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ENTANGLEMENT AND OTHER PLASTIC DEBRIS ON SELECT ALASKA BEACHES, 1994

by

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ABSTRACT

Beaches in the Gulf of Alaska were monitored in 1994 for trends in abundance, deposition rate, and sources of entanglement debris (trawl web, rope, monofilament gill net, and packing straps) and other plastics that had washed ashore. This study was a continuation of Alaska beach surveys conducted periodically since 1972. Eight beach sections near Yakutat were surveyed in March and September 1994 and five beach sections on Kayak Island in September 1994. Some entanglement debris items continued to decline on beaches: from 1990 to 1994 on beaches near Yakutat, significant ($P < 0.05$) declining trends were observed for trawl web and packing straps but not for rope and gill net. Deposition rate of trawl web (1.9 pieces km^{-1} $year^{-1}$) near Yakutat in 1994 was the lowest observed since 1986. At Kayak Island, 73% less trawl web was observed in 1994 than in 1991. Total plastics (all types combined) declined 66% at Yakutat from 1993 to 1994 and 47% at Kayak Island from 1991 to 1994. Plastic items washed ashore were similar at Yakutat and Kayak Island; at least 35–52% originatedy from fishing vessels. Bottles, gill-net floats, and caps and lids were usually the most abundant items and accounted for 54–70% of all plastics. Most bottles that had washed ashore and could be identified were manufactured in Asia or the United States. Some types of plastic debris have declined on Alaska beaches since implementation of MARPOL Annex V in 1988, suggesting that this international law contributes to reduced disposal of plastics at sea from ships.

CONTENTS

INTRODUCTION

Plastic debris in the marine environment has recently been recognized as a form of pollution of international significance (Shomura and Yoshida 1985; Shomura and Godfrey 1990). Plastics enter the sea from ocean- (e.g., commercial fishing vessels) and land-based (e.g., sewer overflows) sources. Plastic debris mars the scenic quality of beaches and can be hazardous to human health. In 1988, several beaches on the east coast of the United States were closed to the public as a result of medical debris washed ashore (Wagner 1990). Plastic debris can also endanger living marine resources. Marine animals can become entangled in trawl-web or gill-net fragments, packing straps, and rope (DeGange and Newby 1980; Fowler 1987; Breen 1990; Henderson 1990; Stewart and Yochem 1990) or ingest pieces of plastic that block their digestive tracts (Ainley et al. 1990; Plotkin and Amos 1990).

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 and may be the best method of evaluating the effectiveness of recent (1988) U.S. legislation implementing Annex V of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol for 1978 (MARPOL 73/78)—the first international agreement to reduce the input of plastics and other garbage into the sea from ships.

In 1994, the National Marine Fisheries Service Auke Bay Laboratory continued Alaska beach surveys that have been conducted periodically since 1972. Although many types of plastic debris were found, only those commonly associated with entanglement of marine animals in Alaska are discussed in detail in this paper: trawl web, rope, monofilament gill net, and packing straps (Merrell 1985; Merrell and Johnson 1987; Johnson and Merrell 1988; Johnson 1989, 1990a, 1993). Emphasis was on trawl web because major trawl fisheries for groundfish operate off Alaska (Low et al. 1985) and substantial amounts of trawl web are lost or discarded each year (Berger and Armistead 1987; Johnson 1989). Trawl web is also one of the predominant items found entangled on northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Alaska (Fowler et al. 1985). Primary objectives of the continued surveys were to monitor deposition rate, trends in abundance from 1990 to 1994, and sources of entanglement debris and other plastics on beaches in the Gulf of Alaska.

METHODS

Survey sites in the Gulf of Alaska were eight beach sections near Yakutat on the Alaska mainland and five beach sections on Kayak Island (Fig. 1). Beaches near Yakutat were surveyed in March and September 1994 and beaches on Kayak Island in September 1994. Beaches near Yakutat had been surveyed in September 1993 and beaches on Kayak Island in August 1991.

Survey methods were similar for all beaches (Merrell 1985). Most beaches were 1 km long. The survey area for each beach included the intertidal zone between the water's edge and the seaward limit of terrestrial vegetation. All plastic debris visible from walking height was counted (e.g., pieces ≥ 5 mm and trawl-web and monofilament gill-net fragments with five or more complete meshes). All rope ≥1 m long was counted.

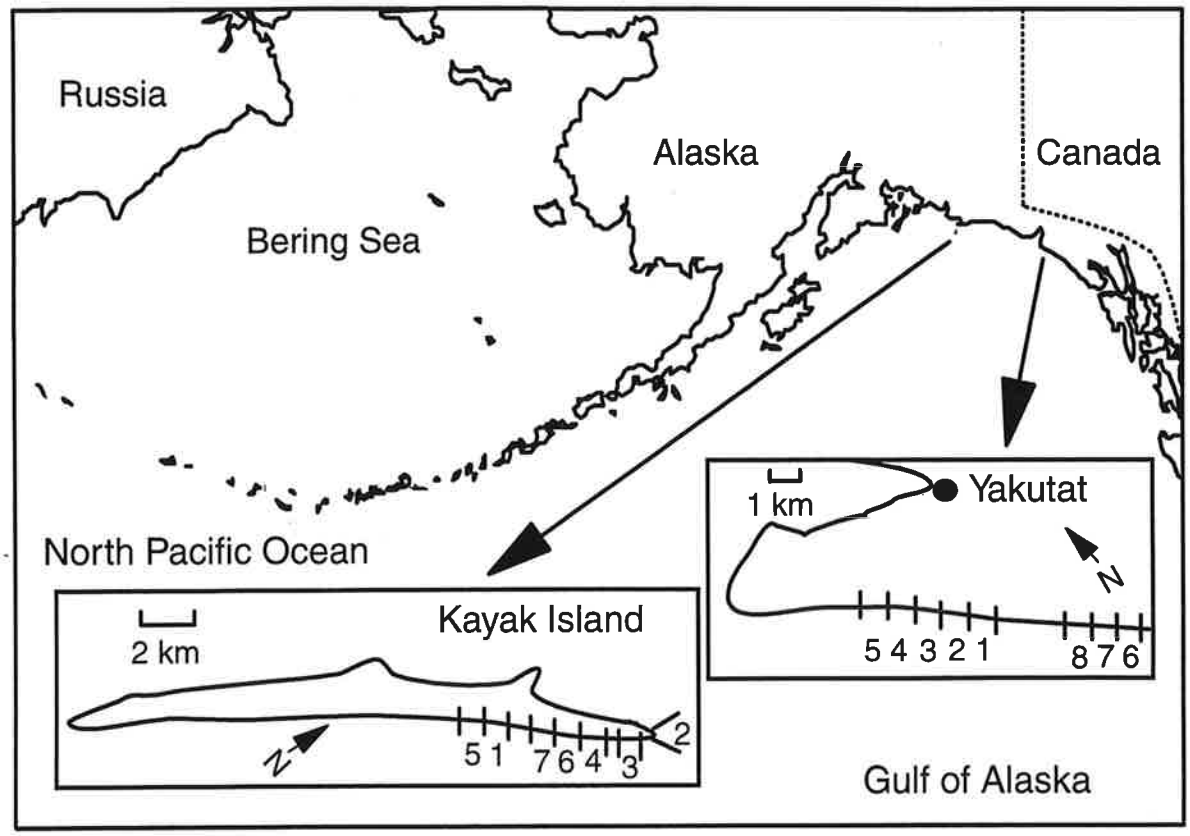

Figure 1.—Location of plastic debris study sites near Yakutat (eight 1-km beach sections) and at Kayak Island (five 1-km beach sections), Alaska, in 1994. Past surveys at Kayak Island included up to seven beaches (Johnson 1993), but only beaches 1, 2, 4, 6, and 7 were surveyed in 1994.

Entanglement debris items (trawl web, rope, monofilament gill net, and packing straps) were counted and removed from beaches at Yakutat during each survey, beginning in September 1993 (Ribic et al., in prep.). Debris was moved to above the high-tide zone. Debris too large to be moved, partially buried, or tangled on drift logs, was marked with paint, flagging, or tags for future identification. Mean deposition rate of entanglement debris (number of pieces km^{-1} $year^{-1}$) was determined by dividing the total number of "new" (untagged debris items; sum of March and September surveys) by eight (number of 1-km beach sections) (Johnson 1994). To determine whether a declining trend existed over the 5-year period 1990–94, the mean deposition rate of each entanglement debris item was examined by curvilinear regression (Snedecor and Cochran 1967). On one study beach near Yakutat (beach 4; Fig. 1) in March and September 1994, all plastics were recorded. In September 1994, on three study beaches near Yakutat (beaches 6–8; Fig. 1), all plastic bottles were examined for country of manufacture, to identify possible debris sources.

To determine deposition of entanglement debris on Kayak Island, pieces of trawl web, rope, monofilament gill net, and packing straps were counted and removed from six beaches in 1991; five of these beaches were resurveyed in 1994 (Fig. 1). In 1994, on one study beach (beach 1; Fig. 1) all plastics were recorded and plastic bottles were examined for country of manufacture.

RESULTS

On beaches near Yakutat, 69 pieces of entanglement debris (all types combined) were deposited ashore in 1994 (Table 1). Rope accounted for 68% of the entanglement debris, followed by trawl web 22%, monofilament gill net 7%, and packing straps 3%. About 50% fewer pieces of entanglement debris were observed on beaches near Yakutat in 1994 than in 1990 (Table 1).

Deposition rate of some entanglement debris declined on beaches near Yakutat from 1990 to 1994. The decline was statistically significant and exponential for trawl web and packing straps (Fig. 2). The regression equation describing the decline in mean trawl web deposition rate ($\hat{Y}$) versus time in years (t) is

$$\ln \hat{Y} = -0.24t + 1.75;\ r^2 = 0.89,\ P = 0.02,\ n = 5 .$$

Similarly for packing straps, the regression equation is

$$\ln \hat{Y} = -0.47t + 1.08;\ r^2 = 0.94,\ P = 0.01,\ n = 5 .$$

In exponential form, the equations are

$$\text{trawl web, } \hat{Y} = 5.75e^{-0.24t} \text{ and}$$

$$\text{packing straps, } \hat{Y} = 2.94e^{-0.47t},$$

where 5.75 and 2.94 = Y_0 = deposition rate at $t = 0$ (1990), $e = 2.718$ the base of natural logarithms, and −0.24 and −0.47 are the relative annual rates of decline. Rope ($P = 0.15$, $n = 5$) and gill net ($P = 0.69$, $n = 5$) did not decline significantly from 1990 to 1994 (Fig. 2).

In 1994, deposition of trawl web near Yakutat followed a pattern similar to previous years: more trawl web was deposited ashore during fall and winter than during spring and summer (Fig. 3). The total number of trawl-web pieces (15) deposited ashore in 1994 continued the declining trend observed since 1988 (Fig. 3).

Table 1.—Total number and type of entanglement debris deposited on eight 1-km beach sections near Yakutat and on five 1-km beach sections on Kayak Island, Alaska, 1990–94. Beaches near Yakutat were cleared of entanglement debris twice each year. Beaches on Kayak Island were cleared of entanglement debris in August 1991 and resurveyed in September 1994.

	Yakutat					Kayak Island	
	1990	1991	1992	1993	1994	1991	1994
Trawl web	43	36	30	27	15	75	20
Rope	84	82	61	80	47	169	88
Gill net	3	3	5	2	5	12	8
Strap	16	7	7	4	2	7	7
Total	146	128	103	113	69	263	123

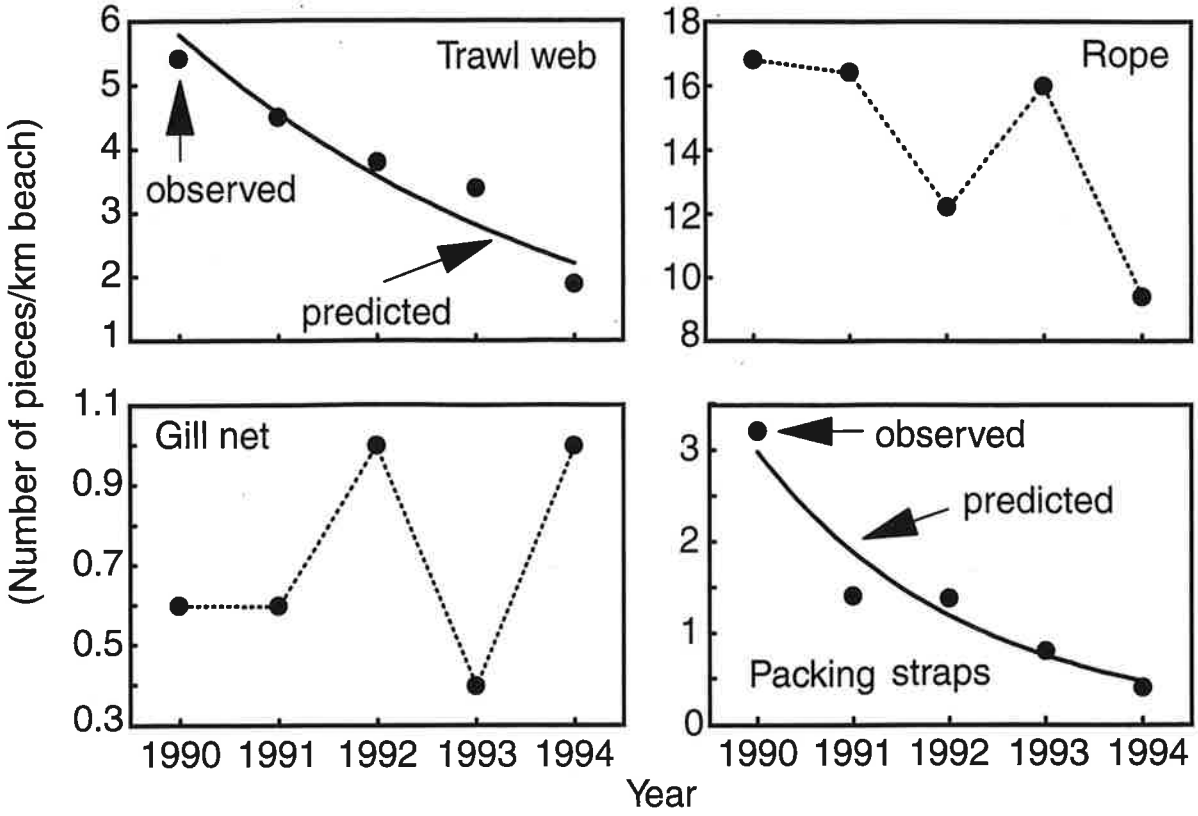

Figure 2.—Deposition rate of trawl web, rope, gill net, and packing straps on eight 1-km beach sections near Yakutat, Alaska, from 1990 to 1994. Significant declining trends were observed via curvilinear regression for trawl web ($r^2 = 0.89$, $n = 5$, $P = 0.02$) and packing straps ($r^2 = 0.94$, $n = 5$, $P = 0.01$) but not for rope ($r^2 = 0.56$, $P = 0.15$, $n = 5$) or gill net ($r^2 = 0.06$, $P = 0.69$, $n = 5$).

On a 1-km beach near Yakutat, total plastics (all types) averaged 218 items per sampling period in 1994 (Table 2). Overall composition (based on total number of items) of plastic debris in 1994 was 35% fishing gear (trawl web fragments, floats, etc.), 56% packaging (bottles, bags, etc.), 4% personal items (combs, cigarette lighters, etc.), and 5% miscellaneous (plastic pipe, sheeting, etc.). Bottles, gill-net floats, and caps and lids were the most abundant items in 1994 (about 70% of the total debris) (Table 2). Most plastic bottles whose country of manufacture could be identified, were made in Asia or the United States (Table 3).

On Kayak Island, 123 pieces of entanglement debris were found in September 1994 (Table 1). Rope accounted for 72% of the entanglement debris, followed by trawl web 16%, gill net 6%, and packing straps 6%. About 50% fewer pieces of entanglement debris were found in 1994 than in 1991 (Table 1).

On a 1-km beach on Kayak Island, total plastics exceeded 500 items in 1994 (Table 4). Overall composition of plastic debris in 1994 was 52% fishing gear, 40% packaging, 4% personal items, and 4% miscellaneous. Bottles, gill-net floats, miscellaneous floats, caps and lids, and rope made up about 74% of the total debris (Table 4). Of the plastic bottles found that were identifiable to country of manufacture, most were made in Asia or the United States (Table 3).

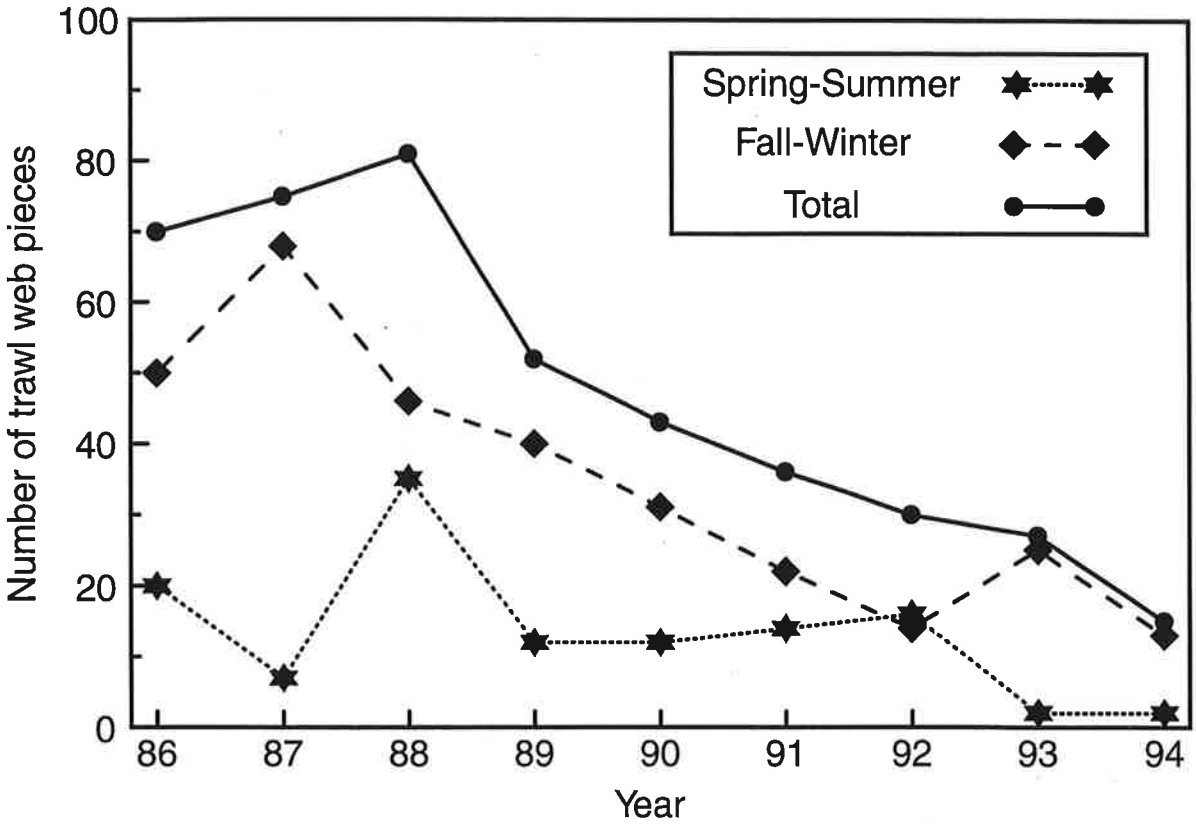

Figure 3.—Total and seasonal deposition of trawl web on eight 1-km beach sections near Yakutat, Alaska, 1986–94. Trawl web was marked or removed from beaches every survey beginning in 1985 (Johnson 1989).

Table 2.—The five most abundant and the total number of plastic debris items found each sampling period on a 1-km beach section near Yakutat, Alaska. The same beach was sampled each survey period.

	1992		1993		1994	
	Apr.	Sep.	Mar.	Sep.	Mar.	Sep.
Bottles	151	139	147	121	85	31
Gill-net floats	484	543	189	135	80	26
Caps and lids	109	120	239	117	45	41
Styrofoam packaging	18					
Pipe and tubing			21		8	
Bags <1 m^2	34	18		17		9
Misc. floats		28	26	17	9	11
Total*	916	990	756	509	281	155
Average	953		633		218	

* All plastic debris found, including items not listed in this table.

Table 3.—Number of plastic bottles by country of manufacture found on three 1-km beach sections near Yakutat and on a 1-km beach section on Kayak Island, Alaska, in September 1994.

Source	Yakutat	Kayak Island
United States	6	19
Asia (Japan, Korea, etc.)	9	20
Russia	0	2
Canada	3	0
Unidentified	38	88
Total	56	129

Table 4.—The five most abundant and the total number of plastic debris items found on a 1-km beach section on Kayak Island, Alaska, in August 1991 and September 1994.

	1991	1994
Bottles	284	129
Gill-net floats	255	113
Caps and lids	96	29
Rope	64	29
Misc. floats	80	76
Total*	949	505

* All plastic debris found, including items not listed in this table.

DISCUSSION

Entanglement Debris

Entanglement debris appears to be decreasing on Alaska beaches. On beaches near Yakutat and on Kayak Island, about 50% fewer pieces of entanglement debris were found in 1994 than in 1990 or 1991, respectively. The 69 pieces near Yakutat in 1994 were the fewest observed since studies began in 1985 (Merrell and Johnson 1987). At two other sites in Alaska (Middleton and Amchitka Islands), 15–50% fewer pieces of entanglement debris were observed during surveys in the early 1990s than in the latter 1980s (Ribic et al., in prep.).

Some entanglement debris items have declined steadily on Alaska beaches. For example, from 1990 to 1994, trawl web and packing straps declined significantly on beaches near Yakutat: the deposition rate of trawl web (1.9 pieces km^{-1} $year^{-1}$) in 1994 was the lowest observed since studies began in 1986 (Johnson 1994). Similarly, on Kayak Island, only 20 pieces of trawl web and 88 pieces of rope were found in 1994 compared to 75 and 169

pieces in 1991 (Table 1). The decline in trawl web deposited ashore at Yakutat and Kayak Island coincided with an increase in the number of domestic trawl vessels that landed groundfish in the Gulf of Alaska from 61 in 1986 (Kinoshita et al. 1993) to 206 in 1993[1] (Fig. 4). Although effort data are limited, the total catch of groundfish in the Gulf of Alaska by domestic fisheries also increased from 144,000 metric tons in 1988 to 276,000 metric tons in 1991; over 80% of the total catch in 1991 was with trawl gear (Narita et al. 1994). Surveys at other sites in Alaska also support a decline in trawl web: at Amchitka Island, an average of 24 pieces of trawl web km^{-1} of beach was observed in 1993 versus 55 pieces km^{-1} in 1987 (Ribic et al., in prep.). Continuing surveys near Yakutat and on Kayak Island and the addition of new sites will help determine whether the decline in trawl web and other debris in Alaska is real and coastwide. However, the deposition rate of any debris item will probably never reach zero—some items will always be lost accidently during normal operations (e.g., blown overboard, lost or damaged fishing gear during storms).

Consistent with the decline of trawl web on some Alaska beaches is the decline in entanglement rate of fur seals in trawl web (Fowler et al. 1992). Both studies suggest that the rates of loss and discard of trawl web fragments in the North Pacific Ocean are

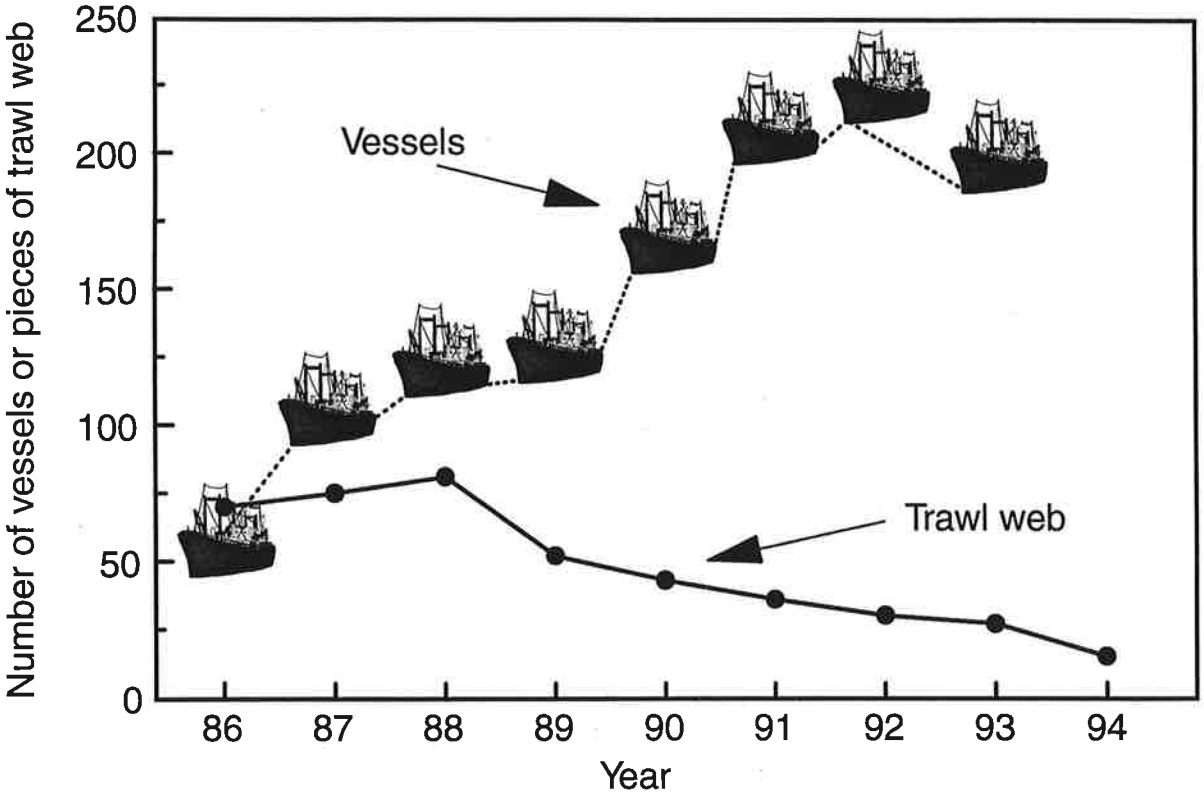

Figure 4.—Number of domestic trawl vessels that landed groundfish in the Gulf of Alaska and total number of trawl web fragments deposited on eight 1-km beach sections near Yakutat, Alaska, 1986–94. Vessel data not available for 1994.

[1]R. Kinoshita, National Marine Fisheries Service, Seattle, WA. Pers. commun., Jan. 1995.

decreasing. Increased public awareness through education programs, U.S. observers on many trawl vessels, the addition of port disposal facilities, evolution of fishing methods, the switch from foreign to domestic fisheries, and Coast Guard enforcement in domestic waters of international law (MARPOL Annex V) are all probably responsible for the decline in trawl web observed on beaches (Johnson 1994).

Total Plastics

The types of plastic debris washed ashore on Alaska beaches are remarkably similar. Bottles, gill-net floats, and caps and lids are usually the most abundant items. On beaches near Yakutat and on Kayak Island, bottles, gill-net floats, and caps and lids were 54–70% of all plastics in 1994. At Amchitka Island in 1993 (Ribic et al., in prep.) and Middleton Island in 1992 (Johnson 1993), bottles, gill-net floats, and caps and lids accounted for 40–80% of all plastics. Although they are not an entanglement hazard, the elimination of these three common debris items would greatly reduce the debris load on many Alaska beaches.

Quantities of total plastics declined at Yakutat and Kayak Island from earlier studies. In 1994, at Yakutat, total plastics declined 66% from 1993 and 77% from 1992 (Table 2), and at Kayak Island, total plastics declined 47% from 1991 to 1994 (Table 4). The decline in total observed plastics at Yakutat was largely the result of about a tenfold decline in gill-net floats: in 1992, gill-net floats averaged about 500 km^{-1} compared to only 50 km^{-1} in 1994 (Table 2). The 1993 worldwide moratorium on high-seas drift-net fisheries (United Nations Resolution 46/215; Richards 1994) probably accounts for fewer floats washing ashore. At Amchitka Island, total observed plastics declined 34% from 1987 to 1993 (Ribic et al., in prep.), and at Middleton Island 21% from 1989 to 1992 (Johnson 1990a, 1993).

The source of much of the debris found on beaches is difficult to determine. Assuming, however, that most U.S.- and east Asian- (Japanese, Korean, etc.) manufactured bottles are lost from like vessels, 1994 beach surveys indicate that these countries are probably major sources of debris on Alaska beaches. Fishing gear (e.g., trawl web, gill net) is also predominately of U.S. or Asian origin (Johnson 1990b).

In summary, entanglement and other plastic debris appears to be decreasing on many Alaska beaches. The deposition rate of trawl web near Yakutat in 1994 was the lowest observed since studies began in 1986. The observed declines in plastic debris have occurred since the implementation of MARPOL in 1988, offering some evidence that this international law contributes to reducing the entry of entanglement and other plastic debris into the North Pacific Ocean. Continuing beach surveys in Alaska for the next several years should help to determine whether the observed declines are real and coastwide.

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