A REVIEW OF SEAL AND SEA LION ENTANGLEMENT

IN MARINE FISHING DEBRIS

by

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ABSTRACT

Plastic debris, much of which has its origins in commercial fishing operations, are found entangled on individuals of a number of species of seals. Ten of the 16 species of otariid seals have been observed entangled in such debris. By comparison, six of the 14 species of phocid seals have been observed entangled. Individual phocid species tend to show lower entanglement rates than do the otariids. This apparent difference between phocids and otariids has not been explained but may be related to body shape, habitat, and behavior.

Entanglement in debris is thought to contribute to the mortality of individuals through starvation, suffocation, infection in resulting wounds, exhaustion, bleeding, drowning, and possibly increased predation. Studies indicate entanglement may be contributing significantly to the decline of the northern fur seal population. Because the population is already at low levels, entanglement may pose some threat to the Hawaiian monk

seal population. Entanglement may be a potential problem for immature northern sea lions (known to be experiencing a decline) and the South African fur seal (some colonies of which have experienced declines) populations.

INTRODUCTION

Concern over the effects of debris on marine life has been increasing as the use of nonbiodegradable plastics continues to grow and affect mammals, birds, turtles and fish (Shomura, and Yoshida, 1985; Wallace, 1985; Laist, 1987). Issues resulting from the presence of plastic debris in the marine environment include identifying the research necessary to fully understand the extent of the problem, action necessary to solve the problem, and responsibilities for causing the problem. These issues have been addressed at recent conferences, workshops, and symposia (e.g. see Shomura, and Yoshida, 1985; Marine Pollution Bulletin vol. 18 no. 6B). In 1985 a special program called the Entanglement Program was established by the National Marine Fisheries Service at the Northwest and Alaska Fisheries Center in Seattle, Washington, in response to these issues. This program coordinates and supports studies and educational programs, helps supply information for development of international and domestic regulation, and serves as a clearinghouse regarding information and data on marine debris.

The entanglement program has funded research on the nature and extent of entanglement on northern fur seals and northern sea lions, two pinnipeds known to be influenced by marine debris. This paper serves as an overview of information concerning the entanglement of pinnipeds (the seals and sea lions) in plastic debris, especially that having its origin in the commercial fisheries.

PINNIPED ENTANGLEMENT

Much of the plastic debris observed to entangle pinnipeds is attributed to the activities of the fishing industry (see lit. in Appendix A). A variety of species of pinnipeds have been observed entangled in discarded or lost trawl and gill-net fragments, lost nets, heavy plastic rope, monofilament line,and plastic packing bands. Entanglement in such debris is believed to cause mortality through starvation, suffocation, infection in resulting wounds, exhaustion, bleeding, drowning, and increased predation.

The following is a summary of information available on seals or sea lions for which entanglement has been observed. References and sources of information are indicated in Table 1. The two groups of pinnipeds (otariids and phocids) are divided and treated separately to permit comparisons.

OTARIIDS

The family Otariidae includes the fur seals and sea lions.

Arctocephalus australis (South American fur seal)

The South American fur seal has been seen entangled in fragments of fishing nets by various observers. Although no formal surveys have been conducted to document entanglement rates, some preliminary information does exist. Majluf (pers. commun., 1987) reported observing 5-10 entangled seals in a colony of about 2000 on Punta San Juan, in Peru, during the most recent field seasons. In 1987, Stirling (pers. commun.) observed two entangled yearlings (one year olds) at the same colony as part of a group of a few hundred and scars of previous entanglement were observed on one adult female. Guerra (pers. commun., 1987) reported that in Chile, individuals of this species were observed to have swallowed the hooks and monofilament line used in a fishery for Bacalao (Dissostichus eleginoides), such debris being the result of animals tearing the line from active gear.

Arctocephalus forsteri (New Zealand fur seal)

The New Zealand fur seal has been observed entangled in plastic packing bands and scraps of fish netting (Cawthorn, 1985; Gentry, pers. commun., 1988). Entanglement appears to occur most commonly around the head and neck area predominantly with plastic strapping bands (polypropylene strapping, 46% of the cases). Netting and rope has also been involved in observed entanglement. It is believed that juvenile fur seals play with the entangling materials which then slip over their heads and become lodged in place. Entangled individuals are observed in areas of important trawl fisheries. Entanglement rates (used in this review to mean the portions of animals entangled) have not been documented for this species.

Arctocephalus gazella (Antarctic fur seal)

A variety of objects have been observed entangled on individuals of this species, the most common being rope circles fastened with knots (Bonner and McCann, 1982). These ropes generally are of synthetic fibers which are buoyant and at the surface where they are available to the seals. Individual seals are believed to play with and encircle themselves in these rings. Other objects found on these seals include fishing net, nylon string, polyethylene bags, rubber O-rings, and very commonly plastic packaging bands. Observed entanglements have involved debris on mature animals of both sexes. The collection of observations on entangled seals of this species indicates that often these seals entangle themselves by swimming into debris floating at sea. Entanglement rates have not been systematically documented for this species.

Arctocephalus philippii (Juan Fernandez fur seal)

Wallace (1985) cites information indicating that this species has been observed entangled. It was reported that entanglement involves predominantly plastic packing bands, although the frequency of entanglement for this species has not been documented.

Arctocephalus pusillus (Cape or South African fur seal)

Shaughnessy (1980) summarizes information on entanglement among Cape fur seals. Most entanglement for this species involves entanglement around the animal's neck. Entanglement rates vary from 0.11 to 0.66% for harvested seals (pups) from colonies near the coast of southern Africa. Entanglement involves string, monofilament lines, fishing net, rope, plastic straps, rubber O-rings, and wire. Plastic strapping bands are commonly found on entangled animals, but monofilament line is the most common. The frequency of occurrence of various types of debris varies from colony to colony. At one colony trawl net material and trawl net rope were the most frequently recorded objects of entanglement. Although entanglement for most species seems to occur predominately among young animals, observed entangled animals for this species include adult males. In view of the observed entanglement rates and fluctuating numbers on the different colonies, further study of the influence of entanglement for this species would be of merit.

<u>Callorhinus</u> <u>ursinus</u> (Northern fur seal)

The northern fur seal has been the most studied of all the pinnipeds, concerning debris entanglement. Since the early 1930's there have been observations of northern fur seals entangled in various objects (mostly plastic). The majority of the debris currently observed on this species consists of trawl net fragments (about 60%) and plastic packing bands (about 33%, Fowler, 1987). Other objects include monofilament gill net material, rope and twine, and assorted miscellaneous objects such as plastic lawn chair webbing. These objects are usually caught around the fur seal's head, neck, and shoulders and sometimes the flippers. As reviewed in Fowler (1987), the incidence of such entanglement increased after the mid-1960's with intensified fishing effort in the North Pacific Ocean and Bering Sea. At that time, as today, plastic materials were used extensively in making trawl netting and packing bands. The current incidence of entanglement observed among subadult males on the Pribilof Islands is about 0.4%. Almost all entangling materials observed on subadult males ashore weigh less than 0.4 kg. Between 60 and 80% of the trawl netting debris found at sea or on beaches in the Bering Sea consists of fragments larger than those found on the seals that return to the Pribilof Islands. Trawl netting debris is sighted in the North Pacific and Southeastern Bering Sea at the rate of 0.2 to 3.1 fragments per 1,000 km as shown from pelagic surveys. Between 10 and 17% of these fragments (total sample of 30) are observed to contain entangled seals. Northern fur seals appear to become entangled after approaching and investigating debris. Entanglement involves both sexes and appears to involve predominantly young animals, which are occasionally observed entangled as groups in large debris. Entanglement in debris results in increased energy expenditure, especially while dragging large fragments of net at sea. Compared to nonentangled seals, entangled seals spend more time at sea, whether foraging, traveling, or both (Bengtson et al., in prep.).

To date, 14 dead entangled northern fur seals have been observed, most at sea, and most in large pieces of debris. Most living entangled seals seen on land are found with small pieces of debris; some have been known to live for several years following the first observation. Those that die from the entanglement, whether observed or not, contribute to the overall mortality rate. This mortality is implicated in the declining trends in the Pribilof population (Fowler, 1987). Rates of changes in the numbers of northern fur seals born (Fig. 1) are correlated with observed entanglement rates. Also, an increase in mortality has been observed in the first several years of life and is correlated with entanglement (Fig. 2), as are rates of change in counts of adult males. Mortality due to entanglement (i.e. the fraction of the population that become entangled and die as distinct from those that survive to die from unrelated causes) as estimated from these correlations, is sufficient to cause observed declines as verified by population models (Swartzman, 1984; Trites, 1984; Fowler 1985).

<u>Eumetopias</u> <u>jubatus</u> (Northern sea lion)

Material causing entanglement in northern sea lions have included two general categories of debris: discarded plastic packing bands and fragments of fishnet material (Calkins, 1985; Loughlin et al., 1986). In both cases it appears that the observed entanglement involves predominately 2- to 3-year-old and older animals; entanglement rates among pups (after they leave land) and 1-year-olds have not been documented. Both sexes are involved. Wounds appear to develop as the animal grows into the band or netting material, which then causes a laceration. Netting fragments found on northern sea lions are usually small, mostly less than 2 m^2. Entanglement rates have been estimated at about 0.07% for adults included in surveys for entanglement. The northern sea lion population of the North Pacific Ocean has experienced a decline since the 1960's. Although it is not known to what extent entanglement may be contributing to this trend, it is a potential factor in need of further study (Merrick et al. 1987).

<u>Otaria</u> <u>flavescens</u> (South American sea lion)

Wallace (1985) summarizes information indicating that the South American sea lion has been observed entangled, primarily in plastic packing bands. Ramirez (1986) lists ropes, wires, and plastic packing bands as entangling objects for this species on Península Valdés in Argentina. Entanglement rates have not been systematically documented for this species. Stirling (pers. commun., 1987) reports sighting an entangled individual in 1984 at Punta San Juan in Peru, and believes the animal may have been a yearling. The entangling material appeared to be a plastic or rubber ring.

Phocarctos hookeri (Hooker's sea lion)

The only documented case of entanglement for this species is a juvenile observed in a piece of discarded monofilament nylon fishing net (Cawthorn, pers. commun., 1987). Juveniles are often observed playing with fragments of man-made materials in the water near rookeries. Entanglement rates have not been systematically documented for this species.

Zalophus californianus (California sea lion)

Approximately 0.08% of California sea lions surveyed on islands off the coast of California by Stewart and Yochem (1985) were observed entangled, including at least one dead entangled animal. Entangling materials included plastic packing bands, rubber bands, monofilament gill-net fragments, and monofilament fishing line caught around their bodies, primarily their necks. These observed entanglement rates, coming from surveys conducted in 1983 and 1984, were slightly lower than the results of a similar survey conducted in 1985 and 1986. In the latter survey (Stewart and Yochem 1987) about 0.16% of the animals observed were entangled with about 0.11% showing scars from previous entanglements. Most of the entangling materials observed on California sea lions are estimated to weigh less than 100 g and consist predominantly of nylon gill-net material. Since nylon is negatively buoyant (sinks), it is probable that animals became entangled either in fishing gear while it is in use or in gill-net debris attached to floats. Entangling material that is clearly from marine debris (as opposed to being cut or broken from actively fished gear to release incidentally caught animals) accounts for 33% of the entanglement observed among California sea lions. Over the past two decades, the population of Zalophus has been expanding along the west coast of North America.

There are six species of otariids not listed above, none of which have been documented as being observed entangled in debris. None of the experienced observers contacted for information for this review were aware of any individuals of these species having been seen entangled. Stewart (pers. commun., 1987) has not observed entanglement among Guadalupe fur seals, nor has Gentry (pers. commun., 1988). The same holds for observations by DeLong (pers. commun., 1988) who also indicated that there is very little debris on the shores of Guadalupe Island. Trillmich (pers. commun., 1978) has not observed entanglement among either Galapagos sea lions or Galapagos fur seals.

PHOCIDS

The family Phocidae includes the true seals, and the elephant seals.

Halichoerus grypus (Gray seal)

Information about observed entanglement among gray seals is largely anecdotal. Contact with pinniped specialists indicates that only a few gray seals have been observed entangled. Reports from opportunistic sightings on Sable Island, Canada, in 1987 indicate that 21 pups were seen entangled in trawl net fragments (Bowen, pers. commun., 1987). This compares with only about three or four per year in previous years. As little data exist on the sex or age specific nature of entanglement, it is important to point out that entangled seals observed in this work have included adult females. Future surveys are planned to estimate entanglement rates for gray seals from Sable Island. About 1 in 2,000 gray seals in the United Kingdom are observed to be entangled in net debris from both drift and trawl nets (Anderson, pers. commun., 1987). For example, about one animal per year is sighted at North Rona in the Outer Hebridies. Others (two to three per year) are sighted with wounds indicating that the animals may have been entangled earlier. The entangled animals are usually nonbreeding individuals. Gray seals caught incidentally in active gear are usually young (less than 2 years old), leading to the possibility that entangled animals are also usually young.

Mirounga angustirostris (Northern elephant seal)

Stewart and Yochem (1985) indicate that 0.08% of northern elephant seals surveyed off the coast of California showed evidence of entanglement. These data, from 1983 and 1984, contrast with data from a similar study conducted in 1985 and 1986 (Stewart and Yochem 1987) in which 0.17% of elephant seals observed on San Nicholas Island and 0.15% on San Miguel Island were observed entangled. Evidence of previous entanglement in the form of scars occurred in similar proportions. Entangling materials included monofilament line, trawl netting fragments, and plastic packing bands. Small pieces of debris (fragments weighing less than 100 g) account for about 47% of the entanglement of northern elephant seals. About one-half of the entangling materials on northern elephant seals are clearly marine debris as opposed to fragments which may have resulted from entanglement in active fishing gear. As in the case of California sea lions, the incidence of entanglement among northern elephant seals was higher in the second survey. The population of northern elephant seals along the west coast of North America has been expanding rapidly over the past two decades.

Mirounga leonina (Southern elephant seal)

Ramirez (1986) indicates that individual southern elephant seals have been observed entangled in ropes, wires, and plastic packing bands on the Valdes Peninsula of Argentina in South America.

Monachus schauinslandi (Hawaiian monk seal)

As an endangered species, the Hawaiian monk seal has received a great deal of attention regarding any potential cause of mortality, including entanglement in marine debris (Henderson, 1985). Studies since 1974 have documented about 28 cases of entanglement (12 incidents were documented in 1987), including at least one mortality due to entanglement (Henderson, pers. commun., 1987). Entangling materials have included fishnet, plastic rings, rope, nylon strapping, life preserver, and plastic bag materials. Hawaiian monk seals are more often entangled about the shoulders and torso than around the head and neck as otariids are. Also, entanglement among Hawaiian monk seals appear to occur on or near shore as compared to the predominance of pelagic entanglement for the otariids. Entanglement rates (proportion of animals observed to be entangled) vary between 1 and 7% depending upon age and location (island). Weaned pups appear to be more susceptible to entanglement than the older age groups.

Phoca groenlandica (Harp seal)

As in the case of gray seals, most information about entanglement among harp seals is largely anecdotal. A few harp seals have been observed entangled (Bowen, pers. commun., 1987) and entangling objects have included fragments of both monofilament gill net and trawl net webbing, along with plastic packing bands. Historical rates have not been systematically documented.

Phoca vitulina (Harbor seal)

In surveys from 1983 and 1984 conducted by Stewart and Yochem (1985) it was found that 0.05-0.06% of harbor seals from islands along the California coast were entangled. In similar surveys conducted in 1985 and 1986 observed entanglement rates ranged from 0.07 to 0.11%. Entangling materials included monofilament line and plastic packing bands. A small number of entangled seals (i.e. one or two per year) are sighted among the major concentrations of this species in the British Isles such as on the Orkney Islands (as observed by Paul Thompson; Anderson, pers. commun. 1987). The entangling materials include both trawl and drift net fragments. No harbor seals on Sable Island, Canada, have been observed entangled (Bowen, pers. commun., 1987)

There are eight species of phocids not listed above, none of which are represented in the literature as having been observed entangled. Field specialists and other field observers reported that no entanglement has been observed among these species. For example, Matthew Iya of the Alaska Eskimo Whaling Commission, and Ben Nageck of the North Slope Borough, Department of Wildlife Management (through contact by Lloyd Lowry of the Alaska Department of Fish and Game) both report no observed entanglement for the bearded seal. This is confirmed by personal observations by Lowry (pers. commun., 1987), and Fay (pers. commun., 1987) for all of the ice seals of the northern high latitudes. The same holds for phocids of the southern high latitudes (Siniff, pers. commun., 1987; Bengtson, pers. commun., 1987; Stewart, pers. commun., 1987; DeMaster, pers. commun., 1987).

DISCUSSION

Plastic fishing debris is scattered throughout the world but tends to be found in highest concentrations in areas of intensive fishing, especially where meterological and oceanographic convergence zones occur (Shomura and Yoshida, 1985). The kinds of net fragments found in any particular area of the oceans are roughly correlated with the kinds of fisheries in that area (Fig. 3, Fowler, 1987). Ocean currents, winds, and displacement by entangled animals move debris from its point of origin. Trawl net fragments, for example, are found in the mid-Pacific and on beaches of Hawaii, great distances from the locations of major trawl fisheries.

One of the less clearly understood aspects of entanglement among pinnipeds is the historical development of the problem. For northern fur seals it is clear that the problem developed following increases in fishing effort in the Bering Sea. The time lag between the increase in effort and the buildup of netting debris resulting in observed entanglement rates is, however, not understood. To understand this phenomena, comparative studies on the chronology of fisheries development and the occurrence of entanglement among pinnipeds could prove helpful.

One pattern apparent in the information on entanglement among pinnipeds is that a difference exists between phocid and otariid seals. Phocid seals seem to be less prone to entanglement than are otariids (Laist, 1987), a possibility first noted in Shomura and Yoshida, (1985). Consistent with this view are the data in Table 1: individuals representing 10 species of otariids (63%) have been observed entangled, many in significant numbers, while only six species of phocids have been observed entangled and in numbers generally thought to be relatively inconsequential.

Potential explanations for the difference between the entanglement rates of otariids and phocids include body shape (otariids tend to have longer more slender necks in proportion to the rest of their body), behavioral differences (otariids may be more inquisitive), and habitat location (phocids may have reduced exposure to debris by virtue of their association with ice or other regions of low fishing activity).

The possibility that body shape influences entanglement rates is consistent with the observation that, for a particular species, entanglement may be less of a problem for older, more robust, animals than for younger animals. It is also possible that because phocids have a more rounded body shape, and larger necks in proportion to their heads, there is less likelihood of their heads becoming entangled in netting material.

The amount of debris in the habitat of a species would seem be an important factor in determining the extent of entanglement. Phocids tend to be associated with high latitude environments where fisheries have not realized the extensive development that has occurred at lower latitudes. In one case, otariid seals and phocid seals in the same area show similar entanglement rates as demonstrated by the California sea lion and the northern elephant seal in Californian waters (see Stewart and Yochum, 1985, 1987). This may indicate that the rate of entanglement is largely dependent on the concentrations of debris to which animals are exposed. Alternatively, in view of differences in feeding area, body size, and behavior, several factors could be acting in unison to bring about the similar levels of entanglement.

The most accepted view among the investigators contacted for this review is that the differences are probably largely due to a distinct difference in the play behavior and curiosity between these two groups of pinnipeds, otariids being more playful and curious than are phocids. Consistent with this possibility is the observation that, regardless of species, it is often the young that seem to become entangled most often; the young of any species being more playful and curious. An example of otariid behavior that may put them at greater risk is their habit of "surfing" which may increase the chances of simply hitting and becoming entangled in a piece of debris. Japanese research with captive northern fur seals has also shown a distinct tendency by these animals to approach, investigate, play with, and entangle themselves in debris placed in the water. The same observations were made in research conducted by the National Marine Mammal Laboratory while studying the chances of pups becoming entangled in webbing of different mesh size (Bengtson et al., in prep).

One factor of observed entanglement that becomes obvious working with data and in field studies, is that the animals observed entangled are the survivors and therefore underrepresent the true extent of the problem. Specialists asked to review this work pointed out the need to underscore the fact that we know that more entanglement related mortality is occurring than indicated by the number of observations. It is clear that more information and more research is required to address the degree to which such problems exist, especially for the preponderance of species and geographic areas about which we have very little information.

SUMMARY

Plastic fishing debris in the world's oceans are a significant source of entanglement for marine mammals, especially the pinnipeds as reviewed in this paper. Observations on northern fur seals, California sea lions, and Hawaiian monk seals have documented mortality caused by entanglement. The northern fur seal is the only species for which there are estimates of mortality rates caused by entanglement. Entanglement is clearly a factor in causing mortality for other species of pinnipeds, and related problems appear to be more significant for the otariids than for the phocids, based on both entanglement rates and percentages of the species involved.

Extended study of entanglement among pinnipeds is of obvious importance. The chronology of the occurrence of entanglement deserves scrutiny. Further research is needed to evaluate the extent of entanglement by seals and sea lions in derelict fishing gear and debris and its influence on populations of species for which entanglement has been observed, and to understand better the differences between entanglement rates observed for various groups. Research on the effects of entanglement at the population level seems of special merit for northern fur seals, Hawaiian monk seals, Cape fur seals, and northern sea lions. Placing emphasis on these species is not meant to diminish the possibility that some of the small and remote populations of other species (especially those in areas of intensive fishing) might be experiencing the effects of entanglement without our knowledge of the problem, and therefore, deserve equal concern.

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Table 1. A list of otariid and phocid pinnipeds that have been observed entangled in plastic marine debris with corresponding lists of sources of information or documents containing information on observations or studies of the effects of entanglement.

OTARIIDS	References[1]
Arctocephalis australis (South Anerican fur seal)	Goebel, M. pers. commun., (1987), Stirling, I, pers. commun., (1987), Majluf, P., pers. commun., (1987)
Arctocephalis forsteri (New Zealand fur seal)	14, Cawthorn, M. pers. commun. (1987), Gentry, R,, pers. commun. (1988)
Arctocephalis gazella (Antarctic fur seal)	10, 11, 45
Arctocephalis phillippi (Juan Fernandez fur seal)	13
Arctocephalis pusillis (Cape or South African fur seal)	53, 54, 55
Callorhinus ursinus (Northern fur seal)	3, 6, 7, 8, 9, 16, 17, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 37, 38, 41, 42, 43, 48, 50, 51, 52, 56, 59, 61, 62, 63, 64, 65
Eumetopias jubatus (Northern sea lion)	12, 43, 44
Otaria flavescens (South American sea lion)	46, Majluf, P., pers. commun. (1987); Stirling, I, pers. commun. (1987)
Phocarctos hookeri (Hooker's sea lion)	14, Cawthorn, M. pers. commun. (1987)
Zalophus califorianus (California sea lion)	17, 18, 36, 44, 57, 58

PHOCIDS	References
Halichoerus grypus (Grey seal)	Mate, B. R. pers. commun. (1987); Bowen, W. D., pers. commun. (1987), Anderson, S., pers. commun. (1978)
Mirounga angustirostris (Northern elephant seal)	57, 58
Mirounga leonina (Southern elephant seal)	47
Monachus schauinslandi (Hawaiian monk seal)	1, 2, 5, 23, 33, 34, 35, 39, 40, 60
Phoca groenlandica (Harp seal)	Bowen, W. D., pers. commun. (1987)
Phoca vitulina (Horbor seal)	57, 58, Anderson S., pers. commun. (1978)

[1]numbers refer to numbered entries in the bibliography found in appendix I

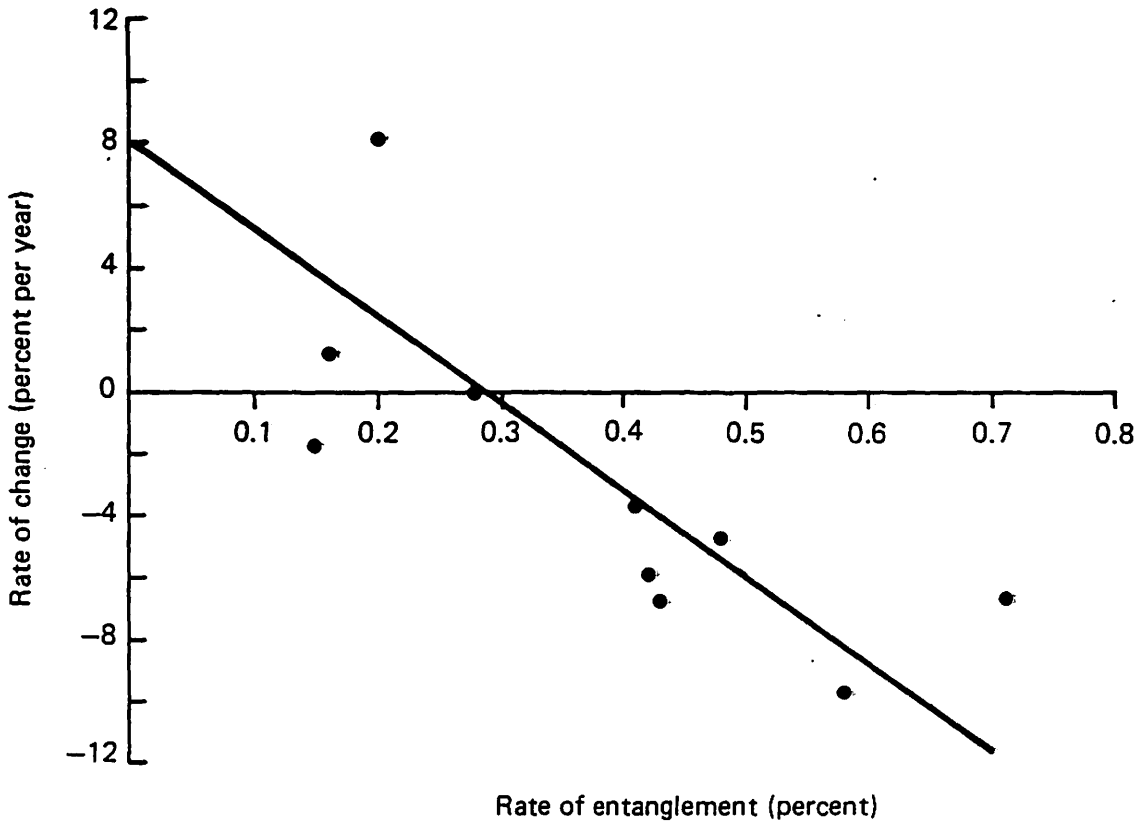

Figure 1. Correlation between the rate of change in estimated numbers of northern fur seal pups born (as determined from a running mean of three for 1972-1984, and the percent of juvenile males observed entangled 6 years earlier (1967-1977, R = .77)

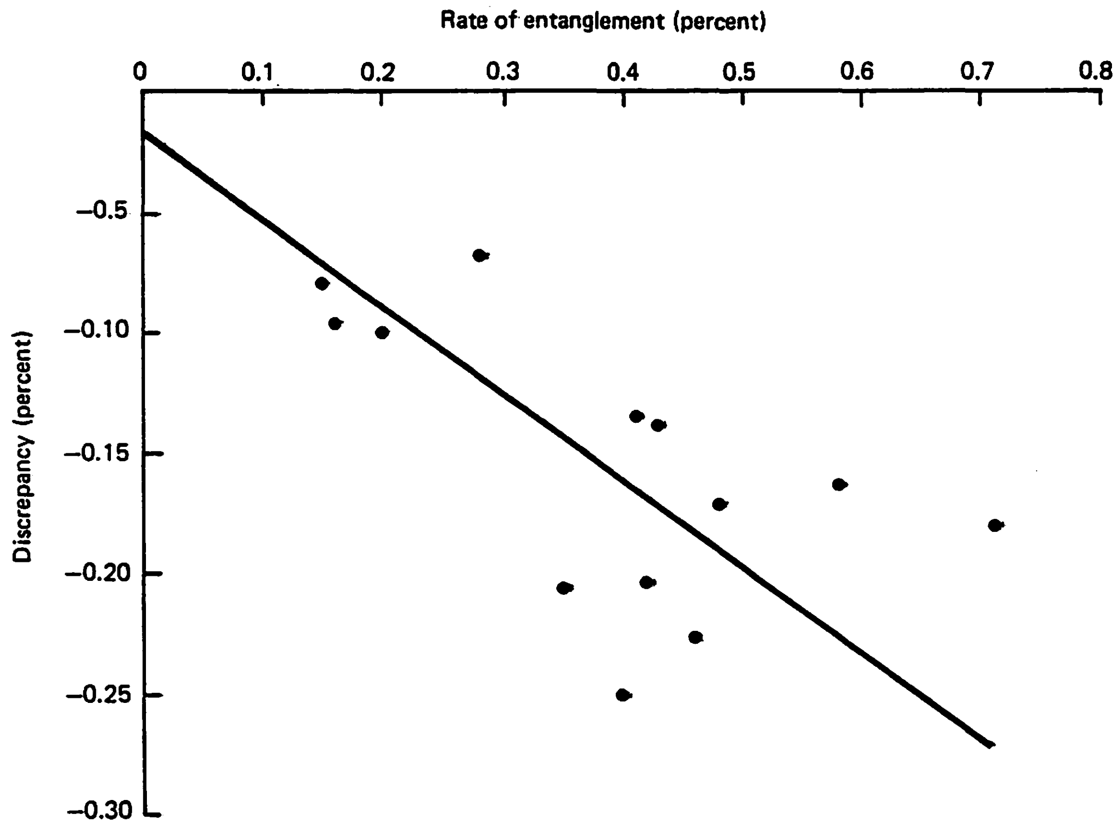

Figure 2. The correlation of the discrepancy between predicted (from a previous correlation with pup survival on land) and observed survival rates of juvenile males observed entangled 1 year later (1967-1979, R = .60, from Fowler (1987))

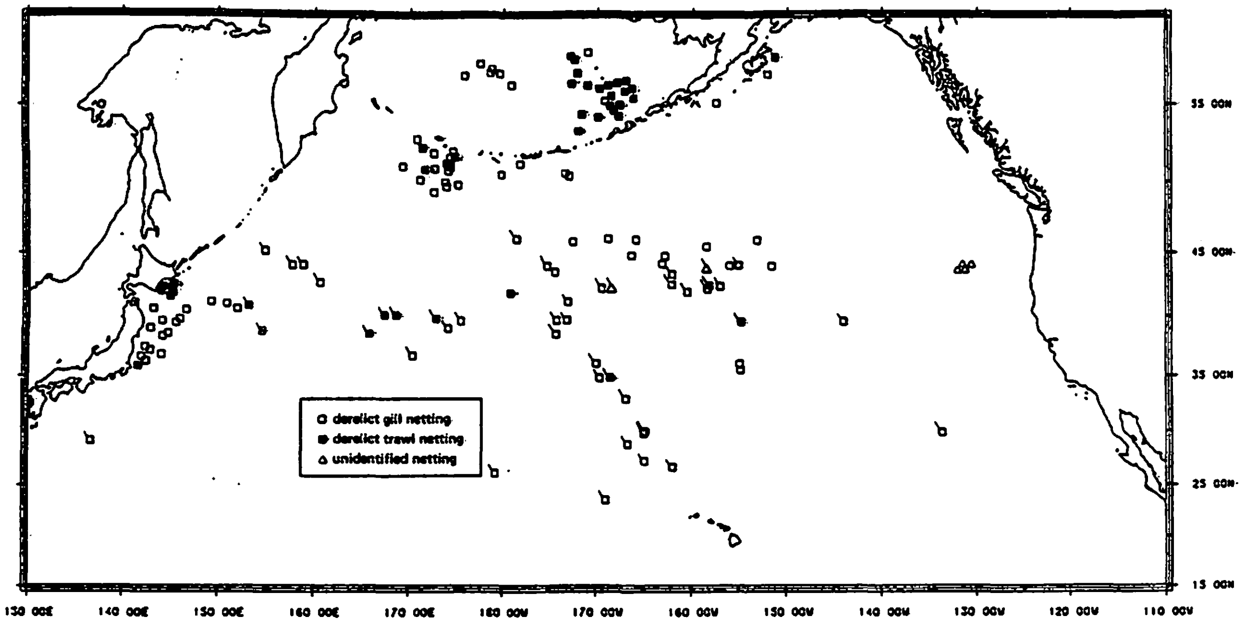

Figure 3. Some of the recorded occurrence of netting debris in the North Pacific Ocean. Simple symbols are for data from surveys, tagged symbols are from opportunistic sightings (See Fowler, 1987, for sources of data).

APPENDIX I

BIBLIOGRAPHY ON PINNIPED ENTANGLEMENT IN PLASTIC DEBRIS

BIBLIOGRAPHY ON ENTANGLEMENT OF PINNIPEDS IN PLASTIC DEBRIS

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