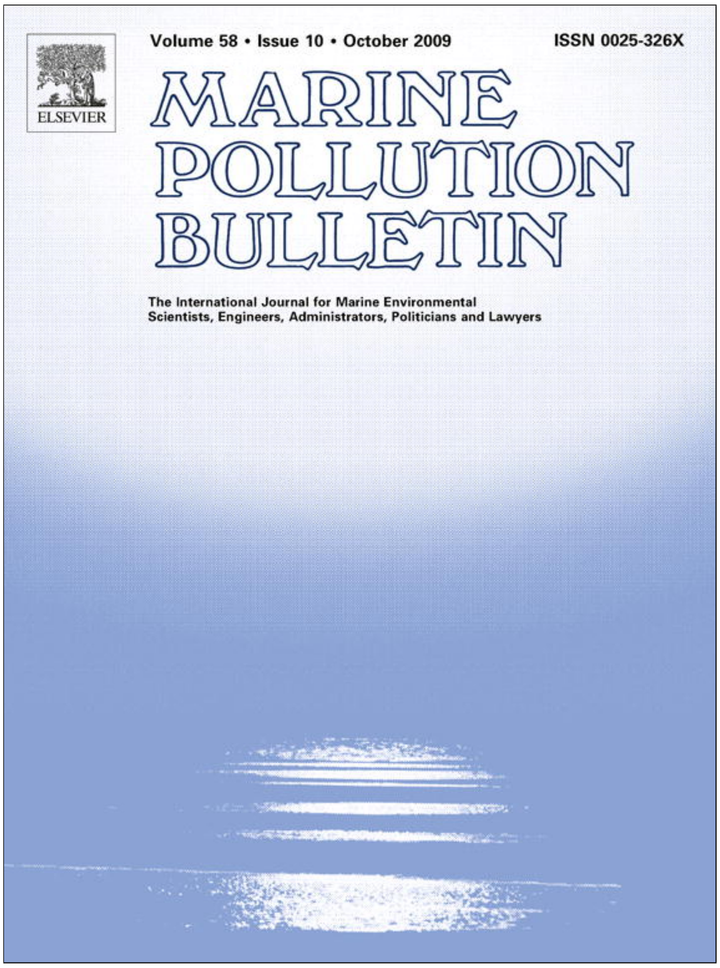
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Entanglement of Steller sea lions (*Eumetopias jubatus*) in marine debris: Identifying causes and finding solutions

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ABSTRACT

Entanglement in marine debris is a contributing factor in Steller sea lion (SSL; *Eumetopias jubatus*) injury and mortality. We quantified SSL entanglement by debris type, sex and age class, entanglement incidence, and estimated population level effects. Surveys of SSL haul-outs were conducted from 2000–2007 in Southeast Alaska and northern British Columbia. We recorded 386 individuals of all age classes as being either entangled in marine debris or having ingested fishing gear. Packing bands were the most common neck entangling material (54%), followed by rubber bands (30%), net (7%), rope (7%), and monofilament line (2%). Ingested fishing gear included salmon fishery flashers (lures: 80%), longline gear (12%), hook and line (4%), spinners/spoons (2%), and bait hooks (2%). Entanglement incidence was 0.26% (SD = 0.0064, n = 69 sites). "Lose the Loop!" Simple procedures such as cutting entangling loops of synthetic material and eliminating the use of packing bands can prevent entanglements.

1. Introduction

Marine debris is a global concern impacting many species in the world's oceans including marine mammals. At least 135 marine species, including a significant percentage of the world's marine mammal, sea turtle, and seabird species, become entangled in marine debris (Laist, 1997). The types of marine debris most commonly associated with entanglement are plastic packing bands, fishing nets, monofilament line, rope, lost crab traps, and fish pots (Laist, 1997). Over the past 40 years, plastic has replaced natural fibers in the fishing industry due to its light weight, low production cost and physical and biological durability (Henderson, 2001). Unfortunately, this durability is at the cost of many species of marine life. Increasing concern over plastics in the ocean led to the introduction of Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) which prohibits the at-sea disposal of plastic wastes. Annex V was formally adopted in 1988 and has been ratified by more than 70 nations. However, illegal dumping of plastics is difficult to enforce and continues to be a threat to marine life.

Because many marine species are either rarely observed or die at sea as a result of their entanglement, accurately estimating entanglement rate or incidence is difficult and likely underrepresented. Previous studies of pinnipeds indicate that the probability of sighting entangled animals on land is reduced by their increased time spent at sea and lower survival rates caused by their entanglement (Fowler, 1987; Page et al., 2004). Entangling debris may cause drowning, lacerations, infection, strangulation, increased energy expenditure (especially while dragging large fragments of net), and mortality. Moreover, marine debris can be a "silent" killer, where ingested hooks or plastic may perforate the esophagus or stomach lining leading to catastrophic infection, organ damage, reduce feeding, and cause starvation; all with no apparent external signs of entanglement.

Entanglement of pinnipeds in marine debris is common worldwide. Laist (1997) reported that 79% of otariid species and 42% of phocid species have been entangled. Reports of entangled pinnipeds include the Antarctic fur seal *Arctocephalus gazelle* (Croxall et al., 1990; Arnould and Croxall, 1995; Hofmeyr et al., 2006), Cape fur seal *Arctocephalus pusillus* (Shaughnessy, 1980; Shaughnessy and Payne, 1979), Australian sea lion *Neophoca cinerea* (Page et al., 2004), New Zealand fur seal *Arctocephalus forsteri* (Page et al., 2004; Boren et al., 2006), Hawaiian monk seal *Monachus schauinslandi* (Donohue et al., 2001; Henderson, 2001), California sea lion *Zalophus californianus* (Harcourt et al., 1994; Hanni and Pyle, 2000), northern fur seal *Callorhinus ursinus* (Fowler, 1987), and Southern elephant seal *Mirounga leonina* (Campagna et al., 2007). Entanglement rates of otariids vary from 0.1% to 7.9% of the populations surveyed (Fowler, 1987; Stewart and Yochem, 1987; Pemberton et al., 1992; Harcourt et al., 1994; Arnould and Croxall, 1995; Page et al., 2004; Hofmeyr et al., 2006).

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Over the past 30 years, Steller sea lions (SSL; *Eumetopias jubatus*) have declined by over 80% resulting in their threatened status in the eastern and endangered status in the western portion of their range (Loughlin et al., 1992; Trites and Larkin, 1996; Sease et al., 2001). While causes of the decline are unknown, entanglement in fishing gear and marine debris is known to contribute to Steller sea lion mortality (Perez, 2006; Angliss and Outlaw, 2007). However, the extent that entanglement related mortality contributed to the decline is unknown. Given the immense expanse of Alaskan waters, we propose that the small numbers of entangled SSLs reported in the current literature is not because SSLs are avoiding entanglement, but rather, because there is little effort to document entanglements and some animals die at sea and, therefore, go unobserved. The primary goal of this study is to provide baseline data on marine debris entanglements affecting SSLs. Objectives in this study were to (1) determine sources of marine debris entangling or ingested by SSLs; (2) estimate SSL entanglement incidence; (3) estimate the sex and age class of entangled animals by entanglement or ingestion type; (4) estimate population level effects of entanglements.

2. Methods

2.1. Study sites

Steller sea lion entanglement data were collected incidentally during other SSL studies at haul-outs and rookeries ($n = 78$ sites; hereafter referred to as haul-outs) throughout Southeast Alaska and northern British Columbia (Fig. 1) from 2000 to 2007.

2.2. Data collection and analyses

Haul-outs were surveyed by boat (~7 m) or shore to count, resight permanently marked (branded) SSLs, and document entangled animals. Search effort for entangled SSLs increased after 2000 when it became apparent that entanglements were not a rare event. Sites were approached by boat at a slow speed and initially surveyed from a distance of >100 meters to allow sea lions to become accustomed to the boat. Observers used binoculars (8× to 14×) from boat and shore to conduct counts and observe animals. When possible, entangled sea lions were photographed (Nikon D1 series digital camera). When an entangled animal was observed we recorded: type of entanglement (e.g., neck entanglement, hook and/or ingested fishing gear), description of entangling material (e.g., white plastic packing band, black rubber band, salmon flasher (lure)), age class (adult, subadult, juvenile), sex (if able to determine), and behavior (e.g., nursing pup, etc.). Adult females were classified as age $\geqslant$4 y, adult males as $\geqslant$9 y, subadult males as 4–8 y, juveniles as 0 y to <4 y. When possible, we compared known-aged (tagged or branded) animals to an entangled animal to help us estimate age of the entangled animal. Additional data included: date, location, observers, photographer, start and end times, and weather.

Using natural marks or brands and entanglement materials, we were able to resight some individuals over months or years to track the retention or loss of entangling debris or ingested fishing gear. Only the initial sightings of individuals were used in population-wide analyses. Animals with scars, but no observable entangling debris remaining, were not included in analyses. A Chi-square goodness of fit test (Zar, 1984) was used to determine if male and female SSLs were equally entangled or had equally ingested salmon flashers.

We collected entanglement data throughout the year, and received opportunistic reports of entangled animals from other agencies, organizations, tour boat operators, and the public. However, to estimate entanglement incidence, we used only dedicated summer (1 June–31 August 2001–2007) surveys in which most sites in Southeast Alaska and northern British Columbia were visited (effort was minimal in 2000 and was not included). To determine entanglement incidence, we first divided the total number of

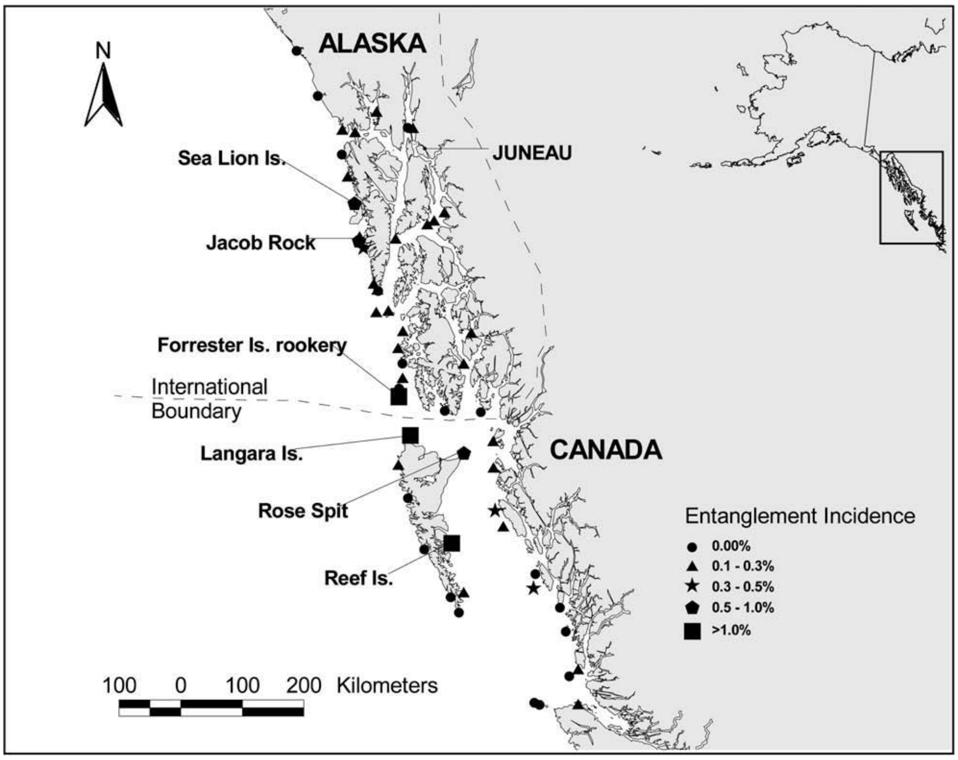

Fig. 1. Map of Southeast Alaska and northern British Columbia indicating entanglement incidence by haul-out or rookery surveyed during 1 June–31 August, 2001–2007.

entangled SSLs counted on a haul-out by the total number of SSLs counted on that haul-out. We then calculated a mean of means for each haul-out site then a grand mean for all sites. An Analysis of Variance (ANOVA) was used to determine if there were significant differences between years or sites. Only sites visited three or more times during the study were included in the ANOVA.

To determine population level effects of entanglements, we used previously published mathematical models to estimate population size based on pup counts (see Calkins and Pitcher, 1982; Trites and Larkin, 1996; Pitcher et al., 2007). This method uses the total pup count in a given year × 0.10 (to account for pups missed during surveys). Using life tables, Calkins and Pitcher (1982) estimated the ratio of total animals to pups in a stationary population would be about 4.5:1. Sensitivity analyses (Pitcher et al., 2007) indicated that for a population increasing at 3.1%, the ratio could be as low as 4.2:1 if the increase was due to elevated fecundity, or as high as 5.2:1 if the increase was due to reduced juvenile mortality. Therefore, our Southeast Alaska entanglement incidence was multiplied by the low and high range of the estimated population size in Southeast Alaska (excluding British Columbia) for a given year to estimate the number of SSLs entangled at one point in time.

Entanglement data were collected at Lowrie Island (Forrester Island rookery complex) during daily shore-based SSL field studies from May–September, 2001–2007. Because this rookery is comprised primarily of adult females and their offspring, entanglement data by age class and sex were analyzed separately from boat-based surveys.

3. Results

3.1. Entanglement type

From 2000 to 2007 in Southeast Alaska and northern British Columbia (including all boat and land-based surveys as well as opportunistic observations provided by others), we recorded 386 individuals as being either entangled in marine debris or having ingested fishing gear (Table 1). We documented 49% ($n = 190$) of SSLs with entangling debris around their necks (e.g., Fig. 2a and b), while 50% ($n = 194$) had interacted with sport or commercial

Table 1
Types of marine debris observed entangling and/or ingested by Steller sea lions in Southeast Alaska and northern British Columbia from 2000–2007.

Debris	2000	2001	2002	2003	2004	2005	2006	2007	Total No.	%
Packing band	1	2	1	4	6	2	4	4	24	6
Rubber band	1	1	0	0	3	5	2	1	13	3
Net	1	0	1	0	0	0	0	0	2	1
Rope	1	0	0	0	0	1	0	1	3	1
Monofilament	0	1	0	0	0	0	0	0	1	0
Flasher (lure)	3	11	21	13	16	42	31	19	156	40
Longline gangion	1	3	5	0	5	4	6	0	24	6
Line	0	1	1	0	0	3	1	1	7	2
Spinner/spoon	0	0	1	0	1	1	0	1	4	1
Bait hook	0	0	0	0	0	0	1	2	3	1
Unknown neck entanglement	2	7	11	22	27	39	23	14	145	37
Other	0	0	0	1	3	0	0	0	4	1
Total (%)	10 (3)	26 (7)	41 (11)	40 (10)	61 (16)	97 (25)	68 (18)	43 (11)	386	

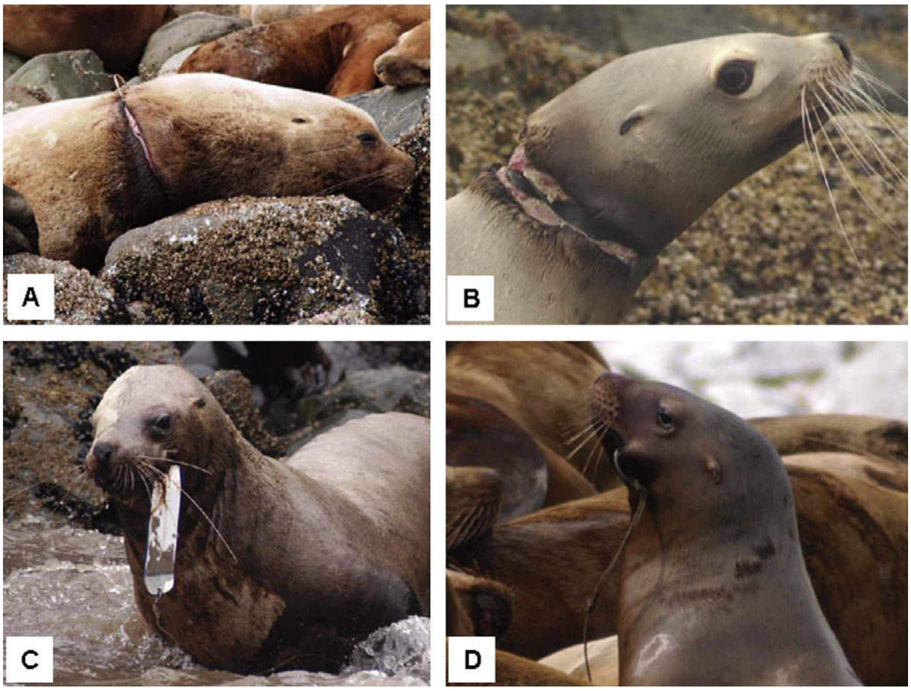

Fig. 2. Most common observed Steller sea lion neck entanglements included (A) packing bands, and (B) rubber bands; and most common ingested fishing gear included (C) salmon fishery flashers, and (D) longline gear, in Southeast Alaska and northern British Columbia from 2000 to 2007.

fisheries and had ingested fishing gear (e.g., Fig. 2c and d). One percent ($n = 2$) had monofilament line wrapped around either the chest or head-mounted satellite transmitter. Although we observed 190 individuals with neck entanglements, we were unable to identify the entangling material on most (77%) animals because the material was too deeply embedded in the neck. Of the 44 identifiable neck entanglements, packing bands were the most common neck entangling material (54%), followed by rubber bands (30%), net (7%), rope (7%), and monofilament line (2%) (Fig. 3a). Of the 194 individuals who had ingested gear or been hooked in the mouth/head/body, we observed primarily salmon fishery flashers (usually at the edge of an animal's mouth, presumably with an ingested hook that is not visible; 80%), longline hook and gangion (12%), line/monofilament hook and line (4%), spinners/spoons (2%), and bait hooks (2%) (Fig. 3b).

3.2. Entanglement incidence

Entanglement incidence, calculated using standardized surveys conducted from June through August, 2001–2007 in Southeast Alaska and northern British Columbia, was 0.26% (SD = 0.0064, $n = 69$ sites). There was no significant difference in entanglement incidence among years ($F_{6,\ 320} = 0.940$, $p = 0.466$), but there was a significant difference among sites ($F_{48,\ 320} = 7.735$, $p < 0.001$) (Fig. 1).

3.3. Age/sex

Of the 325 unique individuals observed during boat-based surveys from 2000–2007 (Lowrie Island shore-based field-camp data excluded), juveniles were the most frequently entangled age class (28%), followed by adult females (24%), adult males (19%) and subadult males (17%) (Fig. 4a). There were significantly ($\chi^2_1 = 9.8$, $p = 0.002$) more males (subadult + adult) than females that had ingested salmon fishery flashers although no significant ($\chi^2_1 = .229$, $p = 0.632$) differences were observed between males and females with neck entanglements overall. Eighty-five percent of documented longline gear ingestion involved juveniles (Fig. 4b). Unfortunately, since it is nearly impossible to distinguish between male and female juveniles without a view of the ventral surface of the

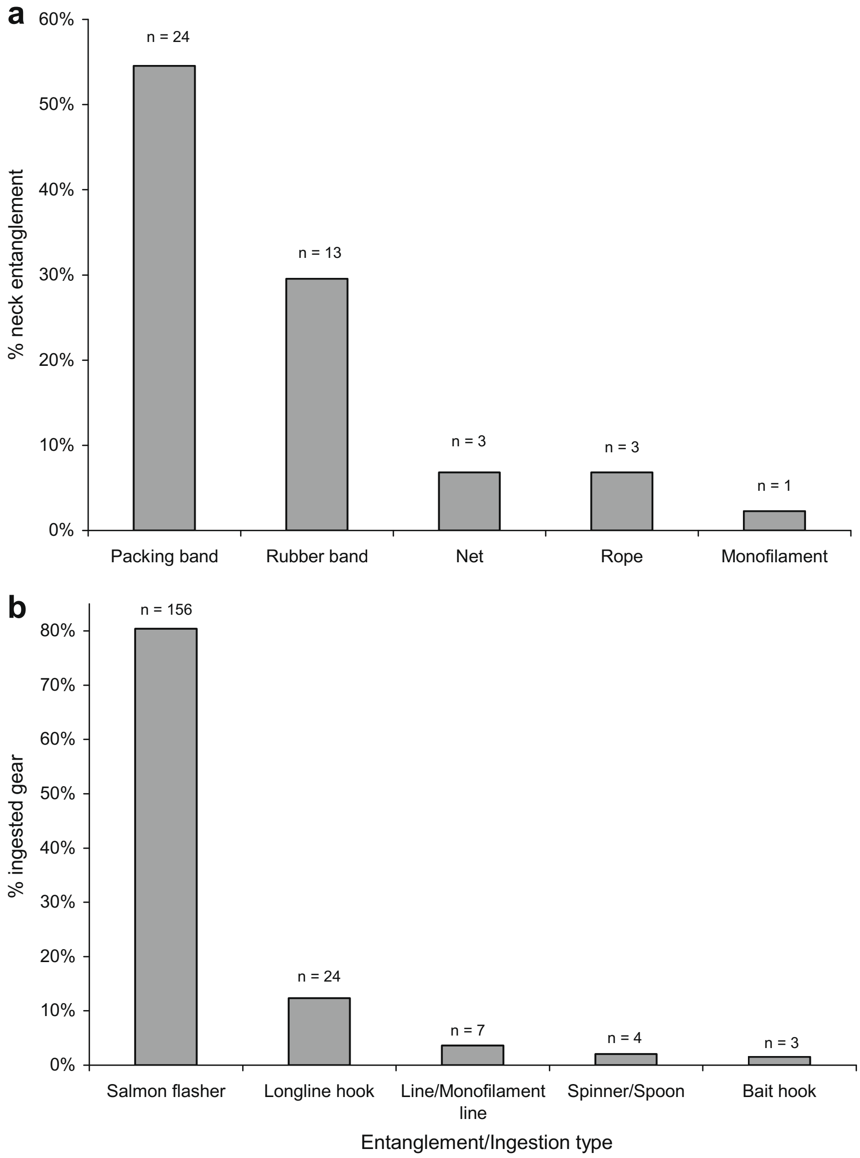

Fig. 3. Percentage of identifiable ($n = 44$) Steller sea lion neck entanglements ($n = 190$); (a) and ingested fishing gear ($n = 194$); (b) observed by entanglement/ingestion type during surveys in Southeast Alaska and northern British Columbia from 2000–2007. Most (77%) of the neck entanglements were too deeply embedded in the necks of the sea lions to determine entanglement material.

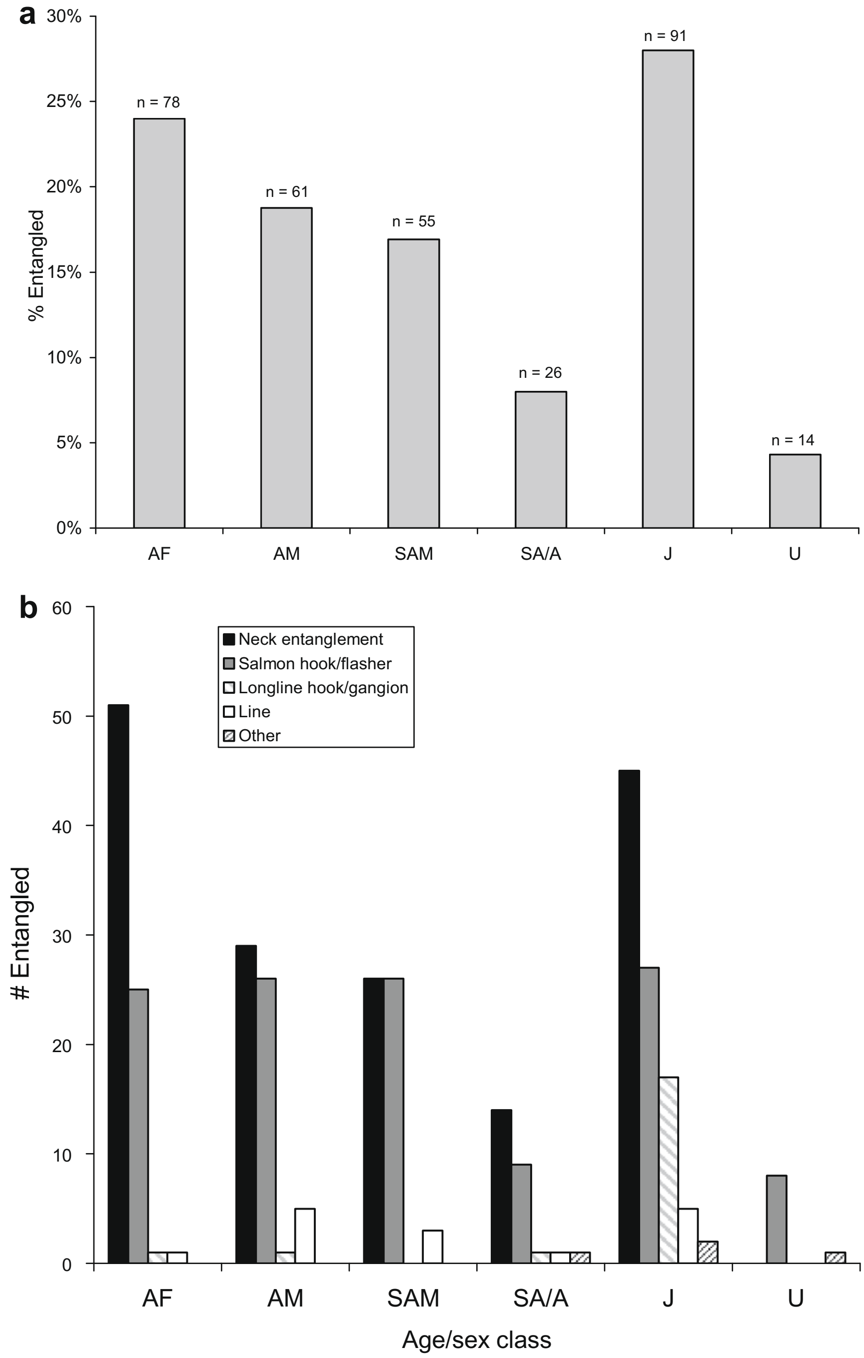

Fig. 4. Percentage of Steller sea lions entangled (neck entanglements and ingested fishing gear) (a) and number of Steller sea lions by entanglement type (b) by age and sex class (AF = adult female, AM = adult male, SAM = subadult male, SA/A = subadult/adult, J = juvenile, U = unknown) observed during surveys in Southeast Alaska and northern British Columbia from 2000–2007.

body, we were unable to determine if the incidence of entanglement varied between entangled juvenile males and females.

3.4. Entanglements of branded sea lions

Entangled branded animals observed ($n = 14$) indicate a disproportionately high number of entangled males ($n = 12$) to entangled females ($n = 2$) (Table 2). Of the branded animals observed entangled or with ingested fishing gear to date, one (7%) is known dead, four (28.5%) have never been observed again and are likely dead, five (36%) are still entangled around the neck or still show signs of ingested fishing gear, and four (28.5%) have either lost their entanglements or the ingested fishing gear is no longer visible (one animal had a salmon flasher tight against his mouth and had probably ingested a hook; the animal was seen later without the flasher but the hook may still be inside the body).

3.5. Population level effects

Based on our entanglement incidence of 0.26% (entanglement incidence for Southeast Alaska only was same as entanglement incidence for Southeast Alaska and northern British Columbia combined) and a population size of SSLs in Southeast Alaska of between 22,575 and 27,950 in 2002 (Pitcher et al., 2007), we determined

Table 2
Number (% total) of identifiable (branded) male and female Steller sea lions observed with either a neck entanglement (neck) or with ingested fishing gear (hook) between first and last (2007) observation.

Gender	Total # entangled (% total)	Still entangled		Unknown/not seen since first observed entangled		Observed dead		Entanglement gone	
		Neck	Hook	Neck	Hook	Neck	Hook	Neck	Hook
Male	12 (86%)	2	3	2	2	0	1	1	1
Female	2 (14%)	0	0	0	0	0	0	1	1

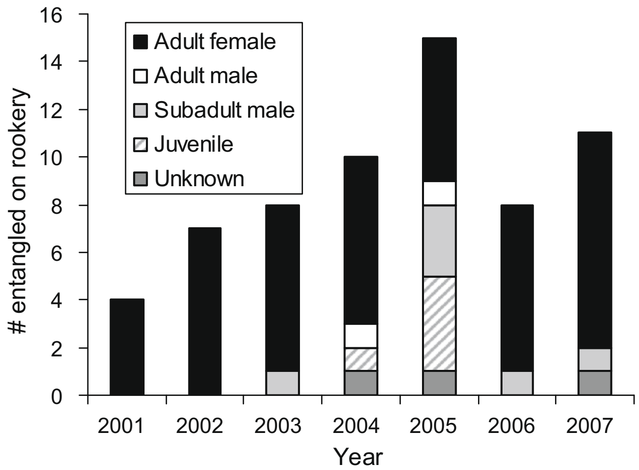

Fig. 5. The number, sex, and age class of entangled Steller sea lions observed during 2001–2007 at Lowrie Island (Forrester Island rookery complex).

that there were between 54 and 67 visibly entangled SSLs in Southeast Alaska in 2002 at any one point in time during the summer (June through August).

3.6. Rookery

From 2001–2007 at Lowrie Island field-camp; we recorded 61 individuals as being either entangled in marine debris or having ingested fishing gear. We documented 38% ($n = 23$) of SSLs with entangling debris around their necks, while 62% ($n = 38$) had interacted with sport or commercial fisheries and had ingested fishing gear. Although we observed 23 individuals with neck entanglements, we were unable to identify the entangling material on most (83%) animals because the material was too deeply embedded in the neck. Of the four identifiable neck entanglements, three were packing bands and one was a rubber band. Ingested fishing gear included salmon fishery flashers (lures; 92%), and longline gear (8%). Because this is a rookery and comprise primarily of adult females and their pups, entanglements observed were primarily adult females (75%) (Fig. 5).

4. Discussion

The results of this study indicate that about half of the entangled SSLs observed in Southeast Alaska and northern British Columbia are entangled around the neck. Most of the identifiable entangling debris appears to be fishery-based (i.e., packing bands, rubber bands, net, rope, line). The other half of entanglements are a result of ingestion of fishing gear due to direct SSL interactions with fisheries. Salmon fishery flashers and longline gear comprise the majority of ingested fishing gear.

Entanglement incidence (0.26%) of SSLs in this study fall within the range of other pinniped entanglement studies. Other reported entanglement rates or incidence include 0.07–0.22% for California sea lions, harbor seals, and elephant seals in California (Stewart and Yochem, 1987), 3.70–7.90% for California sea lions in Mexico (Harcourt et al., 1994), 0.06–0.35% for northern fur seals in Alaska (Fowler, 1987; Zavadil et al., 2007), 0.10–0.40% for Antarctic fur seals (Croxall et al., 1990), 0.18–0.85% for Hawaiian monk seals in Hawaii (Donohue et al., 2001), 1.30% for Australian sea lions and 0.90% for New Zealand fur seals in Australia (Page et al., 2004), and 0.16–6.74% for New Zealand fur seals in New Zealand (Boren et al., 2006).

The entanglement incidence and population level effects calculated for SSLs is likely to be underestimated for several reasons. First, the likelihood of observing all entangled individuals is poor. In Southeast Alaska and northern British Columbia (north of 50°N latitude), SSLs use eight rookeries and over 40 major haul-out sites (sites with >50 animals) on a regular basis during the breeding season, as well as numerous (>50) other sites during the non-breeding season (Raum-Suryan et al., 2004; Pitcher et al., 2005). Second, sea lions may die at sea as a result of their entanglement without first being observed on land. Because of reduced survivorship and increased time at sea due to the drag created by an entanglement (Bengtson et al., 1989; Fowler et al., 1990), entangled individuals are not likely to be sighted (and resighted) onshore as consistently as individuals that are not entangled (Fowler, 1987; Page et al., 2004; Boren et al., 2006). Studies of a California sea lion (Feldcamp, 1985) indicated that entangling net debris can cause a several-fold increase in both drag and power required for swimming, although in our study, we found SSLs entangled only in small net fragments rather than large pieces. Third, external evidence of ingestion may not exist or may be lost over time. For example, some fishing gear may be ingested entirely and so not visible, and when a salmon flasher breaks off a line swallowed by a SSL, the hook may still be embedded inside the sea lion's esophagus or stomach, potentially causing internal injuries or death, but not visible to observers.

Because the collection of entanglement data was ancillary to other SSL studies, there were limitations in the types of analyses we could perform with the data. Although overall counts were conducted at each haul-out site, composition counts by age and sex class were not conducted. We made a concerted effort to identify entangling materials in the field and through photographs of entangled individuals; however, we were only able to identify 23% of materials causing neck entanglements. We believe many of the unidentified neck entanglements cutting deeply into blubber and muscle tissue to be packing bands.

Although entanglement in marine debris is a global problem, there are often regional differences in entanglement type based on local fisheries activities. For example, we commonly observed SSLs with ingested salmon fishery flashers whereas SSLs in the northern Gulf of Alaska are rarely seen with ingested flashers (K. Wynne, pers. comm.) because salmon trolling is not common in this area. Trawl nets, a common source of entanglement in northern fur seals (Fowler, 1987; Zavadil et al., 2007), are rarely observed in Southeast Alaska although SSLs have died in trawl and longline fisheries (Perez, 2006). The differences we observed in entanglement incidence among haul-outs in Southeast Alaska and northern British Columbia may have been a result of interactions with localized sport and commercial fisheries.

The incidence of entanglement we observed in our study area contrasts sharply with an assessment of entangled SSLs conducted in the Aleutian Islands in 1985 (Loughlin et al., 1986). During the Aleutian study, only 11 SSLs, or 0.07% of the counted adult population showed evidence of entanglement with debris. Identifiable materials included trawl net or twine and none were observed to be entangled in packing bands or other materials. The authors indicated that they observed very few 1–4 year old SSLs and conjectured that these animals could have been unable to swim to shore once entangled and may have died at sea.

During our study, the most common *visible* materials causing neck entanglements were packing bands (often used to secure cardboard bait boxes) and rubber bands (used in recreational and commercial crab fisheries and to secure rain gear). Entangling debris observed on and removed from northern fur seals in the Pribilof Islands in 2006 also included a high incidence of plastic packing bands (Zavadil et al., 2007). Neck entanglements are especially lethal to animals that become entangled at a young age. As a sea lion grows, the entangling material tightens, eventually strangling the animal. Lesions from netting or packing bands are often infected and associated with necrotic tissue and if the infection surpasses the ability of the lymph system to control it, the lungs will often become infected, often leading to mortality (Angliss and DeMaster, 1998). In addition, microbes that enter the blood stream can cause secondary infections in the heart (e.g., heart valves), brain, or other vital organs (Angliss and DeMaster, 1998). These entangling materials injure and kill not only SSLs but many other marine species worldwide (Laist, 1997). Arnould and Croxall (1995) reported that Antarctic fur seal became entanglement in packing bands originating from bait boxes used by longline vessels. After an aggressive educational campaign and regulatory efforts under the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), the number of packing bands found during beach surveys diminished, and most of the bands found on beaches in the final two years of the study were already cut, thus reducing fur seal entanglement. During the 1990s, the Tasmanian rock lobster industry tried to reduce the use of packing tape/bands (Page et al., 2004). Cheaper, plastic-free bait boxes were developed to eliminate packing tape from this fishery, however, these bait boxes were not mandatory and were used by few bait-packing companies (Jones, 1995).

Ingestion of salmon fishery hooks and flashers were commonly observed not only in our study but in sea lions off California as well (Hanni and Pyle, 2000). Ingestion of fish hooks can cause not only immediate harm but also long-term infection and death. Where hooks migrate from the stomach to the lungs, pleuritis may develop over a period of weeks. Where hooks embed in the jaw, abscesses may develop over weeks or months and cause tooth loss or the inability to feed (Angliss and DeMaster, 1998). The percentage of salmon flashers to total entanglements (40%) we observed from 2000–2007 was similar to those reported by Hanni and Pyle (2000) at Southeast Farallon Island, California from 1976–1998 (37%). We found two (one adult female and one subadult male) dead SSLs with salmon flashers still attached. The National Marine Fisheries Service (NMFS) Alaska Region Stranding Database has reports of at least two additional SSLs found dead with fishing gear either at the edge of mouth, or in the throat and stomach.

Our observations of branded and scarred individuals indicate that not all entangled SSLs die from infection and secondary complications while entangled. Similar observations have been made of other pinniped entanglements (Boren et al., 2006). However, of the known individuals of marked sea lions in our sample, only 29% lost their entanglements. Furthermore, half of these "lost" entanglements were ingested salmon fishery flashers, and may represent undetectable ingestion rather than self-release.

Juvenile SSLs were the most frequently observed age class entangled in marine debris during this study. Moreover, we observed juvenile SSLs with ingested longline gear far more than any other age class. Most pinniped entanglements noted by Hanni and Pyle (2000) were also immature and subadult animals. It is thought that young inexperienced animals are more likely to investigate and become entangled in synthetic material (Yoshida et al., 1985; Fowler, 1987; personal observations). For pinnipeds, curiosity and play appear to be important factors causing animals to seek out and interact with entangling debris (Laist, 1997). Significantly more Antarctic fur seal (*A. gazelle*) subadults were found entangled than expected from the postulated population age class distribution (Hofmeyr et al., 2006) at the subantarctic island of Bouvetøya. Higher entanglement rates among younger age classes also are reported for Hawaiian monk seals (Henderson, 1984; Henderson, 2001), Antarctic fur seals (Croxall et al., 1990), Australian fur seals (Pemberton et al., 1992), and California sea lions (Stewart and Yochem, 1987).

Based on resights of entangled branded SSLs, males appear to become entangled in marine debris more frequently than females. Pendleton et al. (2006) reported a 0.13–0.11 lower male to female SSL survival rate from 1–2 yr of age and a ~0.05 lower survival per year for male SSLs up to age 9. Moreover, Alaska Department of Fish and Game (ADFG; unpublished data) found that juvenile survival is ~0.05 higher in SSL females than males, adult and subadult males have a lower survival rate, and males >1 yr of age have a lower resight probability. Assuming that entanglements affect resight rates of males and females equally, the lower resight and survival rates of males relative to females supports the conclusion that the proportion of SSLs observed entangled reflect a higher entanglement incidence for males than females (and in fact a potential underestimate of the sex differences). This also may be a contributing factor to the lower survival rates for males. For example, males and females have a marked size difference; the average adult male weighs over twice as much as the average adult female. Females grow rapidly during the first four years but slow by the fifth year, with little growth after age 6. Males continue to grow until the eleventh year. Therefore, if a rapidly growing male becomes entangled around the neck at 4–5 yr of age, his survival prospects are poor, whereas a 5–6 yr old newly entangled female may survive.

Unlike many programs throughout the world that successfully capture and disentangle seals and sea lions (Croxall et al., 1990; Hanni and Pyle, 2000; Page et al., 2004; Boren et al., 2006; Zavadil et al., 2007), there are currently no established protocols in place to safely capture and disentangle SSLs. Therefore, additional effort should be made not only to document entanglements concurrent with ongoing research projects, but to further develop safe methods of disentanglement. Moreover, necropsies on stranded carcasses should be encouraged and results made available to the NMFS Stranding Database for a more complete documentation of these interactions. The Alaska Region of NMFS considers entanglements in marine debris to be "strandings" and the lack of reporting suggests a stronger outreach campaign should be considered to engage both scientists and the public to report these observations.

The quantity of entangling debris in the environment is likely much greater than any of us realize. During a study conducted from 1989–1993 in the United States, entanglement debris made up a greater percentage of the total plastics in Alaska than elsewhere on the Pacific Coast and Hawaii (Ribic et al., 1997). The quantity and sources of entangling marine debris emphasizes the need for further education campaigns to demonstrate the effect of synthetic materials on marine animals. Increased awareness and education of the problem (e.g., video, posters, fliers, bumper stickers, website), and beach clean-up programs should be emphasized. For example, the authors produced a video (http://www.multimedia.adfg.alaska.gov/) discussing causes and solutions of SSL entanglements and ingested fishing gear and distributed it worldwide to fishing industry groups, government agencies, zoos, aquariums, schools, universities, and other non-governmental organizations (NGOs). Monofilament recycling stations should be available at all ports and programs to collect derelict fishing gear should be implemented. Simple procedures such as cutting entangling loops of synthetic material and eliminating the use of packing bands can prevent entanglements. "Lose the Loop™" and "Go bandless" are just a couple of easy slogans that could be used to reduce the impacts of loops and plastics on the marine environment. Although losing a cut packing band overboard is no longer an entanglement threat, it can still be ingested by other marine species as it degrades in the environment. Incentives should be made to the fishing industry to implement simple solutions that could decrease entanglement incidence, particularly with regard to plastic packing bands and rubber bands.

Continued monitoring of SSL populations and quantifying the degree of SSL entanglements is essential to assessing the impact of marine debris on the vital rates and population trends of SSLs in the North Pacific. Finally, there is a need to work closely with the commercial and sport fishers to develop ways to reduce SSL-fishery interactions, in particular, with sport and commercial salmon fisheries.

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