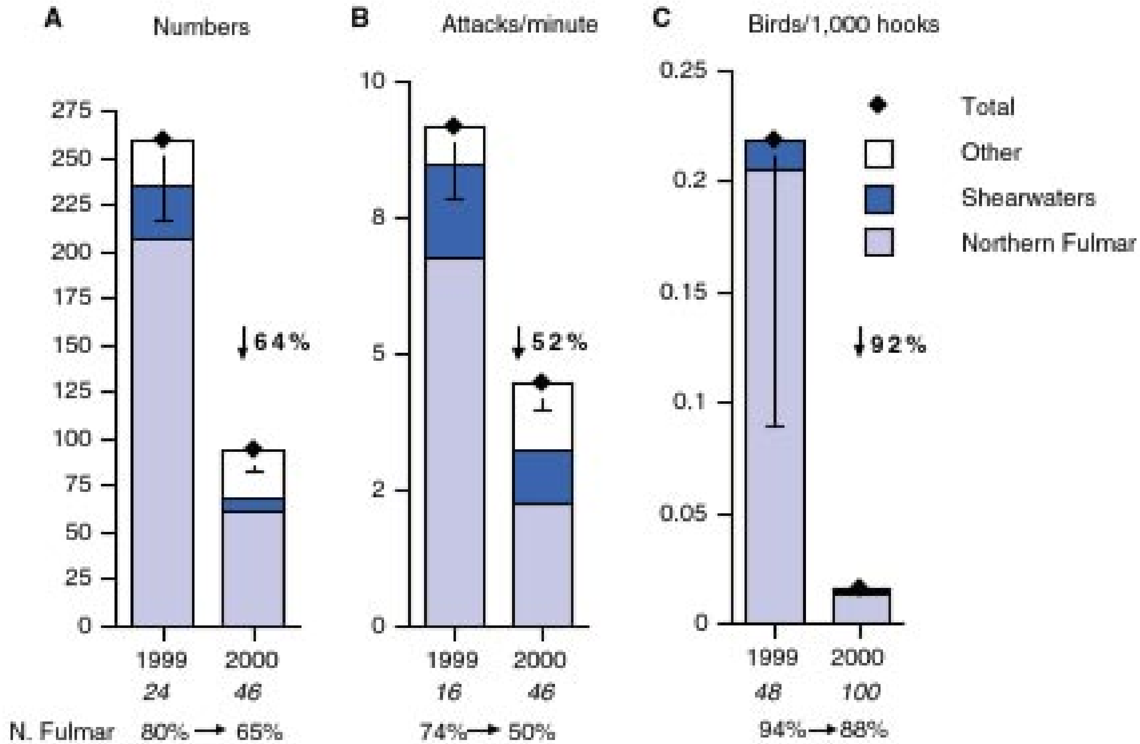

Figure 17. Pacific Cod: Inter-annual comparisons of seabird interactions. Control sets (no seabird deterrent) only. (A) Mean abundance in the aft hemisphere, (B) mean attacks per minute, and (C) mean bycatch per 1,000 hooks. Percent northern fulmar within year shown per variable. Only negative standard error bars are displayed.

all periods except day and were the only species caught at night and at sunset. By contrast, shearwaters were the predominant species caught during the day (67% of the total rate). Because albatross interactions were rare and none of these birds were caught, we can not evaluate the effect of time of day on the rate of albatross bycatch. However, our data strongly suggest that the use of night setting alone as a seabird bycatch deterrent is seriously flawed in Alaska waters, and if maintained, will result in high bycatch of northern fulmars.

Deterrent Comparisons

Multivariate models using the entire data set (i.e., control sets *and* deterrent sets) indicated that "deterrent" was the major factor exerting influence on seabird-gear interactions. Again, we considered years separately, as deterrents tested did not overlap. In 1999, no factor explained a significant amount of the deviation in attack rate. However, both time of day (10%) and deterrent (9%) contributed significant and roughly equal amounts of influence on seabird bycatch rate. Deterrents tested in 1999 were designed to submerge the gear beyond the range of seabirds. Total seabird abundance ($p = 0.732$, $F_{3,76} = 0.43$) and attack rate ($p = 0.715$, $F_{3,53} = 0.455$) did not vary significantly among treatments. However, total seabird bycatch did vary significantly ($p = 0.000$, $X^2 = 136.2$, df = 3; Figure 18 and Appendix 5). Total seabird CPUE significantly increased by 54% ($p = 0.000$, $t = 4.38$) over controls in sets made with the line shooter, whereas seabird bycatch significantly decreased in weighted sets (76%, $p = 0.000$, $t = -3.99$) and in sets using the lining tube (79%, $p = 0.000$, $t = -5.83$).

In general, patterns of mean abundance, mean attack, and mean CPUE were opposite for northern fulmars as compared to shearwaters (Figure 18), although neither fulmar nor shearwater abundance nor attack rates varied significantly by deterrent. Like total seabird CPUE, fulmar ($p = 0.001$, $t = -5.40$) and shearwater ($p = 0.003$, $t = 2.78$) CPUE increased in sets made with the line shooter relative to controls. However only fulmar CPUE decreased in weighted sets ($p < 0.001$, $t = -5.40$) and in sets using the lining tube ($p < 0.001$, $t = -5.95$). These reductions in fulmar bycatch were associated with 50% decreases in mean fulmar attack rates. Although mean shearwater attack rates doubled during sets with weighted gear and lining tube sets, the rate at which shearwaters were caught was relatively consistent among treatments. However, the relative proportion of shearwaters caught (percent of total catch rate) within weighted and lining tube sets was double that of line shooters and 3 times that of controls. These trends strongly suggest that shearwaters are able to reach the line once it has sunk beyond the range of northern fulmars, with the most dramatic effects occurring in

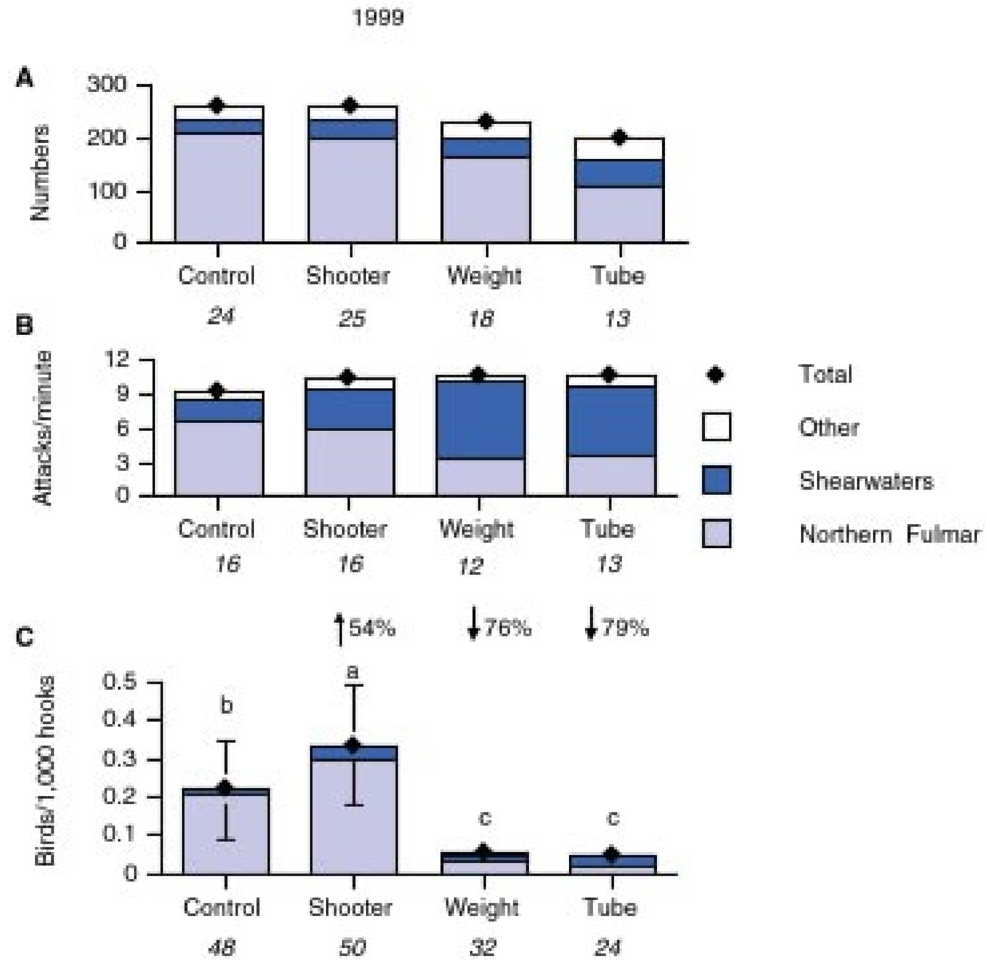

Figure 18. Pacific Cod 1999: Seabird interactions by deterrent.

(A) Mean abundance (aft hemisphere), (B) mean attacks per minute, and (C) mean bycatch per 1,000 hooks by deterrent and species. Control = no deterrent , Shooter = line shooter, Weight = groundline with added weight (4.5 kg every 90 m), Tube = lining tube. Significant post hoc groupings (at least p< 0.05) are indicated by lowercase letters. Error bars are standard errors. Scale obscures some error bars.

the sets designed to enhance the sink rate of the gear (i.e., weighted gear and the lining tube).

In 2000, "deterrent" was the only factor in the multivariate models to significantly influence attack (19%) and bycatch (19%) rates. Unlike the deterrents tested in 1999, the deterrents tested in 2000 were designed to physically prevent the birds from gaining access to sinking baits. Total seabird abundance ($p = 0.009$, $F_{3,145} = 4.051$), attack rate ($p = 0.000$, $F_{3,144} = 11.10$), and bycatch rate ($p = 0.000$, $c^2 = 29.97$, df = 3) varied significantly among treatments (Figure 19 and Appendix 5).

Fewer birds attended sets made with paired streamer lines or paired streamer lines with weight (63.7 birds and 65.7 birds, respectively) than control sets (94.4 birds) or single streamer sets (108.7 birds). Post-hoc comparisons of abundance revealed that none of the treatments varied significantly from controls; however, single streamer sets had significantly more birds in attendance than paired streamer sets ($p=0.004$, $t=-2.90$). Relative to controls, post-hoc comparisons showed that both paired streamer deterrents reduced attacks; however, attack rates during single streamer sets were not significantly different from controls or paired streamer lines. This same relationship holds for northern fulmar attacks, however, differences in bycatch rates were more pronounced. Both paired streamer lines ($t = -2.85$, $p = 0.002$) and paired streamer lines with weight ($t = -3.24$, $p = 0.0006$) reduced seabird bycatch by 94 percent, relative to controls. Although in 1999, weighted gear reduced seabird bycatch relative to controls, in 2000 the addition of weight to longlines set with paired streamer lines did not enhance the efficiency of the paired streamer deterrent. Single streamer lines were less effective and not significantly different from controls ($t = -1.52$, $p = 0.064$).

In 2000 as in 1999, species-specific effects were dramatic. Northern fulmars were the predominant species present during control sets ($p = 0.002$, $F_{3,144} = 5.15$; Figure 19A). However, streamer lines

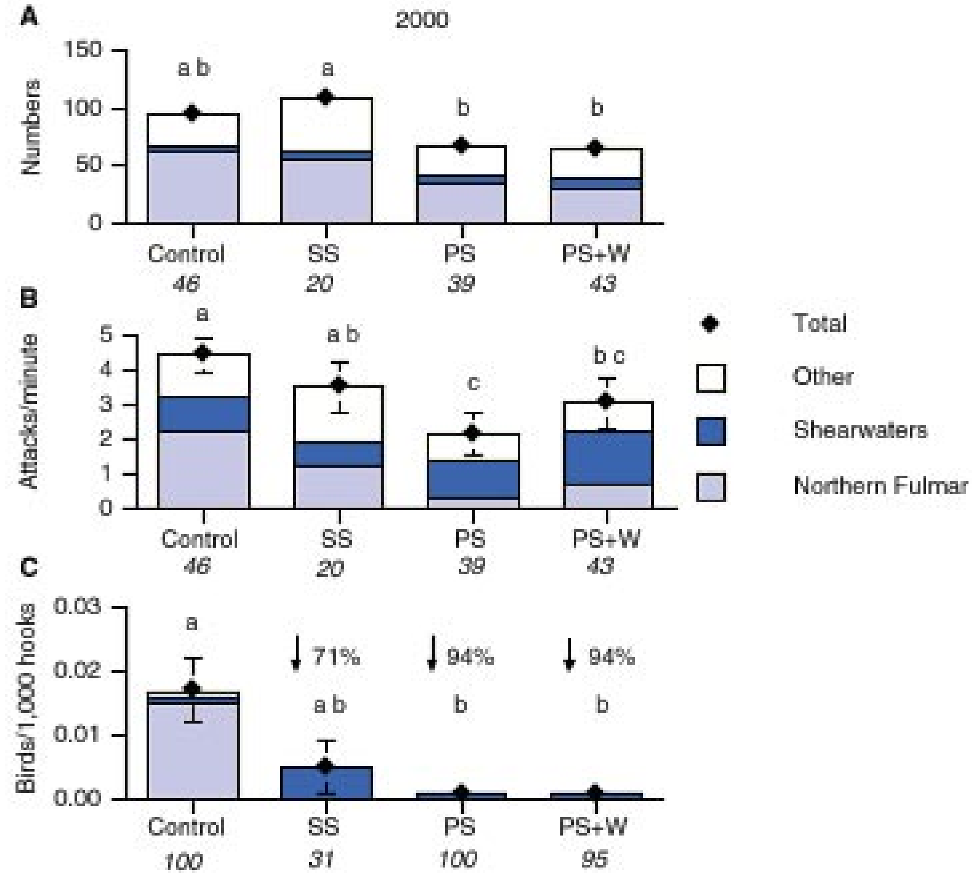

Figure 19. Pacific Cod 2000: Seabird interactions by deterrent.

(A) Mean abundance (aft hemisphere), (B) mean attacks per minute, and (C) mean bycatch per 1,000 hooks by deterrent and species. Control = no deterrent , SS = single streamer, PS = paired streamer, PS+W = paired streamer lines with added weight (4.5 kg every 90 m). Significant post hoc groupings (at least p< 0.05) are indicated by lowercase letters. Error bars are standard errors. Scale obscures some error bars.

appeared to reduce northern fulmar attacks (significantly for paired streamer lines), resulting in no northern fulmar bycatch (Figure 19C). Shearwaters, which accounted for only 22 percent of total attacks in control sets, were the only species caught in all streamer deterrents and became the dominant species attacking, and being caught in sets with paired streamer lines. The mean rate of shearwater bycatch actually increased from control sets (0.001 birds/1,000 hooks) to single streamer lines (.005 birds/1,000 hooks). However, this was not statistically different.

Attack Rate by Distance Astern

Because the distribution of seabird attacks by distance astern of the vessel and by species was identical in sets with no deterrent between years, we present results for 2000 as representative of both years (Figure 20). In controls, seabird attacks on baited hooks occurred over a broad range - from 10 meters to 100 meters - with over 97 percent of all attacks occurring from 10 meters to 80 meters aft of the stern (Figure 20) As with the sablefish fishery, the distribution of seabird attacks along sinking longlines varied by species. Northern fulmars dominated the area from 20 meters to 40 meters astern (73% of northern fulmar attacks) with attacks peaking at 30 meters. Shearwaters, virtually absent in the sablefish fishery, peaked in attacks at 50 meters and exceeded northern fulmars beyond that point (47% of shearwaters attacks). Kittiwakes and gulls mimicked attack distributions of northern fulmars and shearwaters, respectively. Laysan albatross attacks were extremely rare, and none was recorded beyond 80 meters.

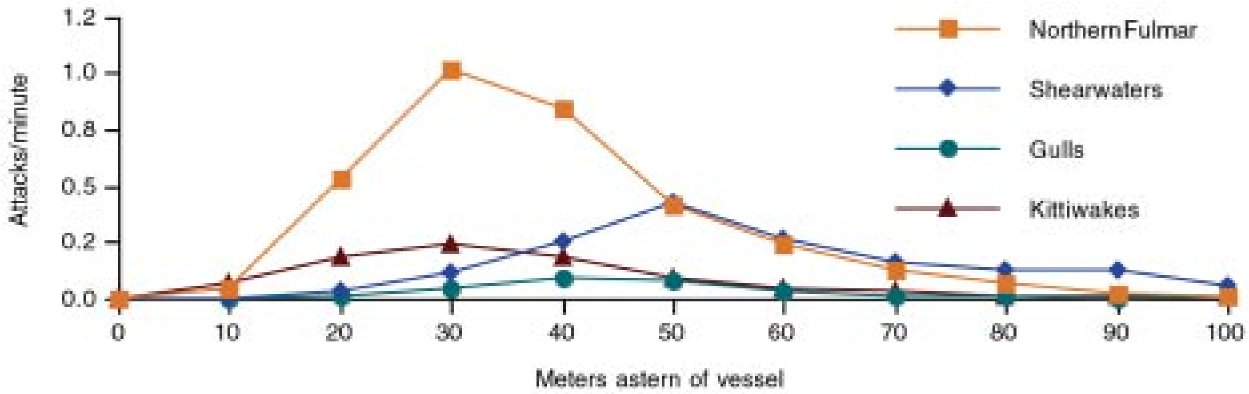

Figure 20. Pacific Cod 2000: Distribution of seabird attacks astern of the vessel by species.
Control sets (no seabird deterrent) only.

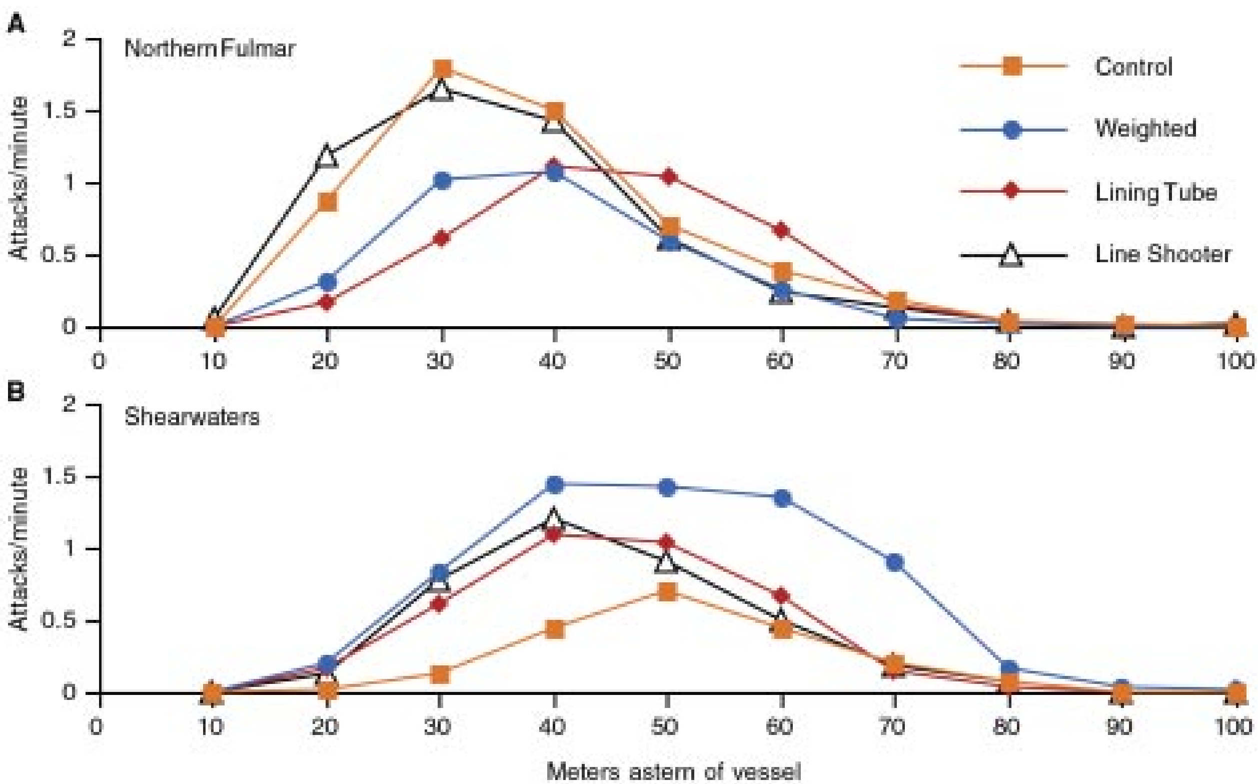

Figure 21. Pacific Cod 1999: Distribution of seabird attacks astern of the vessel by deterrent.
(A) Northern fulmar and (B) shearwaters. Control = no deterrent , Shooter = line shooter, Weight = groundline with added weight (4.5 kg every 90 m), Tube = lining tube.

In 1999, differences in seabird attack rates among and between deterrents and the control were subtle in the cod fishery, and the species-specific response varied (Figure 21). Line shooters appeared to have no effect on either the rate or distribution of northern fulmar attacks. Northern fulmar attacks were fewer and farther back (40 m) in response to weighted gear and the lining tube - the 2 deterrents intended to sink gear faster. For all 3 deterrents, shearwater attacks were more intense and occurred closer to the vessel compared to the control. Shearwater responses to the lining tube and the line shooter were similar, but shearwater attacks were most intense on weighted gear and occurred over the broadest range.

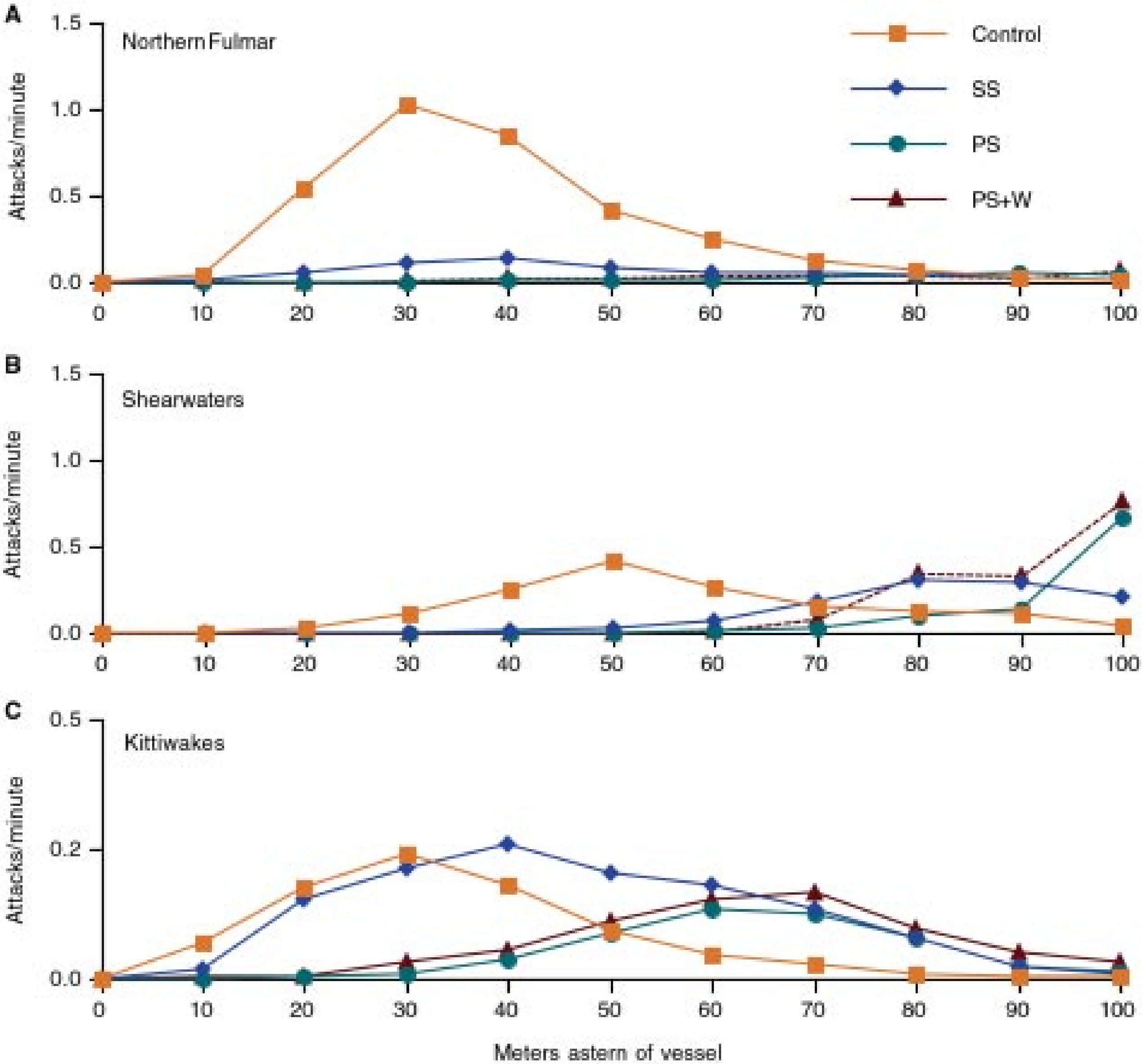

Figure 22. Pacific Cod 2000: Distribution of seabird attacks astern of the vessel by deterrent.

(A) Northern fulmar, (B) shearwaters, and (C) kittiwakes. Control = no deterrent , SS = single streamer, PS = paired streamer, PS+W = paired streamer lines with added weight (4.5 kg every 90 m).

In 2000, all streamer line deterrents displaced attacks farther away from the vessel, and this shift was species-specific (Figure 22). Deterrents reduced bait attacks dramatically in an area out to 60 meters, where over 88 percent of all attacks occurred in controls (Figure 22). However, unlike the sablefish fishery, total attacks using all streamer line deterrents exceeded controls beyond 70 meters. This displacement of attacks away from the vessel was primarily due to increased attacks by shearwaters, but northern fulmars and kittiwakes also attacked farther from the vessel when streamer lines were used (Figure 22). This effect was most pronounced during paired streamer sets in which attack rates peaked at 100 meters (10 m beyond the streamer lines). Although single streamer lines had no effect on northern fulmar distribution or intensity (as discussed in the Deterrents section) compared to controls, they resulted in an increase in kittiwake attacks over controls beyond 30 meters astern of the vessel.

Discussion

Spatio-Temporal Effects

Our study clearly shows dramatic changes in abundance of seabirds at vessels, attack rate, and seabird bycatch as a function of both time (year and time of day; Figures 9, 15, and 17) and fishing region (for the sablefish fishery; Figure 7). Unlike seabird interactions, target fish CPUE remained constant (sablefish fishery) or declined slightly (by 13% in the 2000 cod fishery) between years (Figures 6 and 14). All measures of seabird interaction with the fisheries were two to three times higher in 1999 relative to 2000. Thus, despite a doubling of sampling effort from 1999 to 2000, our absolute seabird catch rate dropped by 74 percent (sablefish fishery) and 93 percent (cod fishery), and sets that captured birds became very rare - 15 percent in control sets and 5 percent overall in 2000 (for both fisheries, Table 4). This inter-annual variation in seabird bycatch is consistent with the threefold variation in estimated total seabird bycatch for the Alaska's groundfish fishery from 1993 to 1999 (Figure 1; Appendix I). Melvin *et al.* (1999) report similar inter-annual effects in a coastal gillnet fishery in Washington state, where a threefold change in seabird abundance and order of magnitude change in seabird bycatch is noted.

Extreme inter-annual variation in rare event phenomena such as seabird bycatch has important management implications. It underscores the need for multi-year studies, both to characterize the extent of bycatch as well as to test solutions. Threefold variation in seabird bycatch creates a dynamic background over which to find changes resulting from management actions. This is because changes in bycatch in any one year could be a function of inherent variation in seabird interactions (such as the apparent change in northern fulmar foraging distributions witnessed in this study) rather than the success or failure of the fleet to reduce those interactions. Given this variability, adequate evaluation of seabird bycatch deterrents will require analysis of multi-year data sets.

There were also marked differences in seabird interactions with the gear within day. Throughout 1999 and 2000, the diurnal pattern of fish catch in the cod fishery remained unchanged (Figure 15A), whereas seabird bycatch was significantly (10 x) higher at night and sunrise relative to day and sunset (Figure 15B). These differences were driven by northern fulmar interaction – northern fulmars were the dominant species caught in this fishery, and the only species caught at night. Night hookings of northern fulmars are consistent with their nocturnal feeding habits (Hatch and Nettleship 1998). One Laysan albatross was caught at night in each year in the sablefish fishery demonstrating that albatross can be active at night. However, our experimental design in the sablefish fishery was not established to test diurnal differences in bycatch rates, therefore these data provide little insight on the relative catch rates of albatross between day and night.

Night hookings of seabirds have been reported by many authors in both pelagic and demersal longline fisheries, most at rates somewhat to significantly less than during the day (Barnes *et al.* 1997, Brothers *et al.* 1999b, Weimerskirch *et al.* 2000). Seabird catch by time of day appears to be species-specific. Cherel *et al.* (1996) reported 62 percent of all seabird bycatch during night sets, the majority of which were white-chinned petrels (*Procellaria aequinoctialis*), a night-active species. In this study in the sablefish fishery, gear deployment was conducted primarily during the day (83% of sets), precluding a quantitative analysis of time of day effects. In short, in regions where night-active seabird species occur, encouraging night fishing is not an effective seabird bycatch mitigation strategy. Thus, it is apparent that in the North Pacific, some seabirds, including Laysan albatross, are active at night and the regulation that allows night fishing alone as a deterrent should be eliminated.

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Finally, regional differences were apparent in the sablefish fishery. Where fishing occurred over a 1,500 nautical miles band stretching from Yakutat to the Aleutian Islands (Figure 5), changes in seabird bycatch were almost an order of magnitude higher in the Aleutian Islands relative to the central Gulf of Alaska in 1999, our "high" bycatch year (Figure 7). In both years, seabird bycatch was highest in the Aleutian Islands and, in general, appeared to increase as fishing moved west (Figure 7).

It should be noted that in the sablefish fishery, seasonal and regional effects were confounded. This result was reinforced by the generalized linear model, which indicated that, in control sets, variation in seabird attack rate was always explained by annual effects (i.e., loading "year"). It was further explained by loading either "date" or "region", but not both. In 2000, we increased the length of the fishing season and increased the regional scope (by fishing farther east and relatively more in the west). In general, fishing effort in this study started in the east and moved west with the season. Thus, within a year (especially 2000), bycatch increased later and was higher in the west (Figure 7). Because our study was not designed *a priori* to examine seasonal-regional interactions, we are not able to tease out these effects. Regional restrictions on fishing to avoid seabird bycatch have been proposed in some fisheries (e.g., Southern

Because comprehensive technical solutions (i.e., paired streamer lines) were effective across regions and are preferred, management action calling for regional closures are unnecessary and are not recommended based on these data.

… seasonal, time of day, and area closures are not recommended for the Alaska demersal longline fisheries. Rather, we advocate the use of deterrents.

Ocean CCAMLR fisheries, Appendix II). Although our results in the sablefish fishery indicate higher seabird bycatch in the Aleutian Island region, we caution that our study covered only 1.5 months out of an 8-month season, and its timing was specifically selected for high bird interactions. Because comprehensive technical solutions (i.e., paired streamer lines) were effective across regions and are preferred, management action calling for regional closures are unnecessary and are not recommended based on these data.

Species-specific differences in control sets were striking, especially within the region of highest bycatch, the Aleutian Islands (Figure 7). Northern fulmars predominated seabird bycatch rates in 1999, accounting for 80 percent of all hookings in the sablefish fishery (Table 4). However, in 2000, northern fulmars were relatively absent from the catch, dropping from 76 percent to 22 percent of the total bycatch rate (Figure 9). This difference was magnified in the Aleutian Islands, where northern fulmar bycatch rate dropped from 0.755 birds per 1,000 hooks in 1999 to 0.017 birds per 1,000 hooks in 2000. By contrast, Laysan albatross hooking rates were fairly constant in the Aleutian Islands, varying by only 0.142 to 0.108 birds per 1,000 hooks.

Regional, temporal (both inter- and intra-annual), and species-specific differences emphasize the need to develop comprehensive mitigation strategies that can effectively cover a wide range of change in seabird interaction intensity, often over an order of magnitude. The fact that these differences do not appear to be entirely predictable, especially among years and species (Figure 1), reinforces this need. Thus, seasonal, time of day, and area closures are not recommended for the Alaska demersal longline fisheries. Rather, we advocate the use of deterrents.

Deterrents

Streamer Lines

Our research clearly demonstrates that paired streamer lines work. In the months that we conducted our research, paired streamer lines reduced seabird bycatch rates by 88 percent to 100 percent relative to controls with no deterrent (Figures 10, 11, and 19). Paired streamer lines successfully reduced seabird bycatch in all years, regions, and fleets, despite the fact that we saw order of magnitude variation in bycatch across years and among regions (the latter within the sablefish fishery). Furthermore, this success comes with no consequence to target-fish catch rates or the rate of capture of other bycatch species, thus satisfying our primary goal. During our research, paired streamer lines were robust in a wide range of wind conditions and required little adjustment as physical conditions changed. Functionally, the pair of streamer lines created a moving fence that precluded seabird attacks.

Paired streamer lines worked because they altered the ability of most seabird species to reach baited hooks. In both fisheries when paired streamer lines were used, patterns of seabird abundance and seabird attack rate mirrored bycatch rates and were significantly reduced in both years, compared to controls (Figures 10, 11, and 19). This was not comprehensively true of any other deterrent tested, including single streamer lines. In control conditions, most seabirds attacked within the first 50 meters behind the vessel (Figures 12A and 20), where the groundline is at or near the surface (Melvin and Robertson, in prep). In addition to decreasing total attacks, paired streamer lines increased the distance at which peak attacks occurred astern of the vessel by 20 meters to 40 meters, depending on species and fishery (Figures 12 and 22) reducing the likelihood of hookings.

In the 2000 sablefish fishery, paired streamer lines virtually eliminated attacks by Laysan albatross and northern fulmar throughout the 100-meter area monitored and completely eliminated albatross and northern fulmar bycatch. In 1999, paired streamer lines were slightly less effective than in 2000 - a difference we attributed to the dramatically higher attack rates in 1999, as well as to improved performance standards in 2000. Shearwaters were the exception, attacking farther astern in control sets than any other species (Figure 22B). Although shearwaters were displaced farther astern with the use of paired streamer lines, these birds were able to attack the groundline beyond the effective range of the streamer lines. Even when paired streamer lines were used, bycatch and total attack rates of shearwaters were unchanged from those in control sets (Figure 19).

Species-specific differences in the efficacy of paired streamer lines can be explained by seabird diving propensities. Shearwaters surface, plunge, and pursuit dive (actively swim below the surface) for extended periods and are capable of diving to beyond 10 meters (Brown *et al.* 1978, Skira 1979). Northern fulmars typically surface dive and have been reported to dive to 3 meters for brief periods (Hatch and Nettleship 1998). In our anecdotal observations, Laysan albatross rarely submerged themselves completely and when they did, returned to the surface within 1 or 2 seconds. Thus, we assumed that both northern fulmars and Laysan albatross rarely reached beyond a 2-meter depth when attacking baits. Alternatively, shearwaters can probably attack baits below the surface and well beyond this depth, and therefore, can attack baits for a considerable distance (greater than 100 m) behind a vessel.

Although comparable controlled studies of paired streamer lines do not exist at this time, many studies have been conducted on the efficacy of single streamer lines. Several studies using post-hoc analyses of observer data have reported significant declines in seabird bycatch or attack rates with the use of single streamer lines (Brothers 1991, Brothers and Foster 1997). However, some studies have reported no effect of streamer lines (Weimerskirch *et al.* 2000) or increases in seabird bycatch (Brothers *et al.* 1999b).

Working in a Norwegian demersal longline fishery for torsk and ling, Løkkeborg (1998, 2001) found that single streamer lines reduced seabird bycatch rates by 92 to 100 percent compared to controls of no deterrent, with no effect on the target catch. Finfish bycatch was not addressed. As with our paired streamer results from the sablefish fishery, target fish catch appeared to increase with the use of streamer lines (Løkkeborg 2000), but differences were not significant in either study. Løkkeborg (2000) reported no seabird bycatch with the use of single streamer lines.

In our study, single streamer lines in 2000 were slightly less effective than paired streamer lines, reducing seabird bycatch by 96 percent and 71 percent in the sablefish and cod fisheries, respectively (Figure 11 and 19). Although the difference between single and paired streamer lines was not significant, we stress that single streamer lines were not tested to the same extent between fisheries or years. In the cod fishery, single streamer deployments were limited to occasions when a fourth set could be made in a given day, resulting in roughly a third of the sample size of all other treatments and no balance across time of day. Because shearwaters were only caught during sunrise and daytime sets (Figure 15), single streamer lines were not adequately tested across all seabird species. Furthermore, single streamer lines were only tested in 2000, when seabird interactions were significantly lower than in 1999 (Figures 9 and 17).

Behavioral evidence also suggests that single streamer lines were less effective. In the sablefish fishery, single streamer lines sets allowed significantly more bait attacks than paired streamer sets (Figure 11B). In the cod fishery, seabird abundance and attack rates during single streamer sets were not significantly different from controls of no deterrent (Figure 19). However, when single streamer lines were used, Laysan albatross attack rates were five times that of paired streamer deployments (Figure 11). This suggests that the risk of hooking albatrosses, including the short-tailed albatross, remains when single streamer lines are used.

Qualitative observation indicated that single streamer lines were effective at reducing seabird bycatch under certain conditions. When flown from the windward side of the vessel in moderate wind, a single streamer line could be quite effective at deterring seabirds from sinking baits, as the streamers were located over the groundline. However, if flown with no wind, from the center of the vessel, or from the leeward side especially in strong wind conditions, single streamer lines were rendered ineffective. Løkkeborg(1998, 2000), Brothers *et al.* (1999b) and Agnew *et al.* (2000) all caution that single streamer lines are less effective in high winds and in winds perpendicular to vessel direction, as the wind can blow single streamer lines off the gear. Løkkeborg (2001) suggested this weather effect be remedied with the use of paired streamer lines, a suggestion confirmed by our study.

Given the strong statistical evidence that paired steamer lines reduce bird abundance in the vicinity of the groundline, reduce attacks on the groundline, and reduce the resultant bycatch of seabirds, we strongly recommend that paired streamer lines be required in Alaska longline fisheries and that paired streamer lines be flown throughout the entire set. If both streamer lines cannot be deployed prior to the first hook due to vessel logistics (in cod the distance between the buoy and the first hook is short), one streamer line should be deployed prior to deployment of the first hook. Both streamer lines must be fully deployed within 90 seconds of the first hook entering the water (roughly the time for one skate of gear to be deployed at 4 knots) until after the last hook is deployed.

… we strongly recommend that paired streamer lines be required in Alaska longline fisheries and that paired streamer lines be flown throughout the entire set.

Streamer Line Performance Standard and Materials

Streamer line effectiveness is a function of the distance astern the line and the steamers fly above the water, the spacing of streamers, and streamer materials. The aerial extent of the streamer line is critical to successful deployment for two reasons: the greater the aerial distance the less chance the streamer line will foul on the groundline and the more effective streamer lines will be at deterring birds. We identify minimum acceptable distances astern to which streamer lines must be airborne as fishery-specific performance standards. Standards are based on our species-specific data parceling attacks on the groundline by distance astern, as well as on our own experiences flying streamer lines in this study.

Northern fulmars, the dominant species in this study and the only species common to both fisheries, appeared to attack baits slightly closer to the vessel in the sablefish fishery as compared to the cod fishery (Figure 23A). Furthermore, sink rate data collected by Melvin and Robertson (in prep) suggest that hand-baited gear sinks faster than cod auto-bait gear (Figures 23 and 24; see "Weighted Gear"). Both of these facts necessitate a change in streamer line performance standard between

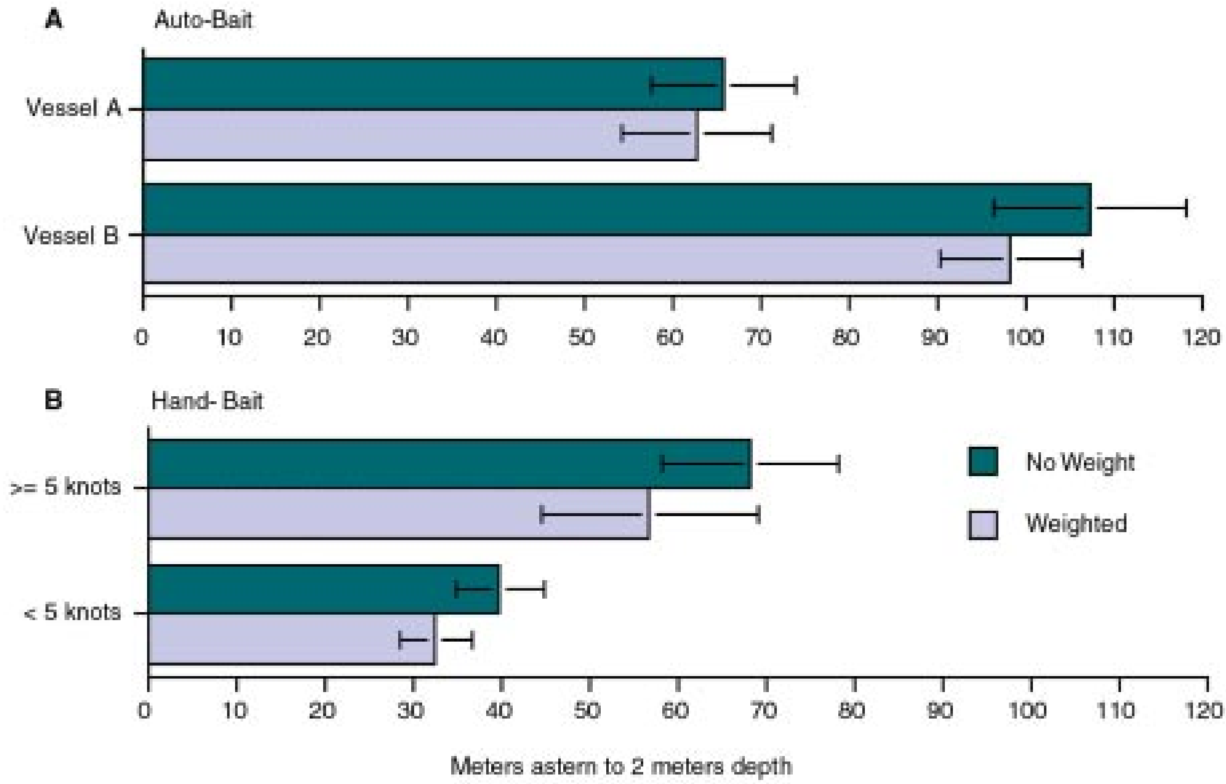

Figure 23. Contrast of northern fulmar attack rate and sink distance of un-weighted groundline by fishery.

(A) Percent total attacks of northern fulmar by distance in control sets. (B) Range of distance astern of vessel that un-weighted groundline reaches depth of 2 meters. BC = best-case scenario. WC = worst-case scenario.

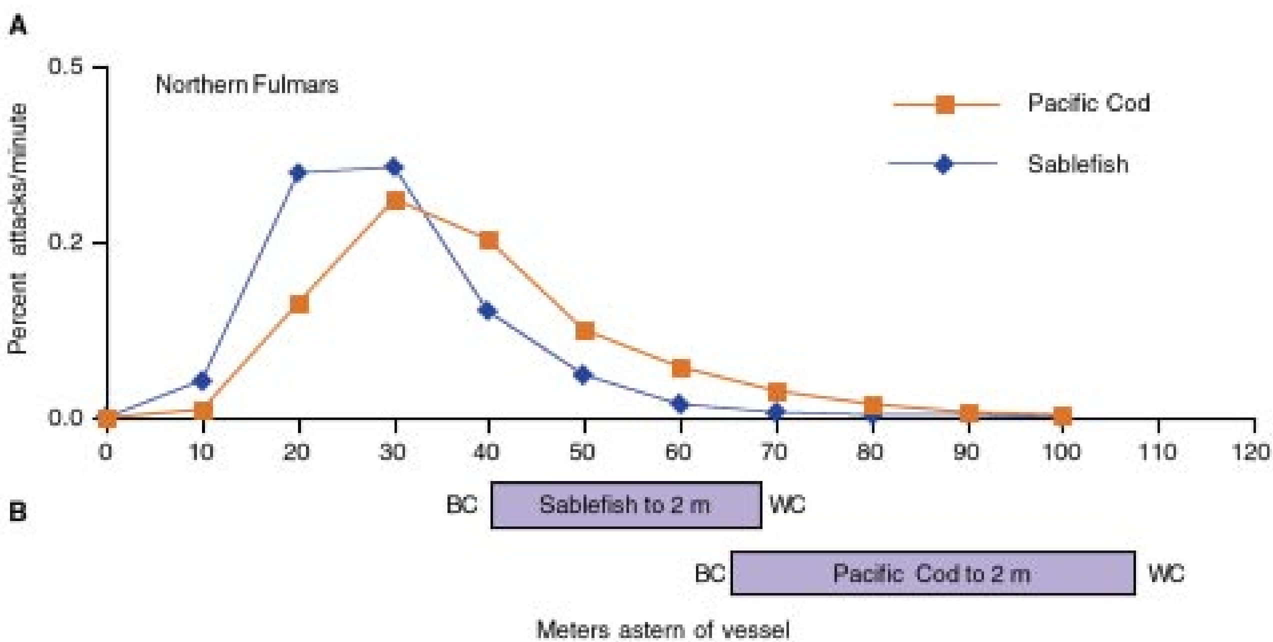

Figure 24. Comparisons of sink rate distances.

Distance astern at which groundlines sink to a depth of 2 meters varies for weighted and un-weighted gear. (A) Auto-bait (cod) by vessel; auto-bait weighted is 4.5 kilograms per 90 meters. (B) Hand-bait (sablefish) by vessel speed; hand-bait weighted is 0.23 kilograms per 11 meters (0.5 lbs per 10 hooks) plus 2 to 3 kilograms at each skate junction. Error bars are 95% confidence intervals.

fisheries if the groundline is going to be adequately protected at depths above the 2 meter benchmark. For our study, we achieved a performance standard of flying streamers 50 meters astern by attaching streamer lines a minimum of 6.1 meters (20 feet) above the water at the stern.

In the sablefish fishery, a performance standard requiring streamers be flown over the gear to 40 meters astern would preclude birds from the area where over 90 percent of all northern fulmar attacks occurred (Figure 23A). Forty meters is also the distance at which gear sank beneath the 2 meter benchmark for slow-setting (< 5 knots) vessels using un-weighted gear (the best case scenario for sablefish; Figure 23B). In our experience working with vessels and crews in this fleet, we are confident that a 40-meter minimum performance standard can be achieved. Vessels that set gear in the 6-knot to 7-knot range and/or experience intense seabird interactions should use a mixture of strategies including extending the streamer flight distance, adding weight to the gear, and reducing vessel speed. We note that flying streamers out to 70 meters or more, where fast-setting un-weighted gear sinks out of the reach of northern fulmars and albatross, is difficult to achieve with the streamer line we used. The aerial distance could be extended with continued innovation of streamer line materials.

In the freezer-longline fleet for cod, groundlines take longer to sink. However, vessels are larger and can fly streamer lines out to greater distances. A performance standard that requires streamer lines be flown to a minimum of 60 meters would span the area where 94 percent of northern fulmar attacks occurred (Figure 23A). Sixty meters is shorter than the distance vessels setting gear into the down-wash of the propeller sank un-weighted gear to the 2-meter benchmark (the best case scenario for cod; Figure 23B). Vessels that set gear into the updraft of the propeller wash should consider extending the streamer flight distance, setting at slower speeds, and/or adding weight to the gear.

Materials used were based on our best judgement and feedback from fishers. The streamer line itself (5/16 diameter 3-strand) was chosen with the assumption that it would be hauled by hand and that smaller diameter line would prove difficult to handle. However, a smaller diameter streamer line might fly farther astern of the vessel due to reduced weight and wind resistance. The 90-meter length was effective in both fisheries and proved practical in all applications we tested. Buoys or drogues, usually with weights attached, were tied to the ends of streamer lines to create drag.

The UV-protected orange tubing we selected for streamers worked well and did not harden or crack with exposure to sunlight. We chose tubing because we sought a material that would break if it became fouled on a hook, as opposed to a material with a higher tensile strength that might interfere with fishing operations if fouled. Yellow polypropylene 3/8-inch diameter line also performed satisfactorily and was more resistant to breakage than tubing, especially when retrieved with hydraulics. The important feature of streamers seemed to be density - streamers need to be heavy enough to maintain a nearly vertical "fence" in moderate to high winds. Streamers must hang to the waterline, without being submerged to minimize the chances that streamers will be hooked. At the same time, streamers that are too short may allow flying birds access to the baits by flying under the streamers. Little is known about effective colors. However, high-contrast, bright colors such as yellow, red, and orange are recommended. We deliberately avoided attaching streamers via hardware for 2 reasons — to minimize cost and make the line as light as possible.

Finally, breakaways are essential for safety. In our experience, breakaways were best placed in multiple locations including at the buoy or drogue and at the attachment point to the vessel. In our study, placement of breakaways were at the discretion of the captain and crew.

Given these data and arguments and the fact that the streamer lines used in this research program proved effective and practical, we recommend that the requirement to fly paired streamer lines include performance standards and material specifications. Specifically, we recommend that vessels under 30.5 meters (100 feet) be required to fly paired streamer lines to a minimum of 40 meters behind the vessel and that vessels 30.5 meters or larger be required to fly paired streamer lines to a distance of 60 meters astern of the vessel. We also recommend the following minimum streamer line specifications be required:
Length: 300 feet (~90 meters)
Spacing of streamers: Every 5 meters until performance standard is achieved.
Streamer material: Brightly colored plastic tubing or 3/8 inch polyester line or material of an equivalent density. An individual streamer must hang from the mainline to a minimum of 0.25 meters above the water in the absence of wind.
Line material: discretionary
Terminal end: discretionary
Breakaways: discretionary, but highly recommended.

Proper deployment of streamer lines requires a clear understanding of the performance standard and a carefully choreographed procedure by crew. Missteps in setting gear can lead to streamer lines tangling with each other or the groundline and great frustration for the crew. Furthermore, if streamer lines are not set according to a relevant

We strongly recommend that a fisher-targeted education program be developed that clearly illustrates how streamer lines work, how to deploy paired streamer lines, and why seabird conservation is important to the fishery.

We recommend that fishers in the sablefish and halibut fleets who add weights to skate junctions while deploying gear be aware of this effect and develop methods to minimize it.

performance standard, they can be ineffective at deterring birds. In our study, setting longline gear with 2 streamer lines required forethought and practice. We strongly recommend that a fisher-targeted education program be developed that clearly illustrates how streamer lines work, how to deploy paired streamer lines, and why seabird conservation is important to the fishery. Considering that most vessels in the sablefish and halibut fleet do not have observer coverage, education is as important or more important than regulatory approaches. In the freezer-longline fishery, most vessels carry observers at all times, but the relatively high turnover rates of sometimes multilingual crews coupled with corporate ownership make education a particular need and challenge in this fleet. Educational approaches might include workshops presented in major longline ports in cooperation with local fishery associations, development of a video and other education materials, and establishment of a full time position to work one-on-one with individual vessels and crews throughout Alaska.

During our final ad-hoc meeting, captains of freezer-longline vessels suggested that, in certain weather conditions, paired streamer lines would have a high likelihood of fouling (on each other or on the groundline), creating dangerous conditions. In addition, there are weather conditions in which the captain would not want crew on the buoy deck deploying or adjusting streamer lines, but not so severe as to preclude fishing. Based on these discussions, we recommend the following caveats to the paired streamer line requirement:

- In conditions of wind speeds exceeding 30 knots (near gale or Beaufort 7 conditions), it is acceptable to fly a single streamer from the windward side of the vessel; and,
- In winds exceeding 45 knots (strong gale or Beaufort 9 conditions), the safety of crew supersedes deployment of streamer lines.

Weighted Gear

Our work in both fisheries clearly showed that weighting gear had no negative effect on target catch, but its effect on seabird bycatch was variable. In 1999, adding weight to the gear significantly reduced seabird bycatch relative to a control of no deterrent by 37 percent for the sablefish fishery and 76 percent for the cod fishery (Figures 10 and 18), although the effect was not as pronounced as for paired streamer lines (Figure 10). Based on these results, we hypothesized that the combination of paired streamer lines and weight would yield seabird bycatch rates approaching zero. However in 2000, the addition of weight to the groundline provided no improvement in the already high bycatch reduction of paired streamer lines (Figures 11 and 19). It is possible that weighting would have a greater effect in higher bird-interaction years (i.e., 1999 versus 2000). In the only other experimental test of the efficacy of added weight, Agnew *et al.* (2000) found an 80 percent reduction in seabird bycatch with the addition of 8.5 kilograms per 40 meters of mainline, but no additional reductions with further weight increases. All sets were made with single streamer lines.

Theoretically, added weight should reduce seabird bycatch because it causes the groundline to sink faster, shrinking the total distance astern that baited hooks are available to seabirds. However, behavioral data do not support this mechanism: added weight alone had no effect on total seabird abundance or attack rate in either fishery (Figures 10 and 18) and actually increased the mean attack rate of shearwaters (the deeper diving species) although this difference was not statistically significant (Figures 18B and 21). Despite the lack of change in seabird behavior, seabird bycatch rates were significantly reduced in weighted sets relative to controls primarily by eliminating fulmars from the catch.

For both fisheries, we used a benchmark of 2 meters as the depth beyond which the majority of seabirds (the exception being shearwaters) cannot access baited hooks on the groundline. Thus, the important variable is the distance behind the vessel that the gear first reaches 2 meters depth— a function of sink rate and vessel speed. The distance at which the groundline reaches a specific depth, is the time to reach that depth (depth divided by sink rate) times vessel speed. In a separate study, Melvin and Robertson (in prep) compared the sink rate of added-weight deterrents to that of un-weighted gear, using time-depth recorders. In the sablefish fishery, where one-half pound (0.23 kg) weight was added to the groundline every 11 meters, weighted lines did sink significantly faster. However, this difference only translated into an approximate 10-meter improvement in the distance astern to our 2-meter depth benchmark (15-20% reduction in total distance; Figure 24). By contrast, groundlines stayed above 2 meters for 25 meters to 30 meters longer on fast (6-7 knots) setting vessels as compared to slow (3-5 knots) setting vessels, regardless of weighting (40% increase in total distance; Figure 24B). Clearly in this case at these weighting schemes vessel speed had a much greater influence on the distance at which longlines were vulnerable to bird attacks.

In the cod fishery, the addition of 4.5 kilograms (10 lbs) of weight per 90 meters made no significant difference in sink rate (Figure 24A). Weight at these intervals merely served to enhance the sink rate within 10 meters to 15 meters of the weight with little effect on the overall line at the surface. However, inherent vessel differences, most probably associated with whether the groundline was set into the down-wash or up-wash of the propeller, translated into a 35 percent to 40 percent increase in total distance astern to 2 meters. We conclude from these data that, although adding weight to groundlines will sink gear faster, differences in vessel speed or setting logistics could reduce or eliminate the advantage of using weighted groundlines.

Independent of our weighted treatment, weights were added to the skate junctions in the sablefish fishery as a matter of course (including controls). With bundled or "skate-bottom" gear, this was accomplished by tying off a 1.8-kilogram to 4.5-kilogram (4-10 lb.) weight at the skate junction and setting it on the bundle of gear. We noted, as did several of the fishers with whom we worked, that adding weight in this manner forced the groundline taut as the tension built to lift the weight up the setting chute. Depending on the mass of the weight and the height of the chute, this occasionally pulled the groundline to the surface or even out of the water 20 meters to 30 meters astern, and made baits more available to birds. Based on this observation and the comments of fishers, we recommend that fishers in the sablefish and halibut fleets who add weights to skate junctions while deploying gear be aware of this effect and develop methods to minimize it. One option might be to modify the chute to allow deployment of the weight from near the top of the chute.

In the cod fishery, the attachment of additional weight to the groundline posed a safety hazard during both deployment and retrieval. Clipping weights to the gear increased the likelihood of crew members getting hooked and stopping the gear to unclip the weight increased the chance of parting the gear. The hazards were exacerbated in poor weather conditions. Based on both performance (sablefish) and safety (cod) concerns, we conclude that, for weighting to be practical and effective at reducing seabird bycatch, the weight must be integrated into the line itself, rather than added at each deployment. Melvin and Robertson (in prep) support this conclusion with the finding that the same amount of weight integrated into the groundline sinks gear up to 2 times faster than clipping weight on at 90-meter intervals. At the present time, line with integrated weight is neither manufactured nor in development. We strongly recommend that the manufacturing industry be encouraged to develop weighted line and that the effectiveness of weighted line as a seabird bycatch deterrent be fully investigated.

Given that adding weight at the levels we tested in this study did not increase the effectiveness of streamer lines and did little to change the distance at which lines sank behind the vessel, we cannot recommend that the fleet be required to weight their gear for seabird avoidance until more investigations are undertaken to determine the optimum weighting regimes for reducing seabird bycatch and the methods to improve the practicality of line weighting. However, we believe that adding weight would be beneficial in some cases. Hand-baiting vessels that set gear at 6 knots to 7 knots or vessels that set gear into the up-wash of the propeller could reduce the distance astern at which the groundline sinks to 2 meters depth by using groundlines with integrated weight. Fleets fishing in areas in which shearwaters are present may similarly benefit, as this species tends to attack baits the farthest astern when compared to other species observed in this study, even beyond the range of the streamer lines (Figure 22B), and is the deepest diving of all seabird species encountered. If vessels opt to weight groundlines to avoid seabirds, we recommend that the amount of weight be increased by reducing the space between weights to intervals smaller than those used in this study.

Line Shooters

The Mustad line shooter tested in the 1999 cod fishery was the only deterrent that significantly increased the rate of seabird bycatch (Figure 18). Because the line shooter required additional crew (in this case the ship's engineer) to set gear, it was also deemed impractical and was unpopular with the crew. Løkkeborg (2000) tested the same line shooter in a Norwegian demersal longline fishery for torsk and ling and found no difference in seabird bycatch (e.g., northern fulmar bycatch) between sets with line shooters and control sets of no deterrent. We speculate that setting gear slack into the propeller turbulence prevented gear from sinking closer to the vessel. Based on these observations, we cannot recommend use of a line shooter as a seabird bycatch reduction device in Alaska demersal longline fisheries. Further refinement of this technology could prove beneficial if coupled with setting the line in the down-wash or away from the propeller-wash or adding weight.

Lining Tube (Funnel)

The Mustad lining tube tested in the 1999 cod fishery significantly reduced bycatch to levels comparable to those of adding weight to the groundline (79% reduction; Figure 18C). In the Norwegian demersal longline fishery, Løkkeborg (1998, 2001) found that the Mustad lining tube significantly reduced seabird bycatch (72% to 93% relative to controls of no deterrent, respectively). As in our study, bycatch was dominated by northern fulmars. However, bycatch rates with the lining tube were highly variable in his studies (0.49 birds per 1,000 hooks in 1996 and 0.08 birds per 1,000 hooks in 1998). He suggested that the depth below the surface at which the tube delivered gear changed

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… we cannot recommend the Mustad lining tube as a comprehensive solution to seabird bycatch in the Alaska groundfish fishery.

We strongly encourage further development of cost-effective subsurface deployment strategies.

Based on our observations, we specifically recommend that vessels eliminate directed discharge of residual bait and offal over sinking longlines during the set.

with sea conditions, and that the loading of the vessel accounted for the variation in the tube's effectiveness. We observed that the tube deployed gear to a meter or less below the surface; however, the line returned to near the surface 40 meters to 60 meters astern. Løkkeborg (1998) also speculated that propeller turbulence may force the line back to the surface, contributing to the lining tube's inconsistent performance. In order to compensate for the line returning to the surface, the vessel's crew reported that they deployed a buoy without streamers ("bird bag") in addition to using the lining tube to minimize seabird interactions during the regular fishing season.

Occasionally, as the gear was first set, the line would jump out of the slot that runs along the side of the tube. Once the line is out of the tube, there is no opportunity to return it to the tube, rendering the tube useless as a seabird deterrent for that entire set, a complication also observed in the toothfish fishery off South Africa (Ryan and Watkins 2000). Although this appeared to happen rarely (~10% of lining tube sets) during our study, the captain of our vessel reported that it took more than one fishing season for the crew to master the skill of setting gear with the lining tube suggesting the need for experienced crew in order to effectively use this device. In addition, the Mustad lining tube is expensive (around $40,000 USD, compared to the estimated cost of paired streamer lines at approximately $150 USD). Finally, the lining tube can only be fitted to vessels that set gear from their lower decks. Given these limitations, we cannot recommend the Mustad lining tube as a comprehensive solution to seabird bycatch in the Alaska groundfish fishery.

However, setting longlines below the surface through an improved setting funnel that sets gear well below the influence of propeller turbulence and below the diving capability of most seabirds is likely to provide an efficient and reliable method of seabird avoidance applicable to many fisheries throughout the world. We strongly encourage further development of cost-effective subsurface deployment strategies.

Additional Measures

Directed Discharge During the Set

Existing regulations specify that offal must be discharged during a haul or set in such a way as to distract birds from baited hooks. Cherel *et al.* (1996) found that strategic offal discharge away from the groundline during setting was a highly effective procedure to reduce seabird bycatch, because most birds preferred the ease of offal capture over attacking baited hooks. Our observations of the cod fishing fleet confirmed that some vessels discharged residual bait continually, and, in some cases, offal was discharged directly over baited hooks through dedicated pipes or chutes at the stern during the set. Both of these activities had the effect of attracting (or chumming) birds into the area where baits were sinking, increasing seabird interactions with the gear. Current Alaska regulations state that offal discharged during the set or the haul "must be discharged in a manner that distracts seabirds from baited hooks to the extent practicable." Based on our observations, we specifically recommend that vessels eliminate directed discharge of residual bait and offal over sinking longlines during the set. This includes both vessels that set gear at the stern as well as vessels setting gear amidships. This recommendation does not include baits falling off the hooks or offal discharged from other locations that parallel sinking gear that might subsequently drift into the wake well aft of the stern.

Report Cards and Peer Systems

Early in this report, we established the paradox of seabird bycatch for both fishers and managers: that vessels are constantly surrounded by seabirds, yet seabird bycatch is rare. From our discussions with industry throughout this project, it is also clear that most vessels do not know how their rates of seabird bycatch compare with those of similar vessels within their fleet. In this system, vessels with consistently high bycatch rates are not aware of their poor performance and, therefore, make little, if any, attempt to improve them.

In the freezer-longline fleet, a voluntary system was established to report and tabulate total bycatch by vessel twice each month, using codes to protect the names of individual vessels (T. Smith pers. comm. to EFM). From these data and from NMFS observer program data since 1993, it is clear that a small numbers of vessels in the cod fleet are responsible for a large proportion of the seabird bycatch. Vessels with the worst records are, in many cases, consistent from year to year. In a situation such as the Alaska groundfish fishery, where the bycatch of as few as 4 to 6 short-tailed albatross can close a $300 million fishery, persistent bad performers and vessels unaware of their bad performance pose a huge risk to over 2,000 vessels as well as to seabirds. Based on these observations we recommend:

- An annual report card system be established using NORPAC data sources to inform the owners and operators of longline fishing vessels of their seabird bycatch numbers and rates (per 1,000 hooks) relative to average performance statistics for their fleet. Fleets include IFQ sablefish, Pacific cod, and Greenland turbot. IFQ Pacific halibut should also be included if observer data become available.
- An industry peer system be developed voluntarily to reward vessels that successfully avoid seabird bycatch and to penalize those who do not. As the industry itself stands to loose the most if poor performers are not identified, self-policing is a workable strategy. In addition, dialog among fishers should be encouraged to share information and methods to minimize the incidental capture of seabirds.

Impacts on Seabird Populations

For species with multiple populations centered around breeding locations, such as seabird colonies, conservation efforts must consider effects at the population level (geographically distinct subgroups of breeders) as well as at the species level (total number). Effects of Alaska bycatch on albatross and other seabirds at the population level are uncertain. With the exception of short-tailed albatross, data on the number, size and geographic extent and mixing of seabird populations are poorly understood. Although northern fulmars make up the dominant proportion of Alaska demersal longline seabird bycatch, conservation concern is focused on albatrosses, due to their smaller population sizes. Short-tailed albatross is the most vulnerable species encountered by Alaska demersal longliners, with a total world population of only 1,500. Recently, short-tailed albatross at both colonies have been increasing. Black-footed and Laysan albatross number 275,000 and 2,500,000, respectively worldwide (Croxall and Gales 1998). Declines in the numbers of breeding pairs of Laysan albatross and black-footed albatrosses attending breeding colonies during the late 1990's triggered concern for these species (USFWS unpublished data). However, it is unclear whether those declines represented adult mortality, change in ocean productivity, change in breeding interval, or some combination of all 3 (Pyle 2000). Recent counts indicate numbers of breeders are increasing (USFWS unpublished data).

The total number of northern fulmars in the Pacific is estimated at 4.6 million individuals, with nearly 1.5 million individuals on 16 colonies in Alaska (Hatch and Nettleship 1998). Northern fulmar trends are uncertain but thought to be relatively stable. In the North Atlantic, northern fulmar populations are increasing in number and range, despite significant bycatch mortality in North Atlantic longline fisheries (Tasker *et al.* 2000). Short-tailed shearwaters (a southern hemisphere breeder and the dominant shearwater species identified by our observers) winter in the North Pacific and are most common in the Bering Sea (Marchant and Higgins 1990). The breeding population of short-tailed shearwaters is estimated at 23 million and is thought to be increasing (Marchant and Higgins 1990).

Without the use of seabird deterrents, the Alaska demersal fleets were estimated to take approximately 350 black-footed albatross and 950 Laysan albatross annually (Appendix I). Although breeding status and age for the bycaught albatross is not known, these estimated take numbers would represent 0.3 percent and less than 0.1 percent of the total breeding populations, respectively. Of the 7 reported short-tailed albatrosses taken to date, only 1 was an adult thought to be of breeding age (NMFS 2001a). With deterrents, specifically properly deployed paired streamer lines, this bycatch should be effectively reduced to zero. However, the Alaska demersal longline fishery represents only a part of the total longline fishing effort in the North Pacific Ocean. When Hawaii pelagic fishery effort is added to the Alaska totals, albatross bycatch jumps to 2 percent of black-footed and 0.2 percent of Laysan albatross breeding populations.

If estimates of all North Pacific effort are included (assuming pelagic bycatch rates based on the Hawaii fishery), albatross bycatch could be as high as 10 percent of black-footed and 1 percent of Laysan albatross breeding populations. (Estimates of fishing effort are approximate and do not include effort data from Russia, Taiwan, China, or Korea). Clearly, the proper use of paired streamer lines to reduce seabird bycatch in the Alaska fleet can be quite successful at reducing albatross, and other seabird bycatch. However, mitigation measures such as paired streamer lines are unlikely to stem the decline in albatross numbers unless adopted comprehensively by all fleets throughout the Pacific. We emphasize that in order for seabird conservation to be achieved, U.S. federal resource management agencies must extend efforts beyond Alaska to national and international levels. Specifically, efforts to develop and test new technologies (Melvin and Robertson 2001) should be encouraged, and the use of paired streamer lines should be institutionalized in all demersal longline fisheries, and, if tests prove them practical, in pelagic longline fisheries.

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Recommendations

I. Regulatory Action

A. Gear

Based on the results of the research program, we recommend that existing requirements for seabird bycatch reduction (50 CFR Part 679.24(e)(3) Gear Limitations) be replaced with the following requirements.

1. Paired Streamer Lines: All Alaska longline vessels must deploy a minimum of two streamer lines while setting longline gear. If both streamer lines cannot be deployed prior to the first hook, at least one streamer line must be deployed before the first hook and both streamer lines must be fully deployed within 90 seconds. In conditions of wind speeds exceeding 30 knots (near gale or Beaufort 7 conditions), it is acceptable to fly a single streamer line from the windward side of the vessel. In winds exceeding 45 knots (strong gale or Beaufort 9 conditions), the safety of crew supersedes deployment of streamer lines.

2. Performance Standard: Streamer lines must be deployed in such a way that streamers are in the air for a minimum of 40 meters aft of the stern for vessels under 30.5 meters (100 feet) and 60 meters aft of the stern for vessels 30.5 meters or over. The performance standard can be achieved in several ways: by increasing the height off the water at the stern (recommended minimum is 20 feet), minimizing the weight of streamer line components, and/or increasing drag at the far end of the streamer line with combinations of drogues, weights, and buoys.

3. Materials Standard: Minimum streamer line specifications include:
<u>Length</u>: 300 feet (~90 meters)
<u>Spacing of streamers</u>: Every 5 meters until performance standard is achieved.
<u>Streamer material</u>: Brightly colored, UV-protected plastic tubing or 3/8 inch polyester line or material of an equivalent density. An individual streamer must hang from the mainline to 0.25 meters of the water in the absence of wind.
<u>Line material</u>: Discretionary
<u>Terminal end</u>: Discretionary
<u>Breakaways</u>: Discretionary, but highly recommended.

B. Operations

We recommend that existing requirements for seabird bycatch reduction (50 CFR Part 679.24(e)(2)(ii) Requirements) be amended to include the following:

1. Directed discharge during the set: All Alaska longline vessels must eliminate directed discharge (through chutes, pipes, etc.) of residual bait or offal from the stern of the vessel while setting gear. Baits falling off the hook or offal discharges from other locations that parallel the gear and subsequently drift into the wake zone well aft of the vessel are not included. Vessels deploying gear amidships must eliminate directed discharge of residual bait or offal over sinking longlines during deployment.

II. Optional Non-Regulatory Actions

Based on qualitative observations, we recommend that the following actions be taken to minimize seabird interactions with longline gear, promote stewardship within the fishing fleet, and address bycatch at national and international levels:

A. Gear

1. Hand-Bait Chutes: Develop methods to deploy weights in a way that prevents longlines from going taut while setting gear. Actions might include a modification to the chute by adding a setting shelf that would prevent the need to lift weights from the deck up the full height of the chute thereby minimizing tension to deployed gear.

2. Auto-Bait Systems: Encourage companies that manufacture and sell auto-bait systems to refine designs to minimize hook foulings.

B. Education and Outreach

1. Report Card: Institute a system to annually inform the owners and operators of longline fishing vessels of their seabird bycatch numbers and rates (per 1,000 hooks) relative to their fleet based on NORPAC data. Fleets include IFQ sablefish, Pacific cod, and Greenland turbot. The Pacific halibut fleet should be included if observer data become available.

2. Peer System: Develop an industry-based peer system to reward vessels that successfully avoid seabird bycatch. Encourage dialogue among fishers to share information and methods to minimize the incidental capture of seabirds.

3. Fleet Education: Develop and deliver an education program targeting vessel owners, operators, and crew, illustrating the proper deployment and use of streamer lines, as well as the need for seabird conservation and related regulations.

4. National Action: Encourage other U.S. fishery management councils, including the Pacific Fishery Management Council and the NMFS Northwest Region, to extend recommended regulatory measures to demersal longline fleets in their jurisdiction. Extend recommended regulatory actions to Pacific halibut fisheries.

5. International Action: At a minimum, all demersal fisheries should use properly deployed paired streamer lines and eliminate directed discharge of residual bait and/or offal over sinking longlines. In the longterm, longlining nations in the Pacific Rim should be encouraged to develop, test and, ultimately, require seabird bycatch deterrents in their demersal and pelagic longline fisheries which virtually eliminate all seabird bycatch under all fishing conditions without the need for oversight and enforcement.

III. Future Research

Research programs testing seabird deterrent strategies are limited by existing technologies. Continued innovation and technology development are required in Alaska fisheries and worldwide to minimize seabird bycatch in longline fisheries. Accordingly we recommend the following:

A. Fleet Innovation.

Encourage continued development of seabird bycatch avoidance measures by the Alaska fleet.

B. Novel Technologies.

Encourage the development of designs and technologies that eliminate the need to fly streamer lines. These include:

1. Underwater Setting. Technologies that deploy longlines below the surface beyond the reach of seabirds (tubes and chutes or novel hull designs).

2. Line Weighting. Fishing line that sinks quickly below the surface but also maintains the handling qualities valued by fishers.

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Year Observed	STAL	BFAL	LAAL	Unid. ALB	NOFU	Gull, Unid.	SHWR	Other	Total	Effort (# Hooks in 1,000's)	Bycatch Rate	% Hooks
					Bering Sea/Aleutian Islands (BS/AI)							
1993	0	16	639	272	4,262	854	81	1,773	7,897	135,381	0.060	22.3
1994	0	28	317	81	5,130	1,684	659	3,083	10,985	134,783	0.080	24.6
1995	0	74	428	78	10,086	3,940	338	4,948	19,892	141,430	0.140	24.3
1996	4	21	248	63	5,432	1,507	567	564	8,404	141,540	0.060	23.8
1997	0	9	353	13	13,898	2,694	305	937	18,208	176,409	0.100	22.6
1998	9	9	1,492	4	15,587	4,616	1,169	1,985	24,871	175,357	0.140	23.5
1999	0	16	616	0	8,310	2,194	620	1,331	13,087	156,087	0.080	25.2
Average 1993-1999	2	25	585	73	8,958	2,498	534	2,089	14,763	151,570	0.094	23.8
					Gulf of Alaska (GOA)							
1993	0	78	371	10	2,009	117	146	371	3,102	56,291	0.060	10.3
1994	0	41	918	41	1,265	41	102	163	2,571	49,452	0.050	4.9
1995	0	454	172	759	931	196	70	344	2,927	42,156	0.070	12.8
1996	0	984	371	0	863	56	19	28	2,321	33,134	0.070	10.8
1997	0	120	50	0	461	70	20	20	741	28,000	0.030	10.0
1998	0	308	247	12	1,542	123	37	0	2,269	29,339	0.080	8.1
1999	0	267	499	0	534	395	93	58	1,846	31,894	0.060	8.6
Average 1993-1999	**0**	**322**	**375**	**117**	**1,086**	**143**	**70**	**141**	**2,254**	**38,609**	**0.060**	**9.4**

Appendix III

Processor Type	Catcher Boats	Catcher/Processors
Target Species	Sablefish, Pacific halibut	Pacific cod/Greenland turbot
Refrigeration	Ice	Freeze
Trip Length (days)	1 to 10	15 to 40
Vessel Size	Range from 30 ft to 100 ft	Range from 90 ft to 200 ft
System	Skate bottom/Tubs /Snap-on/Auto	Auto (Mustad or MARCO) /Tubs
Type	Stuck/Snap	Swivel/Stuck
Hook Size	13/0 to 16/0 Circle	#6 or 7 Eagle Claw Circle (modified J hook)
Gangion (snood) Length (centimeters)	25 to 40	40 to 50
Hook Spacing (meters)	.75 to 3	1.1
Soak Time (hours)	3 to 24	3 to 24
Bait	Herring, Salmon, Squid	Squid
Setting Speed (knots)	3 to 7	6 to 10
Crew Size	1 to 8	10 to 40
Ownership	Owner-operated	Corporate owned
Primary Area	GOA & AI	BS & AI
Season	15 Mar. to 15 Nov.	Jan. - April/Sept. - Nov. CDQ Apr. - Aug.
Sea Conditions (meters)	4	6 to 7

APPENDIX IV

	Sablefish 1999	Sablefish 2000	Pacific cod 1999	Pacific cod 2000	
PHYSICAL Variables					
Cloud Cover (6 categories)	x	x	x	x	
Max. Visibility (4-5 categories)	x	x	x	x	
Moon Phase (15 categories)	x	x	x	x	
Wind Direction (13 categories)	x	x	x	x	
Ave. Wind Speed	x	x	x	x	
Max. Wind Speed		x	x	x	
Barometric Pressure				x	
Sea State (Beaufort)	x	x	x	x	
Swell Height	x	x	x	x	
SET Variables					
Observer (# individuals)	7	5	6	12	
Vessel (# participants)	3	5	2	2	
Treatment	3	4	4	4	
Position (begin & end)	x	x	x	x	
Region (NMFS mgt. area)	x	x	x	x	
Depth (begin & end)	x	x	x	x	
Time of day	target day only	target day only	target 1:1 ratio	3 categories: day; night w. lights; night w.o. lights	
Hooks Per Set (1,000's)	3-4	3-4	3-4	> 12	
Time First Hook Set	x	x	x	x	
Time Last Hook Set	x	x	x	x	
Time Last Hook Retrieved	x	x	x	x	
Bait Species	2	2	1	1	
Bait Condition (3 categories)	x	x	x	x	
Bate Loss Out of Chute (# categories-qualitative/quantitative)		5-qual.	3-quant.	5-quant.	3-quant
Unbaited Hooks			5-quant.	3-quant	
Deck Lights (categories)	6	4	4	9	
Offal Discharge	x	x	x	x	
Vessel Setting Speed	x	x	x	x	
Distance From Last Haul	x	x	x	x	
Number of Vessels in Area & Distance		x		x	
Snarls Upon Retrieval		2	2	2	
Sand Fleas Present/absent		x	x		
Seabird CPUE					
-by Spp. (% set tallied)	100	50	75	66	
-by Hook Location		x	x	x	
Abundance by Species	x	x	x	x	
Attack Rate	x	spp & distance	spp & distance	spp & distance	
STAL Sighted While Setting		x		x	
STAL Sighted While Hauling		x		x	

APPENDIX V

Treatment	Sablefish 1999	Sablefish 2000	Pacific cod 1999	Pacific cod 2000
Control	**0.371 (0.155)**	**0.094 (0.032)**	**0.218 (0.130)**	**0.016 (0.005)**
Paired Streamers (PS)	**0.044 (0.023)**	**0.000 (0.000)**	**-**	**0.001 (0.001)**
Weight (WT)	**0.234 (0.074)**	**-**	**0.052 (0.017)**	**-**
PS + WT	**-**	**0.000 (0.000)**	**-**	**0.001 (0.001)**
Shooter	**-**	**-**	**0.336 (0.156)**	**-**
Lining Tube	**-**	**-**	**0.045 (0.013)**	**-**
Single Steamers	**-**	**0.005 (0.005)**	**-**	**0.005 (0.004)**

Appendix II. Regulations In Effect For Reducing Seabird Bycatch In Longline Fisheries. Compiled by K. Rivera 2001, National Marine Fisheries Service, Office of Protected Resources, Juneau, AK, ***Kim.Rivera@noaa.gov***. (Table adapted from Table 11 in Brothers, N.P., J. Cooper, S. Lokkeborg, 1999, "The Incidental Catch of Seabirds by Longline Fisheries: Worldwide Review and Technical Guidelines for Mitigation", FAO Fisheries Circular, No. 937, Rome.)

COUNTRY/ CONVENTION/ REGION	APPLICABILITY	DEMERSAL OR PELAGIC?	DOMESTIC (EEZ) OR FOREIGN? OBSERVER COVERAGE?	REGULATIONS	OTHER COMPONENTS OF BYCATCH REDUCTION PROGRAM
Australia[1]	In 1995, in Australian Fishing Zone (AFZ), south of 30S Revised in 2001	Pelagic (tuna) Same	Foreign EEZ and Foreign	Bird scaring lines In Southern waters (south of 30°S): 1) Tori pole apparatus is attached to boat for each point that hooks enter the water, 2) Sets must occur between nautical dusk on one day and before nautical dawn on the following day, 3) Thawed baits must be used, 4) Exemptions may apply to those holding scientific permits (for testing alternative seabird measures), for vessels less than 20 m. In Northern waters (north of 30°S): 1) Same tori pole apparatus as above, 2) Same exemptions as above. For Australian (domestic) vessels and foreign vessels in AFZ: 1) No discharge of offal while crew is setting or hauling gear, unless exempted as above, 2) If it's not practical to store offal until the crew has finished hauling, offal may be discharged during hauling while the vessel is not under way and from the opposite side of the vessel to that where the line is being hauled.	· Outreach, workshops, booklets · Seabird bycatch data collected by observers on foreign vessels · Estimations of seabird bycatch · Research
Japan[2]	1997 (for bird line)	Pelagic (tuna)	Distant water, offshore, and nearshore small vessels	1) Use bird scaring line (tori-pole/streamer). 2) Every effort should be made to release the birds caught alive on the vessels and, if possible, remove hooks so that birds may not be harmed. 3) Disposal of offal from the vessels during line setting should be avoided as much as possible. In unavoidable cases, methods to divert the attention of seabirds from the baited hooks (such	· Outreach, booklets, waterproof pamphlets, seminars for fishers · Research to

				as setting the line from the opposite end) should be employed. 4) One or more of the following avoidance measures should be applied, taking into account the situation of seabirds gathering and sea conditions: a) night line-setting b) in baiting, the use of weighted branch line or cone which sink as speedily as possible after line setting, c) the use of automatic bait casting machines, d) the use of properly thawed baits.	improve effectiveness of tori-pole, use of stimulant devices such as noise and light to scare birds away
			Pacific area north of 20N	1) Same as 2) and 3) above. 2) Same as 4) above, adding use of bird-scaring line as one of the options. The bird scaring line (tori-pole/streamer) is used to avoid the catch of seabirds during line setting, on tagging of impediments such as buoys or wooden boards on the sea surface where the baits are sunk.	
			Areas within 20nm from the coast of Torishima, from October to May	1) Two or more of the selective avoidance measures from above are implemented.	
			Other longline fishing operations in the Japanese coastal/ offshore areas (EEZ)	1) Same as 2) and 3) above (for the distant water fleet). 2) When operations take place from October to May within 20 nm from coast of Torishima, two or more of the following list of avoidance measures are implemented, taking into consideration the situation of seabirds and sea conditions: a) the use of bird-scaring lines (tori-pole/streamer) or tagging of impediments such as buoys or wooden board on the sea surface where the baits are sunk in order to avoid seabirds from taking baits on the hook, b) night line-setting, c) use of weighted branch line or cone that sink as speedily as possible after line setting, d) use of automatic bait casting machines, and e) use of properly thawed bait.	
			All fisheries.	The central government requests that information be collected when the incidental catch of seabirds occurs.	

New Zealand[3]	1993	Pelagic (tuna)	EEZ and foreign chartered vessels in EEZ	1) Approved seabird scaring device to be used at all times, day or night, 2) Minimum standard for seabird scaring device is a CCAMLR-designed streamer line (see CCAMLR entry); fishers may add to that design; weight or buoy at the end of the streamer line is optional 3) Seabird-scaring device must be made available for inspection by appointed scientific observer 4) Alternative seabird-scaring devices will be considered on an individual vessel basis	· Fishery Advisory Officer that works one-on-one with vessel skippers on effective use of mitigation measures · Host of International Fishers Forum · Outreach, mailings · Research on seabirds and on improved mitigation measures & gear
South Africa[4]	1998	Demersal (hake)	Longline permit holders east of 20E (offshore, south and east coast) Observer coverage about 15%	1) Must be able to accommodate an observer, upon request, 2) A record of the numbers and species of all seabirds killed shall be kept on a daily basis; where species identification is uncertain, heads shall be kept and given to the Fishery Control Officer on landing, 3) Not more than 20,000 hooks may be deployed per day 4) Set only during hours of darkness and gear deployment should cease at least one hour before nautical dawn. 5) Both main line and branch lines (snood) must be properly weighted and setting speed must be such that sinking rates are maximized. 6) Dumping of offal must be minimized. Offal dumping shall take place on the opposite side of the vessel from that on which lines are hauled; No dumping of offal may take place during setting. 7) No hooks, lines or plastics may be discarded. All fishing hooks must be removed from offal. All fishing hooks must be removed from discards before these are dumped, except where the removal of hooks from live discards (e.g., sharks) may endanger the safety of the crew or be detrimental to the survival of the animals. 8) Deck lighting should be kept to a minimum, without compromising safety. All deck lights should be shaded so that	

				the beam is directed down towards the deck. 9) An approved streamer line (tori line) must be flown during setting of each longline. The streamer must be deployed directly above the main line, unless two streamers are used, in which case they must be deployed on either side of the main line. 10) Discarding of any longline gear at sea is prohibited, and permit holders shall attempt to recover all longline gear loss during fishing operations at sea.	
			Inshore permit conditions	Same as for the offshore demersal permit holders, but no more than 5,000 hooks may be deployed per day.	
		Pelagic (tuna)	Permit holders Observer coverage about 20%	1) Use a tori pole and bird line during setting of gear. 2) See 3), 4), and 9) for the offshore demersal permit holders. 3) No hooks may be discarded; all hooks must be removed from offal and fish by-catch before these are dumped. 4) Unless exempted, whole specimens or heads and feet of all seabirds killed in the EEZ of South Africa must be returned to port for identification and examination. Records shall be kept of all birds killed during longline operations, including the numbers killed and species identified. 5) All information contained on bands recovered from seabirds must be reported.	
United Kingdom[5]	Enacted ?	Demersal	Outer fishing zone of Falkland Islands/ Malvinas Observer coverage required on vessels licensed in Falkland Waters	Bird-scaring line (weighted lines, night setting if instructed specifically)	
US—Alaska[6]	Federal fisheries permit holder in Bering Sea/Aleutian Islands or Gulf of Alaska	Demersal	EEZ Observer coverage is	(1) All permited longline vessels must: (a) Use hooks that when baited, sink as soon as they are put in the water; (b) If offal is discharged while gear is being set or hauled, it must be discharged in a manner that distracts seabirds from baited hooks, to the extent practicable. The discharge site on	· Free streamer lines · Outreach, information bulletins, mailings,

	groundfish fisheries (since 1997) and Pacific halibut fisheries (since 1998); revisions will be proposed in 2001		100% of fishing days on groundfish vessels >=125 ft LOA (length overall); 30% of fishing days each calendar quarter for vessels >60 &<125 ft LOA	board a vessel must be either aft of the hauling station or on the opposite side of the vessel from the hauling station; (c) Make every reasonable effort to ensure that birds brought on board alive are released alive and that wherever possible, hooks are removed without jeopardizing the life of the birds. (2) For a vessel greater than or equal to 26 feet (7.9 m) LOA, the operator of that vessel must employ one or more of the following seabird avoidance measures: (a) Tow a streamer line or lines during deployment of gear to prevent birds from taking hooks; (b) Tow a buoy, board, stick or other device during deployment of gear, at a distance appropriate to prevent birds from taking hooks. Multiple devices may be employed; (c) Deploy hooks underwater through a lining tube at a depth sufficient to prevent birds from settling on hooks during deployment of gear; or (d) Deploy gear only during the specified hours (based on nautical twilight), using only the minimum vessel's lights necessary for safety.	workshops, seminars, website · Seabird bycatch data collected by observers · Estimations of seabird bycatch · Research on mitigation measures and their improved effectiveness
US---Hawaii[7]	Any vessel with a Hawaii longline limited access permit using longline gear north of 23°N; enacted in 2001	Pelagic swordfish and tuna		1) Prohibited from using longline gear to fish or target for swordfish north of the equator (primary purpose to avoid turtle interactions) 2) Use thawed, blue-dyed bait 3) Discharge offal on the opposite side of the vessel from where the longline is being set or hauled (to distract birds); 4) Remove all hooks from offal prior to discharging offal 5) When making shallow sets (targeting swordfish or mixed species) north of 23°N, to set the longline at least one hour after sunset and complete the setting process by sunrise, using only the minimum vessel lights necessary[1]; 6) When making deep sets (targeting tuna) north of 23°N., to employ a line setting machine with weighted branch lines (at least 45g to each branch line within 1m of the hook); 7) Follow certain handling techniques to increase the likelihood that any short-tailed albatross brought onboard the vessels alive is released in a manner that ensures its long-term survival; and 8) Complete a protected species educational workshop conducted by NMFS.	· Outreach, workshops, seminars Seabird bycatch data collected by observers · Estimations of seabird bycatch · Research
CCAMLR[8]	Beginning in 1992, CCAMLR member	Demersal (Patagonian toothfish)	CCAMLR waters, except for	1) Fishing operations shall be conducted in such a way that the baited hooks sink as soon as possible after they are put in the water. Only thawed bait shall be used.	· Outreach, booklets · Seabird

	countries with vessels fishing in CCAMLR waters		waters adjacent to the Kerguelen and Crozet Islands and the waters adjacent to the Prince Edward Islands.	2) For vessels using the Spanish method of longline fishing, weights should be released before line tension occurs; weights of at least 8.5 kg mass shall be used, spaced at intervals of no more than 40 m, or 6 kg mass shall be used, spaced at intervals of no more than 20 m. 3) Longlines shall be set at night only (i.e. during the hours of darkness between the times of nautical twilight). During longline fishing at night, only the minimum ship's lights necessary for safety shall be used. 4) The dumping of offal is prohibited while longlines are being set. The dumping of offal during the haul shall be avoided. Any such discharge shall take place only on the opposite side of the vessel to that where longlines are hauled. 5) Vessels that are so configured to lack on-board processing facilities or adequate capacity to retain offal on board, or the ability to discharge offal on the opposite side of the vessel to that where longlines are hauled, shall not be authorized to fish in the Convention Area. 6) A streamer line designed to discourage birds from settling on baits during deployment of longlines shall be towed. Specification of the streamer line and its method of deployment is given in the appendix to this measure. Details of the construction relating to the number and placement of swivels may be varied so long as the effective sea surface covered by the streamers is no less than that covered by the currently specified design. Details of the device dragged in the water in order to create tension in the line may also be varied. 7) Other variations in the design of streamer lines may be tested on vessels carrying two observers, at least one appointed in accordance with the CCAMLR Scheme of International Scientific Observation, providing that all other elements of this conservation measure are complied with. 8) Every effort should be made to ensure that birds captured alive during longlining are released alive and that wherever possible hooks are removed without jeopardizing the life of the bird concerned. CCAMLR Streamer Line Standards specify that: a) The streamer line is to be suspended at the stern from a point approximately 4.5 m above the water and such that the line is directly above the point where the baits hit the water. b) The streamer line is to be approximately 3 mm diameter, have a minimum length of 150 m and have a device at the end to create tension so that the main line streams directly behind the ship, even in cross winds.	bycatch data collected by observers · Estimations of seabird bycatch · Research on seabirds and seabird mitigation devices by member countries · Annual meeting of Scientific Working Group on Incidental Mortality of Albatrosses by Longline Fisheries (IMALF) to review CCAMLR vessel reports and activities and to make appropriate recommenda-tions to CCAMLR

				c) At 5-m intervals commencing from the point of attachment to the ship, five branch streamers (each comprising two strands of approximately 3-mm diameter cord) should be attached. The length of the streamer should range between approximately 3.5 m nearest the ship to approximately 1.25 m for the fifth streamer. When the streamer line is deployed, the branch streamers should reach the sea surface and periodically dip into it as the ship heaves. Swivels should be placed in the streamer line at the towing point, before and after the point of attachment of each branch streamer and immediately before any weight placed on the end of the streamer line. Each branch streamer should also have a swivel at its attachment to the streamer line.	
	Beginning in 1995		Sub-Area 48.3 (South Georgia)	Progressive move toward a winter fishing season, when the seabird breeding season is over.	
	1999		Divisions 58.4.3, 58.4.4, 58.5.1 (Kerguelen Islands), 58.5.2 (McDonald & Heard Islands) and Sub-Areas 48.3 (South Georgia), 48.4, 58.6 (Crozet Islands)	Start date of fishing season changed from 15 April to 1 May, to avoid seabird breeding season. Fishing season extends from 1 May through 31 August.	
	1999			New Zealand was granted a variation exemption from specific Conservation Measures to allow line-weighting experiments to continue south of 65S in specified area. Variation allows New Zealand vessels to set lines during the daytime south of 65S in Subarea 88.1 if vessels weighted their lines and achieved a minimum sink rate of 0.3 m/s for all parts of the longline. The variation was sought because during austral summer (December to March) there are insufficient periods of darkness at these latitudes for exploratory fishing to occur. New Zealand proposed to place a limit on any potential seabird bycatch during the daylight setting	

				variation on a per-vessel basis. Any vessel catching 3 seabirds would have to revert immediately to full implementation of the Conservation Measures.	

Sources of Information:

[1]Australia Fisheries Management Amendment Regulations 2001 (No. 1) Statutory Rules 2001 No. 32, 6 February 2001

[2]National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries submitted by Japan to FAO's Committee on Fisheries (COFI) in February 2001; and Brothers et al 1999, FAO Fisheries Circular No. 937

[3]New Zealand's Ministry of Agriculture and Fisheries, Fisheries (Commercial Fishing) Regulations 1986, as amended in 1993

[4]Fishery regulations by South Africa's Dept. of Marine and Coastal Management, pursuant to Marine Living Resources Act (Act No. 18 of 1998) and the Sea Birds and Seals Protection Act (Act No. 46 of 1973)

[5]from Brothers et al 1999, FAO Fisheries Circular No. 937, "The Incidental Catch of Seabirds by Longline Fisheries: Worldwide Review and Technical Guidelines for Mitigation", Table 12, page 84.

[6]Regulations in ***Federal Register*** 63: 11161-11167, March 6, 1998

[7]Regulations in ***Federal Register*** 66: 31561-31565, June 12, 2001

[8]CCAMLR Conservation Measures and Resolutions Adopted at CCAMLR-XIX; Report of the Working Group-Incidental Mortality of Albatrosses in Longline Fishing, 2000.