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Twenty-Five Years of Rehabilitation of Odontocetes Stranded in Central and Northern California, 1977 to 2002

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Abstract

Rehabilitation of stranded cetaceans is receiving increasing attention and involves considerable financial and personnel resources, although the survival rate appears to be low. To evaluate rehabilitation success, we examined 25 years (1977 to 2002) of data on live-stranded odontocetes (*n* = 70) from northern California that were rescued for rehabilitation. Thirty-five animals (50%) died within the first 24 h of being rescued, 13 animals (19%) died within the first week, seven animals (10%) died within a month, and five animals (7%) survived longer than one month, but subsequently died. Three animals (4%) were deemed nonreleasable and placed into captivity, whereas five animals (7%) were released back into the wild. Two animals (3%) were relocated and released; these animals were never seen again. Clinical signs were nonspecific, and it was difficult to differentiate medical problems that resulted from stranding from those that may have caused the stranding. Causes of death included pneumonia (*n* = 16), septicemia (*n* = 6), encephalitis (*n* = 3), maternal separation (*n* = 7), and blunt trauma (*n* = 6). No morbilliviral inclusion bodies or typically associated lesions were detected. Cause of death was unknown for 23 cases. Myocardial degeneration and contraction band necrosis (*n* = 9) and nephrosis (*n* = 4) probably resulted from the stress of stranding. Ulcerative glossitis and esophagitis were observed in most animals that were tube-fed in rehabilitation. Four animals that had been in rehabilitation for more than 1 wk had rhabdomyolysis and one had scoliosis. These data indicate that the success of rehabilitating and releasing stranded odontocetes in California is minimal, and the stress of stranding and rehabilitation in addition to pre-existing disease can result in morbidity and mortality. Of the animals released, two common dolphins (*Delphinus delphis*) and one harbor porpoise (*Phocoena phocoena*) were tagged with satellite transmitters. Transmissions were received for up to 5 mo after release. Increased use of telemetry is essential for post-release monitoring and evaluating rehabilitation success.

Key Words: harbor porpoise, *Phocoena phocoena*, common dolphin, *Delphinus delphis*, odontocete, cetacean, strandings, disease, wildlife rehabilitation, radio-telemetry, satellite-telemetry, California

Introduction

Single and mass strandings of odontocetes occur regularly along the world's ocean coastlines, and notice of these events has increased with the increased presence and activity of humans living near the coast (e.g., Geraci et al., 1999). Perhaps as a result, interest in rescuing and rehabilitating stranded animals has also increased. Wiley et al. (2001) reviewed 17 mass-stranding events that occurred on Cape Cod, Massachusetts, USA. Of the 376 stranded animals, most died or were euthanized on the beach. Rescue attempts were made for 77 of those cetaceans, and most survived until they were moved to a suitable release site. Most of those were subsequently released and not seen again. Rehabilitation was not attempted, however, for any of the stranded animals.

Geographic patterns of strandings have been examined for several species (e.g., Berrow &

Rogan, 1997; Silva & Sequeira, 2003), but the rehabilitation efforts and subsequent survival of released animals have received little attention. The limited data available for rehabilitation outcomes suggest that few stranded odontocetes survive long, despite dedicated veterinary medical care and husbandry. Nevertheless, considerable financial and personnel resources continue to be devoted to rescue and rehabilitation of stranded animals. For example, the direct costs for a successful, 14-mo rehabilitation and subsequent release of one gray whale (*Eschrichtius robustus*) calf in California exceeded $350,000 (Andrews et al., 2001). The total costs for a successful 7.5-mo rehabilitation and subsequent release of one Risso's dolphin (*Grampus griseus*) in New York were approximately $400,000 (DiGiovanni, pers. comm., 2006). The high costs and apparent limited success in rehabilitating stranded cetaceans are likely due to the great physiological stresses incurred by these animals during stranding, and the subsequent effects of this stress on health. In contrast, release of cetaceans that did not strand, but were returned to the wild after long periods under human care has been successful (Gales & Waples, 1993; Wells et al., 1998, 1999); these animals did not undergo the stress and health effects of stranding, however.

Herein, we summarize the outcomes of rescue and rehabilitation of 70 live-stranded odontocetes in central and northern California from 1977 through 2002 to evaluate the success of those efforts and to provide some guidance for continuing them. We also summarize the results of studies of the health and disease of live-stranded animals, subsequent causes of death, and the results of post-release monitoring of a few that were rehabilitated successfully. Because dead-stranded odontocetes in California are responded to by different organizations, their data are not included in this analysis.

Materials and Methods

Odontocetes that stranded alive along the central California coast from Guadalupe Dunes State Beach (Santa Barbara County) north to Fort Bragg (Mendocino County) were rescued by The Marine Mammal Center (TMMC, Sausalito, CA, USA). Due to the expansive response area and the reliance on volunteers, TMMC protocol dictates that live-stranded odontocetes be removed from the beach by volunteers and transported to a rehabilitation facility where they can be evaluated by a veterinarian. A harbor porpoise (*Phocoena phocoena*) that stranded in Del Norte County was rescued by the Northcoast Marine Mammal Center and then transported to TMMC. Depending on available facilities, animals were transported either to TMMC, the University of California at Santa Cruz Long Marine Laboratory, Marine World in Vallejo, or SeaWorld in San Diego for medical treatment. The most severely impaired animals were humanely euthanized by a veterinarian; rehabilitation was attempted on the remaining cases. Medical records were kept for each rehabilitating animal, and these records included stranding information, morphometrics (used for determining age), clinical observations, hematology, serum biochemistry, microbiology results, and food and medicines administered (cf. McBain, 2001; Townsend & Gage, 2001).

Virus neutralization tests for antibodies to morbilliviruses (canine distemper virus, phocine distemper virus, porpoise morbilliviris, and dolphin morbillivirus) were performed as described by Duignan et al. (1994) on serum samples from all live-stranded animals since 1995. Postmortem examinations were performed on all animals that died, and representative samples of tissues were fixed in 10% buffered formalin for histological examination (Rowles et al., 2001). Causes of death were determined based on a combination of clinical signs, gross postmortem examination, and histological results. Neonatal animals (age determined by presence of fetal folds, rostral hairs, umbilical stump, and lack of teeth) were deemed to have died as a consequence of maternal separation, unless significant lesions were detected.

Two common dolphins (*Delphinus delphis* sp.) and one harbor porpoise (TMMC field number C147) were equipped with satellite-linked radio-transmitters just prior to their release to monitor their post-release survival. The expected minimum transmission for the former two transmitters was one month. The telemetry tag system deployed on the porpoise consisted of a pair of tags mounted on the sides of the dorsal fin. This pair of tags included a satellite transmitter (Wildlife Computers SPOT 2, Redmond, WA) and a VHF transmitter (Advanced Telemetry Systems [ATS], Inc., Isanti, MN, Model 201, with two AA batteries). The satellite transmitter was designed for placement on the left side of the dorsal fin, and the VHF transmitter was designed for placement on the right side. The satellite transmitter was programmed to transmit for 4 h each morning, with no greater than 150 transmissions per day, on 14 d each month, allowing an expected service life of 9 mo. The VHF transmitter ran continuously at 150 pulses per min., producing an expected service life of 330 d.

The pair of tags was attached with four, 6.3-mm diameter titanium pins (CP GR2), threaded on both ends to accept a 6-mm nut (Hanson, 2001). The tags were positioned on the fin, the approximate sites of the attachment pin holes were marked with a felt-tip marker, and the tags were removed. Each pin attachment site was injected with a local anesthetic. The tags were then repositioned and an 18-gauge needle was inserted through each pin hole and into the fin tissue. This procedure generally allowed for the detection of major blood trunks prior to boring the pin holes. The primary purpose of these needles was to serve as pin alignment guides after the tags had been removed. Attachment pin holes were made with a tool similar to a laboratory cork borer, which had been cold sterilized. A pin of appropriate length was inserted in the holes and the tags positioned on the pins. The tags were secured with a high carbon nut next to a stainless steel flat washer, which acted as a corrodible link to ensure that the package freed itself from the animal after the batteries were exhausted. The tightness of the nuts securing the package was adjusted to minimize any pressure of the saddle on the dorsal fin tissue.

The two common dolphins were released in southern California on 25 August 1994 and 1 March 1995 (Stewart & Yochem, 1998) and harbor porpoise C147 was released on 4 November 2001 in coastal waters west of San Francisco Bay (37º 47.6' N, 122º 34.6' W). This area was chosen for release because there were areas of high porpoise density north and south of the San Francisco Bay entrance (Chivers, pers. comm., 2001).

From 7 November to 7 December 2001, C147 was located from shore using a VHF radio-receiver (R4000, ATS) and a 3-element, collapsible antenna (AF Antonics, Inc., Urbana, IL). Once located, durations of dives and surface intervals were recorded for approximately 30 min. Satellite data were received via Service ARGOS, Inc., and best daily positions based on provided location classes (LC) were plotted using *ArcGIS 9* (ESRI, Redlands, CA) and *Hawth's Tools*, an extension for *ArcGIS*. Positions were averaged for days during which there was more than one LC of greatest value. Best daily positions were used to compute mean rate of travel and distance from shore using methods described in other studies (Read & Westgate, 1997; Westgate et al., 1998). Additionally, best daily positions were examined with respect to bathymetry (Etopo 2' gridded elevation data, Alaska Fisheries Science Center, Seattle, WA).

Results

From 1977 through 2002, 70 live-stranded odontocetes of 13 species were evaluated and removed by stranding network members from mainland beaches from northern Santa Barbara County in central California to Del Norte County

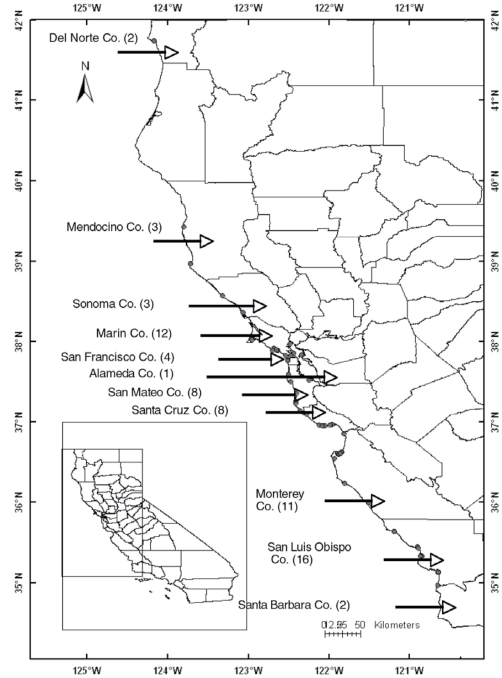

Figure 1. Map of known live odontocete strandings in central and northern California, 1977-2002; dots indicate individual strandings; Co. = county of stranding.

in northern California (Figure 1; Table 1). Known responses resulting in removing the live-stranded animal from the beach averaged three per year (SD = 2.3), although they varied substantially among years (Figure 2). Strandings occurred throughout the year, with peaks in May, July, and October (Figure 3). Adults stranded most often (45.7%), followed by calves (28.6%; Table 1). Overall, more than twice as many males stranded (65.7%) than females (30.0%; Table 1). With the exception of Dall's porpoise (*Phocoenoides dalli*), more males stranded than females within each species. A chi-square test on the variation by sex of strandings reveals that this difference was statistically significant ($\chi^2 = 8.6$, $df = 2$, $p = 0.003$, Yates correction applied).

Thirty-five animals (50.0%) died on the beach or within the first 24 h of rescue. Eighteen of those died on the beach before medical treatment, three were euthanized by injection on the beach, five died during transport, and nine died shortly after entering a rehabilitation facility. Twelve others (17.1%) died within the first week of rehabilitation, six (8.6%) died within a month, and five animals (7.1%) survived longer than one month, but subsequently died. One of the latter, a female Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), died of injuries obtained during rehabilitation when another

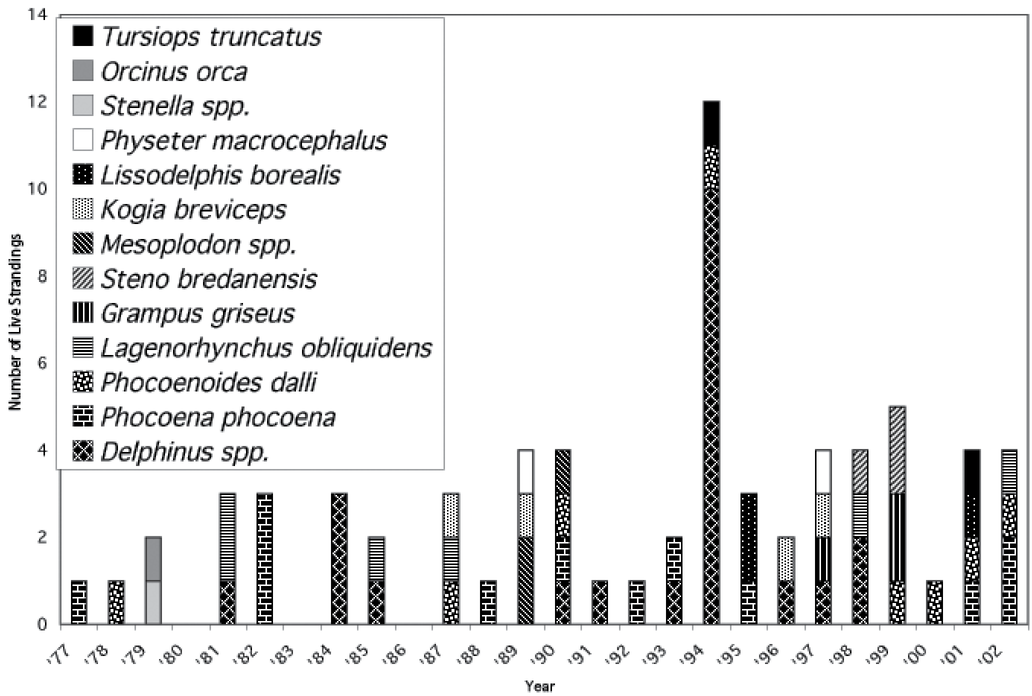

Figure 2. Number of live strandings of odontocetes by species in central and northern California by year, 1977-2002

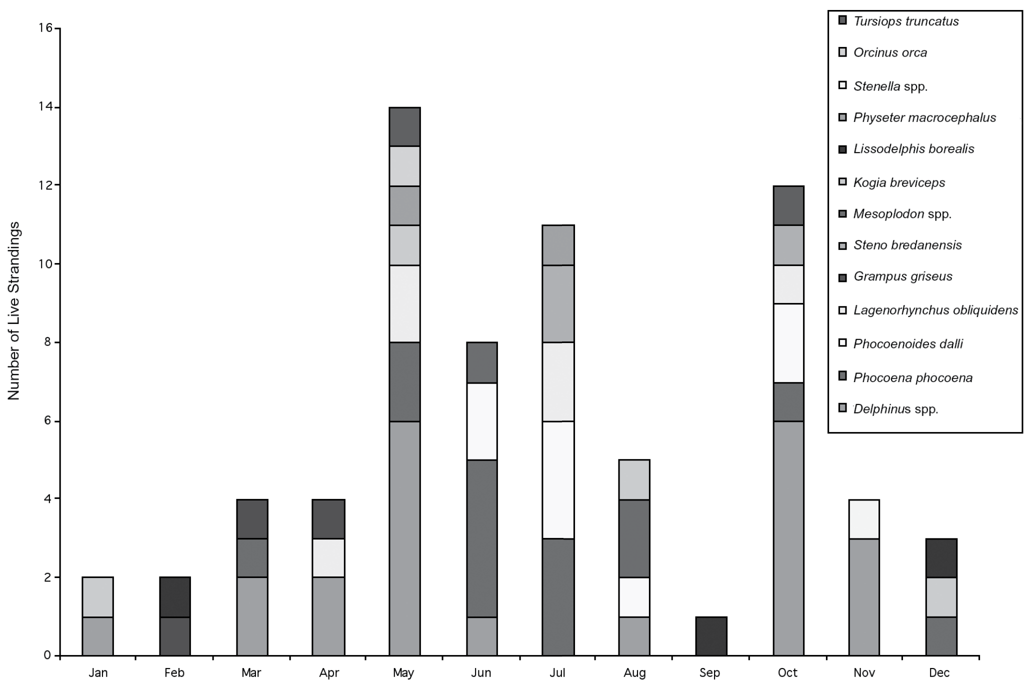

Figure 3. Number of live strandings of odontocetes by species in central and northern California by month, 1977-2002

Table 1. Age, sex, and disposition of known live-stranded odontocetes in central and northern California, 1977-2002

	Species														
	Ds	*Pp*	*Pd*	*Lo*	*Gg*	*Sb*	*Ms*	*Kb*	*Lb*	*Pm*	*Sc*	*Oo*	*Tt*	Total	%
n	22	12	8	6	3	3	3	4	3	2	1	1	2	70	
Sex															
Male	14	8	2	6	2	3	3	4	2	1	1	0	0	46	66
Female	8	4	6	0	1	0	0	0	1	0	0	1	0	21	30
Unknown	0	0	0	0	0	0	0	0	0	1	0	0	2	3	4
Age class															
Adult	16	3	1	3	1	3	0	2	0	0	1	0	2	32	46
Subadult	1	2	1	2	0	0	0	1	0	0	0	0	0	7	10
Juvenile	2	0	2	1	0	0	0	0	1	0	0	0	0	6	9
Yearling	1	0	1	0	0	0	0	0	0	0	0	1	0	3	4
Calf	1	7	3	0	2	0	3	1	1	2	0	0	0	20	29
Unknown	1	0	0	0	0	0	0	0	1	0	0	0	0	2	3
Disposition															
Died on beach	6	4	3	2	0	0	0	2	0	1	0	0	0	18	26
Euthanized	0	0	1	0	1	1	0	0	0	0	0	0	0	3	4
Died during transport	3	1	0	0	0	0	0	1	0	0	0	0	0	5	7
Died 0-24 h	3	2	0	1	1	1	0	0	1	0	0	0	0	9	13
Died 24-48 h	3	0	1	0	0	0	0	0	1	0	1	0	0	6	9
Died 48-72 h	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Died 72 h-1 wk	1	1	1	0	1	0	1	0	0	1	0	0	0	6	9
Died 1-3 wks	0	2	1	1	0	0	1	0	0	0	0	1	0	6	9
Died 3-4 wks	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
Died >1 mo	1	1	0	0	0	1	0	1	1	0	0	0	0	5	7
Released	4	1	0	0	0	0	0	0	0	0	0	0	0	5	7
Relocated	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3
Placed in captivity	1	0	0	2	0	0	0	0	0	0	0	0	0	3	4

Species Key:
Ds = *Delphinus* spp.
Pp = *Phocoena phocoena*
Pd = *Phocoenoides dalli*
Lo = *Lagenorhynchus obliquidens*
Gg = *Grampus griseus*
Sb = *Steno bredanensis*
Ms = *Mesoplodon* spp.
Kb = *Kogia breviceps*
Lb = *Lissodelphis borealis*
Pm = *Physeter macrocephalus*
Sc = *Stenella coeruleoalba*
Oo = *Orcinus orca*
Tt = *Tursiops truncatus*

rehabilitating animal chased it out of the pool. Another was a female harbor porpoise calf that stranded 21 October 1990. This animal was rehabilitated and released on 5 April 1991, but subsequently restranded 8 April 1991 and died in rehabilitation on 2 May 1991. Three animals (4.3%; one common dolphin and two Pacific white-sided dolphins) were unfit for release and consequently were transferred to marine aquaria for permanent residence. Two (2.9%) bottlenose dolphins (*Tursiops truncatus*) were relocated and released after stranding in separate years on a mudflat in Morro Bay, California. These animals were not tagged and were never resighted. Five animals (7.1%), including one harbor porpoise and four common dolphins, were rehabilitated and then released back into coastal California waters. Animals were deemed fit for release after a veterinary evaluation of blood values, nutritional status, and behavior, including feeding behavior, swimming ability, and other factors.

Clinical Results

Clinical signs were described for 53 of the stranded animals. Many of the signs observed were nonspecific, however, and thus might be due to the trauma and physiologic effects of stranding events rather than to causes of stranding. These included tachypnea, tachycardia, lethargy or weakness, listing, disorientation, skin wounds, scoliosis or kyphosis, and corneal lesions. Common diagnostic procedures performed on stranded animals included complete blood counts (CBC), serum biochemistry analysis, blood gas analysis, stomach aspirate cytology, blowhole and fecal cultures, radiographs, sonography, and gastroscopy, as described by McBain (2001). Abnormalities were noted on CBC and serum biochemistry analyses obtained from 31 of the stranded animals. Common abnormalities included increased serum aspartate aminotransferase (AST), increased blood urea nitrogen (BUN), hypernatremia, and hyperchloremia. Hypernatremia and hyperchloremia are also nonspecific and may have been related to muscle damage and dehydration after stranding. Radiographs from a Dall's porpoise revealed unilateral pneumothorax thought to be the result of blunt trauma. Ante-mortem diagnosis of the cause of stranding rarely was obtained from the remaining live-stranded cetaceans.

Postmortem Results

Despite thorough postmortem examination and histological examination of tissues, the majority of deaths remain unexplained, especially those of common dolphins (Table 2). Pneumonia frequently was associated with mortality in many species and was a common finding in animals that died from any cause (Table 3). Type, duration, and severity of pneumonic lesions varied and included interstitial pneumonia, suppurative bronchopneumonia, and aspiration pneumonia. Organisms isolated from cases of suppurative pneumonia included *Aspergillus fumigatus*, *Enterococcus faecium*, *E. zymogenes*, *Pseudomonas putrefaciens*, *P. aeruginosa*, *Flavobacterium odoratum*, *Streptococcus bovis*, *Aeromonas sobria*, and *Clostridium* spp. Two Pacific white-sided dolphins died of encephalitis, which in one case was associated with systemic toxoplasmosis, whereas the cause was not identified for the other. In no cases were viral inclusion bodies detected in lung, lymph node, or brain, and all serology for morbillivirus exposure was negative. Three neonatal Dall's porpoises died from blunt trauma. Lesions included subcutaneous hemorrhages, fractured skulls, and pulmonary hemorrhages.

Myocardial degeneration and contraction band necrosis were observed in a variety of species and varied in severity (Table 3). Nephrosis was observed in four animals and was associated with proteinuria or myoglobinuria. Ulcerative glossitis and esophagitis were observed in most animals that had been tube-fed in rehabilitation. Four other animals that had been in rehabilitation more than a week had rhabdomyolysis and one had scoliosis. One Pacific white-sided dolphin and one common dolphin had thyroid follicular adenomas, one rough-toothed dolphin had nodular follicular hyperplasia of the thyroid, and one Pacific white-sided dolphin had adrenal cortical hyperplasia. One male rough-toothed dolphin had a suppurative epididymitis, which was negative on immunohistochemistry for *Brucella* spp.

Telemetry Results

One of the common dolphins was tracked for 3 d before radio contact was lost within a few km of the release site. The other common dolphin was tracked for 31 d. It immediately moved offshore into deep water and began moving north. It traveled about 400 km within 5 d of release, then covered another 250 km, and then continued traveling north until radio contact was lost when the dolphin was at the northern reach of Monterey Bay.

C147 was radio-tracked from shore from 7 November through 7 December 2001. Ninety-five percent of observations were conducted between 0800 and 1400 h. The distribution of dive durations (range = 1 to 191 seconds [s], n = 1,032 dives), which were recorded over 8.79 h of monitoring time, was bimodal with 887 dives between 1 and 29 s ($\bar{x}$ = 8 s, SD = 5), and 245 dives between 30 and 191 s ($\bar{x}$ = 97 s, SD = 36). Five percent of the time was spent at the surface, with surface intervals lasting 1 to 3 s.

C147 was satellite-tracked from 4 November 2001 until 9 April 2002. A total of 314 positions was received (5% = LC3, 18% = LC2, 25% = LC1, 18% = LC0, 19% = LC-1, 15%

Table 2. Causes of death of live-stranded odontocetes in central and northern California, 1977-2002

	Species												
	Ds	*Pp*	*Pd*	*Lo*	*Gg*	*Sb*	*Ms*	*Kb*	*Lb*	*Pm*	*Sc*	*Oo*	Total
n	17	11	8	4	3	3	3	4	3	2	1	1	60
Unknown	11	1	3	1	0	0	0	2	2	1	1	1	23
Maternal separation	0	5	1	0	0	0	0	0	0	1	0	0	7
Pneumonia	3	3	1	0	1	3	3	2	0	0	0	0	16
Septicemia	3	0	0	1	2	0	0	0	0	0	0	0	6
Trauma	0	1	3	0	0	0	0	0	1	0	0	0	5
Encephalitis	0	1	0	2*	0	0	0	0	0	0	0	0	3

*One of these died of Toxoplasmosis.

Table 3. Lesions observed postmortem in live-stranded odontocetes examined histologically, 1977-2002; *n* = number of animals of each species examined histologically.

	Species									
	Ds	*Pp*	*Pd*	*Lo*	*Gg*	*Sb*	*Ms*	*Kb*	*Lb*	*Sc*
Type of lesion *n*	12	5	7	5	2	3	3	2	2	1
Skin wounds	1 (rostrum)	0	1	0	0	0	0	0	0	0
Ulcerative dermatitis	2	1	1	1	1	1	2	0	0	0
Hypodermal parasitic cysts	6	0	2	0	0	0	0	0	0	0
Ulcerative glossitis/ esophagitis	2	1	1	1	1	0	1	0	0	1
Gastritis	1	1	1	1	1	0	1	0	0	0
Enteritis	1	1	1	0	1	0	0	0	0	0
Colitis	1	1	0	0	0	0	0	0	0	0
Hepatosis	4	1	2	2	1	0	0	0	0	0
Disseminated intravascular coagulation	0	0	0	0	1	0	1	0	0	0
Pneumonia	5	3	4	1	1	3	2	2	0	0
Pleuritis	0	0	0	0	0	0	1	1	0	0
Myocardial degeneration	1	1	2	1	2	2	0	1	1	0
Rhabdomyolysis	0	0	2	0	0	1	0	1	0	0
Scoliosis	0	0	1	0	0	0	0	0	0	0
Lymphadenitis	2	1	0	1	0	0	1	1	0	0
Lymphoid depletion	0	0	0	0	0	0	0	0	0	0
Nephrosis	0	1	0	1	0	1	1	0	0	0
Meningitis/Encephalitis	1	1	0	2	0	0	1	0	0	0
Abscess	1 (hepatic)	2 (retroperitoneal, pulmonary)	0	0	0	0	0	1 (renal)	0	0
Fracture	0	1 (ribs)	2 (rostrum)	0	0	0	0	0	1 (rostrum)	0

= LC-2). With the exception of a few data points, most positions occurred over the continental shelf (water depths ≤ 100 m) until the porpoise traveled south to Monterey Bay (Figure 4). The porpoise traveled an average of 9.1 km from shore (SD = 6.2, range = 2.2-2.9, *n* = 30 best daily positions) from San Francisco Bay to Monterey Bay. Movements thereafter occurred in areas that were much deeper (> 1,100 m) until the porpoise briefly traveled east back into shallow waters (300 to 400 m) near Point Conception. The porpoise then returned to areas offshore and traveled south into waters off Baja California, Mexico, approximately 788 km from the release location. Mean rate of travel during the tracking period was 0.6 ± 0.6 km/h and mean distance from shore was 74.0 km (SD = 82.8 km, range = 2.2-373.1 km, *n* = 67 best daily positions).

Discussion

Common dolphin, harbor porpoise, Dall's porpoise, and Pacific white-sided dolphin were the most common odontocete species to strand along the central and northern California coast. All four species are commonly found in California waters (e.g., Carretta et al., 2002), and thus would be expected to strand occasionally. The three rough-toothed dolphin strandings (one in 1998, two in 1999) are interesting because this species generally lives in tropical and warm temperate waters (Reeves et al., 2002). The strandings in northern California are some of the most northern ones reported for this species in the eastern Pacific (cf. Leatherwood et al., 1988). Both of the sperm whale (*Physeter macrocephalus*) strandings were calves. The first swam into San Francisco Bay in 1989 and had curvature of the spine, possibly due to a boat strike. The second stranded live at Pajaro Dunes in 1997, on the border of Santa Cruz and Monterey Counties, but died before a rescue team arrived.

There was an unexplained occurrence of ten common dolphin strandings in 1994. Domoic acid toxicity is now well-recognized as a cause of strandings with neurological disease both in California sea lions (*Zalophus californianus*) and

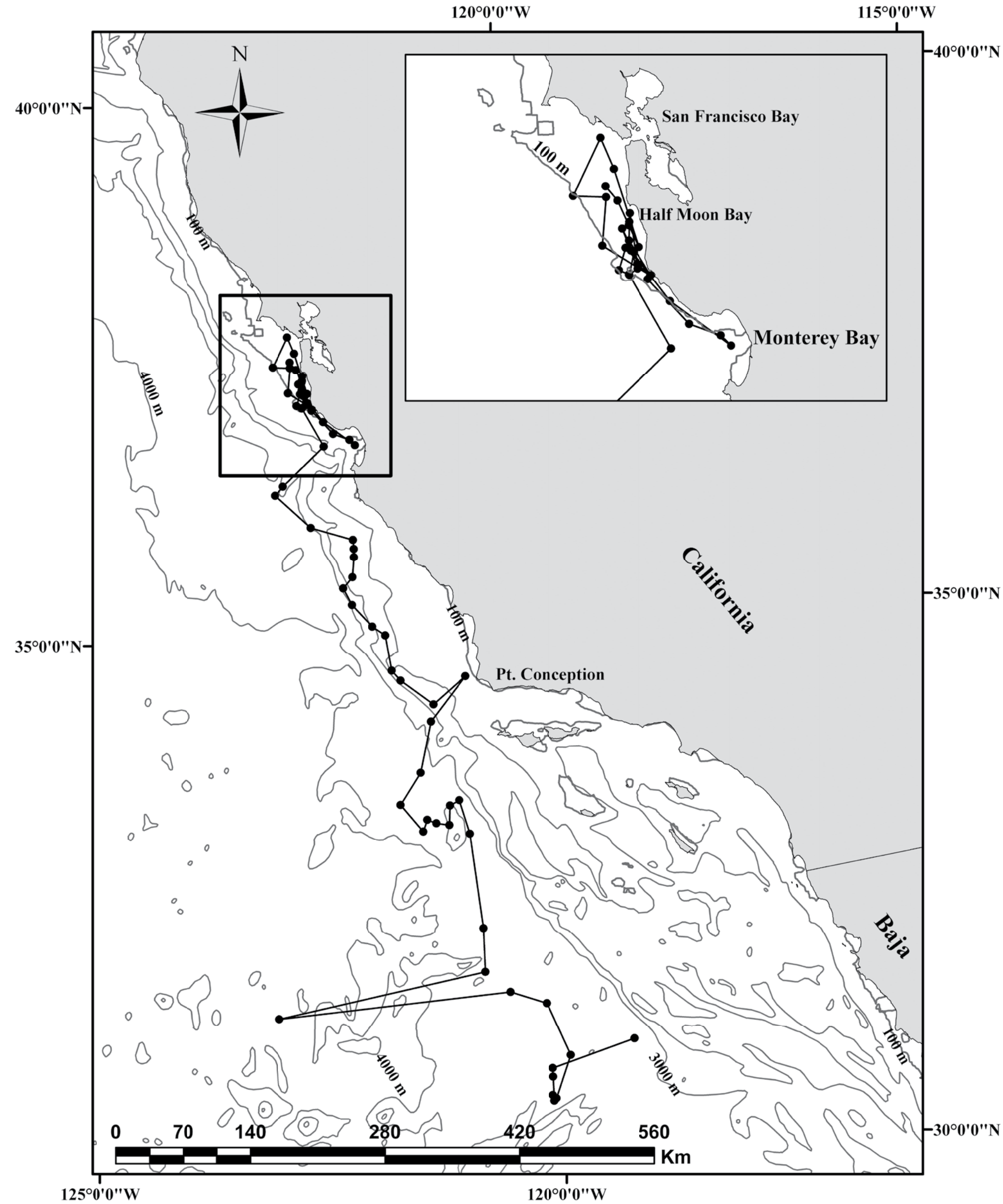

Figure 4. Best daily positions received from a rehabilitated, satellite-tagged harbor porpoise (C147), released west of San Francisco Bay, California

in common dolphins (Gulland, 2000; Scholin et al., 2000; Gulland et al., 2002; Berman et al., 2003); domoic acid toxicity was not tested for prior to its first recognition in marine mammals in 1998, however, so it is possible that the common dolphin strandings during 1994 were associated with domoic acid exposure. Four of the ten dolphins survived to be released, suggesting that it may be possible to rehabilitate these animals.

The greater number of stranded males may reflect sex differences in the social structure and foraging behavior of these cetacean species. Alternatively, male animals may be more susceptible to the causes of stranding, such as infectious disease and trauma, than females. In many mammals, males have been shown to be more susceptible to infection (Weinstein et al., 1984), and male California sea lions stranded more often due to human interaction than females (Goldstein et al., 1999).

Clinical signs and results of CBC and serum biochemistry analyses for stranded cetaceans were nonspecific, and common abnormalities could have been the result of stranding, rather than the cause. Nevertheless, they may have been important factors of mortality. Moreover, they suggest that current methods for handling, transporting, and stabilizing stranded cetaceans might be improved. Ante-mortem diagnosis was not possible for the majority of stranded animals, and this was likely due to a number of factors. Many of the animals died shortly after stranding, not allowing enough time for adequate diagnostic tests.

The cause of death of many of the live-stranded dolphins was unclear, despite thorough postmortem examination. A recent study of the pathology of stranded odontocetes indicated that contraction band necrosis of the cardiac muscle was a common lesion observed in cetaceans that died following stranding (Turnbull & Cowan, 1998). Detection of this lesion requires careful histological examination of the myocardium by an experienced pathologist, so the lesion may have been missed during earlier necropsies. This lesion is thought to result from a surge in plasma catecholamine levels following stress of stranding, as high serum catecholamine levels cause cardiac muscle damage in dogs and humans (Lee et al., 1980; Rona, 1985; Todd et al., 1985). There is a correlation between catecholamine levels in blood and the extent of cardiac damage in humans (Karlsberg et al., 1981). Although some studies have investigated the effects of stress on plasma cortisol and hematological parameters in cetaceans (Thomson & Geraci, 1986), little is known about the changes in plasma catecholamine levels in cetaceans under various conditions (Thomas et al., 1990). Further studies on the levels of catecholamines in live-stranded dolphins are needed to determine the role of stress in mortality of these animals after stranding.

Antibodies to dolphin morbillivirus and morbillivirus RNA have been detected in common dolphins off California, although no characteristic disease or viral inclusions were observed in these animals (Reidarson et al., 1998). To date, diseases associated with morbillivirus infection have not been documented in marine mammals off the Pacific coast of the United States, despite the recurrent outbreaks of canine distemper in terrestrial carnivores and domestic dogs (Williams, 2001) and interactions between marine mammals and terrestrial carnivores (Steiger et al., 1989). This lack of morbillivirus-associated disease in cetaceans stranding along the west coast of the U.S. contrasts dramatically with the prevalence of morbillivirus-associated mortality of cetaceans on the east coast of the U.S., and, thus, warrants further investigation (Kennedy-Stoskopf, 2001).

The cause of the traumatic injuries to Dall's porpoise calves could not be determined from the postmortem examination of stranded animals, although the lesions are similar to those described in harbor porpoise calves in Scotland believed to have been attacked by bottlenose dolphins (Ross & Wilson, 1996).

The post-release data collected for the tagged harbor porpoise (C147) present a unique case study. Harbor porpoises, which are fairly cryptic animals, typically are found in bays and exposed habitats along the coasts of California, Oregon, and Washington (Barlow, 1988). Although density estimates of harbor porpoises vary geographically and temporally, movements along the U.S. west coast generally appear limited to a narrow coastal band in California (Forney, 1995), and surveys conducted by the National Marine Fisheries Service (NMFS) indicated that the majority of harbor porpoises were found between the coast and the 92-m isobath (Barlow, 1988). Initially after release, the behavior of C147 appeared fairly consistent with that described in the literature for the harbor porpoise. Most telemetry fixes were within the 100-m isobath, and the mean rate of travel was slightly less than the range reported for other harbor porpoises tagged with satellite transmitters (Read & Westgate, 1997). In contrast to east coast stocks, genetic analyses have revealed that movements of harbor porpoises off the west coast are restricted (Rosel et al., 1995). The movements appeared unusual after C147 traveled into southern waters, however. Harbor porpoises generally are not observed south of Point Conception, California (Carretta et al., 2002), but the last 2 mo of transmissions received for C147 were from locations south of this area.

The short surface intervals exhibited by C147 indicated an animal surfacing and submerging in a continuous motion, and these are consistent with the "rolls" described by Read & Gaskin (1985). The amount of time that C147 spent at the surface was less compared with wild-caught, radio-tagged harbor porpoises from the Bay of Fundy, Canada (Read & Gaskin, 1985), and implies that C147 spent less time resting at the surface during the times that we monitored his activity.

Kastelein et al. (1997) speculated that if rehabilitation is unsuccessful, released porpoises probably die within weeks. One of the common dolphins was tracked for only a few days after release. Its behavior just after release appeared to be erratic, and it moved only a few km during the few days before radio contact was lost. The other dolphin moved a considerable distance north during the first 31 d after release. Neither of these dolphins appeared to immediately join the group of common dolphins that was nearby when they were released. The tracking data were not adequate to determine whether radio contact ended because the transmitters failed or shed versus the animals died or were killed by predators. The harbor porpoise survived for at least 5 mo after release, although the fact that the full 9-mo service life of the transmitter was not attained suggests that either the tag or attachment failed or the animal did not survive beyond 5 mo. If the animal became ill again, this may have contributed to the apparent disorientation that occurred when the porpoise was beyond its presumed home range. Because data are limited for free-ranging harbor porpoises in this area, it was difficult to assess whether the behavior of C147 during the later months of tracking was normal. For example, as telemetry technology and tag attachments improve, researchers are finding that home ranges of harbor porpoises off the east coast are greater than estimated for past studies (Read & Westgate, 1997). Moreover, a harbor porpoise rehabilitated at the National Aquarium in Baltimore and released offshore Ocean City Inlet, Maryland, moved offshore into water depths greater than 1,800 m immediately after release and mean distance from shore during the first 2 wks was 79.8 ± 49.9 km (Westgate et al., 1998). This may not be an adequate comparison, however, as behavior of rehabilitated individuals may not be indicative of behavior occurring in wild populations.

Overall, survival and release of rehabilitated odontocetes was low (5/68, 7.3%) over the 25 years of data we reviewed, with most mortality occurring within 24 h of stranding. Survival was greater for animals that were still alive after 1 wk in rehabilitation. This pattern of mortality and low survival rate should be considered when designing facilities for cetacean rehabilitation. Because the stress of stranding is a complicating factor in diagnosis and treatment, stress minimization should be a priority when developing husbandry procedures and designing facilities for cetacean rehabilitation.

There are few data on movements and survival of released, rehabilitated cetaceans. It is possible that mortality of rehabilitated animals may occur shortly after release due to stresses of transport and release. Satellite- and radio-telemetry are useful tools for assessing post-release behavior and survival. Thus, increased use of tags and telemetry is essential for post-release monitoring and evaluation of rehabilitation success.

Stranded cetaceans provide opportunities to study species first-hand, to try new rehabilitation techniques, and to learn more about cetacean behavior, physiology, and disease. Although the number surviving is small, stranded cetaceans receive a great deal of public attention. Individual animals as well as mass strandings can be used to generate interest in strandings in general. Thus, the decision as to whether or not to rehabilitate a stranded cetacean is a complex one. The data provided in this paper may help guide decisionmakers by providing information on the likelihood of survival using current techniques, to be weighed with other factors such as public opinion, education and outreach, conservation value, research, resource limitation, as well as animal welfare.

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