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Entanglement of Marine Mammals in Synthetic Debris

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Abstract. In the last decade, fisheries observers, pinniped census takers, and marine mammal rehabilitation clinics began reporting growing numbers of pinnipeds and cetaceans entangled in synthetic debris. During a 3-yr period, 100 samples of such debris were collected, including many from the southern California Channel Islands, by the Marine Mammal Center of Santa Barbara. Most entanglements came from live specimens, although a few dead, beach-cast specimens were also recorded. Entanglements were analyzed by type, size, color, and material of debris. Data thus obtained were then compared with the numbers, species, sex, and age of each marine mammal involved. Subadult California sea lions *(Zalophus c. californianus)* entangled in plastic monofilament gillnet fragments comprised the vast majority of specimens analyzed.

Keywords: Southern California Bight; Channel Islands; California sea lion *(Zalophus c. californianus)*; cetacean; pinniped; gillnet; drift net; set net; ghost net; Marine Mammal Stranding Network; plastic; pollution; fisheries.

Introduction

Entanglement of marine animals in synthetic debris has become a rather well-known global pollution problem. In some areas, this problem has escalated so rapidly that it apparently has significantly contributed to the decline of certain species, particularly the northern fur seal (*Callorhinus ursinus*) in the Pribilof Islands of the Bering Sea (Fowler 1982, 1984, 1985, 1987, 1989; Fowler et al. 1985; Bengston et al. 1988; Fowler and Baba 1991). Entangled marine mammals, perhaps because of their conspicuous size and popularity with the public, gather considerable attention, particularly in areas like Southern California, which has a dense human population. Nonetheless, in the mid 1970s, relatively few such entanglements were reported anywhere in California. Within the past decade, however, reports of such entanglements, especially involving commercial fishing nets, began increasing in California (K. Lee, D. Zumwalt, and G. Hoffman 1990–1993, pers. comms.). Participants in the Marine Mammal Stranding Network, organized by the National Marine Fisheries Service, rescued a number of these entangled animals. Meanwhile, data from fisheries observers obtained over the same period suggested a general corresponding trend toward significantly higher mortality of marine mammals entangled in commercial fishing gear, especially in nets. Finally, pinniped census takers at the southern California Channel Islands began to notice more live entangled specimens (M. Lowry and R. L. DeLong 1990–1993, pers. comms.).

This paper outlines the apparent correlation between increased marine mammal mortality rates (estimated from fisheries observer data and other sources), the increased occurrence of entangled specimens reported by census takers, and the greater numbers of strandings involving entangled specimens. Evidence to support the most significant cause of this increased entanglement is given.

Methods

A literature review was conducted on subjects including fisheries observer data and reports, assessments of marine mammal-fisheries interactions, entanglement of marine animals in synthetic debris, and marine mammal censuses in the Southern California Bight. Certain researchers involved in such studies were interviewed on specific aspects of the entanglement issue. Live sighting records and stranding reports of entangled marine mammals were examined from the Marine Mammal Center of Santa Barbara's files.

Samples of entanglement debris were obtained from all living, stranded, or dead, beach-cast specimens recovered over a 3-yr period from January 1990 through October 1993. Photographs and videotapes were taken of many of these specimens. The number of samples was stopped when the 100 mark was reached to allow time for the preparation of this paper, but samples continue to be taken. The sampling area included the mainland coast of California from parts of Los Angeles County through all of Ventura and Santa Barbara counties, as well as parts of the southern California Channel Islands. One stranding was also recorded from Cambria, California, because of its similarity to another stranding in Santa Barbara County. Reports of entangled animals were channeled to the Marine Mammal Center of Santa Barbara's hotline, which is monitored on a daily basis throughout the year. (Not only were calls received concerning entangled animals, but also sick, injured, and stranded specimens, as well as orphaned pinniped pups.) These reports came from a multitude of sources, including local, state, and federal agencies; universities, museums and other institutions; industries based on or near the water; boats and aircraft, including private, commercial, charter, industrial, and government types; people visiting or staying on the Channel Islands; and surfers, divers, beach walkers, and so on along the mainland coast. This widespread reporting base ensured much greater coverage than would otherwise have been possible. All such sighting reports were random, however, since the Marine Mammal Center of Santa Barbara does not survey this large area, but instead relies upon reports from the previously mentioned sources.

All live strandings, reports of entangled animals at sea, and calls concerning dead, beach-cast specimens were noted. Whenever possible, a team was sent to investigate and to recover specimens as appropriate. (Sometimes an animal would return to the water before the team arrived, an animal would escape before a rescue could be made, an animal would be reported too far at sea to launch a rescue effort the same day, or an animal simply did not need to be rescued.) Also, several trips were taken to Santa Barbara, San Nicolas, Santa Cruz, and San Miguel islands. Entangled animals were seen and captured on all these trips. All captures, both on the mainland and at the Channel Islands, were made under the authority of a permit granted by the National Marine Fisheries Service.

Animals were captured using hoop nets, 2 different types of water nets, a net gun, and, in the case of entangled whales, grappling anchors, buoys, and sea anchors. (Over the past 17 years, in *no instance* has any animal ever escaped that was entangled in any part of the rescue gear used by the Marine Mammal Center of Santa Barbara.)

Data were recorded on each entangled animal, including species, approximate age, measurements, sex, location, date and time of capture, photos taken, and other relevant details. Pinnipeds were marked before release with plastic rotary cattle ear tags issued by the National Marine Fisheries Service. (No tags were available for cetaceans.) All specimens were assigned field numbers through a collaborative effort with the Santa Barbara Museum of Natural History.

Entanglement debris was labeled and recorded with the field number, date, location, species, standard length, and sex of the specimen. Each piece of debris was later catalogued as to type (e.g., gillnet, packing strap, etc.). The material comprising each piece of debris was noted, along with its color. Finally, measurements were taken of all debris. In the case of hook-and-line entanglements, the hook size and line strength were noted. Line strength was obtained by measuring the line diameter and comparing this with industry specifications. Although variations existed from one manufacturer to the next, the measurements taken narrowed the line strength assessment to a range that fell within the specifications. The line strength was recorded in breaking strength in pounds to maintain consistency with industry specifications. For net entanglements, the line strength of the netting was also recorded. With net debris, the distance from 1 knot to the next was measured, and from 1 knot to every other knot. This was a way of ground-truthing the mesh size in case strands of the net had shrunk or stretched. Measurements were made in inches, again for consistency with industry specifications. The measurements were made with a dial vernier caliper to the nearest thousandth of an inch. All measurements were snug but not stretched or compressed.

Results and Discussion

Entanglement analysis

Numerous studies have been conducted and assessments made on the incidental mortality of marine mammals in commercial fishing gear in California (DeMaster et al. 1982, 1985; Miller et al. 1983; Collins et al. 1984, 1985, 1986; Wild 1985, 1986, 1987; Diamond et al. 1986a, 1986b, 1987; Hanan 1986; Stewart and Yochem 1987; Hanan et al. 1989; Barlow et al. 1990; Cranmore 1990; Vojkavich et al. 1991; Woodley and Lavigne 1991; Konno in press; Julian 1993a and b; 1992, pers. comm.). Scores of similar studies have been conducted for other parts of North America.

Of particular interest is the suggestion that the incidental take rates in California for California sea lions have been significant relative to the maximum population growth rate. Annual fisheries-related mortalities reached 3 to 4% of the total estimated minimum population according to DeMaster et al. (1982, 1985). Furthermore, Hanan et al. (1989) estimated that 4,288 California sea lions were killed in the California gill and trammel net fisheries in the 1986–1987 fishing season. The total American population of the species was estimated at 87,000 for 1986 (Boveng 1988), while the annual recruitment rate of the species was estimated at about 10% over the past several years (M. Lowry 1990–1993, pers. comm.). This suggests that the mortality rate was almost 5%, nearly half of the recruitment rate. Cranmore (1990) suggested an annual take of 2,250 California sea lions during a "typical" fishing year. Thus, the mortality rate of California sea lions in commercial fishing gear has clearly been significant at times during the past decade. Some managers apparently do not feel that an impact is significant until a population has actually been reduced. The problem with this thinking is that it can take years for such impacts to be eliminated or reduced so the population can finally have time to recover. Fortunately, the California sea lion population has been steadily increasing despite significant impacts, but the rate of entanglement should continue to be monitored and reduced to minimal levels, as mandated by the federal Marine Mammal Protection Act of 1972.

Fluctuations in the estimated mortality rate over the past decade probably resulted from a variety of factors. The level of effort on the part of the fisheries varied because the number of participants during any one season varied. Herrick and Hanan (1988) noted that in the late 1970s and the early 1980s, the use of entangling nets (drift gillnet, set gillnet, multi-panel, and trammel nets) proliferated. Plastic monofilament net use also increased dramatically. This material was lightweight, inexpensive, and had little bulk compared to net made of twine. These qualities allowed the use of smaller, less expensive fishing boats, thus opening the fishery to more participants, increasing the level of effort and the amount of netting in the water at any one time. But at the November 1990 California elections, voters passed Proposition 132, an initiative sponsored by Assemblywoman Doris Allen (R-Cypress) that banned gillnet fishing in state waters at the end of 1993. (This ban was in effect at the time of completion of this paper, but it will be challenged in court by the California Gillnetters' Association.) According to state officials quoted in a newspaper (Bailey 1994), about 500 gillnet fishers were in operation shortly after the initiative was passed; a little more than 100 reportedly were left when the ban went into effect on 1 January 1994. Even if the ban does remain in effect, entanglement will likely continue to be a problem, especially since the ban does not extend beyond the 3-mile limit of state waters, nor does it apply to neighboring states or countries. Moreover, as discussed in detail later, entangled animals can live for years, although they certainly suffer.

The number of participants in the fishery aside, the level of effort expended by any one vessel often varied because of weather and sea conditions, fishing seasons, availability of target species, and other factors. The level of effort on the part of the observers varied as well, in part because of the above factors, but also because of variations in logistic support, number of personnel, limited funding, a lack of cooperation from some individual fishers, and other factors, several of which are discussed by Lennert et al. (1991) and Perkins et al. (1992). During some quarters of recent years, such a paucity of data from the Channel Islands were obtained that either no mortality estimates could be made for the Channel Islands (Perkins et al. 1992), or at least no reliable mortality estimates (Julian 1993a, 1993b).

Conspicuous by their rarity in the observer data are reports of marine mammals escaping from fishing gear alive, or of being released alive. But observers only watched the nets as they were being pulled, not (understandably) during their entire "soak" time. This explains why animals that escaped alive, many still tangled in net fragments, could rarely be counted and thus could not be included in mortality estimates, even though many probably became mortalities later, either because they became exhausted and drowned while dragging around large, heavy net fragments, because the net fragments became caught on obstructions, causing death by drowning, or on land by overheating, dehydration, and starvation, or because the net fragments chafed their way through the tissues, inflicting steadily worsening wounds. Such grisly occurrences have been documented by participants of the Marine Mammal Stranding Network as well as mentioned, at least in part, by various researchers (Fowler 1982, 1985, 1987; Stewart and Yochem 1987; Fowler and Baba 1991).

Over the past decade, several researchers, particularly DeLong, Stewart, and Lowry, have conducted censuses of the various pinniped species that haul out, and in some cases pup and breed, at the Channel Islands. These censuses were conducted on land with the aid of binoculars and spotting scopes, and by air with the aid of still photography. Also, parts of the rookeries were entered periodically to count, tag, and gather data on pups. The researchers noted a general increase during this period in the number of entangled animals, particularly in plastic monofilament gillnet fragments (R. L. DeLong and M. Lowry 1990–1993, pers. comms.) (Fig. 1). Stewart and Yochem (1987) observed 69 entangled California sea lions during the period from December 1984 through July 1986 at San Nicolas and San Miguel islands. Of these, 36 were entangled in monofilament gillnet fragments. Details of the net fragments, such as measurements, color, and line strength, were not provided.

Sighting records kept by the Marine Mammal Center of Santa Barbara were examined. These records indicated when and where entangled marine mammals were seen. Such data were not included in this paper because the

Figure 1. Plastic monofilament gill net is being removed from the neck of this California sea lion (*Zalophus c. californianus*). Note severe neck wound. This is the most common type of synthetic debris entanglement. Peter C. Howorth photo.

possibility of resighting, thus recounting, entangled individuals could have biased part of the results of this study. Stranding records were also examined. Such records were maintained for every marine mammal that was examined by the Marine Mammal Center of Santa Barbara. These records include strandings of pinnipeds attributed to a variety of causes, including entanglement. The records also include details of at-sea rescues of entangled cetaceans. More specimens were rescued because of entanglements than from any other cause. In fact, during some recent years, entanglement cases outnumbered all other causes combined.

Records were also kept of rescue trips made by boat to the Channel Islands and to other locations. An interesting pattern was revealed in these records. Haul-out areas used by small groups of California sea lions, from several individuals to perhaps 200 or 300 animals, showed a much higher incidence of entangled specimens than had been reported at California sea lion rookeries by R. L. DeLong (1990–1993, pers. comm.) and Stewart and Yochem (1987). A few of these haul-out areas were adjacent to rookeries, but other haul-out areas were found at Santa Cruz Island and on artificial structures such as buoys, oil platforms, and breakwaters, where pupping was so rare that it was virtually nonexistent. In such haul-out areas, entangled specimens consistently comprised approximately 5 to 10% of the animals observed. Since the areas in question were small, and nearly all of the animals could easily be seen at once, no question existed as to the high proportions of entangled animals. These areas were visited many times and always showed relatively high numbers of entangled animals. Many of these animals were captured, freed of debris, and released, either on site or after rehabilitation. Such animals were tagged. Since nearly all animals in these areas could be scrutinized in detail with a little patience, virtually no tagged animals were recounted. Thus, practically no tagged animals were included in this percentage. Moreover, photographs taken at each site of entangled individuals that had not been captured showed a definite turnover. These animals were relatively easy to identify by the type and pattern of entanglement and by their wounds, combined with their individual physical characteristics. While some individuals were resighted, new individuals were always turning up. The rate remained high, even after discounting the resightings.

The question, of course, is why? An easy conclusion to make might be that gillnet fishing activities were commonplace near such areas. But California sea lions range widely. They could become entangled in many places along the way. Also, not all California sea lions, including some adults, return to the rookeries during pupping and breeding season. Some individuals remain instead at various haul-out sites along the mainland coast and at the Channel Islands. Stranding records from the Marine Mammal Center of Santa Barbara reveal that such animals are often sick, malnourished, suffering from heavy parasite infestations, or injured, often from entanglements. Other rehabilitation clinics have found much the same thing (K. Lee, G. Hoffman, D. Zumwalt 1990–1993, pers. comms). Also, records of commercial collections of pinnipeds from the Channel Islands maintained from 1969 through 1981 (Howorth 1993) show that California sea lions captured at Santa Cruz Island consistently had a higher incidence of health problems. Richard Headley, a commercial marine mammal collector who worked the Channel Islands from 1958 through 1981, also remarked on this trend (R. Headley 1990–1993, pers. comm.). Headley stated that virtually no California sea lions were captured for commercial purposes along the mainland coast because the only animals accessible for capture almost invariably had health problems, at least when it came to their marketability. This by no means implies that California sea lions along the mainland coast were universally unhealthy. The only specimens available for capture by Headley were live-stranded individuals, and such specimens indeed were predominantly unhealthy (Marine Mammal Center of Santa Barbara files; K. Lee, G. Hoffman, and D. Zumwalt 1990–1993, pers. comms.).

Possibly, California sea lions occupy peripheral haul-out zones because they are unable to face the stiff competition at the rookeries in their weakened state. Rescue records from rookery areas indicate that entangled animals sometimes cluster near the fringes and outlying areas R. L. DeLong (1990–1993, pers. comm.) noted this pattern at San Miguel Island on occasion. The rookery areas themselves seem to harbor comparatively few entangled animals, perhaps as little as approximately 0.1%, along with similarly small numbers of animals with entanglement scars, according to Stewart and Yochem (1987). This seems to support the competition theory, but more research would have to be done before any conclusions might be drawn.

A note should be added on the difficulties of counting entangled animals on a crowded beach. First, not all the animals can be clearly seen. Often they are packed so tightly together that only a few can be scrutinized. Some beaches harbor literally thousands of animals. During one capture, an extremely experienced National Marine Fisheries Service observer studied a beach from an overlooking bluff. He could see nearly all of the relatively small group of animals present, but not all of their features. He reported 2 entangled animals over the radio, but when the rescue team arrived, they encountered 10 entangled animals. This is by no means a criticism of the observer, who was as good as they come, but rather a comment on the difficulty of spotting entangled animals on crowded beaches. Second, the number of entangled animals on a beach does not necessarily mirror the overall proportion of entangled animals in a population. Stewart and Yochem (1987) pointed out that entangled subadult male northern fur seals at the Pribilofs spend twice as much time at sea between visits ashore as did animals that were not entangled. Once they did come ashore, they stayed for about the same length of time as did the others. As Stewart and Yochem (1987) aptly stated, such a pattern for California sea lions has not been established, so entanglement rates based on shore observations could be biased in either direction. Third, some animals become entangled, end up with severe wounds, then the wound heals over the entangling material. Animals reported by researchers as having entanglement "scars" could thus still be entangled yet not be reported as such. Tiny fragments of entangling material are sometimes seen under close scrutiny protruding from the skin, but these would be virtually impossible to detect in the field except at extremely close range (within a meter or so). Such animals have turned up at rehabilitation clinics (Marine Mammal Center of Santa Barbara files; K. Lee, G. Hoffman, D. Zumwalt 1990–1993, pers. comms.). These animals are by no means out of danger. In such cases, the embedded material can still saw through their veins or throat internally. Animals that show completely healed scars but are marked with the distinctive orange-red tags used by rehabilitation clinics, however, seem much less likely to have entanglement material embedded under their skin. Once rescued from entangling material, such animals seem to rarely become entangled again (Marine Mammal Center of Santa Barbara files; K. Lee, G. Hoffman, D. Zumwalt 1990–1993, pers. comms.).

Synthetic debris analysis

Out of the 100 samples of debris analyzed, 80 came from plastic monofilament gillnet, 5 from synthetic twine net, 7 from monofilament fishing line, 3 from rubber bands cut from inner tubes, 2 from packing straps, 2 from fishhooks, and 1 from a fishing lure.

The miscellaneous debris can be explained as follows. The bands cut from inner tubes are very likely from lobster or crab traps. Such bands are used, with a wire hook, to close the doors on the traps. Since this practice has gone on for decades, the bands probably represent debris from lost traps that have since rusted away. California sea lions, especially subadults, are frequently seen "playing" with non-food items such as kelp. Very likely they end up with these bands around their necks purely by accident as a result of such activities. These bands stretch as an entangled animal grows, and soon the bands crack from exposure to sunlight. Probably most of the bands fall off on their own if they are not removed. I mention this because I strongly feel that such debris poses no threat to marine mammals. Packing straps are another matter because they do not stretch or break from deterioration. Of the 100 samples of debris analyzed, 2 were from packing straps. One encircled the neck of a subadult female northern elephant seal (*Mirounga angustirostris*); the other, a subadult male California sea lion. Though seemingly not a significant factor in the samples discussed here, they should not be disregarded. Stewart and Yochem (1987) listed a total of 32 packing bands seen during their 1984–1986 study alone. California sea lions accounted for 17 such entanglements, northern elephant seals, 13, and harbor seals (*Phoca vitulina), 2.*

Hook-and-line entanglements are a different matter. Eight involved California sea lions. One was snagged with a "Scampi" lure attached to some 20-pound test monofilament line frequently used in sport fishing. Two others had been caught with fishhooks, again attached to light monofilament used by the sportfishing industry. Five specimens were entangled in monofilament fishing line. Two carried line of 12 to 15 pounds breaking strength, which is commonly used in sport fishing. Two were wrapped in 40- to 50-pound test line that is used by the sport and occasionally by the commercial fishing industry, and one was caught in heavy monofilament line more often used in commercial set lines. All 5 animals had wounds around their necks from the line cutting into their tissues. The sample size would seem to indicate that monofilament fishing line does not pose a threat to marine mammals at this time, but scant data are available concerning marine mammals becoming snared in heavy set lines that are anchored to the bottom. Fishhooks that are swallowed presumably can cause severe infections, yet very few such cases have been noted by the Marine Mammal Center of Santa Barbara over the past 17 yr. Two other pieces of light monofilament line were recovered at Santa Barbara Island. These were included because they were found snagged on the rocks at southeast rookery, an area with dense concentrations of sea lions, where no public access is allowed, and where many entangled sea lions have been captured. Quite possibly these pieces had been wrapped around sea lions, become snagged on the rocks, and been wrenched off. Hook-and-line entanglement should continue to be monitored since the sampling size is very small.

Synthetic twine net comprised 5 of the samples. One was wrapped around the neck of a live northern elephant seal at San Nicolas Island. This was made up of 2-in.^{2} mesh, green polypropylene net. Two other samples were recovered from 2 separate strandings of sperm whales (*Physeter macrocephalus*). Both specimens were subadult males; both were dead. An adult male was tangled in 9-in.^{2} mesh, black polypropylene net. It was washed ashore at Cambria, California, in San Luis Obispo County. This was included as a data point because of its similarity to the next case. A subadult male found at San Miguel Island was tangled in 8-in.^{2} mesh, green nylon net (Fig. 2). Another very large fragment of net was observed wrapped around the rear torso, left pectoral fin, and flukes of a live adult humpback whale (*Megaptera novaeangliae*). The net was heavily fouled with growth, suggesting that it certainly was in the water, and may have

Figure 2. A male sperm whale (*Physeter macrocephalus*) washed ashore dead at San Miguel Island, California. Nylon twine gill net is still wrapped around the animal's caudal peduncle. The net pattern can still be seen across the specimen's body. Peter C. Howorth photo.

been on the whale, for a considerable period of time. Healing scars forward of the dorsal fin indicated that the net had probably gradually worked its way back along the creature's body. Unfortunately, this animal was spotted too far at sea, too late in the afternoon, for any rescue to be attempted that day. Subsequent searches failed to turn up any sign of the animal. The entangling net was clearly seen and photographed by several experienced observers, however. It was a large-mesh, green nylon twine net. The last sample of twine net was found floating at a haul-out site for California sea lions, although no animals were entangled in it at the time. This comprised 1.5-in.^{2} mesh, black polypropylene net.

Worth noting is the fact that nylon net sinks slowly. It will easily sink when it has any weight at all, even algae growth, whereas polypropylene floats unless the lead weights remain attached. Thus, a floating fragment of polypropylene net could entangle a marine mammal just as a working nylon net could. Fowler (1982, 1987) and Fowler and Baba (1991) have documented numerous cases of northern fur seals entangled alive in floating net debris in northern waters. Although the sample size of twine net is small, all samples represent net with considerable bulk if not weight. Of the animals entangled in twine net, all were heavy, robust specimens that could not only break out of such strong netting, but could also probably swim a long way despite the resistance of the bulky material. The entangled humpback whale is a good example. In the case of the sperm whales, both specimens were large enough to easily float the entangling mass of net after they died and became bloated with the gases of decomposition. Smaller animals caught in such sizable fragments of heavy netting would likely soon become exhausted and drown, as Stewart and Yochem (1987) proposed for northern fur seals. Monofilament net, on the other hand, is extremely light, and sizable fragments can be easily carried by small pinnipeds. Monofilament fragments do slowly sink and become tangled, however, so I concur with Stewart and Yochem (1987), who felt that entangled pinnipeds at San Nicolas and San Miguel islands had been caught in active fishing gear rather than in debris.

Monofilament gillnet comprised the vast majority of samples collected. Of the 80 samples of this material, 2 were found at the southeast rookery at Santa Barbara Island. Although these were not wrapped around any animals, they were included for the reasons mentioned earlier in the discussion of monofilament fishing line entanglement. One other net specimen was recovered at Webster Point, also at Santa Barbara Island. A cormorant (*Phalacrocorax sp.*) was discovered dead in this sample. The physical size of the net fragment and its position on top of a jagged, 4-m cliff, would have made it virtually impossible for the cormorant to drag it up there, much less fly there. The area was frequented by California sea lions, however, which were often seen on top of this very cliff. Moreover, entangled specimens had been recovered from this site on several occasions. Very likely, the net was wrapped around a sea lion, became snagged on the jagged rocks, and was jerked free by the animal. The unfortunate cormorant probably became entangled in turn.

Since 77 samples of monofilament gillnet remained after the 3 debris items were accounted for, a much higher degree of statistical probability could be inferred from studying these samples. One was recovered from a live-entangled, coastal bottlenosed dolphin (*Tursiops truncatus*) (Fig.3). Particularly noteworthy is that the other 76 fragments were all found on California sea lions. Sex was determined for all 76 gillnetted sea lions: 41 were males; 35, females. Since the difference was relatively small, gender did not appear to be a factor in entanglement. Of the 76, only 3 were dead, leaving 73 California sea lions entangled alive in monofilament gillnet out of a random sampling of 100 pieces of synthetic debris. Of these 73 animals, only 1 adult male and 7 adult females were found. No entangled pups were seen. The remaining 65 animals were all subadults, ranging from scrawny specimens weighing as little as 10 kg to robust individuals weighing up to approximately 80 kg. No category was included for the so-called yearlings scattered throughout the literature because I considered such a classification ambiguous when applied to sick, malnourished, or traumatized individuals. Sea lions suffering from severe wounds inflicted by gillnets often fall prey to infection, disease, and diminished ability to forage, resulting in malnourishment. Such animals, even though they may be older than yearlings, can easily fall into the size and weight range of the true yearlings, thus skewing the data.

The colors of the monofilament gillnet samples were translucent (clear), pink, and green. Of the 77 samples, 22

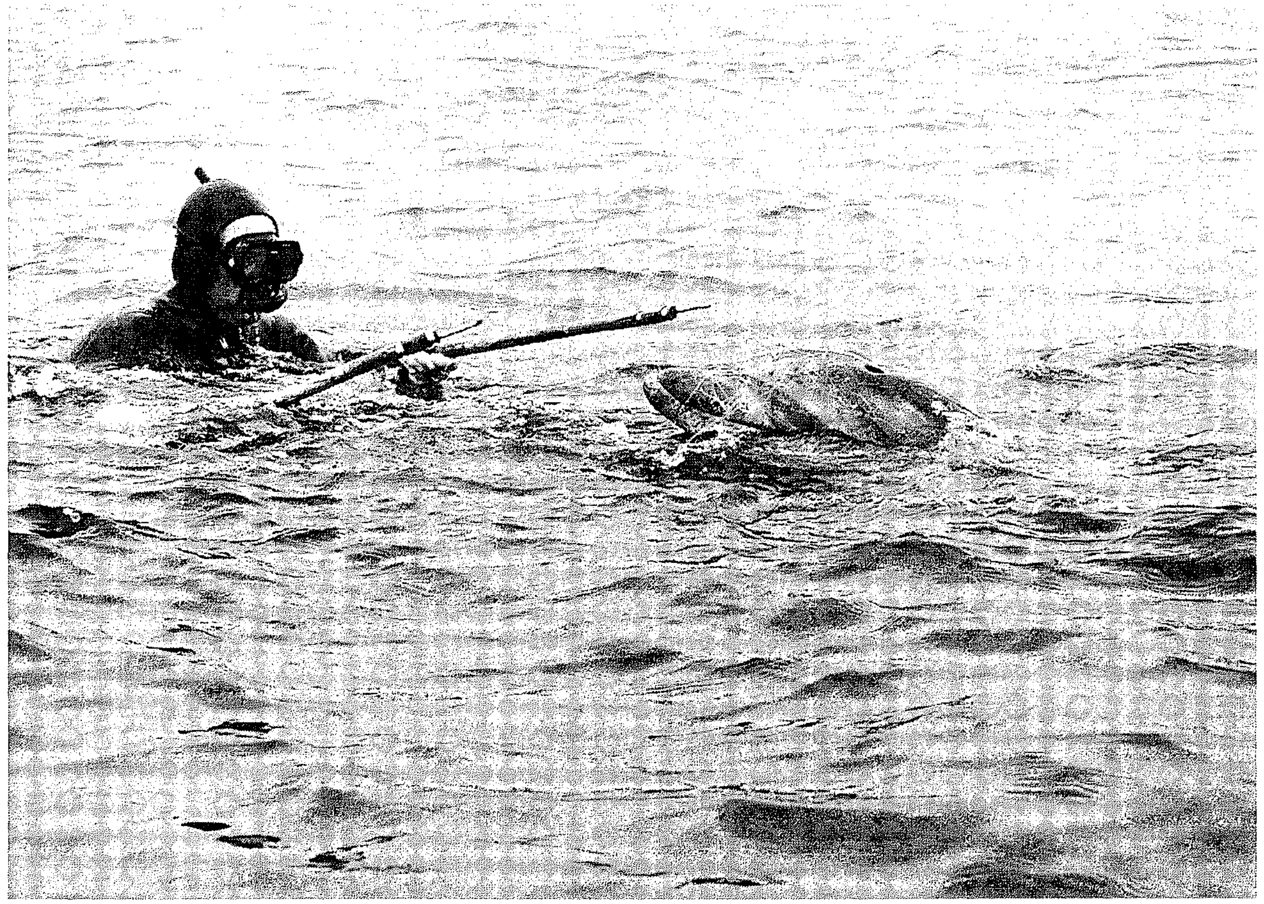

Figure 3. The author is in the process of freeing an adult coastal bottlenosed dolphin (*Tursiops truncatus*) entangled in a plastic monofilament gill net. Glen Allen photo.

were translucent, 25 were pink, and 32 were green. On the surface, color does not appear to be a significant factor in monofilament gillnet entanglements, although the relative popularity of each color with the fishing industry is not known at this time. Also, all monofilament gillnet samples were translucent to some extent, so the colors would change depending on the colors of the environment the nets were set in. Moreover, magenta is the first primary color to be filtered out by sea water as depth increases. Thus, pink monofilament would quickly turn green, the green would probably just get darker, and the clear would turn blue or green depending on water color and clarity.

The strength of the monofilament net was universally rather light, with 72 of the samples in the 30- to 50-pound breaking strength range, only 1 in the 25-pound test range, and 4 in the heavier 60-pound test category. Since monofilament has, by definition, only 1 filament, any nicks, cuts, or abrasions will weaken the line, causing it to break under strain. Monofilament gillnet becomes worn from use as well as damaged by contact with the sea floor and with fish, sharks, and other organisms caught in the net. Sea lions are powerful swimmers and can break out of such nets, especially if the nets have weak points. Twine nets, which have 3 strands, can have a badly damaged strand and still retain considerable strength in the remaining 2 strands. Moreover, twine net used in the Southern California Bight generally is heavier and has a greater breaking strength than monofilament net because twine net is often used to catch larger, stronger, and more abrasive fish. The 5 samples of twine net recovered during this study were all 2 or 3 times stronger than the monofilament gillnet that was recovered. Although mortality rates reported by observers for twine nets are still significant, the number of small marine mammals that escape alive from such nets is probably quite small.

Mesh size appears to be a major factor in entanglement. Of the 77 samples, 12 were in the 3.5- to 3.75-in.^{2} mesh range, 63 were in the 4.0- to 4.5-in.^{2} mesh group, and only 2 in the 5.0- to 5.5-in.^{2} size. The predominant mesh sizes would allow virtually any subadult California sea lion to thrust its snout into the mesh. Fowler (1987) noted that 2- to 3-yr old northern fur seals at the Pribilofs seemed to be more susceptible to entanglement. Many female California sea lions, as well as smaller males, could also force their heads through monofilament gillnet mesh. When such animals break free, the net remains around them. As the animals grow, the net cuts through the tissues like a wire cheese cutter. Since the net is synthetic, it does not deteriorate. Also, monofilament has very little stretch, so it stays around the animals, inflicting what often turn out to be ghastly wounds. Documented cases of hard-to-catch, entangled animals indicate that this process can go on for months or even years (Marine Mammal Center of Santa Barbara files).

California sea lions are found year-round in varying numbers throughout the study area. The sampling effort was also year-round. Considering this, as well as how long an animal can remain tangled, I did not attempt to look at the seasonality of entanglement events. When the animals were captured and freed of the entanglement, such animals recovered extremely well; approximately 90% of the specimens caught by the Marine Mammal Center of Santa Barbara during this period survived and were returned to the wild.

In the majority of cases of entanglement in monofilament, only 1 strand of material encircled the animal. Often 1 strand in this circle was broken, thus opening up 1 square of mesh to the next. This could well occur if an animal tried to blast through a net. In a number of cases, 2 or 3 strands encircled the animal, but never more than this. An animal can easily become fouled in 1 or 2 squares of mesh if the net has some slack and the animal either changes direction or thrashes about in the net. As a commercial collector of marine mammals for 12 yr (Howorth 1993), I closely watched literally thousands of California sea lions caught alive in similar nets. The pattern of entanglement was very much the same, except that we immediately removed the animals alive to bring back to the various marine parks that formed our clientele. Stewart and Yochem (1987) suggested that entangled pinnipeds at San Nicolas and San Miguel islands were probably caught in actively fishing gear rather than debris, and were either cut loose alive or broke free. Given the extreme rarity in the observer data of animals even escaping alive, much less of being cut free, I would have to endorse the breaking free theory. The recovered samples of net from this study do not reveal sharp knife cuts at the edges, but rather chafing, nicks, and abrasions, which could explain why the animals were able to break free, but which also could have been caused when the animals scrambled over rocks at the haul-out areas, thus masking any evidence of knife cuts. The evidence is inconclusive at this point.

Based on countless observations of pinnipeds being caught alive in nets, I cannot imagine that the 76 sea lions recovered in this study were caught in debris rather than in nets set in the water. When nets are fouled and lost, they generally collapse to the bottom, become snarled and encrusted, and sooner or later, stop catching organisms, especially relatively large animals like pinnipeds. Rarely would such debris retain the right configuration for entangling pinnipeds in the manner described in this study. When a set net is lost or abandoned, however, it can go on catching pinnipeds and other organisms for a considerable period. Also, when a floating drift net breaks free from its mother vessel and is lost, it can also go on catching organisms. Fortunately, such active fishing "ghost nets" do not appear to be common in the Southern California Bight.

Perkins et al. (1992) believe that competition between pinnipeds and fishers for the same fish was unlikely. Individual pinnipeds indeed scavenge fish caught in nets, sometimes wreaking havoc with a fisher's catch. Such individuals probably become adept at avoiding entanglement, however, or they would not scavenge for long. A more likely demise for such a problem animal is that it is shot by the fisher, who is allowed, under a marine mammal "exemption" granted by the National Marine Fisheries Service, to kill such an animal when it is seen interfering with the fishing operation, and when other means of discouraging the creature have failed.

Analyses of the stomach contents and scat of pinnipeds in general reveal an abundance of fish and squid (M. Lowry 1990–1993, pers. comm.). Notably, such organisms are not the target species of the fisheries most often implicated in marine mammal entanglements, although they sometimes form part of the bycatch. Thus, while individual pinnipeds undoubtedly scavenge nets, the vast majority of entangled specimens probably became accidentally caught while simply passing through the fishing grounds.

Conclusions and Summary

California sea lions, especially subadults, are the marine mammals in the Southern California Bight most often found entangled alive in synthetic debris. Lightweight plastic monofilament gillnet, with a square mesh size of 4 to 4.5 in. from 1 knot to the next, is by far the most common entangling material. Most, if not all, entangled sea lions that were seen alive very likely broke free from active fishing nets rather than from net debris. Most of these animals likely were merely going through the fishing grounds rather than scavenging the nets, although a few individuals certainly do take fish from the nets. Such animals may be adept at avoiding entanglement, however. Estimates of mortality rates from entanglements that were based on fisheries observer data were conservative because such estimates included virtually no animals that broke free, still entangled in net fragments. Estimates of entanglement rates from rookery observations are understandably conservative as well because of the difficulty of obtaining accurate counts of entangled animals. Moreover, haul-out areas harbor surprisingly large percentages of entangled animals not considered in other studies.

Twine net entanglements may involve cetaceans more than pinnipeds, particularly with live entangled animals. Probably fewer pinnipeds escape alive from such nets, and those that do may well drown from exhaustion before reaching shore. The sample size of live entanglements in twine net, reported from strandings and live sightings, is not large enough to form an assessment of the entanglement rate. The use of both types of net should continue to be monitored, and the incidental take reduced to the minimal levels mandated by the federal Marine Mammal Protection Act of 1972.

Other synthetic debris includes sportfishing hooks, lures, and monofilament line. Based on the samples obtained and on records kept by rehabilitation clinics, such entanglements probably do not constitute a significant impact (K. Lee, G. Hoffman, D. Zumwalt 1990–1993, pers. comm.). The impact of commercial set line fishing with hook and line is unknown, but based on the samples obtained and records kept, it probably is not significant in the Southern California Bight.

Bands cut from inner tubes, probably from the lobster and crab fisheries, do turn up as a very small part of the samples. Such entanglements are not considered life-threatening, however. No impact is perceived from such entanglements at this time. Packing straps can certainly be life-threatening when wrapped around a marine mammal. Although the sample size of this type of debris is small, other researchers have recorded substantial numbers of packing strap entanglements, both at the Channel Islands and elsewhere. If possible, the sources of such entanglements should be located and eliminated.

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