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Seabird Avoidance Measures for Small Alaskan Longline Vessels

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In cooperation with the Alaska Longline Fishermen's Association, Cordova District Fisheries United,
Petersburg Vessel Owner's Association, and U.S. Fish and Wildlife Service.

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Executive Summary

The incidental mortality of seabirds in longline fisheries is an international marine conservation problem. Although estimates of worldwide totals are lacking, hundreds of thousands of seabirds are probably taken in longline fisheries annually. In the Alaskan groundfish longline fisheries, incidental seabird mortality averaged 13,540 birds per year from 1993 to 2003, peaking at 26,000 seabirds in 1998. Procellariiform (or "tubenose") seabirds, a category that includes albatross species, were the most commonly caught (69%). The short-tailed albatross, an endangered species under the US Endangered Species Act (ESA), is the focus of regulatory and conservation attention in the Alaskan longline fisheries. The U.S. Fish and Wildlife Service's Biological Opinion specifies that short-tailed albatross takes exceeding six within a 2-year period (four in the groundfish fishery and two in the Pacific halibut fishery) would trigger reinitiation of a Section 7 consultation in these respective fisheries, and consequently interrupt or close Alaska's $250 million (ex-vessel value) demersal longline fisheries (USFWS 2003).

In 2001, the North Pacific Fishery Management Council (Council) took final action on seabird avoidance measures required in the Alaska longline fisheries for groundfish and Pacific halibut. Streamer lines (also called tori or bird scaring lines) are central to the majority of these regulatory measures, based on recommendations from a collaborative industry–agency–academic research effort conducted in 1999 and 2000, which demonstrated that these lines nearly eliminated incidental seabird mortality. The research, however, focused exclusively on vessels over 55 ft LOA fishing with fixed gear (where individual gangions are permanently attached to the groundline), and the Council recognized that the recommended seabird avoidance measures may not be appropriate for some small vessels (55 ft and less) and for some gear types. Consequently, a separate set of regulations was established for vessels 55 ft and less, and large vessels using snap-on gear (where individual gangions are clipped on or off with snaps as the gear is deployed or retrieved). Given the lack of information on appropriate measures for these two categories of Alaska longline vessels, the Council also strongly encouraged the advancement of a cooperative research program to develop seabird bycatch mitigation measures for small vessels and all vessels using snap-on gear. The research reported herein stems from this directive.

This study was conducted from May to June 2002 on eight vessels ranging from >26 to 55 ft in length. Two vessels were salmon trollers with infrastructure (mast, poles, and rigging) deploying snap-on gear, three vessels were combination vessels with infrastructure deploying fixed gear, and three vessels were bowpickers with no infrastructure deploying snap-on gear. Addressing the effectiveness of seabird avoidance measures required characterizing two variables: (1) the "2-m access window," or the distance astern that longline hooks were accessible to surface foraging Alaska seabirds, which generally dive no deeper than 2 m; and (2) the distance astern that streamer lines were maintained aloft, because it is this aerial extent that deters birds from the sinking hooks. The 2-m access window was measured using two complementary techniques (bottle lines and time–depth recorders) under typical fishing conditions, and during experimental trials in which both vessel speed and weight added to the groundline varied. The performance of currently required mitigation techniques was tested to determine practical performance standards, and alternative materials and deployment approaches were also tested (e.g., streamer lines made of lighter material, weights added to increase streamer line drag, and height of streamer line attachment to the vessel).

For trollers and bowpickers using snap-on gear, the mean distances behind the vessel at which snap-on gear sank beyond the 2-m depth range of most Alaska seabirds were 28 and 38 m, respectively. Speed trials on both types of vessels demonstrated that increases in vessel speed dramatically increased the 2-m access window, lengthening the area behind the vessel in which seabirds are at risk of accessing baited hooks. Streamer line trials on trollers demonstrated that vessel speed and height of attachment point at the stern affected the ability of the lines to meet suggested performance standards. We determined that the current single streamer line requirement for snap-on gear vessels over 55 ft (a 45-m streamer line with a minimum aerial distance of 20 m) was achievable and practical, especially with a lighter streamer line design, and highly likely to be an effective seabird deterrent for vessels under 55 ft as well. For bowpickers, current seabird deterrent recommendations include deploying buoys beyond the entry point of the groundline. Our trials demonstrated that the suggested performance standards could not be met without significant risk of fouling gear; without further work, buoy lines are unlikely to be effective as practical seabird avoidance measures on bowpickers.

For small vessels setting fixed gear, the mean 2-m access window was 90 m, a distance over twice that of trollers and bowpickers setting snap-on gear. This 90-m access window exceeded the mean for fixed gear set by large vessels (68 m) and was more in the range of that measured for large auto-bait freezer/longline vessels fishing cod in the Bering Sea (66–107 m). Large vessels (>55 ft) fishing groundfish are currently required to deploy streamer lines in pairs and to meet performance standards based on vessel length (40 m if vessel length is 55–100 ft, 60 m if vessel length is ≥100 ft). These results suggest that gear type and vessel setting speed are more important than vessel length in determining risk to seabirds. We conclude that the current requirement of a single streamer line with no mandatory material or performance standards for this vessel category (≥26–55 ft setting fixed gear and with mast, boom, and rigging) is unlikely to provide sufficient protection to seabirds, should longline fishing overlap with seabirds.

We note that testimony to the Council has also emphasized that many of the vessels, for which this study is relevant, fish exclusively or primarily in inside waters, where tubenose seabirds are believed to be rare. During all this work with small vessels in Alaska's inside waters, no Procellariiform seabirds were sighted nor were any types of seabirds observed interacting with longline gear, further supporting the view that small vessels fishing in inside waters may pose only minimal risk to seabirds.

Recommendations

General

- An analysis of the extent of overlap between Procellariiform seabirds and longline fishing in Alaska's inside waters should be given the highest priority. On the basis of the results of this risk analysis, seabird mitigation requirements should be adjusted or eliminated wherever risk of seabird mortalities is minimal or absent.
- Gear type and vessel setting speed (as opposed to vessel length) should be primary factors used to determine appropriate mitigation measures, as they best predict the risk posed to seabirds by longline fishing gear.
- Reduced vessel setting speeds should be considered as an option for a secondary seabird avoidance requirement (or "other device," required by small vessels together with a single streamer line or buoy line when fishing outside waters [EEZ]). A slow setting speed can significantly reduce the likelihood of seabird mortality; however, because a maximum vessel setting speed requirement would prove difficult to enforce and a slow setting speed could lead to fouled gear, we do not recommend it as a primary mitigation measure.
- We strongly recommend that a lighter streamer line be designed and made available to longline vessels at no cost in addition to maintaining availability of the current design.
- The following recommendations for vessels using snap-on gear and fixed gear are based on the assumption that longline fishing occurs in locations where Procellariiform seabirds are likely to be present.

Snap-on gear

- The current streamer line requirement for snap-on gear vessels over 55 ft with infrastructure (45-m streamer line and the minimum 20-m performance standard) is appropriate and practical and should be extended to all snap-on gear vessels >26 ft with infrastructure.
- Given that seabird avoidance measures are difficult to deploy from bowpickers (which typify vessels >26–32 ft without infrastructure), and that they pose the same or more risk to seabirds as do vessels with infrastructure using the same gear, we recommend that either the buoy line be adapted so that the buoy can be positioned over the sinking groundline without fouling on the gear or other mitigation options be developed.

Fixed gear

- Current measures for vessels >26–55 ft setting fixed gear and with mast, poles, and rigging (single streamer line with no mandatory material or performance standards) are unlikely to be able to provide sufficient protection to seabirds. We recommend that additional seabird avoidance measures be developed in consultation with industry. Alternatives might include using one or two lightweight 90-m streamer lines with a maximized aerial extent approaching 60 m.

Introduction

Seabird mortality in longline fisheries is a worldwide marine conservation problem (Robertson and Gales 1998). Comprehensive estimates of total takes are lacking; however, hundreds of thousands of seabirds are probably taken in world longline fisheries annually. Because many seabirds are long-lived species with delayed maturity and limited reproductive capability, they are highly vulnerable to adult mortality. Even low levels of adult mortality can halt population growth or cause decline (Croxall et al. 1990, Weimerskirch et al. 1997).

Typically, hundreds to thousands of seabirds attend individual fishing operations, feeding on discarded offal and bait. This attraction can prove fatal to seabirds and can negatively affect fish catch rates. In longline fisheries, seabirds can become hooked and drown as they attack baited hooks during gear deployment. Baits lost to birds result in fewer baited hooks available to catch fish. Seabirds can also be hooked as gear is hauled; however, in most cases the birds can be returned safely to the sea using proper handling techniques.

In the Alaskan groundfish longline fisheries, incidental seabird mortality averaged 13,540 birds per year from 1993 to 2003, ranging from a high of 26,000 seabirds in 1998 to a low of 4,094 in 2002 (National Marine Fisheries Services [NMFS] 2004). Procellariiform seabirds (referred to as tubenose seabirds)—northern fulmars, albatrosses, and shearwaters (Table 1)—were the most frequently caught (68.8%). Procellariiform seabirds are distinguished from other avian species by their minimal dependence on land (some land only to breed or seek refuge from storms) and their tubenose bills. The most common albatrosses taken were Laysan and black-footed. The US Fish and Wildlife Service (USFWS) estimates that two short-tailed albatrosses *(Phoebastria albatrus*) are taken on average each year (USFWS 2003). None have been observed taken since 1998 (NMFS 2003). The extent of seabird mortality in the Pacific halibut (*Hippoglossus stenolepis*) longline fishery is poorly understood owing to the lack of at-sea catch monitoring in this fishery.

Regulatory and conservation attention in the Alaskan longline fisheries is focused on the incidental mortality of the short-tailed albatross, an endangered species under the US Endangered Species Act (ESA). The USFWS' Biological Opinion specifies that short-tailed albatross takes exceeding six within a 2-year period (four in the groundfish fishery and two in the Pacific halibut fishery) would trigger reinitiation of a Section 7 consultation in these respective fisheries, and consequently interrupt or close Alaska's $250 million (ex-vessel value) demersal longline fisheries (USFWS 2003). The Biological Opinion requires that mitigation devices be used in these fisheries and that research be conducted to test their effectiveness.

In December 2001, the North Pacific Fishery Management Council (Council) took final action on seabird avoidance measures required in the Alaska longline fisheries for groundfish and Pacific halibut (NMFS 2001). These revised (seabird avoidance) requirements (NMFS 2004), which went into effect in February 2004, were based on the results of a 2-year study done in collaboration with industry in the sablefish (*Anaplopoma fimbria*) fishery in the Gulf of Alaska and Aleutian Islands, and the Pacific cod (*Gadus macrocephalus*) fishery in the Bering Sea (Melvin et al. 2001). Streamer lines, sometimes called tori lines or bird scaring lines, were found to reduce the incidental mortality of surface foraging seabirds such as northern fulmars and albatrosses by nearly 100%, and were at the core of recommendations to the Council.

A streamer line is a line attached to a high point on the vessel and towed behind the vessel (Melvin 2003). Individual streamers spaced at 5-m intervals are attached to the aerial portion of the streamer line, which is maintained by the drag of a towed object and the streamer line through the water. When deployed properly, the streamer line moves erratically and scares birds from the area above the sinking hookline, thus hindering seabird attacks on baits, and consequently reducing seabird mortality. Flown in pairs, they form a moving fence that bounds the sinking groundline.

Critical to the performance of streamer lines as effective and safe seabird avoidance measures is the distance astern to which streamer lines are aloft (Melvin et al. 2004a), or "aerial extent." It is the individual streamers along the aerial extent that effectively deter birds from the sinking hooks.

Table 1. Seabird species caught by AK groundfish longline fishery, 1993–2003.

Common name	Scientific name	% total seabirds
Northern fulmar	*Fulmarus glacialis*	58.0
Albatrosses (combined)	*Phoebastria* spp.	5.6
Laysan albatross	*P. immutabilis*	4.2
Black-footed albatross	*P. nigripes*	1.4
Shearwaters (combined)	*Puffinus* spp.	3.0
Gulls (combined)	*Larus* spp.	20.0

The aerial extent recommendation for Alaska was based on three factors:

- the distance astern the gear sank beyond the range of most Alaska seabirds, a depth of 2 m,
- the resulting pattern of seabird attacks on baited hooks in response to the sink profile of the gear, and
- the capabilities of the vessels that hosted the research.

The aerial extent also determines whether a streamer line will foul the longline gear as it is deployed and sinks behind the vessels. The research, which focused exclusively on vessels over 55 ft LOA, recommended use of two 90-m streamer lines, one on either side of the groundline, with a required aerial extent of 60 m for vessels 100 ft and over (90/60-m standard) and 40 m for vessels under 100 ft (90/40-m standard).

On the basis of industry testimony in the Council process, the Scientific and Statistical Committee (SSC) noted that recommended seabird avoidance measures may not be appropriate for some small vessels (55 ft LOA and less) or for some gear types. Industry testimony at the Council meetings also revealed that the Alaska longline fleet of approximately 2,000 vessels is in fact very heterogeneous in terms of vessel length, longline gear used, and areas fished. These vessels range from skiffs with no masts, poles, or rigging and in some cases one-man crews, to ships with extensive superstructure and crews exceeding 30 persons.

Many smaller longline vessels participate in multiple fisheries and use snap-on gear where individual gangions are clipped on or off with snaps as the gear is deployed or retrieved.

Slower vessel setting speeds are necessary to clip on individual gangions and maintain the groundline taut so as to provide resistance to quickly apply the clip. As a result of these reduced setting speeds, snap-on gear may sink closer to the stern, providing a shorter distance behind the vessel in which seabirds would have access to baited hooks. If this is the case, performance standards developed for fixed gear may be inappropriate for vessels using snap-on gear. In addition, most vessels using snap-on gear must go in reverse (backdown) at the end of a gear deployment (sometimes with a one-man crew) in order to create enough slack to attach and set the final anchor. Concern was expressed that this backdown procedure could result in a streamer line becoming fouled in the propeller. Finally, testimony also reflected the belief that small vessels present less risk to seabirds because they tend to fish in Alaska's inside and coastal state waters where albatrosses and other Procellariiform seabirds are thought to be rare.

Most large vessels, on the other hand, are dedicated exclusively to longline fishing and deploy fixed longline gear where each gangion is permanently attached to the groundline. Larger longline vessels, which account for most of the longline fishing effort in Alaska, tend to set longline gear at faster speeds and fish further offshore, closer to the shelf break where albatrosses and other tube nose seabirds are most common.

On the basis of the concerns cited above and using the best available information (see NMFS 2004), the final seabird avoidance requirements for vessels using snap-on gear and small vessels (defined as >26–55 ft) were adapted from those required for large vessels (defined as >55 ft).

The requirements are complex but in general terms they call for the following:

- Large vessels using snap-on gear are required to use a single (instead of double) shorter streamer line (45-m instead of 90-m) with a reduced performance standard (20-m aerial distance instead of 40-m; a 45/20-m performance standard vs. the 90/40-m performance standard).
- Small vessels with mast, poles, and rigging (infrastructure) are required to tow a single streamer line. Performance (40-m aerial distance) and material standards (90-m line) were established as voluntary guidelines.
- Small vessels without infrastructure are required to tow a buoy. A performance standard developed in the Council process was established as a guideline and is voluntary (buoy on a line 10- to 40-m long, deployed within 2 m of the groundline, and beyond the point the gear enters the water—essentially over the sinking groundline).
- When fishing outside waters, vessels in all three of these categories were required to use an additional seabird mitigation measure, while vessels fishing inside waters were not. Specialized provisions were established for International Pacific Halibut Commission (IPHC) area 4E (north of Bristol Bay in the Bering Sea).

Terms

Snap-on gear: individual gangions are clipped on or off with snaps as the gear is deployed or retrieved

Fixed longline gear: each gangion is permanently attached to the groundline

Small vessels: >26–55 ft length overall (LOA)

Large vessels: >55 ft length overall (LOA)

Given the lack of information on small Alaska longline vessels, their gear, and appropriate performance standards for these vessels, at its December 2001 meeting the Council strongly encouraged the advancement of a cooperative research program to develop seabird bycatch mitigation measures appropriate for small vessels and all vessels using snap-on gear. This report describes results of a cooperative research effort initiated by the Washington Sea Grant Program and done in collaboration with several industry associations.

The study was designed to accomplish the following:

- Characterize the sink profile (Figure 1) of both fixed gear and snap-on gear deployed from small vessels, defined by two components:
  - the seabird 2-m access window (distance astern that the longline sank to a depth of 2 m below the surface)—a benchmark depth beyond the reach of surface foraging seabirds, and
  - the sink rate (the rate in meters/second, m/s, at which the longline sank to a depth of 2 m below the surface).
- Determine the capability of these vessels to deploy streamer lines or buoy lines, or both, according to performance standard guidelines.
- Recommend seabird avoidance options for small vessels and future research priorities.

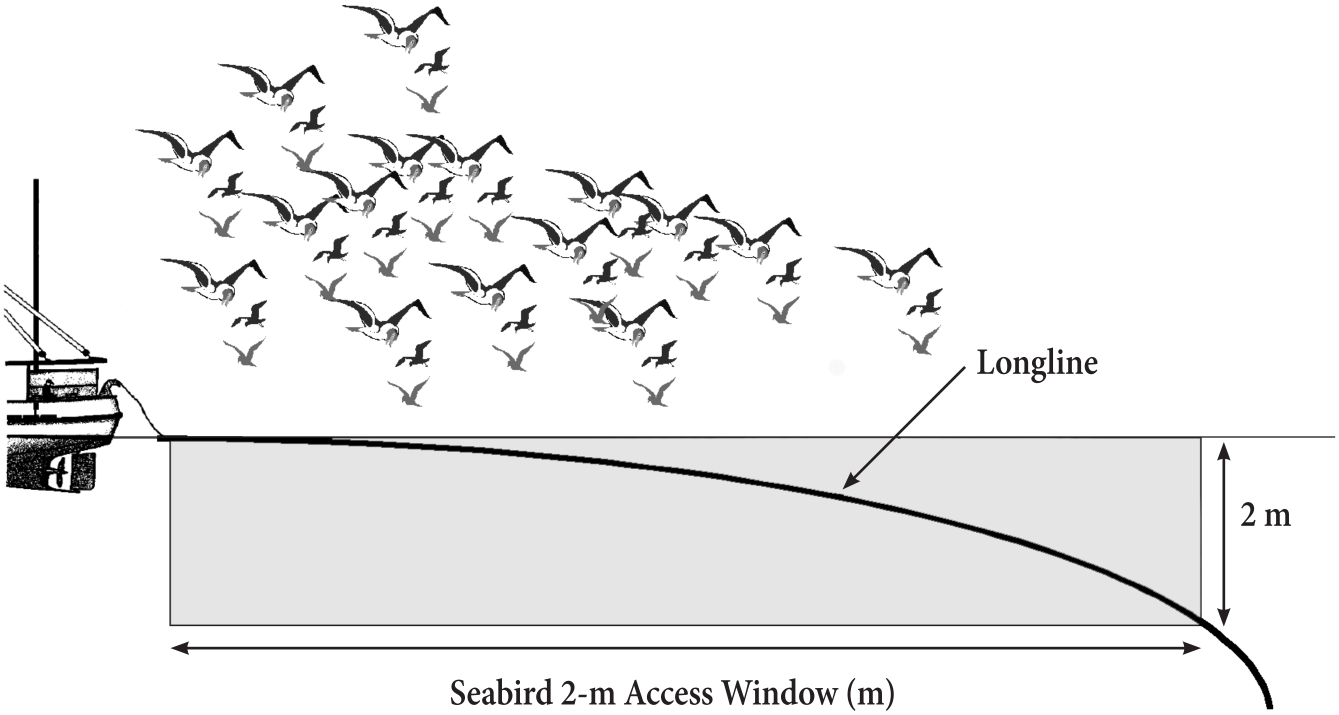

Figure 1. Illustration of the sink profile of a longline to a depth of 2 m as it is deployed from a fishing vessel. The 2-m benchmark was derived from observations that surface foraging seabirds most frequently caught in Alaskan longline fisheries (albatrosses, fulmars, and gulls) do not access baits beyond 2 m from the surface (Melvin et al. 2001). The access window is the distance astern of the vessel that these seabirds have access to baited hooks and is a function of both vessel speed and sink rate [access window (m) = vessel speed (m/s) x seconds to 2 m].

Methods

We characterized sink profiles of longline gear and deployed seabird mitigation measures from eight vessels >26–55 ft in the following vessel categories (see also Table 2):

- Two salmon trollers (F/V *Myriad* and F/V *Morgan*) typical of small vessels with infrastructure (masts, poles, and rigging) and using snap-on gear. One vessel sets gear from containers on deck and the other from a hydraulic drum.
- Three bowpickers (F/V *Jitterbug*, F/V *Cape Fear*, and F/V *Karina Nichole*) typical of small vessels with no infrastructure and using snap-on gear deployed from a hydraulic drum.
- Three combination vessels (F/V *Brandi Raelyn*, F/V *Laurier*, and F/V *Kathi K*) typical of small vessels with infrastructure (masts, booms and rigging) and using fixed gear.

Trials focused on (1) determining the sink profile of the groundline under a range of scenarios appropriate to that vessel class and gear type, and (2) determining what performance standards were achievable and practical for the mitigation measures required for that vessel class or gear type. Groundline sink profiles delineate the area astern of the vessel in which most birds are vulnerable to hooking, and performance standards delineate how much of the vulnerable area can be protected with seabird avoidance technologies. All work was carried out on chartered fishing vessels in protected waters near Sitka, Cordova, and Petersburg, Alaska. Each vessel fished a minimum of two days, making one to three sets per day. Sink profile trials are summarized in Table 3.

Sink Profiles

Access Windows and Sink Rates

Small vessels present unique challenges for research. By virtue of their size, additional personnel are difficult and in some cases impossible to accommodate for extended periods of time. Small vessels tend to set relatively small quantities of gear and in many cases fish in areas with few seabirds, making quantitative comparisons of the effectiveness of seabird avoidance technologies very difficult.

Given these challenges, we took an indirect approach. Rather than compare seabird mortality rates and seabird behavior among seabird avoidance technologies in a controlled experiment, we characterized the groundline sink profiles of gear deployed from vessels in three categories and compared them with existing data on the groundline sink profiles from the original study on which the newly revised regulations are based (Melvin et al. 2001). The first component of the

Table 2. Description of small vessels and their halibut longline gear. T = troller, B = bowpicker, C = combination vessel; S = snap-on gear, F = fixed gear. Partial information for sablefish gear (S) is shown for the F/V *Myriad* and the F/V *Brandi Raelyn*.

Vessel	Size (LOA)	Vessel/ gear	Mast, boom, rigging	Groundline diameter (in) material	Gangion spacing (fa)/ length (in)	Circle hook size	Bait	Weight (lb)/ spacing (fa)
Myriad	47.0	T/S	Yes	5/16 leaded poly	3/24 1/24 (S)	#15 #13	Salmon/herring	~4/100
Morgan	32.0	T/S	Yes	3/8 varied	2/12–24	#13	Herring	~4/110
*Cape Fear**	32.0	B/S	No	5/16 leaded poly	3–4/36	#16	Squid	~10/300
*Jitterbug***	31.0	B/S	No	5/16 varied	3/36	#16	Herring	~5/300
*Karina Nichole***	28.6	B/S	No	5/16 tarred nylon	5/55	#16	Octopus/squid	None
Brandi Raelyn	40.0	C/F	Yes	3/8 proline 3/8 aqualine (S)	3/30	#16	Herring	None 2.5/100 (S)
Laurier	40.0	C/F	Yes	5/16 Norwegian	3/32	#16	Squid	None
Kathi K	35.5	C/F	Yes	5/16 leaded poly	3/36	#15	Herring	None

*The F/V *Cape Fear* sets gear over the starboard side while in forward gear.
**The F/V *Jitterbug* and F/V *Karina Nichole* set gear over the bow roller while in reverse gear.

Table 3. Experimental design for sink profile trials for small boats.

Vessel category	Gear type	Vessels	Location/ Dates (2002)	# sets	Observation platform (V=vessel; S=trailing skiff)
Salmon trollers	Snap-on	F/V *Myriad* F/V *Morgan*	Deep Inlet 2–5 May	*Myriad*–7 *Morgan*–2	V (7) S (2)
Bowpickers	Snap-on	F/V *Jitterbug* F/V *Karina Nichole* F/V *Cape Fear*	Cordova 8–11 May	*Jitterbug*–3 *Cape Fear*–2* *K. Nichole*–4	V (4) S (5)
Combination vessels	Fixed	F/V *Kathi K* F/V *Brandi Raelyn* F/V *Laurier*	Scrow Bay 5–7 June	*Kathi K*–2* *B. Raelyn*–4* *Laurier*–5	S (11)

*Data quality was poor and data were not included from a third set on the *Cape Fear*, 2 additional sets on the *Kathi K*, and a fifth set on the *Brandi Raelyn*.

sink profile is the seabird 2-m access window: the distance from the stern to where the longline sinks to a depth of 2 m below the surface (Figure 1). The 2-m benchmark is based on observations that surface foraging seabirds most frequently killed in Alaska longline fisheries (albatrosses, northern fulmars, and gulls) do not forage or attack baits beyond 2 m of the surface (Melvin et al. 2001). Because the access window is a function of vessel speed and the sink rate of the gear to the benchmark depth of 2 m, we also determined this sink rate (the rate in meters per second at which longlines deployed from each vessel sank to 2 m) as the second dimension of the sink profile. We characterized sink profiles while varying vessel speed and adding varying amounts of weight to the gear (altering sink rate). These trials allowed us to assess the relative importance of vessel speed and sink rate in determining the 2-m access window, and therefore the relative value of changes in vessel speed and sink rate (by adding weights) as potential seabird avoidance mitigation measures.

This approach assumes that the groundline sink profile is a primary factor dictating the access of seabirds to baited hooks, and therefore, the likelihood of seabird mortality. If the sink profiles for small vessels are shorter (access window) and steeper (rate) than those documented for large sablefish vessels in the previous study, or can be made shorter and steeper by manipulating speed or adding weight to the groundline, then it follows that streamer line performance standards for small vessels can be reduced or that other avoidance techniques may be appropriate (or both). If the assumption is true that sink profiles dictate seabird bycatch risk, then mitigation research need not necessarily be conducted in the presence of seabirds, but rather research can capitalize on the relationships between groundline sink profiles and seabird attacks established in the previous study in the absence of seabird avoidance measures (Melvin et al. 2001).

Each sink profile set consisted of approximately three to four, 300-fathom skates of baited halibut gear. In the case of the F/V *Myriad*, a troller using snap-on gear and the first vessel we worked on, we also set sablefish gear for which gangions are spaced closer together (Table 2). For each vessel, we documented the sink profile of its gear based on the speed, gangion spacing, weight, and bait type typically used by that vessel. Where possible, we documented the sink profiles during experimental sets that varied vessel speed or the amount of added weight, provided weights were available in sufficient quantity. To minimize the confounding effects of weather and current between sets, we conducted speed and weight trials when possible within a single set. However, the relatively small amount of gear available constrained the number of bottle lines (see following) we could deploy for any particular experimental manipulation within a set, and therefore precluded useful statistical comparisons. All sink rate measurements began at a point when we were sure that the leading anchor was on the seabed. Wind speed and direction, swell height, and weather conditions were recorded for each set.

We used 1- and 2-m bottle lines and time–depth recorders (TDRs) to measure groundline sink profiles.

Bottle Lines

Bottle lines are an inexpensive alternative to TDRs for determining the sink profiles of longline gear (Fenaughty and Smith 2001, Wienecke and Robertson 2004). Our bottle lines consisted of a specific (1- or 2-m) length of gangion-like line. One end of each line was attached to a 750-ml plastic bottle with a sport water bottle cap (opens in or out with your teeth); the line was tied to the bottle through small holes drilled on each side at the base of the bottle's neck. The other end of the line was attached to a halibut clip, by which the entire bottle line was clipped to the groundline. As the groundline sank the 1- or 2-m length of line extended from the clasp of the clip on the groundline towards the surface to the fulcrum of the buoyant bottle. When the groundline reached the relevant depth (1 or 2 m) the bottle would flip to a vertical position at the surface. Brightly colored landscaping flags were attached to the vertical axis of the bottles with colored duct tape and reflective tape to maximize visibility of bottles as they assumed a vertical position. Each bottle was deployed with the cap opened so that bottles would quickly fill with water and sink, minimizing any possible effect on the sink rates of the groundline. Two-meter bottle lines directly measured the biological benchmark of 2 m, while 1-m lines were included to estimate a distance beyond the stern at which streamer lines were unlikely to foul on the groundline.

One- and 2-m bottle lines were deployed alternately on the groundline as the gear went out with approximately 100 m between bottles. To determine access windows, we used an 80-m measuring line marked at 10-m intervals trailing from the vessel, recording the distance astern that the groundline entered the water and the distance at which each bottle (on 1- and 2-m lines) flipped from a horizontal to a vertical position as the groundline reached the predetermined depth. To calculate sink rates, we used a stopwatch to measure the time to the nearest tenth of a second that the clip of a bottle line on the groundline entered the water to the time the bottle flipped to vertical. Bottle-line distance and time measurements were made from either onboard the vessel setting the gear, or from a trailing vessel or skiff. When watched from a vessel trailing in the wake of the vessel setting gear, one could observe the entire bottle line as it went taught when the bottle assumed a vertical position. This method provided a very accurate and immediate estimate of the depth and distance of the groundline that was obvious to cooperating fishermen, as well as scientists. In weight trials, both bottle lines and TDRs (see following) were deployed at the midpoint between adjoining weights, thus generating the most conservative estimate of the sink profile.

Time–depth Recorders (TDRs)

On a subset of gear deployments, we also used Mk7 TDRs made by Wildlife Computers (Redmond, WA) to estimate longline sink profiles, employing methods similar to those described by Wienecke and Robertson (2004). The six TDRs available for this study were deployed in (three) pairs to ensure that at least one high-quality record was obtained for each pair. However, this precaution limited our ability to collect data of a volume comparable with bottle lines. For this reason we did not statistically compare the two techniques, but rather simply described them to determine how gear sink profiles might best be measured in the future.

TDRs were joined into pairs with electrical tape and seized with gangion material with a loop at the end creating an array similar to a snap-on gangion approximately 6 in long. Each TDR pair was placed in a plastic bag filled with seawater that was sealed with a wire-tie and acclimated in running seawater on deck for a minimum of 30 minutes prior to each deployment. Each TDR array was attached to the groundline by passing the TDR pair through the loop around the groundline. TDRs were activated every morning and data were downloaded to a PC laptop at the end of each day. Drift was corrected by calibrating TDR clocks to synchronized wristwatches, which were used to carefully record the time each TDR pair entered the water. TDRs recorded depth (to the nearest 0.5 m) and temperature (to 0.1°C) every second. In interpreting TDR data, the 2-m benchmark depth was reached when the instrument recorded 2 m and subsequent measurements were ≥2 m.

Performance Standards

Practical aspects of using seabird mitigation measures are as important as effectiveness. If a measure is impractical or a performance standard is difficult or impossible to achieve, neither fishermen nor seabird conservation are served, creating a lose–lose situation. This is one reason the revised seabird avoidance regulations do not specify performance standards for the small vessels. Guidelines were provided for suggested standards. To address issues of practicality, we deployed mitigation techniques that are required for each of the three vessel categories, and determined what performance standards could be achieved and under what conditions. Streamer line trials focused on achieving the 45/20-m performance standard suggested for snap-on gear and the 90/40-m performance standard suggested for small vessels using fixed gear. Buoy line trials were focused on achieving the voluntary performance standard suggested in the Council process of placing the buoy aft of the entry point of the groundline into the water and forward of the 2-m depth benchmark but within 2 m either side of the groundline.

On the F/V *Myriad*, we measured the distance astern that four streamer line designs remained aloft under a range of scenarios. Streamer line designs were categorized as heavy or light. The heavy lines were 90-m or 45-m long and made from 3/8-in, three-strand blue steel poly. The 90-m line has been made available since 2000 by the USFWS. The lighter lines were either 90 m and made from 1/8-in seine cord with streamers permanently attached with plastic wire ties or 45 m and made with #48 gangion material with streamers clipped on with halibut snaps at 5-m intervals as the line was set and retrieved. In all four designs, individual branched streamers were made from ¼-in UV- protected, orange plastic tubing. Streamer lines were attached to a length of line tied to the crosstree of the mast at a height of 31 ft above the water. Scenarios included varying the size and weight of the towed object (and therefore the drag it created in the water), vessel speed, and the height of the line at the stern. Height at the stern was manipulated via a lazy line to the line running from the mast to the streamer line. On the F/V *Morgan*, we compared the distance astern the 90-m heavy streamer line was aloft under similar scenarios (variations in towed object, vessel speed, and height of attachment). The streamer line was attached to a line tied to the mast at a height of approximately 25 ft above the water.

On the F/V *Laurier* and the F/V *Brandi Raelyn*, 90-m heavy (3/8-in diameter) streamer lines were attached to the boom at a height of 20 ft at the stern, and trials were focused on achieving a 40-m aerial extent. On the F/V *Kathi K*, we also compared the 90-m heavy and 90-m light streamer lines. The lines were attached to the boom at either 10 or 15 ft above the water (end of the boom was near the stern), and a lazy line was used to adjust height at the stern.

Bowpicker trials depended on the configuration and setting direction of each vessel. We deployed a buoy from a line from the rail (about 5 ft above the water) near the bow on the F/V *Jitterbug* and the F/V *Karina Nichole* as they set gear in reverse, and from the top of the house (about 10 ft above the water) on the F/V *Cape Fear* as it set gear forward.

Results

Seabirds

During all this work with small vessels in Alaska's inside waters, no Procellariiform seabirds were sighted nor were any types of seabirds observed interacting with longline gear.

Sink Profiles: Bottle Lines

Salmon Trollers with Snap-On Gear

For all sets combined, the 2-m access window (distance from the stern to where the snap-on gear sank to 2 m) ranged from 21 m at the slowest vessel speed (2.2 knots) to 54 m at the fastest speed (4.4 knots; Figure 2), with an overall mean of 31 m (2.1 m, 95% confidence interval [CI]).

For sets deployed under typical speed and weight conditions (no speed or weight trials), the mean access window was 28 m (2.6 m, 95% CI).

The smallest 2-m access window measured 21 m, and occurred during a sablefish trial with a setting speed of 2.2 knots. Sablefish sets are made at slower speeds than halibut sets to allow for spacing gangions closer together. The largest access window under typical fishing conditions was 46 m, and occurred during a faster (3.5-knot) halibut set.

Speed and weight trials showed that varying both speed and the spacing of weights altered the access window of snap-on longline gear on these vessels, but to different degrees.

An increase in speed from 2.4 to 4.4 knots nearly doubled the 2-m access window from 30 m to 54 m. In contrast, only the heaviest

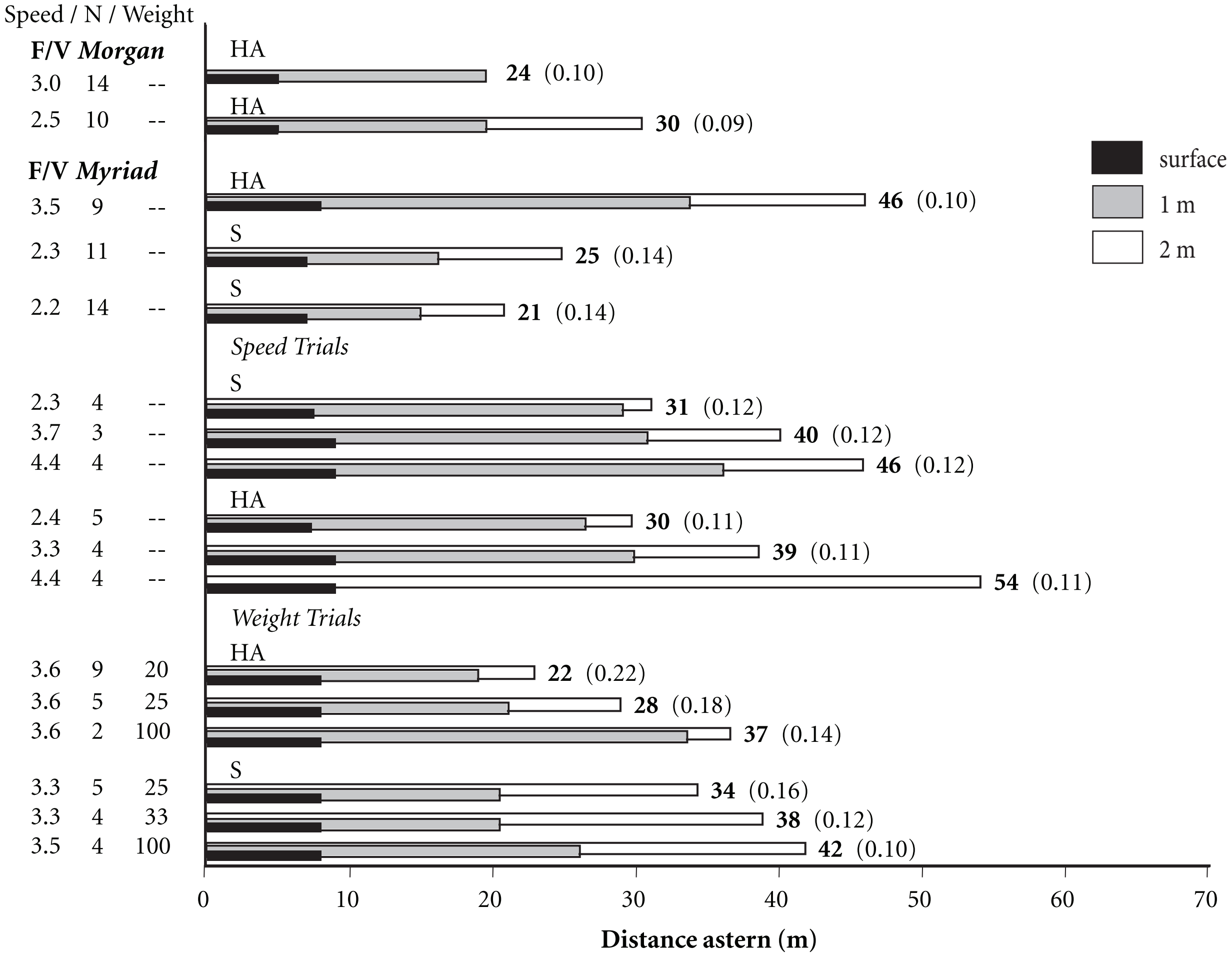

Figure 2. Snap-on gear sink profiles for trollers, measured with bottle lines. Distance astern (m) that the groundline entered the water and reached 1-m and 2-m depths, and sink rate (in parentheses) to 2 m (m/s) are provided for typical halibut (HA) and sablefish (S) gear deployments (sets) and for speed and weight trials for the F/V *Morgan* and the F/V *Myriad*. Setting speed (knots), the number of 2-m bottle lines per set, and the distance between 4-lb weights in weight trials are shown on the left. Speed and weight were varied within sets in speed and weight trials. Only typical halibut sets were made from the F/V *Morgan*. 2-m access window ranges: halibut = 22–54 m; sablefish = 21–46 m. Sink rate range = 0.09–0.22 m/s.

weight scenarios (4 lb every 20 or 25 fathoms) had an obvious effect, producing 2-m access windows of 22 m and 28–34 m, respectively. The lighter scenarios (33 and 100 fathoms) produced 2-m access windows ranging 37–42 m, profiles similar to un-weighted gear set over 3 knots (39–54 m).

Overall the mean 2-m sink rate for typical un-weighted sets on troll vessels was 0.13 m/s (0.01 m/s, 95% CI). For typical halibut sets, the rate at which groundlines sank to 2 m varied narrowly (0.09–0.11 m/s). Typical sablefish sets with gangions spaced at 1 m sank slightly faster (0.12–0.14 m/s) than halibut sets with gangions spaced at 2 to 3 m. In parallel with the pattern seen in access windows, only the heaviest weight scenarios (20- and 25-fathom spacings) exceeded 0.14 m/s (0.22 m/s and 0.16–0.18 m/s, respectively). Weights spaced at greater than 25 fathoms produced sink rates (0.10–0.14 m/s) similar to sets of un-weighted gear.

Bowpickers with Snap-On Gear

Overall, the distance astern at which snap-on gear sank to 2 m ranged from 16 m (at 2.6 knots, 5 lb added per 100 fathoms) to 76 m (at 3.5 knots; Figure 3), with a mean distance of 39 m (3.2 m, 95% CI). **For typical halibut sets on all three vessels, the mean distance astern at which snap-on gear sank to 2 m was 38 m (3.0 m, 95% CI).** The seabird 2-m access window ranged from 28 m (F/V *Jitterbug* at 2.2 knots) to 46 m (F/V *Cape Fear* at 3.3 knots).

As with trollers using snap-on gear, vessel speed and weight trials on bowpickers showed that varying both speed and the spacing of weights altered the access window, with changes in speed having a more dramatic effect. Increases of more than 0.5 knots nearly doubled the 2-m access window: The F/V *Jitterbug* increased from 26 m at 2.4 knots to 42 m at 3.0 knots, and the F/V *Karina Nichole* increased from 36 m and 40 m at 2.3 knots to 71 m and 76 m at 3.5 knots. On the F/V *Cape Fear*, a 2-knot increase nearly tripled the 2-m distance from 21 m at 2.3 knots to 58 m at 4.3 knots. In the only weight trial (on the F/V *Jitterbug*), 5-lb weights every 100 fathoms reduced the 2-m access window from 24 m to 15 m.

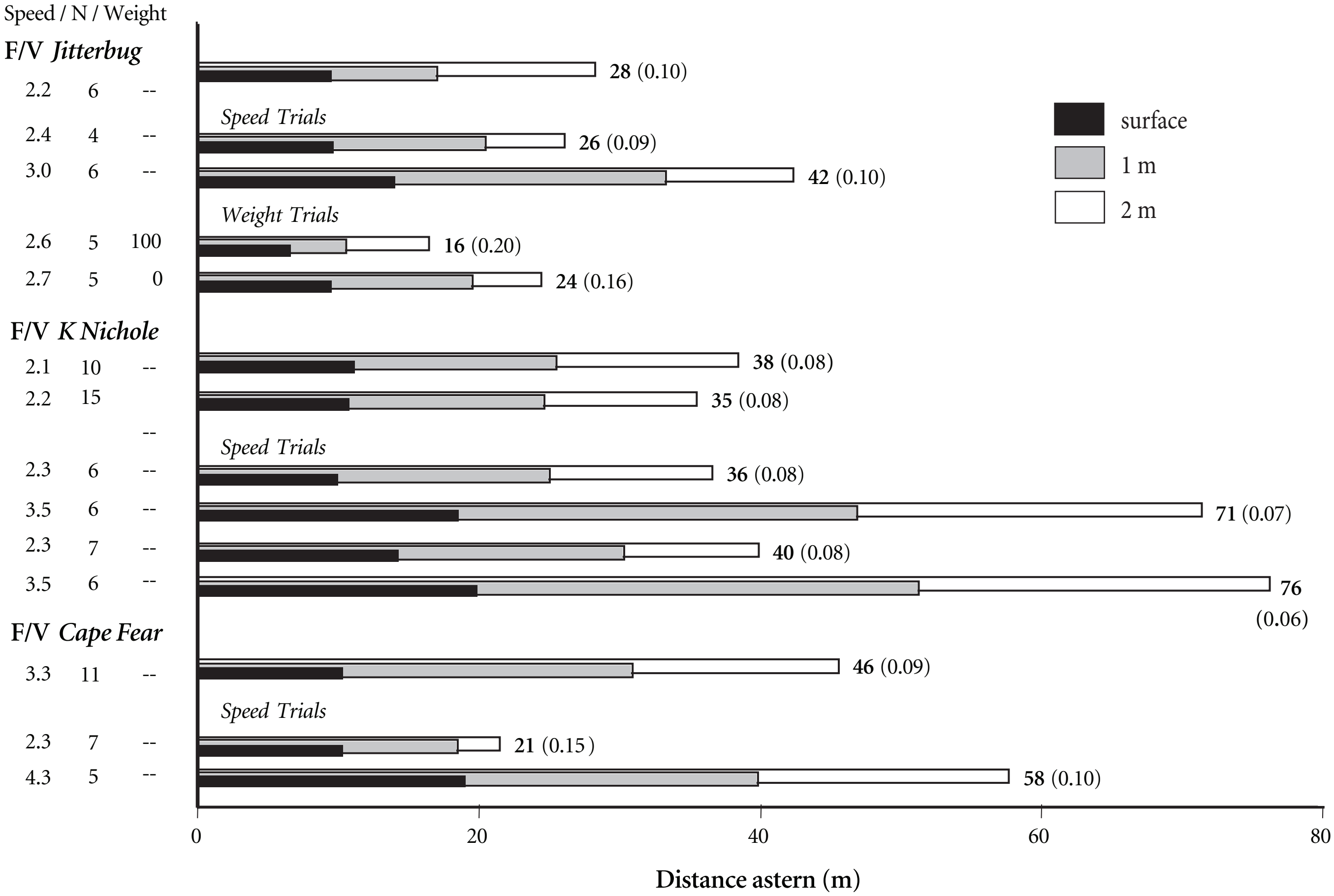

Figure 3. Snap-on gear sink profiles for bowpickers, measured with bottle lines. Distance astern (m) that the groundline entered the water and reached 1-m and 2-m depths, and sink rate (in parentheses) to 2 m (m/s) are provided for typical halibut gear deployments (sets) and for speed and weight trials for the F/V *Jitterbug*, F/V *Karina Nichole*, and F/V *Cape Fear*. Setting speed (knots), the number of 2-m bottle lines per set, and the distance between 5-lb weights in weight trials are shown on the left. Speed and weight were varied for entire sets in speed and weight trials. Weight trials were done only on the F/V *Jitterbug*. 2-m access window range = 16-76 m. Sink rate range = 0.06 - 0.20 m/s.

Overall the 2-m mean sink rate for typical un-weighted sets on bowpickers was 0.09 m/s (0.01 m/s, 95% CI). Sink rates of un-weighted gear in 11 of 13 sets varied little (0.06–0.10 m/s). Faster sink rates for un-weighted gear in the F/V *Jitterbug* weight trial (0.16 m/s) and in the F/V *Cape Fear* speed trial (0.15 m/s) were anomalous and are difficult to explain. As expected, the fastest sink rate was recorded for the weighted set (F/V *Jitterbug*, 0.20 m/s).

Combination Vessels with Fixed gear

Note that combination vessels typically set fixed longline gear up to twice the speed (4.9 to 7.4 knots) of snap-on gear vessels (2.2 to 3.6 knots). This faster speed limited the number of bottle lines that could be deployed during an individual set, and therefore, precluded comparing the effect of vessel speed within a single set. Instead we made entire sets at differing speeds to evaluate the effects of vessel speed on sink profiles. Faster setting speeds also forced the deployment of bottle lines before the previous bottle flipped to a vertical position, leading to data loss or compromised data quality. In addition, 2-m access windows occasionally exceeded the 80-m measuring line and had to be estimated. Manipulations of weight were not conducted because these three vessels rarely used weights and weights were unavailable.

Overall, distance astern at which fixed gear sank to 2 m ranged from 50 m at 5.4 knots to 134 m at 4.1 knots, with a mean access window of 88 m (6.7 m, 95% CI; Figure 4). **For gear set at typical speeds, the 2-m access window ranged 50–133 m, with a mean of 90 m (7.6 m, 95% CI).** **The tremendous variation in each vessel's 2-m access windows for a range of setting speeds demonstrates that changes in speed of near 1 or 2 knots can double the 2-m access window.** On the F/V *Laurier*, the access window increased from 72 m to 133 m, with an increase in speed from 5 knots to 7.4 knots. Similarly, on the F/V *Brandi Raelyn*, the access window increased from 50 m to 115 m with a speed increase of 5.4 knots to 6.5 knots.

Fixed gear sink rates to 2 m averaged 0.07 m/s (0.01, 95% CI) and varied from 0.3 m to 0.8 m.

Sink Profiles: Time–Depth Recorders

On the F/V *Myriad* (a troller), mean 2-m access windows obtained from TDRs (range 36–64 m) were either nearly identical or 8–10 m greater than the mean 2-m access windows obtained from bottle lines (range 30–54 m; Figure 5). Sink rate estimates were also similar between methods (0.08–0.11 m/s for TDRs and 0.10–0.16 m/s for bottle lines).

For bowpickers, mean TDR access windows (range 30–63 m) were also comparable with or larger than bottle-line access windows (28–76 m; Figure 6), with one exception: on the F/V *Karina Nichole*, a TDR 2-m access window estimate (63 m) was considerably less than the complementary bottle–line estimate (76 m). Sink rate estimates were similar between methods in this vessel category as well (0.07–0.11 m/s for TDRs, 0.06–0.10 m/s for bottle lines).

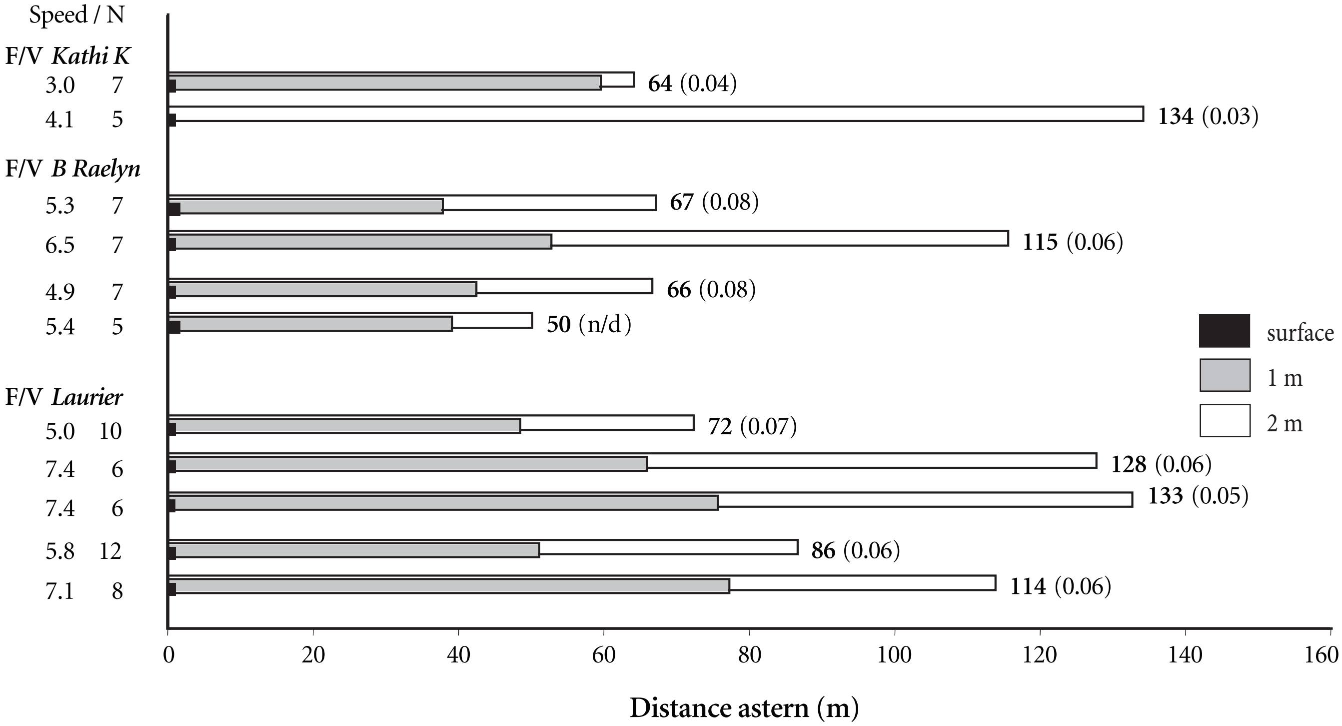

Figure 4. Sink profiles for fixed (tub) gear, measured with bottle lines. Distance astern (m) that the groundline entered the water and reached 1-m and 2-m depths, and sink rate (in parentheses) to 2 m (m/s) are provided for typical halibut gear deployments (sets) and for speed trials for the F/V *Kathi K*, F/V *Brandi Raelyn*, and F/V *Laurier*. Setting speed (knots) and the number of 2-m-bottle lines per set are shown on the left. Speed was varied for entire sets in speed trials. 2-m access window range = 50–134 m. Sink rate range = 0.03 - 0.08 m/s.

Results were less consistent between TDR and bottle-line methods for fixed gear set at faster speeds (Figure 7)**.** The two methods yielded differences in access window estimates ranging from 16 m (F/V *Brandi Raelyn*) to 59 m (F/V *Kathi K*). Two TDR estimates exceeded bottle-line estimates, while the remaining two bottle-line estimates exceeded TDR estimates. TDR sink rates ranged from 0.05 m/s to 0.11 m/s and were less similar to bottle-line estimates than for other vessel categories. Because the sample sizes for TDRs were generally high (3–6 TDRs per line) and bottle lines were difficult to deploy on these vessels, TDR data are probably the best estimates of both access windows and sink rates for fixed gear.

Performance Standards

Streamer Lines

On the F/V *Myriad* at speeds under 3 knots and at heights (at the stern) of less than 13 ft, only the light streamer lines (45-m and 90-m) met the 20-m performance standard (Table 4A). At these same speeds the heavier 90-m streamer line met the 20-m performance standard only when the attachment point exceeded 13 ft. At less than 3 knots, the 40-m performance standard was met only when the light streamer lines (45-m and 90-m) were used and the attachment height was 18 ft or more. Because the 90-m and 45-m heavy streamer lines performed similarly, only data for the 90-m heavy line are presented.

At speeds over 3 knots and at heights less than 13 ft, all streamer line designs with a towed object met the 20-m performance standard, but only the 90-m light streamer line with the maximum drag met the 40-m performance standard (Table 4B). At speeds over 3 knots and at heights exceeding 13 ft, all streamer line designs met the 20-m standard, but only the two 90-m lines (heavy and light) deployed at heights above 23 ft and with maximum drag met the 40-m standard.

On the F/V *Morgan* (Table 5) at speeds 3 knots and over (all trials), the heavy 90-m streamer line suspended at heights under 13 ft met the 20-m performance standard under all scenarios that included a towed object with weight; however, only the heaviest drag (deflated A2 buoy, 7.4 lb of weight, a heavy chain link, and three crab buoys) just met the 40-m standard. At heights exceeding 13 ft and speeds over 3 knots, all towed object scenarios met the 20-m standard, but only the heaviest drag at the greatest height (17 ft) met the 40-m standard.

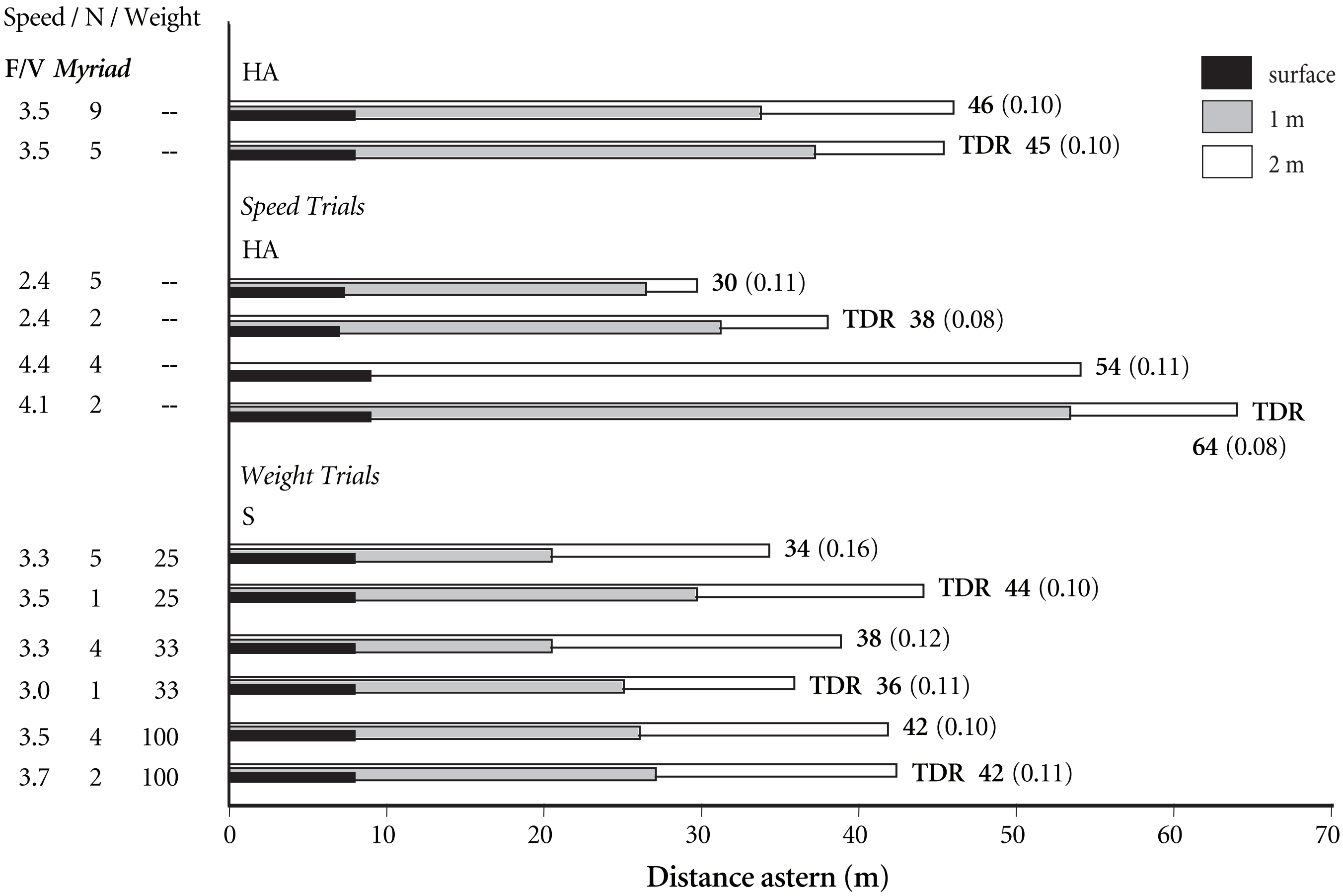

Figure 5. Snap-on gear sink profiles for troller (F/V *Myriad*), measured with bottle lines and Mk7 time depth recorders (TDRs) in the same set. Distance (m) astern that the groundline entered the water and reached 1-m and 2-m depths, and sink rate (in parentheses) to 2 m (m/s) are provided for typical halibut and sablefish sets, and for speed and weight trials. Setting speed (knots), the number of 2-m bottles lines, the number of TDR records per trial, and the distance between 4-lb weights in weight trials are shown on the left. Speed and weight were varied within a set in speed and weight trials. 2-m access window ranges: halibut = 30–64 m; sablefish = 34–44 m. Sink rate range = 0.08–0.16 m/s.

On the vessels setting fixed gear (F/V *Kathi K*, F/V *Brandi Raelyn*, and F/V *Laurier*), we deployed a 90-m heavy streamer line from the aft end of the boom on each vessel, 15–20 ft above the water (see Methods). Using a low drag buoy (LD2) with 7.4 lb of weight, we achieved the 40-m streamer line performance standard in the first attempt on each vessel at their typical setting speeds of 4.9–7.4 knots.

On the F/V *Kathi K*, we compared the distance aloft of the 90-m heavy and 90-m light streamer lines at 10-ft and 15-ft heights at the stern. At 10 ft the heavy streamer line extended 35–41 m (4.8–5.0 knots), and the light streamer line extended 58 m (4.9 knots). At the 15-foot height, the heavy streamer line extended 40–43 m (4.3–5.1) knots and the light streamer line extended 65 m (4.9 knots).

Buoy Lines

On bowpickers using snap-on gear, the groundline is maintained taut off a hydraulic drum and in the air from 7 m to 20 m beyond the vessel, while the buoy line is set relatively slack with about 2 m of the line in the air. As a consequence, anytime the buoy was positioned at or beyond the point where the groundline entered the water, the buoy or buoy line chaffed or crossed the groundline. This was especially true while setting in reverse as vessels rarely maintained a straight course. The suggested performance standard could not be met as we were unable to position the buoy over the sinking gear within 2 m of the groundline without the potential for fouling the lines. The risk of fouling is particularly troublesome on these vessels, many of which fish longline gear with only one person.

The participating captains suggested that a cone fitted to the buoy and tapering to the line might eliminate the potential for hang-ups, but circumstances did not allow for fabricating and testing such a device during our time in Cordova. We found the only way to maintain a buoy without the potential for hanging it up on the groundline was to maintain it in a position forward of the point that the line on the buoy enters the water. If seabirds were present and attacking baits, a buoy positioned this way likely would be ineffective. Raising the attachment point on the vessel might eliminate this problem but owing to the lack of superstructure, poles, and rigging, this option was not practical on these vessels. For bowpickers setting in reverse, there is little room near the roller to add a davit or stanchion near the bow. Without further work, buoy lines are unlikely to be effective as practical seabird deterrents on bowpickers, and the suggested standard will not be met.

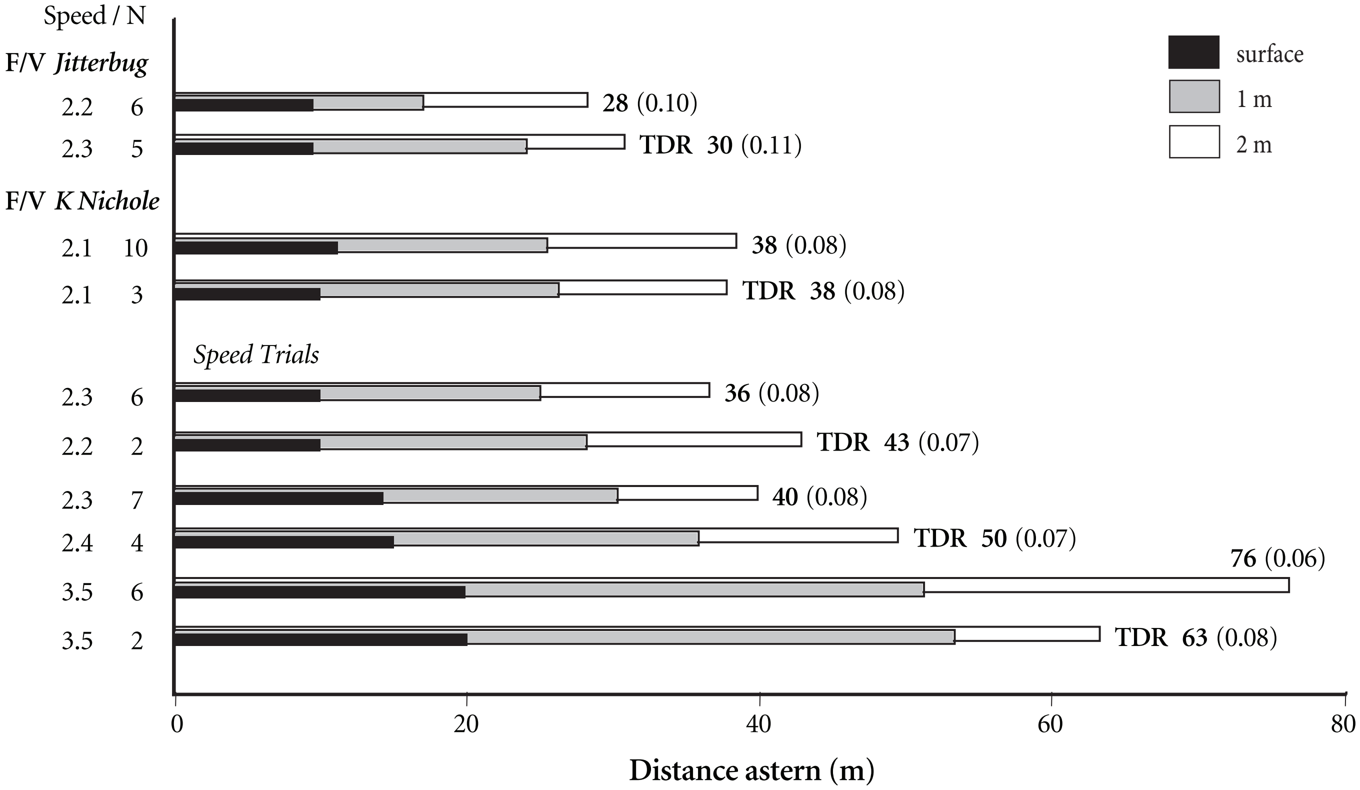

Figure 6. Snap-on gear sink profiles for bowpickers, measured with bottle lines and Mk7 time depth recorders (TDRs) in the same set. Distance (m) astern that the groundline entered the water and reached 1-m and 2-m depths, and sink rate (in parentheses) to 2 m (m/s) are provided for a typical halibut (HA) set on the F/V *Jitterbug* and typical halibut sets and for speed trials for the F/V *Karina Nichole*. Setting speed (knots), the number of 2-m bottles lines, and the number of TDR records per set are shown on the left. Speed was varied for entire sets in speed trials. 2-m access window range = 28-76 m. Sink rate range = 0.06 - 0.11 m/s.

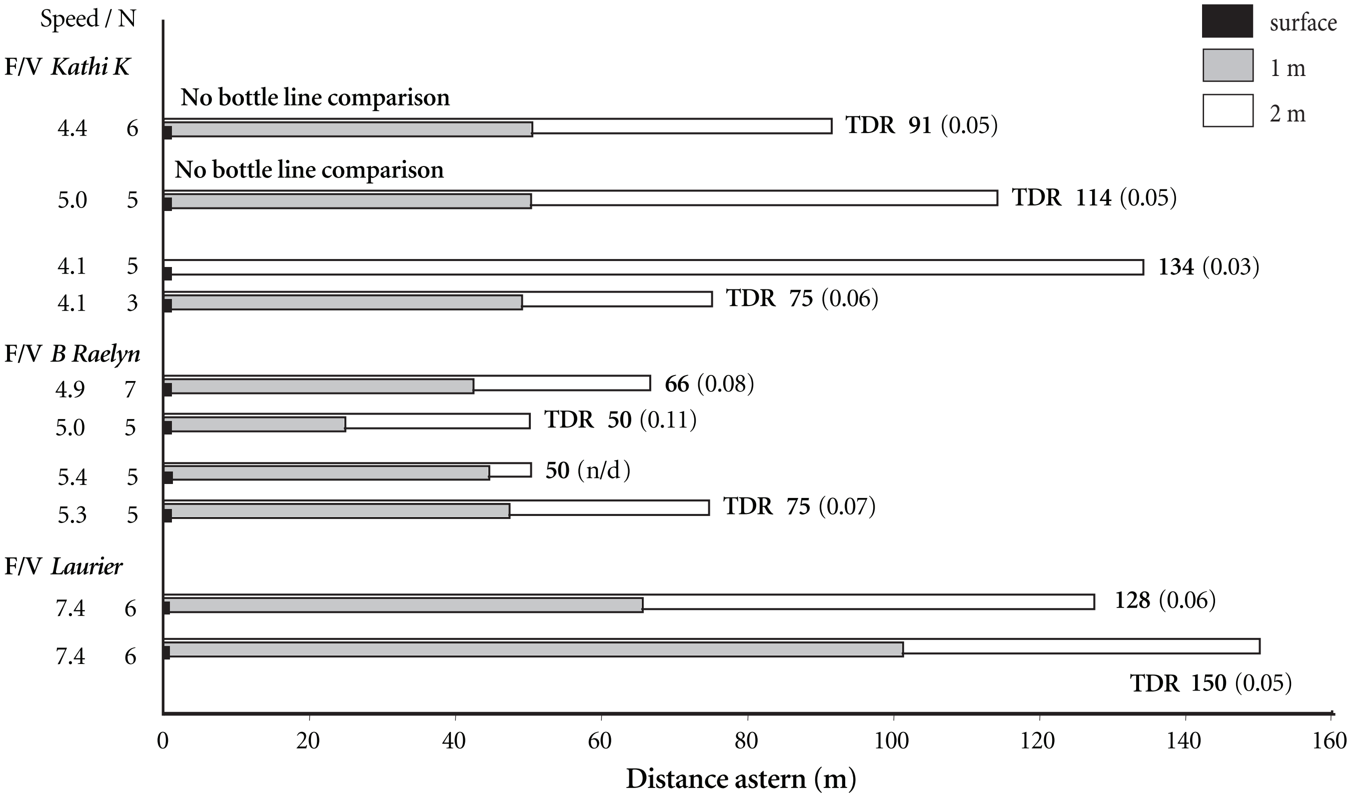

Figure 7. Sink profiles measured for fixed (tub) gear, with bottle lines and Mk7 time–depth recorders (TDRs) in the same set. Distance (m) astern that the groundline entered the water and reached 1-m and 2-m depths, and sink rate to 2 m (m/s) are provided for typical halibut (HA) sets and for speed trials on the F/V *Kathi K*, F/V *Brandi Raelyn*, and the F/V *Laurier*. Setting speed (knots), the number of 2-m bottles lines, and the number of TDR records per set are shown on the left. Speed was varied for entire sets in speed trials. 2-m access window range = 50-150 m. Sink rate range = 0.03 - 0.11 m/s.

Table 4. Distance streamer line for F/V *Myriad* is aloft (m) as a function of the streamer line type, object towed, vessel speed (knots), and height (ft) of the streamer line attachment point above the water at the stern. (A) Vessel speed <3 knots; (B) vessel speed >3 knots. 90-m heavy = 90-m 3/8-in blue steel poly streamer line available through the USFWS (data from 45-m heavy streamer lines were similar to 90-m heavy lines and are not shown here); 90-m light = 90-m 1/8-in seine twine streamer line with streamers permanently attached; 45-m light = 45-m #48 gangion material streamer line with clip-on plastic streamers; A2 = deflated polyform A2 buoy; C = 3 crab buoys + 4.4 lb; light shading = combinations that do not meet any Alaska performance standard; dark shading = combinations that meet the 40-m performance standard.

Streamer line	Towed object	Speed (knots)	Height (ft)	Aloft (m)
	A. Vessel speed <3 knots			
Height <13 feet				
90-m heavy	None	2.4	10.0	13.0
90-m heavy	A2 + 7.4 lb	2.2	10.0	15.0
90-m heavy	C	2.2	10.0	16.0
90-m heavy	A2	2.3	12.0	18.0
45-m light	A2	2.3	10.0	33.0
45-m light	A2 + 7.6 lb	2.7	10.0	34.0
90-m light	A2 + 7.4 lb	2.3	10.0	35.5
Height >13 feet				
90-m heavy	C	2.4	16.0	23.0
90-m heavy	A2	2.4	24.0	23.0
90-m heavy	A2 + 7.4 lb	2.3	14.0	24.0
90-m heavy	A2 + 7.4 lb	2.2	18.0	25.0
45-m light	A2 + 7.6 lb	2.1	20.0	38.0
45-m light	A2	2.3	18.0	40.0
90-m light	A2	2.2	20.0	45.0
90-m light	A2 + 7.4 lb	2.3	21.5	48.0
	B. Vessel speed >3 knots			
Height <13 feet				
90-m heavy	None	3.7	10.0	17.0
90-m heavy	A2	3.6	10.0	25.0
90-m heavy	C	3.5	10.0	26.0
45-m light	A2	3.4	10.0	30.0
90-m heavy	A2 + 7.4 lb	3.8	10.0	30.0
45-m light	A2 + 7.6 lb	3.5	10.0	31.0
90-m light	A	3.5	10.0	34.5
90-m light	A2 + 7.4 lb	3.5	10.0	47.0
Height >13 feet				
90-m heavy	A	3.3	24.0	33.0
90-m heavy	C	3.5	20.0	34.5
90-m heavy	A2 + 7.4 lb	3.8	14.0	36.0
45-m light	A2 + 7.6 lb	3.5	19.0	37.0
45-m light	A2	3.6	18.0	38.0
90-m heavy	A2 + 7.4 lb	3.7	28.0	44.0
90-m light	A2 + 7.4 lb	3.6	24.0	65 +

Table 5. Distance streamer line for F/V *Morgan* is aloft (m) as a function of object towed, vessel speed (knots) and height (ft) of the streamer line attachment point above the water at the stern. All streamer lines were 90-m heavy (90-m 3/8-in blue steel poly streamer line available through the USWS); A2 = deflated polyform A2 buoy; I-A2 = inflated A2 buoy; C = 3 crab buoys + 7.4 lb; light shading = combinations that do not meet any Alaska performance standards; dark shading = combinations that meet the 40-m performance standard.

Towed object	Speed (knots)	Height (ft)	Aloft (m)
Streamer line height <13 ft			
None	3.0	10.00	13.0
None	3.0	12.00	14.0
A2	3.3	10.00	18.5
I-A2	3.2	10.00	19.0
A2 + 7.4 lb	3.0	10.00	26.0
A2 + 7.4 lb + chain link	3.1	10.00	27.0
I-A2 + 7.4 lb	3.1	10.00	28.0
I-A2 + 7.4 lb + chain link	3.2	10.00	33.0
A2 + 7.4 lb + chain link + C	3.1	10.00	40.0
Streamer line height >13 feet			
C	3.0	14.00	20.0
A2	3.3	14.50	20.0
I-A2	3.2	14.00	21.0
A2 + 7.4 lb	3.0	16.00	30.0
I-A2 + 7.4 lb	3.1	15.25	32.0
A2 + 7.4 lb + chain link	3.1	17.00	32.0
I-A2 + 7.4 lb + chain link	3.2	16.00	36.0
A2 + 7.4 lb + chain link + C	3.1	17.00	45.0

Discussion

Seabirds

Several factors came to our attention that suggest smaller vessels of Alaska's longline fishing fleet are likely to pose less risk to seabirds than large vessels. The complete absence of Procellariiform seabirds (albatrosses, fulmars and shearwaters) throughout this study supports the repeated testimony to the Council that these seabirds are not observed in Alaska's inside waters and consequently do not interact with longline vessels fishing inside waters. In addition to the likely lack of spatial overlap, several operational characteristics of small vessels also minimize risk to seabirds. Most small boat owners participate in a variety of fisheries using a range of fishing gears; many fish with longlines for as little as 1 or 2 weeks per year. In some cases, target species, especially sablefish, are delivered to shoreside processors whole; consequently, little to no offal is discharged, minimizing the attraction of seabirds to these vessels. In some cases, smaller vessels set gear once per day, return to port and haul gear the following day, thereby interrupting any association seabirds may have with the vessel as a food source.

On the basis of these observations, an analysis of the extent of overlap between Procellariiform seabirds and longline fishing in Alaska's inside waters should be given the highest priority. The results of this risk analysis suggest that seabird mitigation requirements should be adjusted or eliminated wherever risk of seabird mortalities is minimal or absent.

Sink Profiles

Results from this study clearly showed that the mean distance behind the vessel at which snap-on gear sank beyond the 2-m depth range of most Alaska seabirds (28 and 38 m, for typical troller and bowpicker hanging sets, respectively) was less than half that of fixed gear (90 m; Figure 8). This difference in the 2-m access window was primarily due to the slower setting speeds of snap-on gear vessels (2 and 3.5 knots) compared with fixed gear vessels (over 4.5 knots), but it was also possibly due to the slightly higher mean sink rate of snap-on gear (0.09 m/s and 0.13 m/s, respectively) compared with fixed gear (0.07 m/s).

That the 2-m access window was on average smaller for troll vessels (28 m) than for bowpickers (38 m) is probably explained by the difference in the distance astern at which the groundline entered the water. On average, groundline from trollers entered the water at nearly half the distance (6.3 m) of gear from bowpickers (10.5 m), suggesting that bowpickers set their gear with more tension in the groundline.

If it is assumed that the troll vessels in this study typify snap-on gear vessels likely to tow streamer lines, the 20-m streamer line aerial distance now required of snap-on vessels over 55 ft LOA would protect over 70% of the area in which most Alaskan seabirds can access baited hooks (within 2 m of the surface). It is also unlikely that the streamer line will foul on the groundline if the 20-m performance standard is applied, as the groundline was on average 1 m below the surface at 20 m (Figure 8). We conclude that the current single streamer line requirement for snap-on gear vessels over 55 ft LOA (45-m streamer line and the minimum 20-m performance standard) is highly likely to be an effective seabird avoidance technology for small and large vessels using snap-on gear.

In contrast, the 2-m access window for fixed gear used on small vessels in this study (90 m) exceeded the mean for fixed (sablefish) gear set by large vessels at similar speeds (≥5 knots, 68 m) and was more in the range of that measured for large auto-bait freezer/longline vessels fishing cod in the Bering Sea (66–107 m; Figure 8). Large vessels (over 55 ft LOA) fishing groundfish (e.g., sablefish and Pacific cod) are required to deploy streamer lines in pairs and to meet performance standards based on vessel length (40 m if 55–100 ft, 60 m if ≥100 ft).

We conclude that gear type and vessel setting speed are more important than vessel length in determining risk to seabirds and that current measures (single streamer line with no mandatory material or performance standards) for this vessel category (≥26–55 ft LOA setting fixed gear and with mast, boom, and rigging) are unlikely to provide sufficient protection to seabirds, should longline fishing overlap with seabirds.

Being that time and resources were insufficient to develop an alternative in response to this unexpected result, we recommend that additional measures be developed in consultation with industry. Alternatives might include using a light, 90-m streamer line with a maximized aerial extent approaching 60 m, or using light streamer lines in pairs with adequate performance standards. Because a maximum vessel speed requirement would be difficult to enforce, we do not recommend that vessel speed be regulated as a seabird avoidance technique.

Trials contrasting the effect of vessel speed and added weight indicated that both speed and weight altered the distance astern at which birds could be vulnerable to gear, but that even small changes in speed had a greater effect than changes in weight. On vessels using snap-on gear, an increase in speed of 2 knots doubled or tripled the size of the 2-m access window, extending it from 26–40 m out to 42–70 m. Similarly, on vessels using fixed gear, increases of 1 or 2 knots doubled the 2-m access window—an increase of over 60 m.

Clearly, vessel speed has a huge effect on the exposure of seabirds to longline gear. A slow setting speed can significantly reduce the likelihood of seabird mortality; however, because a maximum vessel setting speed requirement would prove difficult to enforce and a slow setting speed could lead to tangles in the gear under some circumstances, we recommend it only as a secondary seabird avoidance requirement (or "other device," required by small vessels together with a single streamer line or buoy line when fishing outside waters [EEZ]).

Weight trials on a troller (F/V *Myriad*) demonstrated conclusively that only the heaviest weight scenarios, 4-lb weights spaced at ≤25 m, considerably reduced the size of the 2-m access window, primarily by increasing the sink rates. Though results of the single weight trial on a bowpicker (F/V *Jitterbug*) were inconsistent with those on the

F/V *Myriad*, the F/V *Myriad* trials are probably most representative of the effects of adding weight because they were repeated, involved multiple scenarios, and were consistent with earlier work (Melvin et al. 2001).

We conclude that added weight can reduce the distance behind the vessel that birds are vulnerable to gear, but that many closely spaced weights are required to significantly alter the sink profile.

Performance Standards

Streamer line trials on both trollers (F/V *Myriad* and F/V *Morgan*) showed that the 20-m aerial distance was easily achieved under all scenarios with a light streamer line and most scenarios with the 90-m heavy line at speeds typical of vessels deploying snap-on gear (2–3.5 knots). The 40-m aerial distance was achieved under few scenarios with the light line and even fewer with the heavy line.

We strongly recommend that a lighter streamer line be designed and made available to longline vessels at no cost in addition to maintaining the availability of the current streamer line design. Further, we conclude that the 45-m streamer line with a 20-m performance standard (now required of snap-on gear vessels >55 ft LOA and fishing outside waters) is practical as well as appropriate for snap-on vessels >26 ft LOA with mast, boom, and rigging and should be required in areas where seabirds may be taken by longline gear.

We note that the 90-m heavy streamer line was designed with 3/8-in blue steel poly line primarily to maximize durability and to allow for easy handling when retrieved manually and coiled either into a container or on the deck. On the F/V Myriad, the 45-m streamer line made from #48 gangion material was efficiently hauled aboard using a salmon gurdy; however, this specific material is not recommended because it is a sinking line. Any streamer line should be made with floating line to avoid fouling it in the propeller.

We found that we could avoid hanging up the streamer line on the groundline or in the propeller during the backdown to set the anchor on snap-on gear vessels in two ways. By continuing to set groundline

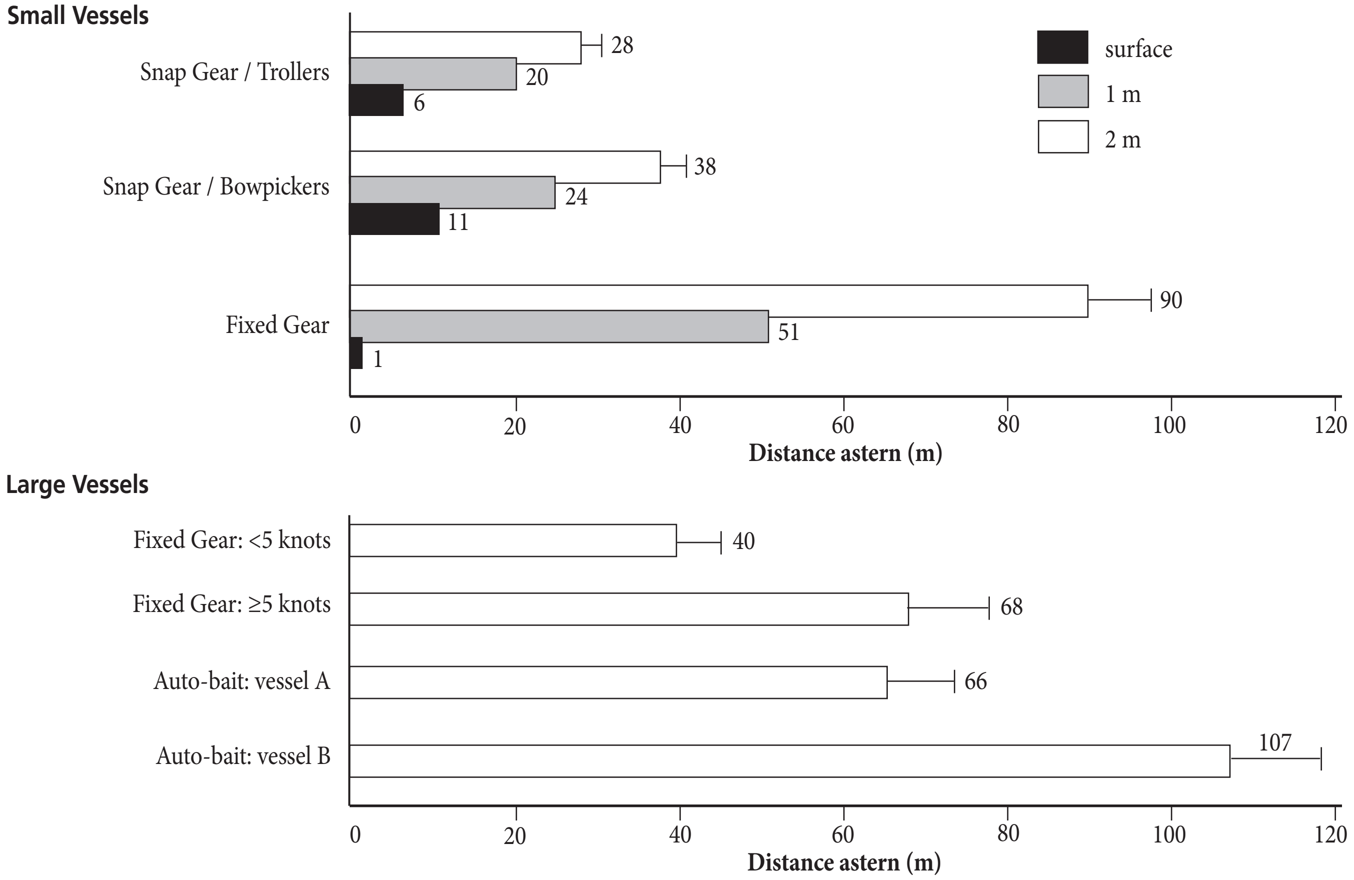

Figure 8. Comparison of the mean access windows of Alaskan longline gear for small (>26–55 ft) and large (>55 ft) vessels. Small vessels (top panel): the average distance (m) astern where the groundline entered the water, reached 1-m and 2-m depths by vessel, and gear type for typical halibut (all categories) and sablefish sets (troll only). Large vessels: the average distances astern to 2-m depth by gear type (data from Melvin et al. 2001, Figure 23 [page 30]). Error bars are 95 % CI of 2-m access window. Fixed longline gear = hook permanently attached to groundline. Snap-on gear = hooks attached and removed each set. Auto-bait = hooks permanently attached to groundline but set from racks and mechanically baited as the gear is deployed.

without hooks, we could maintain course and retrieve the streamer line prior to the backdown, eliminating potential hang-ups of the streamer line on hooks or clips on the groundline. Alternatively, we could turn the vessel greater than 10° just prior to the backdown. This maneuver removed the floating streamer line from the area near the stern, allowing us to backdown and set the anchor without potential hang-ups on either the groundline or the propeller. We note that our trials were conducted under mild weather conditions and that the practicality of the turn maneuver may be limited by weather.

Our experience with vessels <55 ft LOA using fixed gear and with a mast, boom, and rigging demonstrated that the 40-m performance standard using 90-m heavy streamer line can be achieved easily by this vessel category when setting gear at typical speeds (>4 knots). In all cases, the 40-m aerial distance now required of vessels >55 ft LOA could be achieved.

In that aerial distances of 58 and 65 m were achieved using a light streamer line (at heights at the stern of 10 and 15 ft, respectively), the 60-m aerial distance streamer line performance standard proposed above (see Sink Profiles) as one of several options for this vessel category is certainly achievable with a light streamer line. This underscores the need to design a lighter streamer line and make it available to longline vessels at no cost.

The experience with bowpickers in Cordova demonstrated that without additional innovation, towing a buoy over the gear aft of the entry point of the groundline to the water was impractical and potentially unsafe. Given that the mean 2-m access window documented for snap-on gear set from bowpickers (no infrastructure) exceeded that of snap-on gear set from trollers by 10 m, it can be assumed that bowpickers may pose the same (or more) risk to seabirds as do troll vessels (with infrastructure). This finding suggests that in areas where seabirds are likely to interact with longline gear, bowpickers should use mitigation at least as effective as that required for vessels typified by trollers.

Because bowpickers have limited range and fish primarily in inside waters where seabirds of concern are probably few or absent, and both streamer lines and buoy lines are difficult to use on these vessels, an analysis of the extent of overlap on this fleet (>26 ft–32 ft with no mast, boom, or rigging) with seabirds at risk is the highest priority. **If there is no spatial overlap between this class of small vessels and seabirds, then seabird mitigation should not be required on these vessels.**

If there is overlap, we recommend that either the buoy line be adapted so that the buoy can be positioned over the sinking groundline without fouling (as with a cone at the junction of the buoy and the line as suggested by Cordova fishermen) or other mitigation options be developed.

Bottle Lines vs. Time–Depth Recorders

This study demonstrated that both bottle lines and TDRs can be used to measure the access windows and sink rates of longlines reliably and that the two techniques generally produce comparable results. These results are similar to those of Wienecke and Robertson (2004) who found no significant difference in sink rate measurements to 2 m using bottle lines and Mk7 TDRs. The accuracy of sink profile measurements made with bottle lines was limited when applied to the faster-paced gear deployment characteristic of fixed longline gear set at vessel speeds exceeding 4.5 knots. However, accuracy issues could be mostly addressed by setting more gear and thus having more time to deploy and watch each individual bottle line, and by using a measuring line of at least 150 m. We also found that the light line we used for bottle lines occasionally fouled on the snaps as they were deployed, yielding no useful data. At times fouling rates were as high as 10–20% suggesting that several bottle lines should be deployed to yield an accurate measure of sink profiles. Meanwhile, we found that 21% of our 78 TDR records were erratic, and therefore, were discarded. In conclusion, these results suggest that 2-m bottle lines accurately estimate longline sink profiles at shallow depths, especially when observed from a remote platform trailing the vessel setting gear, and that they are a cost-effective alternative to TDRs. Unlike Wienecke and Robertson (2004), who concluded that the 0.5-m resolution limits the use of Mk7 TDRs for measuring sink rates to shallow depths, we maintain that Mk7 TDRs deployed in multiple pairs per gear deployment also accurately estimate sink rates to 2 m.

Conclusions

General

An analysis of the extent of overlap between Procellariiform seabirds and longline fishing in Alaska's inside waters should be given the highest priority. On the basis of results of this risk analysis, seabird mitigation requirements should be adjusted or eliminated wherever risk of seabird mortalities is minimal or absent.

Gear type and vessel setting speed (as opposed to vessel length) should be primary factors used to determine appropriate mitigation measures, as they best predict the risk posed to seabirds by longline fishing gear.

Reduced vessel setting speeds should be considered as an option for a secondary seabird avoidance requirement (or "other device," required by small vessels together with a single streamer line or buoy line when fishing outside waters [EEZ]). A slow setting speed can significantly reduce the likelihood of seabird mortality; however, because a maximum vessel setting speed requirement would prove difficult to enforce and a slow setting speed could lead to fouled gear, we do not recommend it as a primary mitigation measure.

We strongly recommend that a lighter streamer line be designed and made available to longline vessels at no cost in addition to maintaining availability of the current design.

The following recommendations for vessels using snap-on gear and fixed gear are based on the assumption that longline fishing occurs in locations where Procellariiform seabirds are likely to be present.

Snap-on gear

The current streamer line requirement for snap-on gear vessels over 55 ft with infrastructure (45-m streamer line and the minimum 20-m performance standard) is appropriate and practical and should be extended to all snap-on gear vessels >26 ft LOA with infrastructure.

Given that seabird avoidance measures are difficult to deploy from bowpickers (which typify vessels >26–32 ft without infrastructure), and that they pose the same or more risk to seabirds as do vessels with infrastructure using the same gear, we recommend that either the buoy line be adapted so that the buoy can be positioned over the sinking groundline without fouling on the gear, or that other mitigation options be developed.

Fixed gear

Current measures for vessels >26–55 ft setting fixed gear and with mast, poles, and rigging (single streamer line with no mandatory material or performance standards) are unlikely to provide sufficient protection to seabirds. We recommend that additional seabird avoidance measures be developed in consultation with industry. Alternatives might include using one or two lightweight, 90-m streamer lines with a maximized aerial extent approaching 60 m.

Epilogue

We established a collaborative program with the IPHC, NOAA Fisheries, and the Alaska Department of Fish and Game (ADFG) to collect seabird distribution data on the Alaska longline fishing grounds in the course of longline fish stock assessment surveys. Data from 2002 (Melvin et al. 2004b) and 2003 suggest that Procellariiform seabirds do not occur in the inside waters of Southeast Alaska and Prince William Sound. A final report of 3 years of these data will be produced in 2006. In addition, we are collaborating with IPHC and ADFG to determine the distribution of longline effort by vessel length category for inside and outside waters. Collectively, these analyses will inform managers making decisions on necessary seabird avoidance requirements by location and vessel size class.

A lighter (3/16-in diameter) streamer line was developed under the auspices of the University of Alaska Sea Grant Marine Advisory Program (ASG-MAP) and is being made available to the Alaska longline fleet together with the original streamer line design at no cost through the Pacific States Marine Fisheries Commission with funding from the USFWS. Small boat seabird avoidance development is continuing under the auspices of ASG-MAP.

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Troller: F/V *Myriad*

Bowpicker: F/V *Cape Fear*

Combination vessel: F/V *Brandi Raelyn*
Front cover, **Combination vessel:** F/V *Laurier*

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