

SEABIRD BYCATCH IN ALASKA DEMERSAL LONGLINE FISHERY TRIALS: A DEMOGRAPHIC SUMMARY

ELIZABETH M. PHILLIPS¹, HANNAHROSE M. NEVINS^{1,2}, SCOTT A. HATCH³,
ANDREW M. RAMEY³, MELISSA A. MILLER² & JAMES T. HARVEY¹

¹Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, California, 95039, USA (ephillips@mml.calstate.edu)

²California Department of Fish and Game, Marine Wildlife Veterinary Care and Research Center,
1451 Shaffer Road, Santa Cruz, California, 95060, USA

³US Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, Alaska, 99508, USA

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SUMMARY

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The seasonal and spatial demographics are summarized for seabirds killed incidentally during gear modification trials for a demersal longline fishery in the Bering Sea. We examined 417 carcasses, including Northern Fulmar *Fulmarus glacialis* (n = 205), Glaucous-winged Gull *Larus glaucescens* (n = 103), Short-tailed Shearwater *Puffinus tenuirostris* (n = 48), Glaucous Gull *Larus hyperboreus* (n = 23), Slaty-backed Gull *Larus schistisagus* (n = 4), Black-legged Kittiwake *Rissa tridactyla* (n = 1), Laysan Albatross *Diomedea immutabilis* (n = 1), and unidentified gull species *Larus* spp. (n = 32). There was a significant male bias in the sex ratio of fulmars but not of gulls or shearwaters. For the top three species killed, the age composition of resident species was dominated numerically by adults (Northern Fulmar—86%; Glaucous-winged Gull—63%), whereas migrant species were primarily immature birds (Short-tailed Shearwater—71%). The majority of migratory Short-tailed Shearwaters (88%) were caught in July and August, whereas 70% of resident fulmars and gulls were caught in October and November. Age-class frequencies did not differ by month of capture, indicating that adult mortality is substantial. Eighty percent of the fulmars caught during July and August were within 200 km of two colonies in the Bering Sea, whereas only 7% of fulmars were caught in the same area during September to November. This is one of the first demographic summaries of seabird bycatch in Alaska longline fisheries. Additional studies of the species, age and sex of seabirds subject to fisheries-related mortality will provide data necessary to evaluate population-level impacts.

Key words: demersal longline fishing, Alaska, seabird bycatch, sex bias, age composition, albatross, fulmar, gull, shearwater

INTRODUCTION

Incidental mortality of seabirds in longline fisheries is a worldwide conservation concern (Tasker *et al.* 2000). Because most seabirds are long-lived and monogamous, with delayed maturity and low annual reproductive rates, populations are vulnerable to subtle but chronic adult mortality (Melvin & Parrish 2001). Population-level recovery from significant adult mortality tends to be slow (Russell 1999), and the death of a breeding adult can affect reproductive success of the widowed mate in subsequent years, considering the costs involved in finding and successfully mating with another partner (Wooller *et al.* 1989).

Procellariiforms, as far-ranging oceanic seabirds (Shaffer *et al.* 2006), are in frequent contact with industrial fishery operations, which provide a potential food source in the form of bait or discarded offal (Brothers 1991). Once attracted to a vessel, birds can become entangled in or injured by the fishing gear and drown. Procellariiform birds account for 70% of worldwide seabird longline fishery bycatch (Brothers *et al.* 1999), and consequently many Procellariiform populations are in decline (Weimerskirch & Jouventin 1987, Croxall *et al.* 1990, Nel *et al.* 2002, Cuthbert *et al.* 2003). In addition, seabird populations are subject to other mortality factors, including predators at colony sites (Croll *et al.* 2005), oil

spills (Ford *et al.* 2001), plastic ingestion (Robards *et al.* 1995), entanglement (Moore *et al.* 2009), harmful algal blooms (Jessup *et al.* 2009), and variation in prey availability (Piatt *et al.* 2007). The impact of various mortality factors on population viability is important to measure, and an understanding of the demographic implications of fishery-related mortality on seabird populations is of significant conservation and research interest.

Researchers of longline fisheries bycatch in the Southern Hemisphere have identified age biases (a preponderance of adults) in the take of Wandering Albatrosses *Diomedea exulans* (Weimerskirch & Jouventin 1987), White-capped Albatrosses *D. cauta steadi*, Southern Buller's Albatrosses *D. b. bulleri*, and Grey Petrels *Procellaria cinerea* (Murray *et al.* 1993). Further, studies have indicated a female bias in the bycatch of Wandering Albatrosses (Weimerskirch & Jouventin 1987, Croxall & Prince 1990, Croxall *et al.* 1990) and Grey Petrels (Bartle 1990, Murray *et al.* 1993) and a male bias in the take of White-chinned Petrels *P. aequinoctialis*, Grey-headed Albatrosses *Thalassarche chrysostoma*, Yellow-nosed Albatrosses *T. chlororhynchos* and Grey Petrels (Ryan & Boix-Hinzen 1999, Nel *et al.* 2002). Possible explanations for demographic biases in various longline fisheries include species-specific differences in foraging ranges among age classes or sexes (Weimerskirch & Jouventin 1987, Bartle 1990, Croxall *et al.* 1990) and competitive exclusion of

smaller or less aggressive seabirds attending fishing vessels, resulting in dominance hierarchies (Bartle 1974, Bartle 1990, Brothers 1991, Murray *et al.* 1993, Camphuysen & Garthe 1997, Weimerskirch *et al.* 2000, Nel *et al.* 2002). Whatever the cause of these observed age and sex biases, it is clear that fisheries mortality exacerbates the demographic effects of naturally slow population growth rates (Weimerskirch *et al.* 1997, Croxall *et al.* 1998). Despite numerous studies of the demography of seabirds affected by fisheries in the Southern Hemisphere, basic demographic data is lacking for seabirds killed in Northern Hemisphere fisheries, preventing estimates of population-level impacts.

In Alaska longline fisheries, an average of 12 021 seabirds (0.050 birds/1000 hooks) were killed annually from 1993 to 2006 in the three fishing areas defined by the North Pacific Fisheries Management Council (Aleutian Islands, Bering Sea and Gulf of Alaska; Fitzgerald *et al.* 2008). Mitigation measures, especially the use of paired streamer or tori lines, have significantly reduced mortality since implementation in 2002. Despite mitigation implementation, an estimated 5 138 seabirds (0.017 birds/1000 hooks) were killed annually between 2002 and 2006 in Bering Sea fisheries, where mortality rates continue to be greatest, particularly in the winter months (Fitzgerald *et al.* 2008). The most common species killed in this fishery were resident Northern Fulmar *Fulmarus glacialis* and Glaucous-winged Gull *Larus glaucescens*, and migratory Short-tailed Shearwater *Puffinus tenuirostris* and three North Pacific albatrosses: Black-footed *Phoebastria nigripes*, Laysan *P. immutabilis*, and Short-tailed *P. albatrus* (Stehn *et al.* 2001).

Although bycatch mitigation has been directed at preventing the take of threatened seabirds, the benefits of these control measures extend to other species. For example, the use of paired streamer lines to reduce albatross bycatch has substantially reduced bycatch of other surface-foraging seabirds, including fulmars and gulls (Melvin *et al.* 2001). To assess whether a faster-sinking longline could reduce the mortality of diving birds such as shearwaters, Dietrich *et al.* (2008) tested integrated-weight and unweighted longlines with and without paired streamer lines on two vessels in the Bering Sea demersal longline fishery. Despite achieving remarkable results, the researchers reported a small number of seabirds were killed incidentally during experimental trials. Here we report the species, sex, age and body condition of seabirds collected during these gear trials, and we summarize the temporal and spatial distributions of the fulmar bycatch relative to colony areas.

STUDY AREA AND METHODS

To evaluate and develop new seabird bycatch mitigation technology, the Washington Sea Grant conducted longline fishing trials that used a variety of gear configurations in the demersal longline fishery for Pacific Cod *Gadus macrocephalus* in the Bering Sea during July–December 2005 (Dietrich *et al.* 2008). Two commercial fishing vessels each conducted four experimental fishing trips in the Bering Sea and operated similar to the rest of the fleet, including discharging offal intermittently during fishing. Fishing effort was concentrated on the Pacific Cod fishing grounds in the Bering Sea, north of False Pass (Unimak Island), including the outer continental shelf and shelf break waters from the Alaska Peninsula and eastern Aleutians to the international border with Russia. Because of NOAA confidentiality restrictions, fishing effort is not presented graphically. However, fishing effort and bycatch were relatively evenly distributed on the longline fishing grounds between July and December. Observers

from the NOAA North Pacific Groundfish Observer Program were present during trial fishing and collected all hooked seabirds that came aboard. Observers attached a label indicating date, haul number, sample number, species and collector to each carcass before freezing. Subsequently, NOAA provided information on the position of the vessels during fishing activities when seabirds were caught. Of 443 birds killed, 417 carcasses were sufficiently intact (i.e., not scavenged by amphipods) for thorough examination.

Standardized necropsies were conducted at the California Department of Fish and Game Marine Wildlife Veterinary Care and Research Center (MWVCRC) in Santa Cruz, California, in 2006. We confirmed species identification; morphometric measurements, sex, age and body condition were recorded using published methods (van Franeker 2004).

To determine the sex and approximate age of examined seabirds, the gonad length and width was determined for both sexes, and, in females, the diameter of the largest ovarian follicle (DLF) and description of the oviduct were recorded following van Franeker (2004). In addition, the bursa of Fabricius was recorded as large and easily visible (i.e., hatch-year or immature) or not visible (i.e., after hatch-year or adult). The bursal length and width were recorded for immature birds following the techniques of Broughton (1994). Combining data from gonad and bursal examinations yielded standardized criteria for ageing seabirds. Juvenile (hatch-year) females had a prominent bursa, a small ovary, a skinny and straight oviduct and small ovarian follicles (DLF < 1.0 mm); immature females had a visible or prominent bursa, a small ovary, a visible oviduct and moderate ovarian follicles (DLF ≤ 1.5 mm); subadult females had no visible bursa, a larger ovary, an enlarged oviduct and larger ovarian follicles (DLF < 2.0 mm); and adult females had no visible bursa, a large ovary, a prominent, convoluted oviduct and prominent ovarian follicles (DLF ≥ 2.0 mm). All juvenile, immature and subadult females were categorized as immature for comparisons to adult age classes. Male seabirds were considered immature (juvenile or subadult) if they had a prominent or visible bursa and small testes (< 30 mm²), and adult if they had no visible bursa and medium to large testes (> 30 mm²). Birds with missing gonads or bursa (due to scavenging) were considered unknown age class. Plumage characteristics were used to assist in separation of gulls as immature (from hatch year to third year) and adult (≥ fourth year), and molt of the primary feathers was used to modify age characterization of fulmars, shearwaters and albatrosses. We also recorded the presence or absence of a brood patch to determine breeding status.

The total number of birds taken for each month of fishing effort was tabulated and examined for deviations from a 1:1 sex ratio for each month in which the sample size exceeded 20 birds. Age classes of gulls and shearwaters taken in each month were compared with the overall sample. The age-class ratios of fulmars taken each month were compared with published age-class ratios for colonies in Alaska (Hatch 1987). Sex and age differences were evaluated with *t*-tests and χ^2 goodness-of-fit tests that incorporated Yates' continuity correction (Zar 1999). No attempt was made to compare gear type with demographic data because the majority (87%) of birds were killed in experimental sets without gear modifications (unweighted longline, no paired streamers; Dietrich *et al.* 2008).

Following Dietrich (2003), a 200 km colony radius was defined to assess spatial associations of bycatch composition with fulmar colonies in the Bering Sea and Aleutian Islands closest to where

fishing effort involved bycatch. Because albatrosses and shearwaters do not breed in Alaska, and gulls captured in this study breed at numerous small islands throughout the region, the spatial analysis was conducted only for fulmars, a species for which source colonies are localized, large, discrete and well characterized. The sex and age of fulmars caught within and outside of a 200 km radius of these colonies were summarized and compared by month of capture.

Fulmars from the four major colony areas in Alaska are predominantly (> 99%) lighter morphs in the north (Bering Sea) and darker morphs (75–100%) in the south (Gulf of Alaska, Aleutian Islands; Hatch & Nettleship 1998). We assigned each fulmar specimen to one of four color morphs: light (L), double light (LL), dark (D) and double dark (DD), following Hatch & Nettleship (1998). When it was impossible to discriminate between L and LL color or D and DD color morphs due to heavy scavenging or waterlogging from prolonged immersion, we recorded the plumage as either generally light or dark after van Franeker (2004). We then compared the calculated ratio of light to dark morph fulmars with proportions reported by Hatch & Nettleship (1998) as an indicator of potential colonies of origin.

Because body mass is an inaccurate measure of body condition in drowned, waterlogged birds, we quantified body condition with a subjective scoring system that was not based on mass (van Franeker 2004). Following van Franeker's (2004) protocol, we scored subcutaneous fat as 0 (no fat); 1 (some fat); 2 (moderate fat); or 3 (very fat). When subcutaneous fat was present, we measured its depth in millimeters over the mid-breast muscle approximately 1 cm to the right of the keel. We scored the condition of the breast muscle (*Pectoralis-supracoracoideus* complex) as 0 (strongly emaciated; pectoral muscle mass is markedly concave and outer surface is well below keel height); 1 (emaciated; pectoral muscle mass is mild to moderately concave and outer surface is moderately below keel height); 2 (moderate condition; pectoral muscle mass is mildly convex and outer surface is slightly below keel height); or 3 (good condition; pectoral muscle mass is convex and outer surface is at or above keel height). Fat depth, fat score and muscle score were compared among species with Kruskal–Wallis one-way analysis of variance (ANOVA) on ranks and Dunn's pairwise multiple comparisons (Zar 1999).

RESULTS

We identified seven seabird species (Table 1). Procellariids (61%) and larids (39%) predominated, and nearly 80% of the birds examined consisted of three species: Northern Fulmar, Glaucous-winged Gull and Short-tailed Shearwater. Thirty-two birds (8%) were not identifiable except as gull species owing to scavenging or injury.

Most seabird species had no significant deviation from a predicted 1:1 sex ratio, with the exception of Northern Fulmars, which had a significant male bias (3.0 males:1.0 females; $\chi^2_{192} = 47.8$; $P < 0.001$; Table 1). Seventy-five percent of all procellariids were adults, 21% were immature and 4% were of unknown age. Overall, 54% of larids examined were adults, 33% were immature and 13% were of unknown age. Interspecific variation was evident: 85% of the Northern Fulmars were adults, whereas only 29% of the Short-tailed Shearwaters were adults. Most of the Glaucous-winged Gulls (63%) were adults, compared with only 4% of the Glaucous Gulls. No well-developed (vascularized) brood patches were identified in any species.

Species composition varied with season (Fig. 1). Most (88%) of the migratory seabirds (Short-tailed Shearwaters) were caught in July and August, whereas 70% of the resident seabirds were caught during the post-breeding period in October and November, including 82% of gulls and 75% of the Northern Fulmars.

Age distributions of shearwaters and gulls did not differ significantly from the sample mean values in any single month (*t*-tests; $P > 0.05$), indicating a relatively consistent age composition throughout the study period. Similarly, an average of 91% of fulmars taken each month from July to December were adults, which was not significantly different from the age ratio reported from colonies (83% adults; $\chi^2_{194} = 0.94$ $P = 0.39$; Hatch 1987).

The spatial distribution of fulmar bycatch varied temporally. During July and August, 80% of fulmars ($n = 17$) were caught within 200 km of two source colonies in the Bering Sea, and 58% were adult females. In contrast, from September through November, when the majority ($n = 179$) of fulmars were taken, only 7% were caught inside the 200 km colony radius, and 73% were adult males.

TABLE 1

Proportion of adult and male seabirds caught during experimental demersal longline fishery gear-modification trials in Alaska, 2005^a

Species	Age		Sex		Sex ratio	
	% Adult	n	% Male	n	M:F	<i>P</i> ^b
Northern Fulmar	90.2	195	75.1	193	3.0:1.0	< 0.001
Glaucous-winged Gull	79.3	82	48.5	103	0.9:1.0	NS
Short-tailed Shearwater	29.2	48	56.3	48	1.3:1.0	NS
Gull species	53.1	32	29.0	31	0.4:1.0	NS
Glaucous Gull	4.4	23	47.6	21	0.9:1.0	NS
Slaty-backed Gull	100	4	25.0	4	0.3:1.0	-
Black-legged Kittiwake	100	1	0	1	0.0:1.0	-
Laysan Albatross	100	1	0	1	0.0:1.0	-

^a Birds of undetermined age and/or sex excluded from analyses.

^b *P*-value indicates probability that the sex ratio differs from an equal 1:1 male:female ratio.

The majority of fulmars caught (66%) were classified as light (L) or double light (LL) color morphs. This color morph ratio is consistent with a predominant influx of birds from the northern (Bering Sea) colonies to forage in fished areas. However, the proportion of light morph birds varied from 43% in July to 100% in December, suggesting changes in monthly distribution patterns.

Most seabirds examined were in moderate (70%) or good (17%) body condition. Approximately 13% of birds appeared thin or emaciated. There were no detectable differences in pectoral muscle scores among the three most frequently caught species (mean = 2.0 ± 1.0 [standard deviation]; $H_2 = 0.620$, $P = 0.734$; Table 2). Northern Fulmars, however, had significantly higher fat scores than Short-tailed Shearwaters ($H_2 = 14.8$; $P < 0.001$) and greater fat depths than both Glaucous-winged Gulls and Short-tailed Shearwaters ($H_2 = 21.3$; $P < 0.001$).

DISCUSSION

A significant male sex bias was confirmed for fulmars taken during the experimental trials in the Bering Sea demersal longline fishery, similar to findings of male bias in bycatch of petrels and albatrosses in the Southern Hemisphere (Ryan & Boix-Hinzen 1999, Nel *et al.* 2002). We found that nearly two thirds of all seabirds caught in experimental trials were adults. Our study includes one of the first demographic summaries of larids affected by longline fisheries and indicates that slightly more than half of gulls killed were adults, with some variation among species.

Sustained sex- and age-biased mortality in the Bering Sea demersal longline fishery could have long-term impacts on Alaskan seabird populations. Procellariid pairs breed together for several years before attaining maximal productivity (Wooller *et al.* 1989), and therefore a large reduction in adult males could impair breeding success for years (Hatch 1987). Studies of seabird movements during breeding and post-breeding will help determine whether adult male fulmars are subject to higher mortality away from the colony, or during the post-breeding season, as we document in this study. Although bycatch rates during the breeding season were low, 58% of fulmars caught near the colony in July and August

were adult females, suggesting sex-related variation in foraging location. Other possible explanations include increased chick provisioning rates by females, or increased overall foraging rates by females during July and August. However, in small samples of satellite-tagged fulmars, Hatch *et al.* (2010) detected no sex-related differences in fulmar movements during the same part of the year. Continued investigation of foraging differences between sexes and of the potential exposure to increased fisheries mortality in certain areas or seasons is recommended.

The adult bias we observed in resident gulls and fulmars merits further attention, as mortality of this age class will directly affect population viability (Russell 1999, Melvin & Parrish 2001). Natural mortality of Northern Fulmars at the Semidi Islands is approximately 3%/yr (Hatch 1987); hence, a 2% annual fisheries-

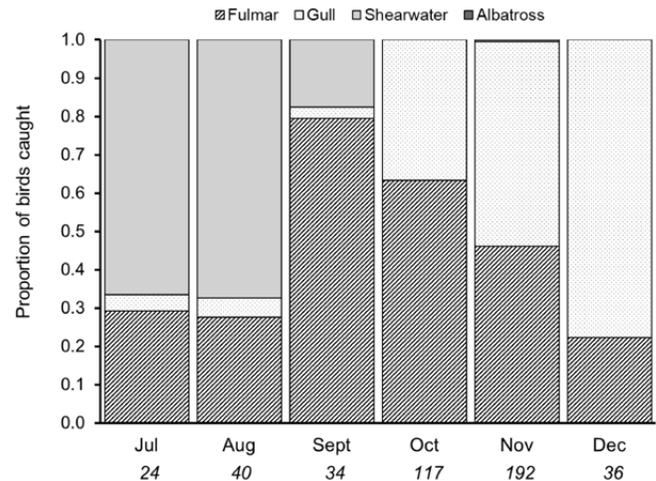


Fig. 1. Proportion of migratory and resident seabird species killed in Alaska demersal longline fishing trials, July–December 2005. Patterned shading indicates resident species (all gulls and Northern Fulmar); solid shading represents migratory species, including Short-tailed Shearwaters and Laysan Albatross (one individual in November). Sample sizes (collected birds positively identified to species and/or group per month) are shown below the x-axis.

TABLE 2

Body-condition indices of seabirds caught during experimental demersal longline fishery gear-modification trials in Alaska, 2005

Species	n	Fat score, 0–3 ^a		Fat depth, mm		Muscle score, 0–3 ^b	
		Mean	SD	Mean	SD	Mean	SD
Northern Fulmar	198	2.5	0.9	3.9	2.1	2.1	0.6
Glaucous-winged Gull	103	2.4	0.9	3.0	1.8	2.0	0.5
Gull species	32	2.3	0.9	2.8	1.5	2.0	0.3
Short-tailed Shearwater	23	1.7	1.1	2.5	2.4	2.0	0.4
Glaucous Gull	23	1.9	1.0	2.2	1.5	1.7	0.6
Slaty-backed Gull	4	1.7	1.2	1.7	1.2	2.0	0.0
Black-legged Kittiwake	1	0.0	-	0.0	-	2.0	-
Laysan Albatross	1	3.0	-	8.0	-	3.0	-

^a Subcutaneous fat: 0 (no fat); 1 (some fat); 2 (moderate fat); 3 (very fat); following van Franeker (2004).

^b *Pectoralis-supracoracoideus* muscle complex: 0 (strongly emaciated); 1 (emaciated); 2 (moderate condition); 3 (good condition); following van Franeker (2004).

related mortality rate that was additive would likely result in population declines (Hatch *et al.* 2010). Recent estimates of gull population sizes in Alaska are variable, but there is evidence that some species may be in decline (Denlinger 2006). Demographic studies of the impacts of fisheries bycatch on adult seabirds may help direct future mitigation and compensation (*sensu* Wilcox & Donlan 2007).

Mortality from industrial fishing operations has caused serious declines in many populations of Procellariiforms (Weimerskirch & Jouventin 1987, Croxall *et al.* 1990, Nel *et al.* 2002, Cuthbert *et al.* 2003). In this study, 61% of the birds killed were Procellariiforms, although only one was from a seabird population that is considered vulnerable (Laysan Albatross, US Fish and Wildlife Service 2008). Northern Fulmar and Short-tailed Shearwater populations are considered healthy, and world population estimates of each range into the millions (Marchant & Higgins 1990, Hatch & Nettleship 1998). Nonetheless, continued fishery-related mortality may affect the long-term stability of these populations. Short-tailed Shearwaters are harvested off Tasmania, Australia, where an estimated 220 000 young birds were taken in 1994 (Warham 1996), and harvesting has exceeded the maximum sustained yield in the past (Skira *et al.* 1986). Also, North Pacific driftnet fisheries killed approximately 100 000 shearwaters/yr between 1978 and 1992 (DeGange *et al.* 1993), and a total of 4.6–21.2 million birds between 1952 and 2001 (Uhlmann *et al.* 2005). Short-tailed Shearwaters breed only in Australia, and populations are estimated to be ~23 million breeding birds (Skira *et al.* 1996). In our sample, a high proportion of immature Short-tailed Shearwaters were killed, an age class that may not play an important role in current population viability, but could affect future reproductive success. For example, Meathrel & Carey (2007) concluded that at-sea survival was a more important factor to recruitment success of Short-tailed Shearwaters than factors at breeding colonies. The catch of mostly immature shearwaters could also indicate differences in the at-sea distribution between juveniles and adults. The effects of incidental fishery bycatch, in addition to directed harvest, should be taken into account when managing this far-ranging species.

Efforts should be made to identify the source colonies of birds killed in Alaska longline fisheries and to count the total numbers of birds killed. Judging from the known proportions of fulmar color morphs at various breeding colonies, we estimate that nearly 66% of fulmars killed probably originated from Bering Sea colonies, which are predominately light-morph, and include St. Matthew and Hall Island (~250 000 birds; Hatch *et al.* 2010) and the Pribilof Islands (~80 000 birds; Hatch & Nettleship 1998). The proportion of dark-morph fulmars in this study was greater than reported in Bering Sea colonies, and varied monthly, suggesting that one-third to one-half of fulmars killed in this fishery originated from more distant colonies, most likely Chagulak Island in the Aleutian Islands and possibly the Semidi Islands in the Gulf of Alaska. These colonies are exceptionally large (>500 000 birds and ~440 000 birds, respectively) and consist of 85% to 99% dark-morph birds. Although we cannot definitively say which colonies are affected based on assessment of color morph, our data suggest that fishery-related mortality in the Bering Sea demersal longline cod fishery may be an issue primarily for fulmar colonies in the eastern Bering Sea. For example, Hatch *et al.* (2010) found that a high proportion of birds from the Pribilof Islands foraged in the major longline fishing area of the eastern Bering Sea.

Although the greatest proportion of bycatch occurred during October and November, when juvenile gulls and fulmars would have recently entered the population, we found no significant change in the ratio of adults to immature birds between breeding and post-breeding seasons. The percentage of adult fulmars remained approximately 91% throughout all months of the study, indicating that juveniles and immatures are no more susceptible to demersal longline bycatch than adults, and that adult mortality is substantial. Similarly, over 87% of seabirds examined were in good nutritional condition, indicating that most seabirds killed in longline fisheries are experienced foragers.

Many of the species killed in this study are regular visitors to fishing vessels, and the observed increase in bycatch rates post-breeding may be related to changes in other local fisheries. For example, Dietrich (2003) found that bycatch rates of fulmars and gulls in the Bering Sea cod longline fishery were lower when the pollock trawl fishery was also open, suggesting discards from that fishery may attract birds that might otherwise follow longliners. The timing of closure of the pollock trawl fishery coincides with an observed increase in longline bycatch, and fishermen report that gulls following longline fishing vessels in October and November are “extremely competitive” in their attempts to consume bait and discards (E. Melvin, pers. comm.). Whether factors such as changes in local fishery closures, increased intraspecific competition between age classes, variation in natural prey, or other causes are affecting bycatch rates remains to be determined.

To assess more fully the importance of longline fisheries mortality, we recommend studies to project population growth (Lewison & Crowder 2003) using available demographic data from colonies and fisheries bycatch, including this study, and telemetry studies to address colony-, age- and sex-specific movements of gulls, shearwaters and fulmars throughout the North Pacific and in the Bering Sea (e.g., Hyrenbach & Dotson 2003, Shaffer *et al.* 2006, Suryan *et al.* 2007, Hatch *et al.* 2010). Seabirds from robust populations could provide a proxy for threatened sympatric species, and information obtained from population modeling and telemetry could greatly increase our knowledge of possible conflicts with fisheries.

Resident Alaska seabirds probably interact with longline vessels throughout the year because these fisheries operate year-round (Fitzgerald *et al.* 2008). In contrast, migratory shearwaters may be at less risk of incidental mortality in Alaska longline fisheries because their abundance peaks when fishing effort is lowest. However, migratory seabirds encounter a broad range of fisheries using different gear types along their migratory routes (Uhlmann 2003). Most seabird populations are subject to a combination of mortality factors that are difficult to measure and predict, both at the colony and at sea. We assume the catches in this test fishery study are representative of the entire longline fleet. However, continued studies of the species, sex and age of seabirds killed in the Bering Sea demersal longline fishery and other Alaska fisheries would greatly increase our knowledge of impacts and provide important data to inform population growth models and estimate population-level effects.

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