Marine Pollution Bulletin 58 (2009) 1045–1051

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001–2005

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ARTICLE INFO

Keywords:
Entanglement
Fishing gear
Marie debris
Marine mammals
Seabirds
West Coast of the United States

ABSTRACT

Entanglement records for seabirds and marine mammals were investigated for the period 2001–2005. The entanglement records were extracted from databases maintained by seven organizations operating along the west coast of the United States of America. Their programmes included beach monitoring surveys, rescue and rehabilitation and regional pinniped censuses. Records of 454 entanglements were documented in live animals and in carcasses for 31 bird species and nine marine mammal species. The most frequently entangled species were Common Murres, Western Gulls and California sea lions. The entanglement materials identified were primarily fishing related. Entanglements were recorded every year suggesting that although the incidence level differs annually, entanglement is a persistent problem. It is recommended that each programme records details in standardized categories to determine entanglement material sources. Numbers of entanglements observed during these surveys are likely to be a conservative view of the actual entanglement rate taking place at sea.

1. Introduction

One of the most visible impacts of pollution in the ocean is the entanglement of marine life. Entanglement is 'an interaction between marine life and entanglement material whereby the loops and openings of various types of anthropogenic debris entangle animal appendages or entrap animals' (Laist, 1997). Entanglements can result in death or injury. Observations of scarred individuals indicate that not all entangled animals die from infection and secondary complications (Hanni and Pyle, 2000).

The materials observed in entanglements are active fishing gear, discarded fishing gear and general marine debris such as balloons and six-pack drink holders. Other types of fisheries interactions include by-catch and ghost-fishing. Plastic ingestion is a further form of interaction with marine debris that can cause injury and death of individual animals of many species.

Documentation of entangled animals can take place at sea but sightings are often by chance; hence systematic entanglement studies tend to be made from land-based observations, where animals strand on beaches or are viewed as visibly entangled during population surveys (Laist, 1997). Entanglement studies amongst pinniped populations have resulted in a calculation of rates of entanglement which can be examined to determine any significant demographic effects (Fowler, 1987; Stewart and Yochem, 1987; Henderson, 2001; Page et al., 2004; Boran et al., 2006). A review of entanglements by Laist (1997) revealed records of 135 marine species documented as entangled globally.

This study presents an analysis of marine mammals and seabirds recorded as entangled by seven organizations along the west coast of the United States from 2001 to 2005. The range of species recorded as entangled is detailed, rates of entanglement are

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doi:10.1016/j.marpolbul.2009.02.006

calculated and the materials involved in the entanglements are analyzed where possible. Data on California sea lions (*Zalophus californianus*) from one of the organizations are also investigated by sex and age class. The results are discussed and recommendations made to refine and standardize data collection to improve the ability to share and exchange data and to aid future monitoring and analysis of entanglements.

2. Methodology

Data were collated from seven organizations that conduct land-based scientific programmes along the west coast of the United States (Table 1, Fig. 1). During data collection, by these organizations, entanglements were recorded as incidental data since the primary purpose of each programme was either, beach monitoring survey, rescue and rehabilitation or regional pinniped censuses. Entanglements logged by each organization were recorded in a different way and the frequency of survey also varied.

The beach monitoring programmes were Beach Watch, Coastal Ocean Marine Mammal and Bird Education and Research Surveys (BeachCOMBERS) and Coastal Observation and Seabird Survey Team (COASST). Each programme covered a distinct geographic region. COASST surveyed in Washington and Oregon and Beach Watch and BeachCOMBERS surveyed in California. Trained beach monitoring surveyors from each programme collected data on bird carcasses by surveying while zig zagging predetermined coastal areas on foot. The surveyors photographed and recorded any bird carcasses encountered either monthly or bi-monthly. Surveyors from Beach Watch and BeachCOMBERS also collected data on marine mammal carcasses.

Staff at the rescue and rehabilitation centres, The Marine Mammal Center (TMMC) and WildCare, recorded stranded animals that were admitted to the centres and animals that they were alerted to throughout the year. A stranded animal describes any animal left in a helpless position, such as a marine mammal that comes ashore ill, weak or simply lost (Geraci and Lounsbury, 2005). Both TMMC and WildCare covered regions within central California.

Each of the two regional pinniped census surveys was carried out by staff and trained volunteers using telescopes or binoculars. Point Reyes Bird Observatory (PRBO) surveyors conducted a weekly census throughout the year on the Southeast Farallon Islands; the islands are 28 miles west of San Francisco (37.7 N, 120 W). Records were made of 5 pinniped species; California sea lions, northern elephant seals (*Mirounga angustirostris*), steller sea lions (*Eumetopias jubatus*) northern fur seals (*Callorhinus ursinus*) and harbor seals (*Phoca vitulina*). Point Reyes National Seashore (PORE) surveyors monitored populations, within Point Reyes, more frequently during specific periods of the year, depending on the pupping and moulting seasons for harbor seals and northern elephant seals.

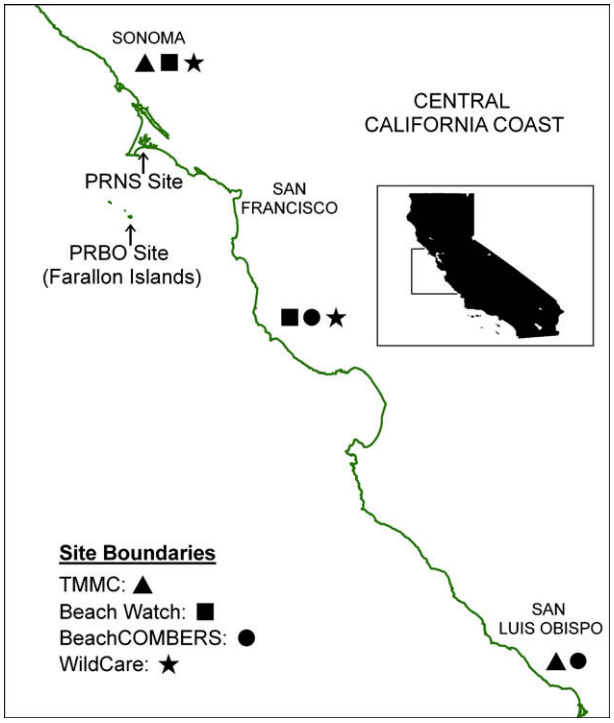

Fig. 1. Map of site boundaries for the six research programmes in central California. (The boundaries for the COASST programme are further north on the west coast, in Oregon and Washington.).

The data types extracted from each programme were data source (i.e., research programme), date, area (county), species, entanglement material and comments. Sex and age class data for California sea lions were also extracted from the TMMC database. Animals were identified to species level or the lowest possible tax-

Table 1
Research organizations and their research programmes grouped according to the primary objective of the programme.

Programme primary objective	Research organizations	Research programme	Entanglements recorded as	Data collection frequency	Data collected by
Beach monitoring survey	Gulf of the Farallones National Marine Sanctuary (GFNMS) & Farallones Marine Sanctuary Association (FMSA)	Beach Watch	Probable cause of death: plastic or fishing line	Monthly or bi-monthly	Scientists & trained volunteers
	Moss Landing Marine Laboratories (MLML), Monterey Bay National Marine Sanctuary (MBNMS)	BeachCOMBERS (core programme)	Probable cause of death: plastic or fishing net/line	Monthly or bi-monthly	Scientists & trained volunteers
	University of Washington & Olympic Coast National Marine Sanctuary (OCNMS)	COASST	Entangled Y or N? If Y details recorded in comments	Monthly or bi-monthly	Scientists & trained volunteers
Rescue and rehabilitation	The Marine Mammal Centre (TMMC)	The Marine Mammal Centre	Cause of stranding (human interaction)	Ongoing	Staff
	WildCare	WildCare	Cause of stranding	Ongoing	Staff
Pinniped census survey	Point Reyes Bird Observatory (PRBO)	Weekly pinniped surveys	Comments	Weekly	Scientists & trained volunteers
	Point Reyes National Seashore (PORE)	Annual pinniped surveys	Comments	Seasonal	Scientists & trained volunteers

Table 2
Definition of entanglement rate for each programme type.

Programme primary objective	Entanglement rate
Beach monitoring survey	% of entangled carcasses of all carcasses recorded
Rescue and rehabilitation	% of entangled animals of all animals stranded
Pinniped census survey PRBO	% of entangled animals of average weekly counts
Pinniped census survey PORE	% of entangled animals of maximum population count

onomic level. It is possible, although unlikely, that the same animal may have been recorded by more than one of the organizations. Incidences of entanglement, entanglement materials and rates of entanglements were calculated for each species and for each programme type. The definition of 'entanglement rate' varied depending on the primary objective of each research programme (Table 2).

Table 3
List of identified species with records of entanglement from seven data sources (2001–2005).

Common name	*n*	Entanglement material detail (where identified)
Birds		
American Coot	1	Fishing hook
American White Pelican	1	Fishing hook
Black-crowned Night Heron	1	Fishing line
Black-footed Albatross	1	Rope
Brandt's Cormorant	13	Fishing line, fishing hook, rope and metal
Brown Pelican	13	Fishing line, fishing hook, hook, mano & sinker
California Gull	10	Fishing line, fishing hook
Caspian Tern	1	Fishing hook
Clark's or Western Grebe	2	Fishing line
Common Loon	1	Fishing line
Common Merganser	1	Fishing line
Common Murre	52	Balloon, fishing line, fishing hook, fishing net, hook, line & sinker, plastic, salmon gear
Double-crested Cormorant	7	Fishing line, fishing hook
Glaucous-winged Gull	6	Fishing line, fishing hook, fishing net
Great Blue Heron	1	Fishing hook
Great Egret	1	Fishing line
Heerman's Gull	2	Fishing line, fishing hook
Lesser Scaup	1	Fishing hook
Northern Fulmar	3	Balloon & string, fishing line & sinker
Pacific Loon	1	
Pelagic Cormorant	6	Fishing line, fishing hook, line & sinker
Pied-billed Grebe	2	Fishing hook
Ring-billed Gull	1	Fishing hook
Rock Dove	1	Fishing hook
Short-tailed Shearwater	1	Fishing line
Snowy Egret	1	Fishing hook
Sooty Shearwater	11	Fishing line, fishing hook
Surf Scoter	1	Fishing line
Western Grebe	12	Fishing line, fishing hook, string
Western Gull	50	Fishing line, fishing line, hook & sinker
Western X Glaucous-winged Gull Hybrid	1	Fishing line
Marine mammals		
California sea lion	157	Fishing line, fishing line and hook, fishing hook, fishing net, packing strap, salmon flasher, other marine debris
Guadalupe fur seal	3	Fishing line, fishing net
Harbor seal	11	Fishing line, Rope, Plastic ring
Humpback whale	1	Crab pot and line
Northern elephant seal	22	Packing strap, Plastic ring
Northern fur seal	2	Fishing line and hooks, monofilament netting
Sea otter	1	Fishing line, fishing line and weight
Sperm whale	1	Monofilament netting
Steller sea lion	6	Salmon flasher
Other		
Leatherback turtle	1	Fishing line

3. Results

Records of 454 entanglements were extracted from the seven research programmes and of these, 411 records were identified to species level (Table 3). Entanglements occurred in 40 species; 31 bird and nine marine mammal species and in both live and dead animals.

Species recorded with entanglements of special note due to their status on the US endangered species list included a sea otter (*Enhydra lutris*), a leatherback turtle (*Dermochelys coriacea*), 3 Guadalupe fur seals (*Arctocephalus townsendi*), 3 Steller sea lions and three whales. A sperm whale (*Physeter macrocephalis*) and a humpback whale (*Megaptera novaeangliae*) were found as entangled carcasses. The third whale recorded entangled was a humpback whale that was disentangled successfully from crab pots and fishing line in 2005.

3.1. Beach monitoring programmes

The percentage of all bird carcasses recorded as entangled each year by the beach monitoring programmes ranged from 0.2% to 1.2% (Fig. 2). The average number of entangled birds encountered during each 100 km of beach surveyed was calculated. BeachCOMBER data had an average of 1.70 entangled birds in 100 km of beach surveyed. The average for Beach Watch was 0.71 every 100 km and for COASST was 0.52 every 100 km. The total bird carcass deposition for BeachCOMBERS was 250 carcasses per 100 km surveyed and for Beach Watch and COASST was 110 carcasses per 100 km surveyed. Common Murres (*Uria aalge*) and Western Gulls (*Larus occidentalis*) were the most frequently documented bird carcasses entangled. Entangled Common Murre accounted for 27.5% ($n = 153$) of all entanglement records for the beach monitoring programmes.

Five records of entangled marine mammal carcasses were recorded by Beach Watch. There were no records of marine mammal carcass entanglements in the BeachCOMBERS data and COASST surveyors did not note marine mammal carcasses.

Entanglement materials identified in bird carcasses for the beach monitoring surveys were primarily fishing related (91.7%) (Fig. 3).

3.2. Rescue and rehabilitation centers

At the rescue and rehabilitation centre for birds, WildCare, the most frequently entangled birds were Western Gulls and Common Murres. Entangled birds arrived at the centre as both live injured birds and carcasses. Fishing related entanglement materials were involved most frequently (85.7%) ($n = 84$). The type of fishing related material varied depending on the species entangled. In Western Gulls 81.3% ($n = 16$) of the fishing related entanglements involved fishing hooks, while in Common Murres, fishing line was involved in 50% ($n = 8$) of the fishing related incidences. WildCare also treats land mammals and in the past has treated domestic pets affected by entanglement in marine debris, for example fish hooks left on beaches have been swallowed by dogs.

At the rescue and rehabilitation centre for marine mammals, TMMC, the percentage of marine mammals recorded with entanglements was between 2.7% and 3.9% each year with an annual mean of 3.2% of animals admitted to the centre entangled or displaying evidence of entanglement (Fig. 4). One entangled animal was admitted for every 32.5 animals at the centre. The majority of these animals, 70.1% ($n = 97$), were released successfully once

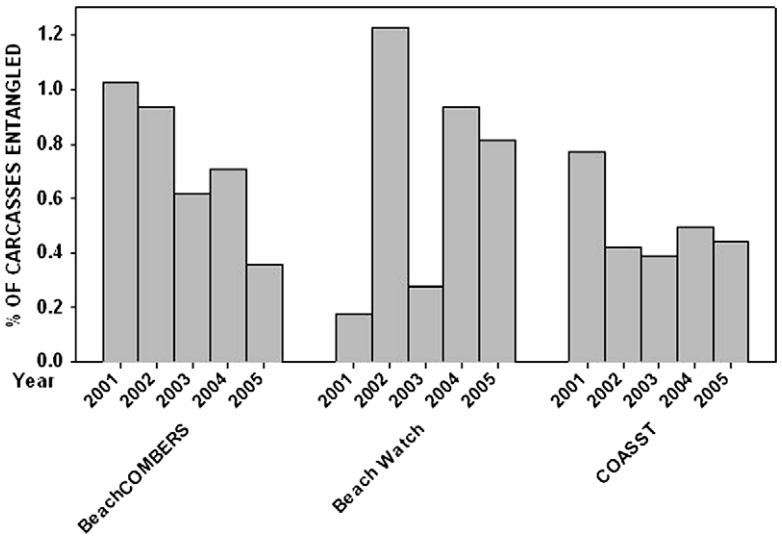

Fig. 2. Percentage of bird carcasses recorded as entangled each year by the beach monitoring programmes.

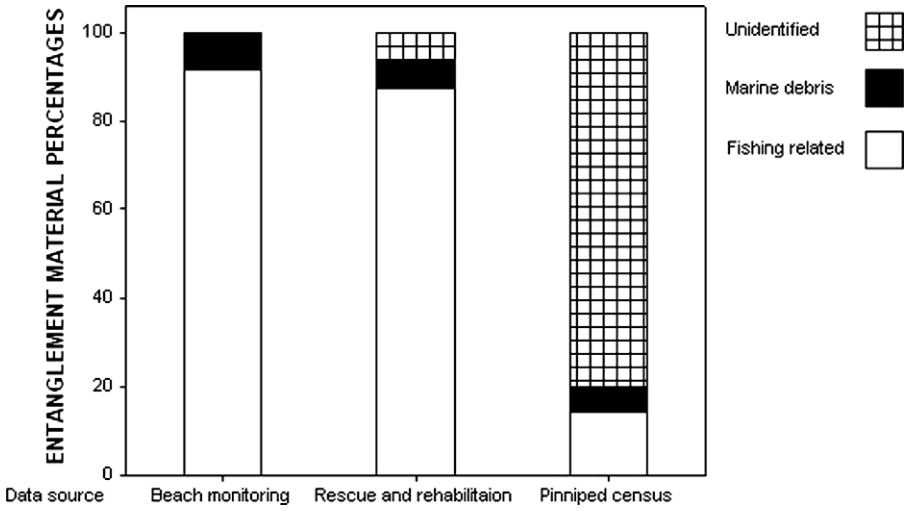

Fig. 3. Entanglement material percentages by research programme type.

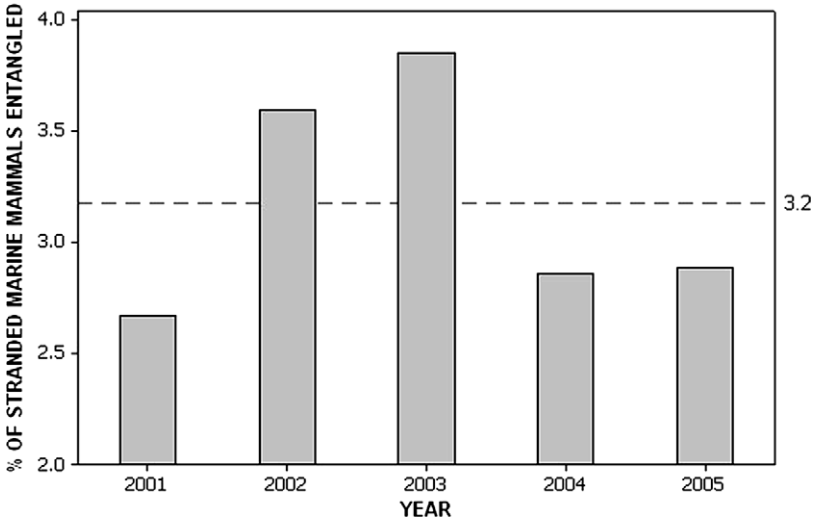

Fig. 4. Percentage of stranded marine mammals recorded as entangled each year by TMMC.

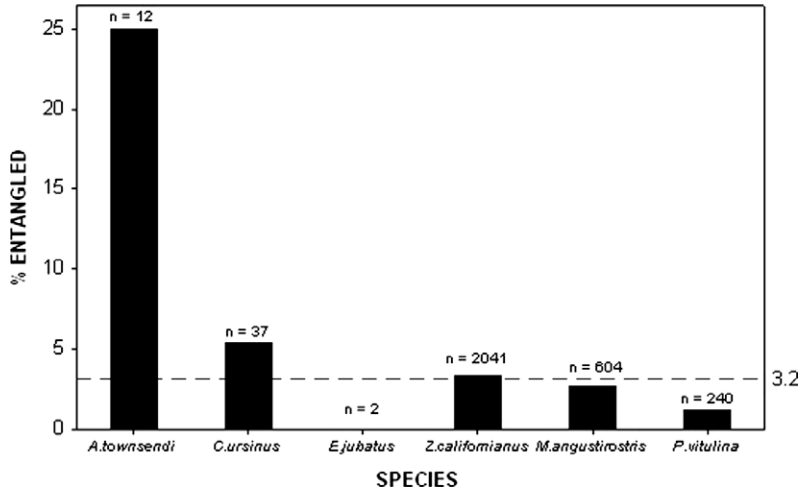

Fig. 5. Percentage of stranded pinnipeds entangled, by species, admitted to TMMC 2001–2005.

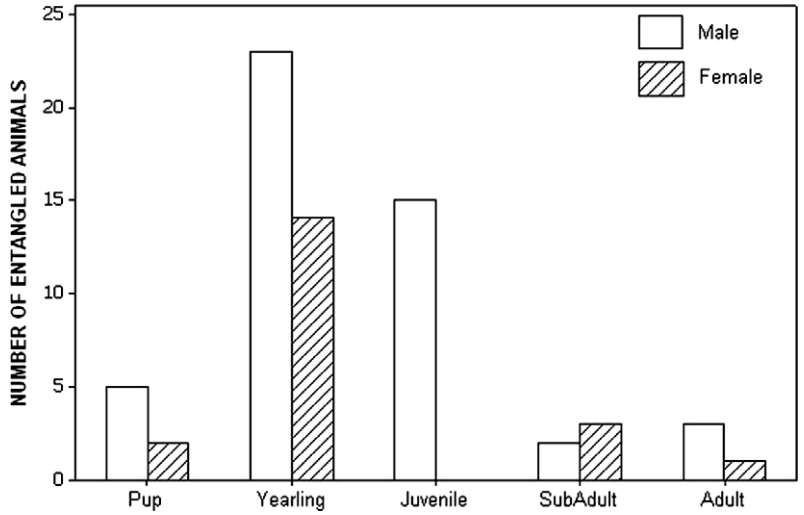

Fig. 6. Number and demographics of entangled *Zalophus californianus* at TMMC 2001–2005.

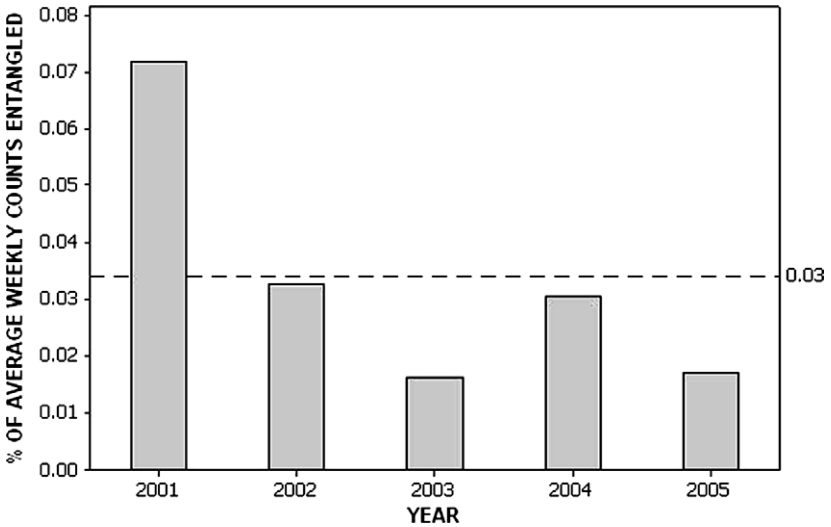

Fig. 7. Percentage of average weekly counts of *Zalophus californianus* recorded as entangled each year by PRBO.

the entanglement had been removed and the animal had been rehabilitated.

There were records of entanglements in five of the six species of pinnipeds at TMMC (Fig. 5). There were no records of entanglements in steller sea lions. Guadalupe fur seals deviate most from the annual entanglement mean of 3.2% with 25% of animals admitted being entangled ($n = 12$). Both records of entangled northern fur seals occurred for the first time in 2005. California sea lions were recorded entangled the most frequently, with 68 entangled individuals being admitted over the five year period. 70.6% of these California sea lions were male and 54.4% were yearlings (1–2 years) (Fig. 6).

Entanglement materials recorded at TMMC were primarily fishing related and the type of fishing related material varied across pinniped species. For example 32.3% ($n = 68$) of California sea lions entangled in fishing gear were entangled in monofilament line and 58.3% ($n = 12$) northern elephant seals entangled in fishing related gear were entangled in packing straps. The 2 northern fur seals were entangled in fishing line and hooks and nylon netting. One Guadalupe fur seal had an entanglement scar and the other two were entangled in fishing related gear.

3.3. Regional pinniped censuses

The California sea lion was the species observed most frequently as entangled by PRBO with 93 animals, a mean of 0.03% of the average weekly count each year, reported with entanglements or evidence of past entanglements over the five year period (Fig. 7). PRBO also had records of entangled steller sea lions ($n = 6$).

The PORE surveys had only 12 records of pinnipeds with entanglements from 2001 to 2005. The entanglements were recorded on California sea lions, northern elephant seals and harbor seals. The average entanglement rate for harbor seals was 0.04% of annual maximum population count with observations of only one entangled harbor seal each year until 2005 when four entangled harbor seals were recorded.

Entanglement materials were unidentified in 80.2% of the recorded entanglements by the pinniped census surveys (Fig. 3). Notably in six steller sea lions reported as entangled by PRBO, three were entangled in salmon flashers, the materials on the remaining three were unidentified.

4. Discussion and recommendations

Each type of data programme had a peak percentage of entanglement occurring in different years (Fig. 2, 4 and 7), indicating a lack of trend amongst programmes. Entanglements have been recorded in a wide range of Western North American species (Table 3). Entanglement records for bird species not previously recorded in Laist's world review (1997) included one Common Loon (*Gavia immer*), one Pacific Loon (*Gavia pacifica*) and two Pied-billed Grebes (*Podilymbus podicpes*). These findings support Laist's (1997) findings 'that marine debris is a broad-scale pollutant affecting individuals of a significant percentage of the world's marine species.'

The beach monitoring surveys recorded approximately one entanglement in every 150 bird carcasses (BeachCOMBERS 1 in 137, BeachWatch 1 in 146 and COASST 1 in 200). TMMC, admitted an average of one in every 32.5 stranded animals with an entanglement. It was reported that records at WildCare were lower than actual due to record keeping inconsistencies. Approximately one in every 400 animals was sighted with entanglements during the regional pinniped censuses. These differences in entanglement incidences are to be expected due to the differing primary objective of each research organization. However it is notable that entanglement records existed for each programme every year, suggesting that entanglement in the area is a persistent problem.

The pinniped census surveys by PRBO had an entanglement rate of 0.03% for California sea lions while PORE population surveys had records of 0.04% of the harbor seal population entangled. Yet since neither of these populations has decreased (Caretta et al., 2005) we may conclude that entanglements have little impact on populations. However entanglement at low levels can be important, Fowler (1987) surmised that entanglement in synthetic debris was contributing to the declining trend of northern fur seal populations at an entanglement rate of only 0.4% therefore we should be cautious in drawing such conclusions from the data in this study. Furthermore, relatively high levels of entanglements amongst juveniles may mean that effects of population decline may not be detectable for several years (Stewart and Yochem, 1987). In this study relatively high levels of entanglements were found amongst young California sea lions at TMMC where 76.5% of the entangled animals were juveniles and yearlings.

The frequency of entanglements observed in different species reflects, to an extent, the species abundance in the area. Common Murre and California sea lions are the species with the greatest number of entanglement records and are both considered to be locally abundant species (Leet et al., 2001). From 2001 to 2004 there were no records of entangled northern fur seals, then in 2005 two animals were recorded as entangled at the TMMC. Northern fur seals were observed breeding in the study area (on the Farallon Islands) for the first time in recent years in 1996 (Pyle et al., 2001) with increasing numbers being recorded each year since (PRBO unpublished data).

From 2001 to 2005 of the small number of Guadalupe fur seals admitted to the TMMC 25% ($n = 12$) showed evidence of entanglement. This finding is comparable to the findings of an earlier study (Hanni et al., 1997), where 33% ($n = 9$) of Guadalupe fur seals stranded in central and northern California from 1988 to 1995 showed evidence of entanglement. The Guadalupe fur seal is rarely observed in the study area. The current breeding range is almost exclusively limited to Guadalupe Island off the Pacific of Baja, California and seals are only occasionally seen as far north as the study area (Folkens et al., 2002). The Guadalupe fur seal is classified under the US Endangered species act as 'Threatened' and fur seals seem especially susceptible to entanglements (Fowler, 1987; Page et al., 2004; Boran et al., 2006).

Potential entangling debris sources could be boat and fishing traffic or land-based sources. The fishing gear involved in entanglements in this study could be either active gear or discarded gear. It is difficult to tell whether an animal entangled in a fragment of fishing gear was caught in active fishing gear that was cut away or fishing gear that had been previously discarded (Laist, 1997). In this study the ability to refine categorization of entanglement material is affected by the programme type. During beach monitoring surveys, researchers photograph the carcass and entanglement material; hence, potential analysis with experts may enable the identification of the material type as either active or discarded fishing gear. At the rescue and rehabilitation centres, the entanglement material is removed from the animals and available for further analysis. In some cases close examination of the gear and the way in which, for example, ropes are frayed can lead to a conclusion that the gear was active or discarded, although this can still be challenging (personal communication David Laist, June 2006). During the pinniped censuses, observations are usually carried out with binoculars and telescopes, therefore collection and analysis of the entanglement material is often impossible.

Different species were recorded entangled more frequently in certain entanglement materials than others. For example, 36% ($n = 24$) of entangled northern elephant seals in this study were entangled in packing straps. Similarly, in a study at the Channel Is-

lands Stewart and Yochem (1987) found strapping bands were the most commonly seen entangling debris on this species. This may be a reflection of behavioural disposition in feeding and foraging patterns which results in certain species interacting with particular entanglement material types (Laist, 1997).

To further understand entanglement issues within the study area and develop effective solutions it is recommended that standardized protocols for recording entanglements and materials be adopted by each of the programmes. The data fields suggested for each organization are; data source (research programme), date, location (county and state), species, age class, sex, condition (live or dead) and entanglement material, with additional categories for live entangled animals to include treatment and outcome. A database such as this would provide broad-scale integration of local knowledge valuable for conservation management decisions and action.

In addition it is recommended that refined documentation of types of entanglement materials is recorded. The entanglement material type can first be categorized into either fishing related or general marine debris, followed by a secondary level of categorization. These categories would be similar to those used in the marine debris collection study carried out by the Ocean Conservancy on International Coastal Clean up day (The Ocean Conservancy, 2006). Data from the Ocean Conservancy could provide context each year for the entanglement findings. Furthermore, collection of marine debris data during at sea surveys can complement the beach debris data, by monitoring potential entanglement threats, thus exploiting current research activities to provide an overview of entanglement threats and occurrences within a specific coastal area.

The entanglements recorded represent an unknown proportion of entangled animals that die at sea; thus, it is difficult to establish what impact entanglements are having on any of the species populations in the study area. However, the collation of data from different sources operating within a similar area provides a unique overview of entanglement incidences and a potential to note trends over time and geographical area, whether positive or negative, across a broad spectrum of species.

Acknowledgements

Thank you to the hundreds of volunteers who have spent thousands of hours on data collection over the years and to all the scientists involved in running the programmes and training the volunteers.

BeachCOMBERS was supported by a grant from the Science Integrated Monitoring Network – Monterey Bay National Marine Sanctuary. Beach Watch is a federal program through the Gulf of the Farallones National Marine Sanctuary (GFNMS) and is funded by GFNMS and the Farallones Marine Sanctuary Association (FMSA). Partial funding for COASST was provided by the NOAA Fisheries Protected Resource Division. WildCare is a 501(c) 3 Non profit funded by monies earned through fund raising events, grants and public donations. The Marine Mammal Center is a non-profit 501(c) operating under the authority of the National Marine Mammal Health and Stranding Response Program (part of NOAA fisheries). Supporters of the PRBO Farallon pinniped surveys are Marisla Foundation, U.S. Fish and Wildlife Service, and Friends of the Farallones. Point Reyes National Seashore Monitoring Program funders include the National Park Service and the Vicki and David Cox Family Fund.

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