Journal of Wildlife Diseases, 45(2), 2009, pp. 355–362

FISHING GEAR–RELATED INJURY IN CALIFORNIA MARINE WILDLIFE

Brynie Kaplan Dau,[1,6] Kirsten V. K. Gilardi,[1] Frances M. Gulland,[2] Ali Higgins,[3] Jay B. Holcomb,[4] Judy St. Leger,[5] and Michael H. Ziccardi[1]

[1] Wildlife Health Center, School of Veterinary Medicine, One Shields Avenue, University of California, Davis, California 95616, USA
[2] The Marine Mammal Center, 1065 Fort Cronkhite, Sausalito, California 94965, USA
[3] Project Wildlife, 887½ Sherman Street, San Diego, California 92110, USA
[4] International Bird Rescue Research Center, 4369 Cordelia Road, Fairfield, California 94534, USA
[5] Sea World California, 500 SeaWorld Drive, San Diego, California 92109, USA
[6] Corresponding author (email: bkdau@ucdavis.edu)

ABSTRACT: We reviewed medical records from select wildlife rehabilitation facilities in California to determine the prevalence of injury in California Brown Pelicans (*Pelecanus occidentalis*), gulls (*Larus* spp.), and pinniped species (*Zalophus californianus*, *Mirounga angustirostris*, and *Phoca vitulina*) due to fishing gear entanglement and ingestion from 2001 to 2006. Of 9,668 Brown Pelican, gull, and pinniped cases described during the 6-yr study period (2001–06), 1,090 (11.3%) were fishing gear–related. Pelican injuries caused by fishing gear were most common in the Monterey Bay region, where 59.6% of the pelicans rescued in this area and admitted to a rehabilitation center were injured by fishing gear over the 6-yr period. The highest prevalence of fishing gear–related injury in gulls was documented in the Los Angeles/Orange County region (16.1%), whereas the highest prevalences in pinnipeds were seen in the San Diego region (3.7%). Despite these higher prevalences of gull and pinniped fishing gear–related injuries in these specific regions, there was no statistical significance in these trends. Juvenile gulls and pinnipeds were more commonly injured by fishing gear than adults (gulls: $P=0.03$, odds ratio=1.29; pinnipeds: $P=0.01$, odds ratio=2.07). Male pinnipeds were twice as likely to be injured by fishing gear as females ($P<0.01$, odds ratio=2.19). The proportion of fishing gear–related injury cases that were successfully rehabilitated and released (percentage of cases successfully rehabilitated to the point of release out of the total number of fishing gear–related injury cases) was high in all three species groups (pelicans: 63%; gulls: 54%; pinnipeds: 70%). Fishing gear–related injuries in Brown Pelicans and gulls were highest in the fall, but there was only a significant difference between seasons for fishing gear–related injuries in pelicans. Fishing gear–related injuries in pinnipeds most commonly occurred in summer; however, a statistical difference was not detected between seasons for pinnipeds. Derelict fishing gear—lost, abandoned or discarded sport and commercial line, nets, traps, etc.—in the marine environment is a significant cause of injury in California coastal marine wildlife. We evaluated data for stranded animals only; our results may underestimate the true number of coastal marine animals injured by lost or discarded fishing gear in California.

Key words: California, derelict fishing gear, entanglement, gull, hook, pelican, pinniped, rehabilitation facilities.

INTRODUCTION

An estimated 267 marine species have been reported to be affected by fishing gear entanglement and ingestion injuries (Laist, 1996). Injury to marine mammals, turtles, and birds due to entanglement in, or ingestion of, fishing gear has been identified as a major cause of morbidity and mortality in some populations (Stewart and Yochem, 1985; Fowler, 1987; Nakajima, 1990). Fishing line and hooks, fragments of nets, or ropes can become tangled around heads and appendages, restricting an animal's movement or foraging ability, and causing minor to major wounds (Laist, 1987). Birds and mammals swallow fishing gear, leading to severe injury of the alimentary tract, including perforation, obstruction, or toxicity (e.g., lead poisoning due to ingestion of fishing weights) (Hanni and Pyle, 2000; Franson et al., 2003; Zabka et al., 2006).

The effects described above have been observed both with active (legally deployed for the purposes of commercial or recreational harvest) as well as derelict (lost, abandoned, or discarded, and capable of remaining intact in seawater for

years) fishing gear in the marine environment. In the Northwest Hawaiian Islands alone, an estimated 52 metric tons of derelict fishing gear are predicted to accumulate annually (Dameron et al., 2007). Marine debris in general is thought to be the largest anthropogenic threat to the endangered Hawaiian monk seal (Boland and Donohue, 2003): annual rates of entanglement in fishing gear ranged from 4% to 78% (from 52 to 1,014 individuals out of the total estimated population of 1,300) in recent surveys (Donohue and Foley, 2007).

To reduce risk of injury and death for coastal marine wildlife and people, the SeaDoc Society, a marine ecosystem health program of the University of California Davis Wildlife Health Center, launched the California Lost Fishing Gear Recovery Project in 2005. To date, more than 11 tons of lost fishing gear have been removed from nearshore marine waters surrounding the Channel Islands, and hundreds of pounds of recreational fishing gear (such as fishing line and hooks, tackle, and ropes) have been cleaned off public-access fishing piers. To prevent the reaccumulation of discarded gear at these piers, monofilament disposal stations have been established. Efficacy of this lost fishing gear recovery project will be determined in part by assessing rates of injury in select coastal wildlife species after removal and prevention efforts have been instigated. In order to make such comparisons, rates of injury must be assessed prior to the start of the project.

Therefore, the objective of our study was to retrospectively evaluate the prevalence of injury due to fishing gear entanglement and ingestion in representative marine wildlife of the California coast: Brown Pelicans (*Pelecanus occidentalis*), gulls (*Larus* spp.), California sea lions (*Zalophus californianus*), northern elephant seals (*Mirounga angustirostris*), and Pacific harbor seals (*Phoca vitulina*) identified in rehabilitation facilities.

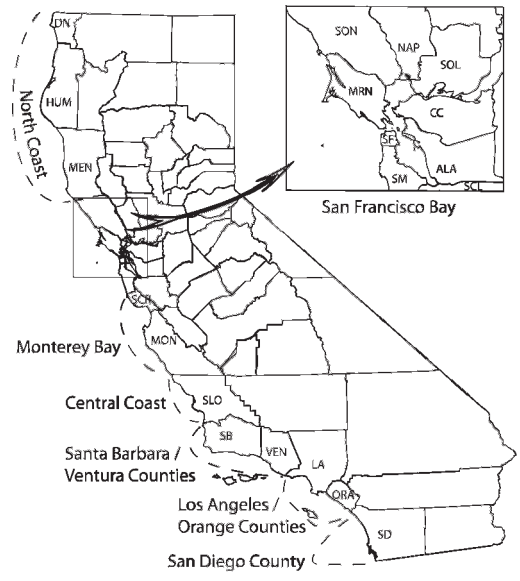

FIGURE 1. Map of defined geographic regions in coastal California. County abbreviations: ALA = Alameda, CC = Contra Costa, DN = Del Norte, HUM = Humboldt, LA = Los Angeles, MEN = Mendocino, MON = Monterey, MRN = Marin, NAP = Napa, ORA = Orange, SB = Santa Barbara, SCR = Santa Cruz, SD = San Diego, SF = San Francisco, SLO = San Luis Obispo, SM = San Mateo, SOL = Solano, SON = Sonoma, and VEN = Ventura.

MATERIALS AND METHODS

We conducted a retrospective cohort study by analyzing 6 yr (2001–06) of medical case records (9,668 case records total) at five select marine wildlife rehabilitation facilities in California to determine the prevalence of injury and mortality in pelicans, gulls, and pinnipeds caused by fishing gear (Fig. 1). Cooperating rehabilitation organizations were selected based on the size of their annual caseload, the quality of their record keeping, and their proximity to areas of proposed monofilament disposal stations.

Records for Brown Pelicans, gulls, California sea lions, northern elephant seals, and Pacific harbor seals were examined because these species are common in nearshore waters off the California coast and often congregate or forage in areas frequented by sport and commercial fishermen. The three pinniped species included in this study were combined to represent pinnipeds as a group for the majority of the analysis, because the numbers of both total admission and fishing gear–related injuries were low for two species

(northern elephant seals and Pacific harbor seals).

When available, the following data from each medical record were recorded: species, intake date (divided into seasons, where fall included September through November, winter included December through February, spring included March through May, and summer included June through August), age (juvenile included yearlings and hatch-year birds, adult included 1-yr or older animals), sex (data available for pinnipeds only), injury type (described below), stranding county and when possible specific stranding location, and disposition (released, died, or euthanized).

Fishing gear–related injuries were categorized into four classes: 1) entanglement with line only (injury due to a net fragment or monofilament line), 2) entanglement with line and an associated hook injury (a hook-related puncture or laceration with monofilament line attached, where both were involved in the injury), 3) hook injury only (injury with no line involved), or 4) ingestion (hook located internally in the alimentary tract, anywhere distal to the bill or lip margins). To generate a robust sample size for statistical comparison, injury-type data were divided into two main groups: "entanglement in line and/or hook injury" and "ingestion."

We divided the coast into seven regions to provide a level of geographic specificity in the data that would best serve future comparisons. Regions were delineated according to the responding range of the rehabilitation organizations working with injured wildlife. The seven regions were: North Coast (Del Norte, Humboldt, and Mendocino counties); San Francisco Bay (Sonoma, Napa, Solano, Marin, Contra Costa, Alameda, San Mateo, and Santa Clara counties); Monterey Bay (Santa Cruz and Monterey counties); Central Coast (San Luis Obispo County); Santa Barbara/Ventura counties; Los Angeles/Orange counties; and San Diego County (Fig 1). We omitted counties with less than five total cases within the 6-yr study period in our analysis of geographic distribution. Finally, we determined survivability (the proportion of cases that were successfully rehabilitated and released) by species for all fishing gear–related injury cases in this study.

Not all records included in this study contained every parameter of interest (e.g., age, sex, region, disposition), and where data were not available, these incomplete records were excluded from analyses; for example, records of pinnipeds for which sex was not specified were not included in our analysis of injury differences between the sexes either as contributing to the numerator or the denominator in the calculation. Similarly, we did not determine whether the fishing gear injury cases in this study were due to actively deployed fishing gear or lost or discarded fishing gear; data suggesting source of injurious gear were not evaluated.

Data were transcribed into an Excel™ (Microsoft, Redmond, Washington, USA) spreadsheets and scored and counted using a binary system. Basic descriptive statistics were used to calculate prevalence of fishing gear–related injuries by species, year, age, sex (mammals only), region, and season. Prevalence odds ratios (OR) and 95% confidence intervals (95% CI) were calculated; chi-square tests of homogeneity were used to test the degree of associations between fishing gear–related injury status and explanatory variables using standard statistical software (EpiInfo™, Centers for Disease Control and Prevention, Atlanta, Georgia USA). Statistical significance was set at P-values <0.05.

RESULTS

A total of 9,668 cases were included in this study, of which 1,090 (11.3%) were fishing gear–related injuries (Table 1). Specific details regarding the nature and severity of gear-related injuries were not consistently recorded and therefore were not quantified for the purpose of this study. However, typical injuries were described qualitatively as leg entanglements, wing lacerations and/or entanglements, hooks embedded in the oral cavity and alimentary tract, and hooks embedded in the wings, legs, or flippers with associated line causing entanglement. One severe case described a hook embedded in the oral cavity of a gull with associated line entangling the wing, such that the wing was tightly bound to the head and neck, preventing the animal from flying or foraging for food.

Over the 6-yr study period (2001–06), the prevalence of fishing gear–related injuries varied by species (Table 1), ranging from 2.9% of all pinniped cases to 31.1% of all pelican cases. Interannual variation in the prevalence of fishing gear–related injuries in pelicans ranged from 13.6% (18 of 132) in 2005 to 61.9% (208 of

TABLE 1. Distribution of species (Brown Pelicans, gulls, California sea lions, northern elephant seals, and Pacific harbor seals) with fishing gear–related injuries admitted to select wildlife rehabilitation centers in California within the 6-yr study period (2001–06).

Species	Prevalence (c/t)[a]	Range[b]
Brown Pelicans (*Pelecanus occidentalis*)	31.1% (589/1,894)	13.6–61.9%
Gulls (*Larus* spp.)	11.1% (375/3,376)	8.6–13.9%
All pinnipeds	2.9% (126/4,398)	1.2–3.8%
California sea lions (*Zalophus californianus*)	3.3% (106/3,216)	1.7–4.9%
Elephant seals (*Mirounga angustirostris*)	1.9% (16/827)	0.7–2.6%
Harbor seals (*Phoca vitulina*)	1.1% (4/355)	0–3%

[a] Prevalence calculated as c (number of gear-related injury cases) divided by t (total number of individuals of that species admitted by year).

[b] Range of prevalence across all 6 yr is also shown.

336) in 2001. Pinnipeds were much less likely to be affected by fishing gear as an overall proportion of admitted rehabilitation cases than were seabirds (gulls or pelicans), with the highest pinniped proportional morbidity of 6.6% occurring in the San Diego region in 2004.

Prevalence of fishing gear–related injuries occurring in juveniles comprised a substantial proportion of the overall gear-related morbidity in each of the study populations when compared with adults (Table 2). Although there was no statistical difference between juvenile and adult pelicans in fishing gear–related injury cases, juvenile gulls were 30% more likely to be injured by fishing gear when compared to adults ($P=0.03$, OR=1.29, 95% CI=1.01–1.64). For gulls, juveniles were twice as likely to be affected by ingestion compared to entanglement injuries, ($P=0.02$, OR=2.1, 95% CI=1.09–4.07). Juvenile pinnipeds were equally likely to be affected by both entanglement and ingestion injuries, and juvenile pinnipeds were more than twice as likely to be injured by fishing gear in general compared to adults ($P=0.01$, OR=2.07, 95% CI=1.13–3.87).

Male pinnipeds were more than twice as likely to be admitted to a rehabilitation facility with fishing gear–related injuries compared to females ($P<0.01$, OR=2.19, 95% CI=1.38–3.51). However, males were not more likely to be admitted for one injury type over another. Of the pinniped entanglement injury cases in this study, 62% were male (71 of 115 cases) and 75% of pinniped ingestion injury cases were male (three of four cases).

TABLE 2. Prevalence[a] (and range of prevalences) of juveniles by species (Brown Pelicans, gulls, and pinnipeds [California sea lions, northern elephant seals, and Pacific harbor seals]) in animals with fishing gear–related injuries admitted to select wildlife rehabilitation centers in California within the 6-yr study period (2001–06).

Species		Juveniles with entanglement with line and/or hook injury	Juveniles with ingestion
Pelicans ($n=546$)[b]	Prevalence	50.9% (271/532)	57% (8/14)
	Range	11.3–88.7%	0–100%
Gulls ($n=337$)	Prevalence	36% (104/289)	54% (26/48)
	Range	27.3–50%	25–85.7%
Pinnipeds ($n=126$)	Prevalence	88.5% (108/122)	100% (4/4)
	Range	77.8–100%	100%

[a] Prevalence calculated as c (number of juvenile cases) divided by t (total number of individuals of that species admitted by year).

[b] $n=$ total number of cases for which age was recorded.

We determined the prevalence of fishing gear–related injuries by coastal region of California (Table 3). Some regions (North Coast, Santa Barbara/Ventura, and Los Angeles/Orange regions) had very few total cases from the facilities included in this study. Pelican injuries due to fishing gear were most common in the Monterey Bay region, where the overall prevalence was 59.6% and ranged from 0% to almost 75% of yearly cases. As compared to all other regions, pelicans in the Monterey Bay region were on average four times more likely to be admitted with fishing gear injury than for other reasons ($P<0.001$, OR=4.11, 95% CI=3.14–5.36) Gulls were most commonly injured by fishing gear in the Los Angeles/Orange region (16.1%); however, the average prevalence over the 6-yr period was not statistically different across regions. The range of prevalences of gear-related injuries in gulls remained essentially under 26.5%, except in the Santa Barbara/Ventura region which had a gull fishing gear–related injury prevalence of 50% in 2001. The highest injury prevalence in pinnipeds occurred in the San Diego region (3.7%); however, the different regions were statistically indistinct from one another.

The proportion of cases with gear-related injuries that were successfully rehabilitated and released was calculated for each animal class when disposition data was available (Table 4). Release percentages in hook and entanglement injuries were 63.5% for pelicans, 52.8% for gulls, and 70.5% for pinnipeds. For ingestion injuries, release percentages were 42.9% for pelicans, 64.2% for gulls, and 50% for pinnipeds. Overall, the proportion of pinnipeds released was significantly higher than seabirds ($P=0.03$, OR=1.57, 95% CI=1.03–2.39), and pelicans were more apt to be released than gulls ($P<0.01$, OR=1.43, 95% CI=1.08–1.88). In all species, there was no significant difference in the proportion of released animals between entanglement and ingestion injuries.

Over the 6-yr period of this study (2001–06), although there were no statis-

TABLE 3. Overall prevalence[a] (and range[b] of prevalences) of fishing gear–related injuries in Brown Pelicans, gulls, and pinnipeds (California sea lions, northern elephant seals, and Pacific harbor seals) admitted to select wildlife rehabilitation centers in California within the 6-yr study period (2001–06), by region.

Species (*n*)		North Coast prevalence	San Francisco Bay prevalence	Monterey Bay prevalence	Central Coast prevalence	Santa Barbara/ Ventura prevalence	Los Angeles/Orange prevalence	San Diego prevalence
Pelicans (1,698)	Prevalence	0% (0/4)	22% (27/123)	59.6% (180/302)	8% (2/24)	7.9% (10/127)	18.9% (76/403)	35.5% (254/715)
	Range	0%	0–42.9%	0–74.5%	0–25%	5.9–100%	12.6–33.3%	10.9–50%
Gulls (2,985)	Prevalence	0% (0/5)	9.2% (28/306)	0% (0/13)	0% (0/2)	10.4% (11/106)	16.1% (92/572)	10.8% (213/1,981)
	Range	0%	3.4–14.6%	0%	0%	0–50%	0–26.5%	5.8–14.2%
Pinnipeds (4,398)	Prevalence	0% (0/57)	2.1% (22/1,032)	2.8% (42/1,485)	3.4% (30/879)	0% (0/71)	0% (0/4)	3.7% (32/870)
	Range	0%	0.7–6%	1.4–4.1%	1.6–5.4%	0%	0%	1.4–6.6%

[a] Prevalence calculated as c (total number of cases for which stranding location information was recorded) divided by t (total number of individuals of that species for which stranding location information was recorded).

[b] Range of prevalence across all 6 yr is also shown.

TABLE 4. Prevalence[a] (and range[b] of prevalences) of Brown Pelicans, gulls, and pinnipeds (California sea lions, northern elephant seals, and Pacific harbor seals) with fishing gear–related injuries that were successfully rehabilitated and released over the 6-yr study period (2001–06).

Species		Entanglement with line and/or hook injury	Ingestion
Pelicans (n=557)	Prevalence	63.5% (345/543)	43% (6/14)
	Range	50–71.5%	0–100%
Gulls (n=360)	Prevalence	52.8% (162/307)	64% (34/53)
	Range	45.7–58.8%	33.3–85.7%
Pinnipeds (n=126)	Prevalence	70.5% (86/122)	50% (2/4)
	Range	46.7–100%	0–100%

[a] Prevalence calculated as c (number of gear-related injury cases) divided by t (total number of individuals of that species admitted by year).

[b] Range of prevalence across all 6 yr is also shown.

tically significant differences in fishing gear–related injury prevalences between seasons for pelicans, gulls, or pinnipeds, seasonal trends were detected in all species (Fig. 2). Pelicans and gulls were more likely to be admitted to rehabilitation facilities with fishing gear–related injuries in the fall than during any other season, whereas pinnipeds with fishing gear–related injuries were more prevalent in the summer months.

DISCUSSION

Fishing gear in the marine environment is a significant cause of injury in coastal California marine wildlife. Between 2001 and 2006, a significant proportion of pelicans and gulls entering California rehabilitation facilities were admitted with fishing gear–related injuries. Pinnipeds had a far lower prevalence of fishing gear–related injuries compared to seabirds (pelicans or gulls). Although this may well be the case, it is possible that the proportional morbidity in these animals is lower because they were more difficult to rescue than seabirds, or that fishing gear–injured pinnipeds were less likely to strand live on beaches. Furthermore, entanglement and ingestion injuries may not have been as severe in pinnipeds as they were in seabirds. An injury caused by small gear such as a hook or lead fishing weight would likely cause much higher morbidity in a small seabird than in a pinniped because of their relative body size differences. An entanglement injury with monofilament line may be much worse for a seabird whose wings are tied and is therefore unable to forage, than an entanglement involving the flipper of a pinniped.

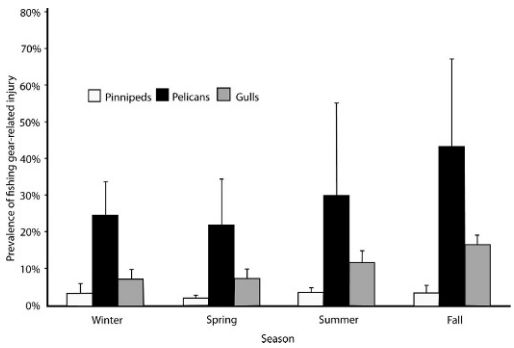

FIGURE 2. Seasonal variation in average prevalence of fishing gear–related injury cases in coastal California wildlife, 2001–06 (data are shown with standard error bars).

Nonetheless, pinnipeds in this study had a higher prevalence of gear-related injury (2.9%) when compared to previous studies of entanglement in wild California pinniped populations (Stewart and Yochem, 1985, 1987; Goldstein et al., 1999; Hanni and Pyle, 2000). It is difficult to directly compare our findings to previous work; however, because the studies referenced above relied on prevalence estimates from sampling wild populations rather than animals in rehabilitation facil-

ities. Future field studies would help determine if the prevalence of fishing gear–related injuries is indeed increasing throughout California.

The majority of fishing gear–related injuries in pinnipeds occurred in juveniles. This finding is consistent with previous studies (Stewart and Yochem, 1985; Hanni and Pyle, 2000). This increased prevalence is likely a result of juvenile pinniped curiosity and lack of experience in foraging and avoiding debris. However, some bias may result from the difficulty in capturing adult pinnipeds with fishing gear–related injuries for admission to rehabilitation facilities. Previous studies have determined that both sexes are susceptible to entanglement (Goldstein et al., 1999); however, males in this study were significantly more likely to become entangled than females. Male pinnipeds tend to migrate over a greater range than females, leading them to potentially encounter more lost or discarded fishing gear.

Although the nature of our data did not allow us to determine the exact location where an animal became injured by fishing gear, for the purposes of this study, we assumed that birds generally became grounded or stranded in the same region as where the injury occurred. Therefore, based on our data there appear to be injury "hot spots" in California, which should inform and guide future cleanup and public education efforts. The Monterey Bay and San Diego regions are fishing gear injury hotspots for pelicans, whereas the Los Angeles/Orange region is a fishing gear injury hotspot for gulls. Pinnipeds had the highest prevalence of fishing gear–related injury in the San Diego region, although statistical significance was not found. Follow-up studies to increase the sample size for pinniped entanglements may help to determine whether this difference is because of a low statistical power or if there are truly no geographic differences for this group.

Pelicans and pinnipeds with entanglement injuries were more likely to be released than pelicans and pinnipeds with ingestion injuries, whereas the opposite was the case for gulls. Because many factors contribute to successful release in rehabilitated wildlife, such as overall fitness and nutritional condition and presence of secondary injuries and other diseases, and because the sample sizes were low for total ingestion injuries, we were unable to assess from our data analysis whether entanglement or ingestion injury cases are more severe and therefore less likely to result in successful release.

Injury prevalence in pelicans and gulls fluctuated by season, with the highest prevalence occurring in summer and fall for both species, likely because of increased recreational fishing efforts in summer and fall when ocean and beach conditions are ideal. In addition, summer and fall are when the highest numbers of young of the year birds are learning to forage. By winter, these birds have become more experienced in their foraging abilities.

This study is the first attempt to determine the prevalence of fishing gear–related injuries in seabirds of coastal California. Although the results of our study suggest significant effects on California populations, our study population of stranded and rescued individuals does not necessarily represent the wild population. The data presented here must be interpreted in light of the fact that proportions of gear-related injuries (and subsequent analyses) are being compared with overall admissions to rehabilitation facilities, and not to the general wild population as a whole. Also, geographic data may be skewed for a number of reasons. Regions of the coast with increased human traffic are more likely to have animals reported than more isolated coastal areas, thereby potentially overrepresenting the effect in these regions. However, such areas do tend to have increased recreational fishing activity, which may increase the prevalence of such injuries in certain regions.

By the same token, data from dead birds and pinnipeds were not included in this study; therefore, our data may well be underrepresenting the overall effect of fishing gear–related injury in California marine wildlife. Ease of capture, perceived value of the study species, and other dynamics of collection of these wildlife groups may have affected the overall proportion of gear-related cases presented. The results of this study must therefore be interpreted with care when extrapolating to the overall wild population in coastal California.

Access to high-quality medical records from marine rehabilitation facilities provided a robust data set for analysis. Wildlife rehabilitation facilities can be an excellent source of information for wildlife researchers, depending upon quality and completeness of data and record keeping. Wildlife rehabilitation data can provide an excellent initial glimpse into population-level effects of disease and other stressors, and can help guide and inform future research and management.

ACKNOWLEDGMENTS

We thank the Morris Animal Foundation (grant D07ZO-626) and the University of California Davis School of Veterinary Medicine for financial support. The National Fish and Wildlife Foundation provided funding to support the overall derelict recreational fishing gear recovery project (grant 2006-0001-015). Staff members at participating rehabilitation organizations were indispensable in the data collection phase of this project. D. Dau assisted with medical record review, analysis, and database development. No live animals were used for the purposes of this project so institutional animal care and use protocols were not required.

LITERATURE CITED

Boland, R. C., and M. J. Donohue. 2003. Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, *Monachus schauinslandi* 1999–2001. Marine Pollution Bulletin 46: 1385–1394.

Dameron, O. J., M. Park, M. A. Albins, and R. Brainard. 2007. Marine accumulation in the Northwestern Hawaiian Islands: an examination of rates and processes. Marine Pollution Bulletin 54: 423–433.

Donohue, M., and D. Foley. 2007. Remote sensing reveals links among the endangered Hawaiian monk seal, marine debris, and El Niño. Marine Mammal Science 23: 468–473.

Fowler, C. W. 1987. Marine debris and northern fur seals—A case-study. Marine Pollution Bulletin 18: 326–335.

Franson, J. C., S. P. Hansen, T. E. Creekmore, C. J. Brand, D. C. Evers, A. E. Duerr, and S. Destefano. 2003. Lead fishing weights and other fishing tackle in selected waterbirds. Waterbirds 26: 345–352.

Goldstein, T., S. P. Johnson, A. V. Phillips, K. D. Hanni, D. A. Fauquier, and F. M. D. Gulland. 1999. Human-related injuries observed in live stranded pinnipeds along the central California coast 1986–1998. Aquatic Mammals 25: 43–51.

Hanni, K. D., and P. Pyle. 2000. Entanglement of pinnipeds in synthetic materials at Southeast Farallon Island, California, 1976–1998. Marine Pollution Bulletin 40: 1076–1081.

Laist, D. W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine-environment. Marine Pollution Bulletin 18(6B): 319–326.

———. 1996. Marine debris entanglement and ghost fishing: A cryptic and significant type of bycatch? *In* Solving bycatch: Considerations for today and tomorrow. Alaska Sea Grant College Program, AK-SG-96-03, Seattle, Washington, pp. 33–39.

Nakajima, M. 1990. Histological observations of damage to dermal tissue of fur seal caused by net entanglement. *In* Proceedings of the Second International Conference on Marine Debris. R. S. Shomura and M. L. Godfrey (eds.). Honolulu, Hawaii, 2–7 April 1989, NOAA TM: NMFS-SWFSC-154, pp. 531–539.

Stewart, B., and P. Yochem. 1985. Entanglement of pinnipeds in net and line fragments and other debris in the southern California Bight. *In* Proceedings of the workshop on the fate and impact of marine debris, Honolulu, Hawaii, 26–29 November 1984, pp. 315–325.

———, and ———. 1987. Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San-Nicolas and San-Miguel islands, California, 1978–1986. Marine Pollution Bulletin 18(6B): 336–339.

Zabka, T., M. Haulena, B. Puschner, F. Gulland, P. Conrad, and L. Lowenstine. 2006. Acute lead toxicosis in a harbor seal (*Phoca vitulina richardsi*) consequent to ingestion of a lead fishing sinker. Journal of Wildlife Diseases 42: 651–657.

Received for publication 26 December 2007.