ENTANGLEMENT DEBRIS ON ALASKAN BEACHES, 1986

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In 1986, 13 Alaskan beaches were surveyed to determine type, abundance, deposition rate, and fate of entanglement debris stranded ashore. Seven beaches near Yakutat were surveyed four times in 1986 to determine seasonal trends in abundance, and six beaches on Middleton Island were surveyed once. From 1985 to 1986, debris increased 130% on five beaches at Yakutat and 45% on four beaches on Middleton Island.

KEYWORDS: *Middleton Island, *Refuse, *Beaches.

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ABSTRACT

In 1986, 13 Alaskan beaches were surveyed to determine type, abundance, deposition rate, and fate of entanglement debris stranded ashore. Seven beaches near Yakutat were surveyed four times in 1986 to determine seasonal trends in abundance, and six beaches on Middleton Island were surveyed once. Three types of entanglement debris were common (>5 pieces per kilometer of beach)--rope, trawl web, and packing straps--whereas derelict gill nets were not common. Debris was nearly twice as abundant at Middleton Island than at Yakutat. From 1985 to 1986, debris increased 130% on five beaches at Yakutat and 45% on four beaches on Middleton Island. Two beaches cleared of surface debris on Middleton Island in 1985 had accumulated debris to previous levels in 1986. Most (99%) of the debris items marked with paint in September 1985 at Yakutat disappeared by January 1986; during this same period, however, there was also a 40% accrual of new (previously unseen) debris. Trawl web fragments stranded ashore at Yakutat were tagged and mapped; recoveries of tagged fragments showed that once stranded, many fragments (>50%) remained ashore and movement to adjacent beaches was infrequent. Storms buried and reexposed some trawl web fragments and washed some inland off the beach. More fragments were stranded or uncovered in the fall and winter than in spring and summer. A deposition rate of seven fragments of trawl web per kilometer of beach per year was determined at Yakutat.

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INTRODUCTION

Recently, concern about the amount of plastic debris found at sea and on beaches has increased (Coleman and Wehle 1984; Norris 1986; Murphy 1986; Pruter 1987). Because most plastics are light-weight and durable, they float at sea and persist in the environment for many years. Debris washed ashore mars the scenic quality of beaches, and while adrift at sea, can endanger marine animals. Marine mammals can become entangled in fragments of trawl web, packing straps, and rope (Scordino 1985; Fowler 1987); seabirds and fish can become entrapped in derelict gill nets (Degange and Newby 1980); and seabirds and sea turtles can ingest pieces of plastic that block their digestive tracts (Balazs 1985; Day et al. 1985).

Plastic debris washed ashore represents, to some degree, the types and quantities lost or discarded at sea. Therefore, beach surveys can provide information on the magnitude of the debris problem at sea. Although beach surveys of plastic debris have been conducted in Alaska (Merrell 1980, 1984, 1985; Merrell and Johnson 1987), few studies have determined trends in abundance, deposition rate, or fate of debris stranded ashore.

In 1986, the National Marine Fisheries Service continued Alaskan beach surveys that have been conducted periodically since 1972. Primary objectives were to determine 1) deposition rate of trawl web, 2) types and quantities of plastic debris on beaches, 3) fate of debris stranded ashore, and 4) trends in abundance of plastic debris by sampling beaches that had been surveyed in previous years. Although many types of plastic debris were found on beaches, only those commonly associated with entanglement of marine animals are discussed in detail in this paper: trawl web, monofilament gill net, packing straps, and rope. Emphasis in 1986 was on trawl web because a major trawl-fishery for groundfish operates off Alaska (Low et al. 1985) and substantial amounts of trawl web are lost or discarded each year (Berger and Armistead 1987). Trawl web is also the predominate item found entangled on northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Alaska (Fowler et al. 1985).

METHODS

Survey sites in 1986 were seven beaches near Yakutat on the Alaska mainland and six beaches on Middleton Island in the central Gulf of Alaska (Fig. 1). All beaches sampled in 1986 had been surveyed in 1985 (including two beaches (nos. 3 and 4) on Middleton Island cleared of all surface debris in 1985; Fig. 1). Survey methods (Merrell 1985) were the same for all beaches. Each beach was subdivided into 100-m transects (most beaches were 1 km long; therefore, each beach had ten 100-m transects). The survey area for each beach included the intertidal zone between the water's edge and the seaward limit of terrestrial vegetation, at the upper limit

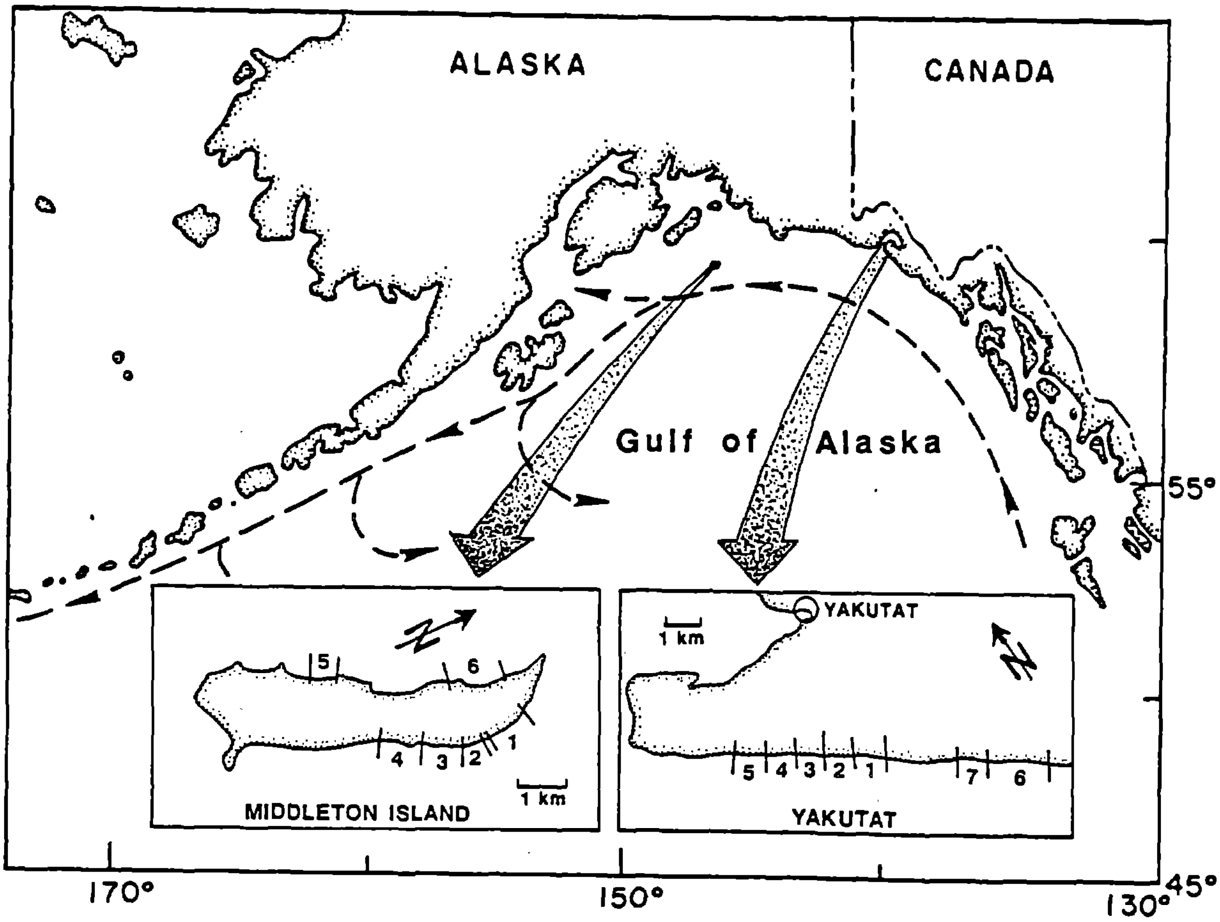

Figure 1.--Location of 1985-86 study beaches on mainland Alaska (Yakutat) and in the Gulf of Alaska (Middleton Island). Broken arrows indicate approximate locations of major ocean currents (Day et al. 1985).

of normal high tide. We counted plastic debris visible from walking height (i.e., pieces 25 mm and net fragments with five or more complete meshes). We did not count fragments of larger pieces (e.g., gill net floats and plastic bottles) if they were less than one-half their original size. We weighed or estimated the weight of trawl web fragments depending on size and whether they were loose on the beach, buried, or snarled on drift logs. We did not search for debris within piles of driftwood or seaweed.

To determine trends in annual accumulation of plastic debris on Middleton Island, two beaches were cleared of all surface debris in 1985 and sampled in 1986, in addition to the four beaches where debris was left in place. On cleared beaches, -debris which could be carried was moved to terrestrial areas above the high tide zone. Debris too large to move, partially buried, or snarled on drift logs, was marked with paint and flagging so items could be recognized on subsequent surveys.

At Yakutat, trends in accumulation and disappearance of debris were assessed with emphasis on trawl web. We chose a 5-km beach, subdividing it into five adjoining l-km sections and permanently marking the boundaries with flagging and paint on trees above high tide. In September 1985, all plastic items (bottles, rope, strap, net floats, six-pack yokes) in each l-km section were marked with spray paint. A different color paint was used for each section. In addition, each trawl web fragment was marked with a numbered tag, and its location on the beach mapped. Two adjoining sections approximately 3 km from the 5-km beach (Fig 1.) were surveyed for trawl web only, and during each survey, fragments were tagged and mapped. The numbers and locations of marked recoveries were determined on surveys conducted in January, April, July, and September 1986. Search efficiency (the ability to find marked debris) was good on study beaches in all sampling periods: however, efficiency was low during cursory searches in terrestrial areas immediately inland from the upper limit of normal high tide because of piles of drift logs, vegetation, and snow in winter.

For both Middleton Island and Yakutat, annual differences in quantities of individual debris items (i.e., trawl web, rope) were examined by two-sample t-tests. We estimated seasonal changes in quantities of debris at Yakutat by one-way analysis of variance (ANOVA) where number of plastic items per 100 m of beach was the dependent variable and month was the independent variable. Prior to the ANOVA, quantity of debris was transformed to square-roots because the within-month variance was associated with the mean (Dixon et al. 1983). A Student-Newman-Keuls (SNK) test (Sokal and Rohlf 1969) was used to examine between month differences in debris abundance.

RESULTS

Entanglement debris (number of pieces per kilometer of beach) increased from September 1985 to September 1986. Debris increased 130% on five Yakutat beaches: this was attributed to significant increases in strapping (P = 0.03), rope (P = 0.04), and a nearly significant increase in trawl web (P = 0.08) (Fig. 2). Debris on four beaches on Middleton Island increased 45%, although there was no significant difference in any single debris item (Fig. 2). The overall increase at Middleton Island was primarily the result of an 88% increase in rope.

The number of debris items varied greatly on different beaches at Middleton Island. Two beaches (nos. 1 and 2) on the northeast side of the island, exposed to prevailing southeasterly winds, had 15 times the amount of debris as two beaches (nos. 5 and 6) on the northwest side of the island (Fig. 1).

The relative proportion of each type of entanglement debris was similar at Yakutat and Middleton Island; at each location, rope was always the most abundant and monofilament gill net was always the least abundant. In 1986, entanglement debris was nearly twice as abundant at Middleton Island (62 pieces per kilometer of beach) than at Yakutat (36 pieces per kilometer of beach).

Two beaches on Middleton Island, cleared of all plastic debris in 1985 and sampled in 1986, had over a 100% accrual of debris in one year (i.e., the number of entanglement debris items removed in August 1985 had been replaced, or for some items (strapping and rope) increased by July 1986 (Fig. 3)). The relative abundance of different types of debris were similar in both years; rope was the most numerous item and gill net the least numerous.

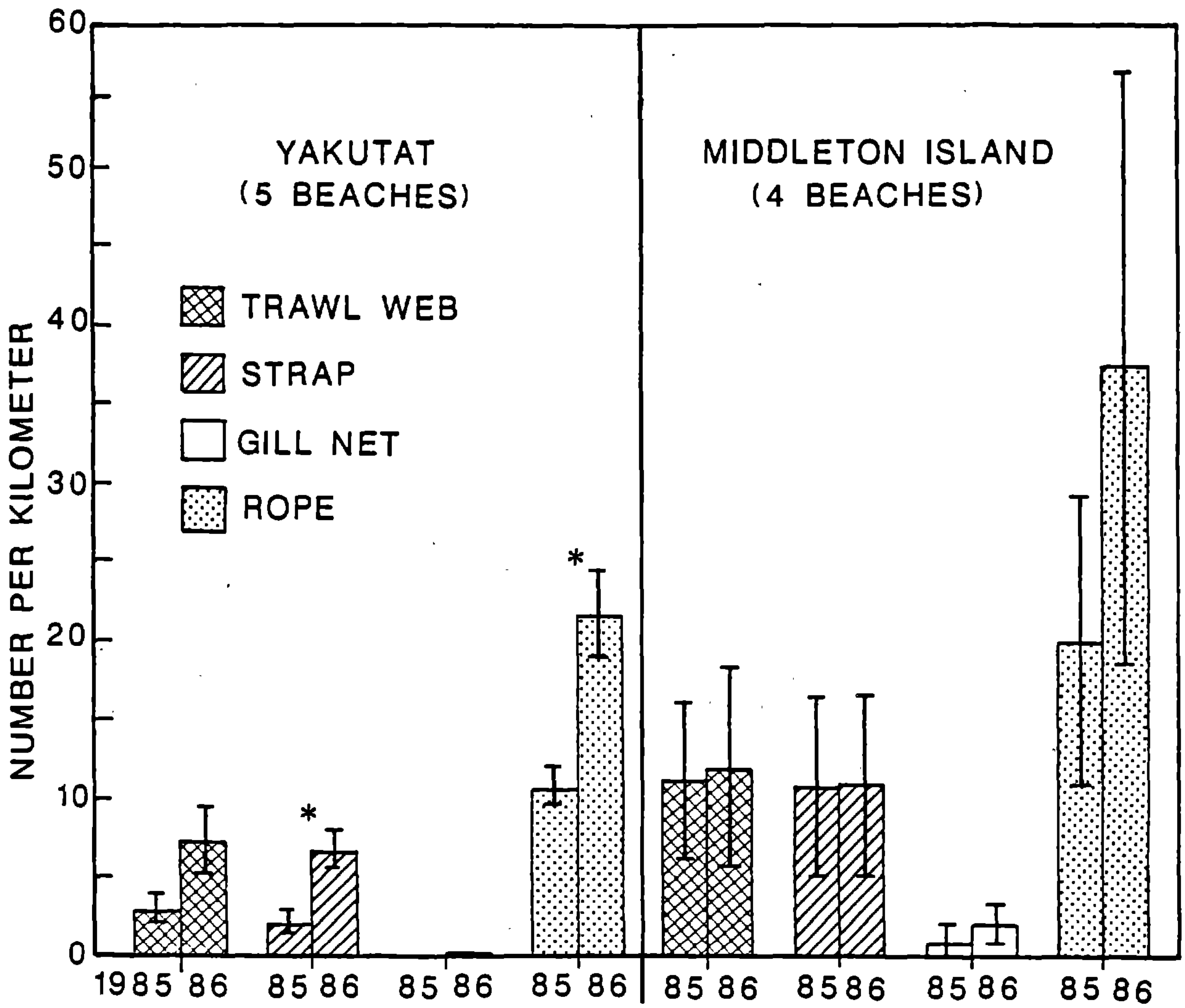

Figure 2.--Quantities of entanglement debris found on Alaskan beaches in 1985 and 1986. Data are mean ± standard error. Asterisk denotes significant difference, $\underline{P} < 0.05$. Data represents "new" debris found at time of sampling and does not include marked debris from previous surveys.

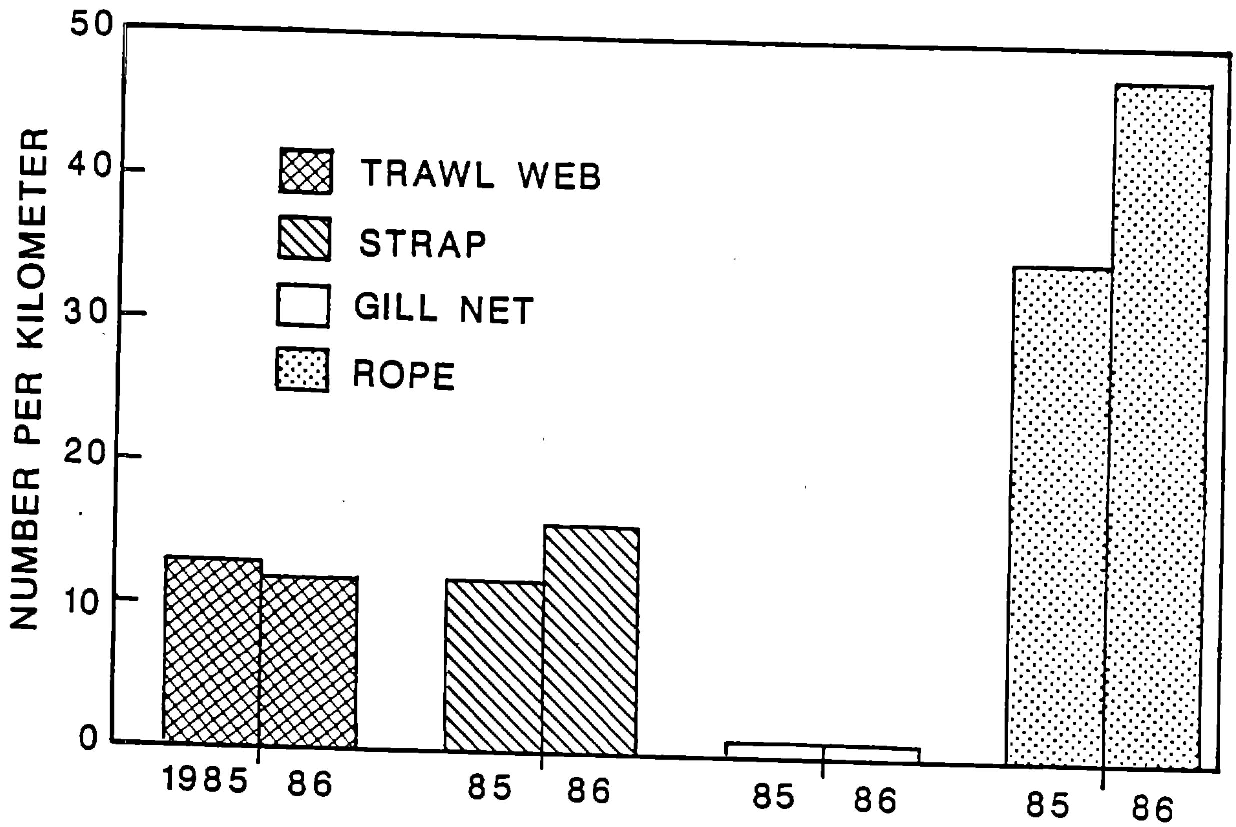

Figure 3. -- Recruitment of entanglement debris from 1985-86 on two beaches at Middleton Island that were cleared of all debris in 1985.

In September 1985, at Yakutat, we marked a total of 721 plastic debris items, excluding trawl web. In four subsequent surveys, less than 1.0% of these marked items were recovered (Table l), and these were mostly near the place they were marked. Two marked items were recovered in the terrestrial area inland from the beach. It is presumed that more marked items were not recovered because a major storm occurred in November 1985. The unusual severity of that storm was evidenced by weathered drift logs and other debris washed high up in the terrestrial area inland from the beach, uprooting l0- to 12-year-old spruce trees. Most (99.0%) of the marked items disappeared soon after marking between September 1985 and January 1986; during this same period, however, there was also a 40% accrual of new (previously unseen) debris on the beaches (i.e., the number of debris items found on beaches in January 1986 were 40% of that in September 1985).

At Yakutat beaches, quantities of plastic debris other than trawl web were significantly ($P < 0.001$) different on a monthly basis from January to September 1986 (Fig. 4). Significantly ($P < 0.05$) more debris was present in July and September than in January and April. September had the most debris of any sampling period (Fig. 4).

From September 1985 through July 1986, 85 fragments of trawl web were tagged and mapped at Yakutat. A typical fragment of trawl web weighed approximately 4 kg (mean of 77 fragments). In September 1986, 41 (48%) of the tagged

Table l. --Number of marked and unmarked plastic debris items on five l-km beaches at Yakutat, Alaska 1985-86. All items were marked in September 1985; recoveries are in parentheses.

Beach	Number Marked[a] Sept. 1985	New Pieces (Recoveries) 1986 Jan.	April	July	Sept.
Yakutat 1	115	38(0)	87(2[b])	171(1)	199(1)
Yakutat 2	110	30(0)	56(0)	166(0)	249(0)
Yakutat 3	148	49(0)	61(0)	167(0)	155(0)
Yakutat 4	151	91(0)	94(0)	201(0)	222(0)
Yakutat 5	197	81(2[c])	78(0)	181(0)	254(0)
Total	721	289(2)	376(2)	886(1)	1079(1)

[a]Excluding trawl web.

[b]One- in terrestrial area: the other item recovered on beach again in July and September.

[c]One in terrestrial area.

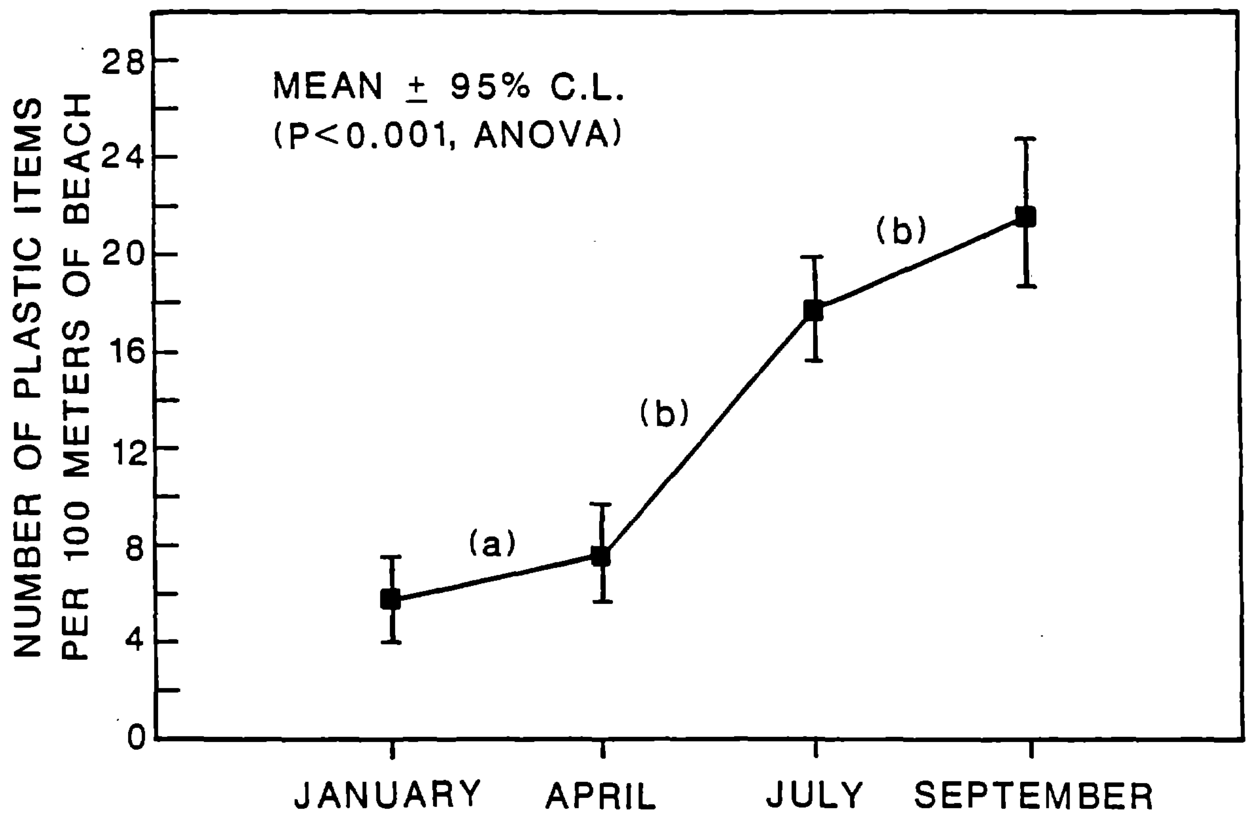

Figure 4.--Quantities of plastic debris found by season on Yakutat sections in 1986. Data based on fifty 100-m beach transects for each sampling period. Significance between means determined by SNK test; a = ns, b = significant $\underline{P} < 0.05$.

fragments were found (Table 2). Most (>70%) of the 44 missing tagged fragments had been tagged in September 1985 and January 1986 (Table 2). Some of the missing tagged fragments were probably washed inland to terrestrial areas as evidenced by three incidental tag recoveries found inland from the beach; some were probably buried. Mapping showed that 10% of the tagged fragments recovered in September 1986 had disappeared for at least one sampling period before recovery; four tags had been buried and then reexposed, usually in their original tagging location.

Movement of stranded fragments of trawl web to adjacent beaches was uncommon at Yakutat. Of the 41 tagged fragments recovered in September 1986, 30 were found at their original tagging location, 7 moved less than 500 m, and 4 moved more than 500 m (range 1.0 to 2.6 Jan).

More trawl web appeared to wash ashore at Yakutat in the fall and winter months than in the spring and summer months. The proportion of the total number of trawl web fragments found that were tag recoveries increased from January to September 1986 (Fig. 5); this was due primarily because 1) more tagged fragments were added to the survey area during each successive sampling interval and thus more tags were available for recovery with time, and 2) fewer new (previously unseen) fragments of trawl web were found on beaches in July and September than in January and April (Fig. 5). Because tagged fragments of trawl web already stranded ashore could be distinguished from new fragments

Table 2.--Trawl web tagged and recovered on 8 km of beach at Yakutat, Alaska 1985-86.

Date	Number of trawl web fragments	
	Tagged	Recovered (tagging date)
Sept. 1985	21	-
Jan. 1986	25	1 (Sept.)
April 1986	27	11 (3-Sept., 8-Jan.)
July 1986	12	26 (3-Sept., 8-Jan., 15-April)
Sept. 1986	9	41 (4-Sept., 10-Jan., 16-April, 11-July)

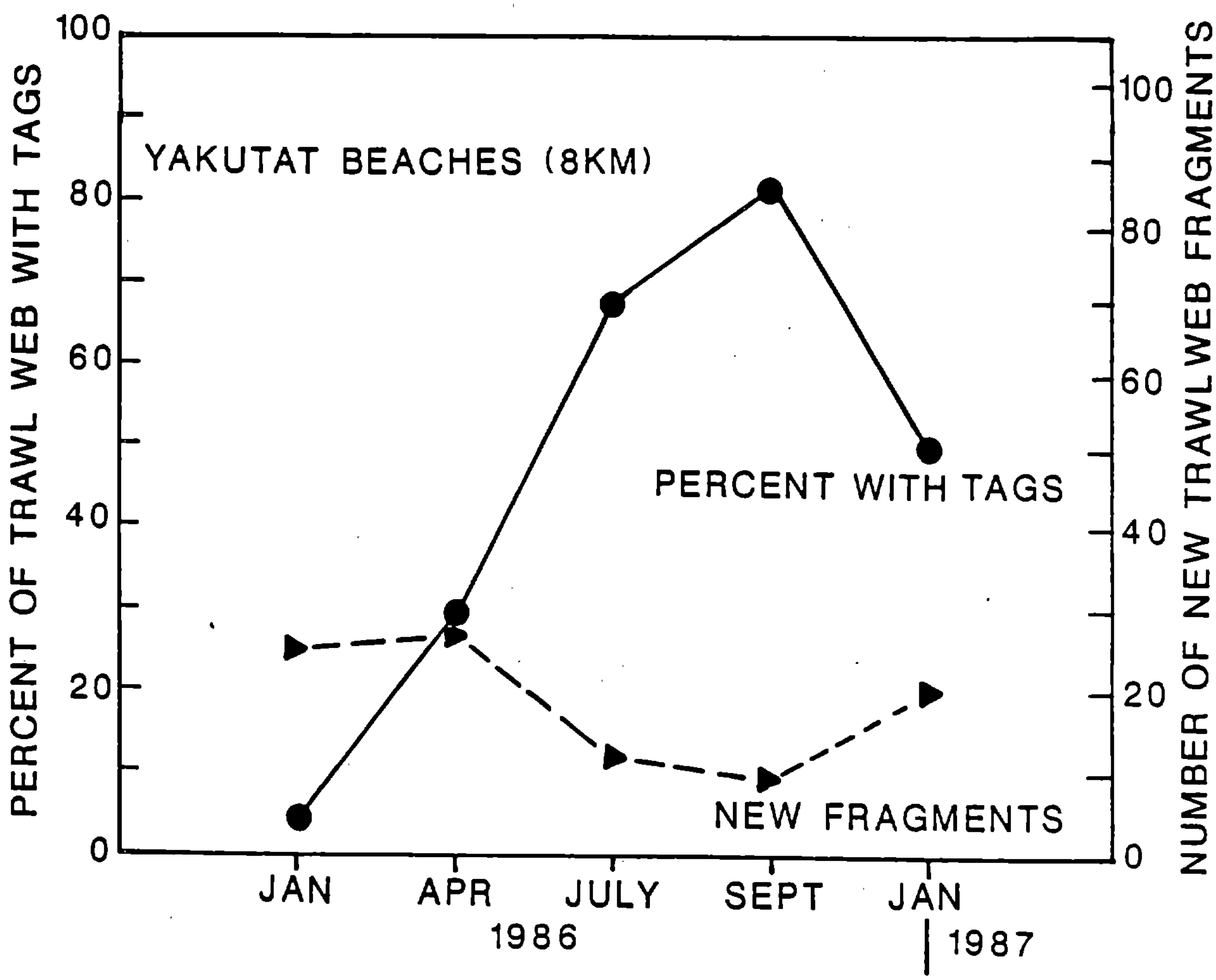

Figure 5.--Recovery of trawl web based on percent of the total trawl web found with tags and number of new (previously unseen) trawl web fragments that appeared on Yakutat beaches from January 1986 to January 1987. Initial tagging began in September 1985.

appearing on shore, we know that from September 1985 to September 1986, 73 new fragments of trawl web appeared on 8 km of beach at Yakutat (Table 2). The assumption that all of these fragments were newly washed ashore corresponds to a deposition rate of approximately nine fragments of trawl web per kilometer of beach per year at Yakutat.

DISCUSSION

In 1986, common entanglement debris on Alaskan beaches were rope, trawl web, and packing straps. Entanglement debris, especially rope and packing straps, increased on beaches at Yakutat, and to a lesser extent, on beaches at Middleton Island from 1985 to 1986. This trend contradicts our results from 1984 to 1985 when we observed a decrease in entanglement debris at both sites (Merrell and Johnson 1987). Increased debris in 1986 may be a result of recent and large increases in domestic fisheries (Low et al. 1985) or annual differences in ocean currents **or** storms. As in 1985 (Merrell and Johnson 1987), more entanglement debris was found at Middleton Island than at Yakutat in 1986, possibly because of its proximity to fishing operations in the Gulf of Alaska, but more likely due to prevailing wind and current patterns in the area.

Entanglement debris accumulated quickly on beaches previously cleared of debris. The number of entanglement items on two beaches on Middleton Island cleared of all debris in 1985 and sampled in 1986 was over 100% of that recorded the previous year. Results from our 1985 survey at Middleton Island, however, showed only a 43% accrual of new debris within 1 year (Merrell and Johnson 1987). Based on our marking of all plastic debris on Yakutat beaches in September 1985 and resampling in January 1986, there was a 40% accrual of new (previously unseen) debris in just 4 months. The relatively quick accumulation of debris on Alaskan beaches in 1986 would seem to indicate that there is a substantial amount of debris adrift at sea.

Our observations also suggest that the accumulation and eventual fate of plastic debris stranded ashore is related to storms. During fall and winter, when storms are usually more severe, debris stranded ashore is buried or transported quickly, inland by surf and wind (especially light-weight plastics like bottles, six-pack yokes, etc.), and replaced by new debris from the sea. Of the over 700 plastic items marked with paint on beaches at Yakutat in September 1985, less than 0.5% were recovered 4 months later and less than 1.0% were recovered a year later. Similar results were found on beaches in England in winter: 2 months after marking plastic items, only 1.4% were recovered (Dixon and Cooke 1977). We did find a few painted items in the- forested area inland from the beach, supporting our belief that some plastic items are washed or blown inland during storms and eventually are hidden between drift logs or covered by vegetation. Because we found less plastic debris on Yakutat beaches in winter than in summer does not necessarily mean that less debris was washed ashore in winter, but that it was probably added and removed at irregular intervals by storms. As storms subside from winter to summer, debris may begin to accumulate as new debris from the sea is added to that already present on the beach. More than 1 year of data are needed, however, to determine if our monthly observations were a random trend or an annual cycle. Based on 1 year of data, the optimum time for sampling appears to be in late summer when debris may have accumulated over several months.

During years in which storms are more frequent and intense, it is probable that more debris from the sea is deposited and more buried debris on beaches is uncovered. This may be occurring even though the addition of new debris into the ocean may be remaining the same. Therefore, when examining short-term trends in abundance of plastic debris on beaches, ocean currents and weather data in a given year need to be considered.

More new fragments of trawl web were found at Yakutat in January and April 1986 than in July and September 1986, probably because storms are more intense in fall and winter and tend to strand or uncover more fragments on shore. This is supported by 1) weather data that show monthly maximum wind velocity at Yakutat ranged from 45-63 mph from 'October 1985 to April 1986 compared to only 28-41 mph from May to September 1986 (NOAA 1985; 1986), and 2) data collected in January 1987 which show the proportion of the total fragments of trawl web found on beaches that were tag recoveries decreased in winter as more new fragments appeared on beaches (Fig. 5).

Our short-term study indicates that once trawl web becomes stranded much of it remains ashore. At the end of 1 year of intensive tagging of trawl web at Yakutat, we recovered nearly 50% of our tags. Of the missing tagged fragments, some were washed inland to terrestrial areas as evidenced by three tagged fragments recovered inland from the beach. Some were also buried as indicated by the burial and reexposure of 10% of our recovered tagged fragments. Dixon and Cooke (1977) found 6% of beach debris reexposed by storms after burial.

Determining. the deposition rate of trawl web in a specific location requires the ability to separate new debris from 1) trawl web already stranded ashore and moving laterally along the beach during storms, and 2) trawl web already stranded ashore and buried and reexposed by storms. Tagging and mapping of trawl web fragments have shown that 10% of stranded fragments can move more than 1.0 km laterally along the beach and that 10% of our tag recoveries were buried and reexposed again within 1 year. We have estimated that the deposition rate at Yakutat was nine fragments of trawl web per kilometer of beach per year. If we consider that 20% of these fragments had already been on the beach and were reexposed or moved laterally down the beach from other areas, then a more realistic deposition rate would be seven fragments of trawl web per kilometer of beach per year.

Since the average weight of a fragment of trawl web stranded ashore at Yakutat is approximatley 4 kg, then 28 kg per kilometer of beach per year would have been deposited.

Tides, currents, and storm winds affect the distribution of debris. Since these factors differ by location and year and probably interact in unknown ways with each other, the deposition rate at Yakutat cannot be extrapolated to other geographic locations. In the Yakutat area, however, extrapolation of our results to the beach extending from Ocean Cape (at the head of Yakutat Bay) to Dry Bay, a distance of approximately 75 km, would indicate that 525 fragments (2,100 kg) of trawl web may have been deposited on this section of beach from 1985 to 1986. This extrapolation may not be unrealistic. considering that from 1982 to 1984 over 2,700 pieces of trawl web were discarded overboard into Alaskan waters from net-mending operations, over 1,500 pieces of net material were brought up in trawl catches and the majority discarded back into the sea, and 160 complete or large portions of net were lost (Berger and Armistead 1987). In most cases, these numbers represent only a portion of what is actually lost or discarded.

In conclusion, entanglement debris increased on the surveyed Alaskan beaches from 1985 to 1986. Approximately seven fragments of trawl web were deposited per kilometer of beach per year at Yakutat. More information is needed, however, in 1) determining the role of ocean currents and storms in debris distribution, and 2) determining whether the deposition rate for trawl web at Yakutat is representative of the Gulf of Alaska. One year of tagging and mapping of trawl web indicated that once trawl web is stranded, most remains ashore and does not reenter the ocean (although this may change over many years). Future studies, such as clearing beaches of debris at Middleton Island and tagging trawl web at Yakutat, will add to our long-term understanding of the dynamics of marine debris.

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