MARINE DEBRIS

in Alaska: Coordinating Our Efforts

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University of Alaska Fairbanks

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in Alaska: Coordinating Our Efforts

MICHAEL WILLIAMS AND ERIKA AMMANN, EDITORS

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Marine Debris Toast

Toast offered at McGinley's Pub, Anchorage
During the "Great Guinness Toast"
February 15, 2008

To the guys and the gals
We consider our pals
And who make their livin' out on the sea.

Their life's based on fishin'
And what we be wishin'
Is there ain't no more marine debris.

Cause there ain't no cash
In fishin' for trash,
And to those who clean it we offer a cheer.

Cause if we want more fish, then
We need a clean ecosystem;
To those who protect it, we raise our beer.

Synthesis of Proceedings Book

The National Marine Fisheries Service convened this marine debris workshop to begin engaging and coordinating the marine debris removal and assessment community in Alaska. There is significant work to be done in the future to continue coordination of efforts, share future progress and advances with the public, and engage fishing communities to help reduce derelict fishing gear. Marine debris continues to degrade the marine and nearshore environment in Alaska. Marine fish and wildlife are entangled in and ingest debris that may be a day or decades old from foreign and domestic sources. It is likely that thousands of tons of marine debris exist within three nautical miles of the Alaska coastline. Approximately 175 metric tons were collected from Alaska coasts by the ten Marine Conservation Alliance Foundation cleanup projects in 2007.

The workshop participants identified the top criteria to use as decision-making factors in allocating marine debris funds: (1) ecological importance, (2) prevention/outreach strategies, (3) human use, (4) high accumulation, and (5) long-term sustainability. We do not have the resources and capacity to clean the current accumulation of marine debris on Alaska's coasts. While other factors may also influence allocation of funds, participants recognized that not all areas are equally sensitive to the effects of marine debris. Those areas deemed most sensitive or ecologically important are the areas where marine debris removal, prevention, and outreach should happen sooner rather than later. We must begin funding projects to prevent new debris from entering the marine environment. Human use of coastal and marine areas is not equal, and focusing marine debris removal, prevention, and outreach in areas of high commercial, recreational, or public use is a high priority. Areas of high accumulation represent opportunities to use resources cost effectively and maximize logistics, labor, and transportation. Given the re-accumulation rates at many sites, the current marine debris removal projects must be sustainable until prevention results in a measureable reduction in new debris. Long-term sustainability also relates to the local capacity and infrastructure to continue the program and gain efficiencies with project management and administration. Participants considered other decision-making factors for prioritizing the distribution of funds, such as project cost effectiveness/efficiency, realistic completion, measurable outcomes, and ability to create partnerships.

Participants discussed how marine debris entangles, injures, and kills marine birds, mammals, and fish. Marine debris smothers benthic habitat and corals, and in some cases can create habitat in areas with little or no relief. Few observations are ever made of entangled marine wildlife, and extrapolations from these limited samples are highly speculative. Regardless of the uncertainty, much of the debris entangling Alaska wildlife is related to past and present fisheries of unknown origin. The biochemical effects are of growing concern because they act on the lowest trophic levels of the marine food web. Some data suggest entanglement and ingestion rates of marine debris are increasing, while other data are too limited to resolve differences. What is clear is marine debris is a source of preventable human-caused injury and mortality for marine fish and wildlife.

Participants identified the critical need to develop a standardized data collection system. Statisticians and database designers must be consulted to develop a nested series of data forms, a central database, and debris monitoring sites to inform future decisions and program direction. Participants suggested forming a coordinating committee to direct the development of marine debris projects related to data collection, prevention outreach, and education, disposal, and recycling. The expense of transportation and labor for removal, compounded by disposal and recycling costs, prevent development and expansion of programs and burden rural landfills. Participants indicated the need for a statewide marine debris coastal survey to identify accumulations for future cleanup.

The National Research Council recently released their review of the effectiveness of international and national measures to prevent and reduce marine debris and its impacts. The focus is on debris discharged at sea and NRC recommends many specific actions consistent with general themes and recommendations from workshop participants in Anchorage, including standardization of data collection and coordination of programs. Clearly, standardized data collection and statewide coordination must be resolved for the effective use of limited resources to prevent and remove marine debris from the environment.

Future representation is necessary to clarify regional data gaps, state authority and responsibility, fishery management agencies' roles, U.S. Coast Guard enforcement, and fishermen's capacity to assist in collection and prevention. We must work cooperatively to remove disincentives for proper disposal of waste and debris resulting from fishing. Incentives for fishermen to collect marine debris at sea and dispose of it on land must be developed. Fishermen must be given the opportunity to participate in the creation of effective marine debris prevention and removal programs; without their support, success will be limited.

Purpose of the workshop

The Marine Debris in Alaska workshop was organized to share information, coordinate local programs, and develop a process to prioritize statewide marine debris removal, education, and outreach.

Tangible outcomes from the workshop include this proceedings report; sharing and identifying resources for education, outreach, and emerging marine debris programs; and a list of participants with contact information. Intangible outcomes from the workshop include increased communication among marine debris organizations and a process for developing standardized data collection and prioritizing regional marine debris–related programs. The workshop highlighted the importance of direct communication and the diversity of removal efforts with the intent to ultimately align the statewide programs with goals of the NOAA Marine Debris Program.

Workshop structure

Participants attended the workshop in Anchorage at the Alaska Forum on the Environment, February 14-15, 2008. The workshop began with presentations about the current programs operating to remove shore-cast marine debris around the state, and the national NOAA Marine Debris Program. Local Alaska program presenters were asked to share information with attendees during the morning session regarding

1. How and why did your shore-cast marine debris cleanup program get started?
2. How do you collect, categorize, and dispose of debris?
3. How have your programs/projects changed?
4. What is the origin of the debris?
5. How are your programs/projects limited or constrained?

The afternoon session presented the latest technology for detecting marine debris, followed by three presentations regarding the known and predicted environmental effects. The final day 1 presentation described how derelict fishing gear and other marine debris can be recycled. Speakers prepared summaries of their presentations, published in this book.

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Introduction

Alaska has about 44,000 miles of mostly uninhabited coastline. Alaska's marine and freshwater ecosystems support the largest array of commercial fisheries in North America. The fishing grounds attract both foreign and domestic fleets providing commercial, recreational, and subsistence resources. Alaska's oceans also serve as major national and international cargo transportation routes and tourist destinations. These coastlines are all affected by marine debris directly or indirectly through its impacts on tourism, fishing, subsistence, human health, fish and wildlife populations, and ecosystems. It is a complex problem with land and sea, foreign and domestic, and accidental and intentional debris sources. Limited infrastructure and road access to the affected coastlines further complicate assessment and response. Coastal landfill erosion and rivers also transport trash and debris into the marine environment.

Very little is known about the derelict fishing gear, trash, and debris in Alaska's marine waters. Most of the information we have comes from coastal residents, scientists, fishermen, and recreational visitors who have observed the accumulation of derelict fishing gear, trash, and debris on local and remote shorelines around the state. Alaska marine debris removal efforts are currently scattered regionally and often opportunistic. Government agencies, environmental organizations, landowners, and tribes attempt to identify and solve these natural resource issues with no centralized organization. As a result, regional marine debris removal programs often operate in isolation, modestly funded and using a combination of volunteer and paid staff. Furthermore, difficult access to Alaska coasts, safety and weather considerations, and limited landfill sites and recycling options result in high removal costs. Effective outreach and education is difficult because debris sources are often unknown; however, the bulk in weight and volume of marine debris collected on shore is derelict fishing gear.

The Marine Debris in Alaska workshop, held February 14-15, 2008, was organized under the belief that sharing experiences and understanding current efforts will lead to better prevention, removal, and assessment activities. As a result, the potential to share resources and coordinate statewide activities will create more cost effective projects. Workshop participants were able to develop an informal Alaska marine debris network, and have discussions to identify priority areas and actions for prevention, funding, and restoration. Currently there is no focused effort for organization of marine debris removal and prevention efforts in Alaska. As a larger player in conserving and protecting marine living resources, NOAA (National Oceanic and Atmospheric Administration) volunteered to support and coordinate the growing interest in marine debris in Alaska through this workshop. Throughout this proceedings the term "marine debris" is used for debris in the marine and coastal environment. Derelict fishing gear is considered a subtype of marine debris. Marine debris has been legally defined as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes."

The complexity of Alaska's coast, communities, climate, marine debris deposition rates, and marine debris sources clearly suggests that no solution will be applicable to all regions. This is exemplified by the three longest-running debris cleanup and removal programs described in more detail by program leaders. The programs originated in Homer, St. Paul Island, and Prince William Sound. All three originated using volunteer labor, but slowly diverged for a number of reasons.

The Center for Alaskan Coastal Studies coordinated the CoastWalk program in Homer. CoastWalk uses citizen-scientists to collect environmental data. The environmental observations resulted in the identification of debris, and its collection and removal by CoastWalk volunteers, some of whom have surveyed the same sections of Kachemak Bay every spring or fall for over 20 years. This 20-year program has created a time series of observed and collected debris data, and shown that a vast majority of the debris is now from local sources. The sources in Kachemak Bay have changed from debris created from shoreline development and ocean activity during the 1980s and early 1990s to trash that is predominantly from recreational and sport users more recently. The collected debris is disposed at the Homer landfill. The CoastWalk program disposed of approximately 400-1,800 pounds in recent years. The program expanded in 2007 by granting funds to communities and organizations outside Kachemak Bay for marine debris–related programs. The overall program has a salaried coordinator to administer the grants and volunteers.

On the Pribilof Islands (St. Paul and St. George) community members and scientists have observed northern fur seals entangled in small pieces of derelict fishing gear and other marine debris for over 50 years. In addition, derelict fishing gear and other marine debris circulate on and around the islands. St. Paul and St. George are the primary breeding and resting grounds for northern fur seals. About 600,000 northern fur seals intermittently visit at least 12 sites comprising about 20-30% of St. Paul's coast from late May to November. When the fur seals are in residence these areas are inaccessible for marine debris cleanup. Community members have, in the past, collected and burned or disposed of debris at coastal areas not used by fur seals during the summer. Subsequent volunteer efforts were coordinated with students, seasonal fish processor staff, and U.S. Coast Guard staff to collect and remove debris from the coast during the spring. Volunteers disposed of debris in the local landfill during the early 1990s. Volunteer efforts have been unsustainable during the past 5-10 years and the vast majority of labor is currently paid. Cleanup areas are not surveyed in advance of cleanup actions, due to the high density of debris along a majority of the coast. The main reasons for the transition from volunteer to paid labor are the inclement weather in May and physically demanding labor for a one-week period. Approximately 10,000 to 60,000 pounds of debris are removed from a portion of the coast annually by a 7-12 person crew. Over 99% of the debris by mass or volume is nonlocal derelict fishing gear. The annual organization and implementation of the marine debris removal program on St. Paul is supported by a staff person (10% of their time) within the Ecosystem Conservation Office of the Tribal Government of St. Paul Island.

Concerned citizens began coordinating an annual summer marine debris cleanup on remote islands and coasts in Prince William Sound after the 1989 *Exxon Valdez* oil spill. The cleanups were coordinated by Prince William Sound Keeper. The coordinating group that focused mainly on marine debris reorganized as Gulf of Alaska Keeper (GoAK) in 2001. Tour and charter operators from the region donate vessel time to transport volunteers to and from cleanup sites. Vessels are also needed to transport collected debris from these remote sites to landfills. The cleanup program has added paid laborers in recent years to supplement volunteers. Because of logistical challenges related to access, pre-cleanup surveys are used to more effectively distribute cleanup crews among multiple sites. Debris composition is dominated by derelict fishing gear and polystyrene foam, followed by recreational user trash. In Prince William Sound GoAK has recently begun to spend multiple days to months in the field to remove high-density debris accumulations. Cleanup crews remove 10,000-100,000 pounds of debris annually, which is transported back to Seward or Whittier for disposal. Gulf of Alaska Keeper employs a full-time staff person to coordinate and implement the marine debris removal program.

History of marine debris problem in Alaska

The presence of marine debris is not new in Alaska, nor is the awareness that marine debris is harmful to the marine environment and its inhabitants. But the marine debris problem is escalating as plastic production and use increase, and over many years debris that was lost or dumped into the ocean circulates and accumulates on our shores. The amount of debris, its persistence, and its insidious presence on even the most remote beaches of Alaska have brought to the forefront the need for addressing the issue, to maintain a healthy marine ecosystem. In face of a building debris problem, in this publication we aim to summarize past research to estimate and understand marine debris in Alaska.

Historically marine debris has been identified and recorded in various ways. Federal scientists and managers first recorded entangled fur seals in 1923 (Proctor 1923). The work with marine mammals in Alaska, northern fur seals in particular, focuses on marine debris as it is impacting a resource. Other efforts have included estimates of discards by fishermen, bottom trawls to estimate debris presence on the seafloor, and beach surveys to determine marine debris accumulation rates. All of these early efforts tell a slightly different story based on data collection biases before, during, or after implementation of the Magnuson Fisheries Conservation and Management Act of 1976, and the Sustainable Fisheries Act of 1996 and MARPOL 73/78. In addition, physical characteristics and composition of debris influence buoyancy, persistence, and detection; therefore sampling localities, currents, and fisheries also showed important biases and variation. When taken together these studies illustrate some common themes: plastics are persistent; marine debris affects marine mammals, birds, and fish and habitat; and marine debris in Alaska is not all of local origin.

Low et al. (1985) quantified the trawl fishing effort in the Gulf of Alaska and Bering Sea–Aleutians from 1954 to 1984. They sampled the foreign fishery and the general expansion of the domestic fishery from 1979 to 1984. Foreign fisheries observers recorded discarded gear. Low et al. (1985) is the first assessment of this localized fishery to estimate amounts of marine debris generated by the fishing industry. Back-extrapolating one year of data to the 30 years prior suggests that fairly substantial amounts of fishing gear were discarded during this period, assuming significant assumptions are met. The paper also demonstrates the need for specifically tasked observers in current and future fisheries to identify the source and frequency of debris from each fishery.

In addition to the extrapolation of marine debris deposition from observations of gear being discarded, actual discarded fishing gear and other trash were collected in bottom trawl surveys northwest of Unimak Island in the Bering Sea and the northeastern Gulf of Alaska. Thirty-three out of 58 trawls (57%) in the northeastern Gulf of Alaska contained debris in 1975. Although the relative amounts were not analyzed, the main kinds of debris found were plastic associated with fishing or shipping and numerous items of Japanese and Korean origin (Jewett 1976). In the Unimak section of the Bering Sea, 46 of the 106 trawls (41%) contained metal, rope, plastic, or glass. Debris of Asian origin was obtained primarily from areas trawled west of 170°W (Feder et al. 1978).

Beach surveys for marine debris can show the variety of debris accumulated up to the time of recording. The majority of data from shoreline surveys may can indicate trends when compared to other shoreline data sets; it cannot tell the entire story of what is being deposited in our oceans and when. Accumulation data do not tell the entire story of what debris exists in the ocean, as the shore findings are influenced by debris type and season.

Early work in Alaska indicates seasonality in accumulation. Accumulation studies conducted on Amchitka Island determined plastic marine debris increased 2.4 times in the two-year period from 1972 to 1974 (Merrell 1980). Merrell estimated 1,664 metric tons of marine debris was lost or dumped from fishing vessels in 1972. Plastic debris from Soviet and Japanese fishing vessels was prevalent in these surveys (Merrell 1980). In 1985-1986, beaches in Yakutat and Middleton Island were surveyed to determine type, abundance, deposition rate, and fate of beach debris. From this work it was determined that fall and winter seasons have high marine debris deposition on beaches and that rope, trawl, nets, and various fishing gear were common debris. Trawl net debris movement on beaches was minimal as the nets persisted in the same area for years. In Yakutat, the average weight of trawl net sections deposited was 4 kg (Merrell 1980; Johnson and Merrell 1988; Johnson 1989, 1990).

The ratification of MARPOL Annex V was critical to preventing marine debris. Annex V regulates the disposal of waste from ships, and makes it illegal to discard plastic anywhere in the ocean. Yakutat and Middleton Island beach surveys were repeated after the implementation of MARPOL Annex V to determine the effects of the legislation on the actual debris seen on the beaches. Surveys conducted on Yakutat beaches indicated a 60% deposition reduction from 1988 to 1992. Results suggest that initially the legislation had a substantial role in preventing marine debris (Johnson 1994).

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The NOAA Marine Debris Program: Implementing a Program to Address the Nation's Needs

Sarah E. Morison, Program Coordinator
NOAA Marine Debris Program, Silver Spring, Maryland

The NOAA (National Oceanic and Atmospheric Administration) Marine Debris Program (MDP) was unofficially created in 2005 to support national and international efforts focused on preventing, identifying, and reducing the occurrence of marine debris in order to protect and conserve our nation's natural resources, oceans, and coastal waterways from its impacts. In December 2006, the Marine Debris Research, Prevention and Reduction Act (Act) was signed, formally establishing the MDP. The Act authorizes $10,000,000 for activities such as mapping; identification and impact assessment; reduction and prevention activities; research and development of alternatives to reduce the creation of derelict fishing gear; and outreach activities. It allows NOAA to engage local communities, NGOs, and universities in efforts to educate the public about marine debris, target problem areas, and encourage innovative solutions to marine debris issues. Only through partnerships with large and small entities can NOAA address all aspects of marine debris. Marine debris is defined, for the purposes of implementing the Act, as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes.

MDP staff are located in Silver Spring, Maryland (headquarters); Seattle, Washington; and Honolulu, Hawaii. Staff have rotated to a large project in Louisiana, but this will end in 2008 or 2009, and no staff are permanently located there. The MDP has funded more than 120 projects since 2005, with an average annual budget of approximately $4,000,000.

The program goals are to prevent, assess, and reduce debris, through the cross-cutting goals of research, education/outreach, and capacity-building. More information on all our activities, including projects, outreach materials, and funding opportunities, can be found at the MDP Web site, http://www.marinedebris.noaa.gov. Specific objectives within these goals are to

- Develop procedures and programs to prevent the loss or disposal of persistent debris into the marine, coastal, urban, and upland environments;
- Identify, assess, and evaluate adverse impacts of persistent marine debris upon the marine environment and living marine resources; and
- Design and implement educational materials and programs to inform industry and the public of the problems caused by persistent marine debris and of the range of available solutions.

The MDP strategies to accomplish the MDP goals and objectives are

- Reestablish the Interagency Marine Debris Coordinating Committee as stated in the U.S. Ocean Action Plan and Act;
- Work with our partners to develop comprehensive educational materials on problems caused by marine debris and actions people can take to reduce the impacts of marine debris on the environment;
- Seek opportunities to work with external partners in various regions to cosponsor projects aimed at reducing marine debris relevant to that area;
- Support research and assessment activities to more precisely determine impacts of persistent marine debris on human, fish, and wildlife populations; and
- Support international and national laws that aim to reduce marine debris from commercial and recreational boating activities.

The Marine Debris Program works in several priority areas, including derelict fishing gear, education/outreach, partnerships, research and assessment, and on-the-ground efforts. Working through partnerships is an important aspect of all work the MDP undertakes because we can't do it alone. The marine debris issue varies widely both within and across states, and only by working with local and regional organizations can we begin to address the local problems with the right methodology. To support partnerships, the MDP has two competitive grant programs, one administered by the NOAA Restoration Center, and the other administered by the National Fish and Wildlife Foundation. Each of these has a separate focus and target applicant pool, and operates on a different schedule. The MDP also supports NOAA researchers focusing on marine debris projects that strengthen NOAA's activities, including research and assessments, reducing the impacts and preventing derelict fishing gear, and reducing and preventing other types of marine debris.

The MDP has identified six hot spots for marine debris in the United States. These hot spots are determined by known debris problems; additional

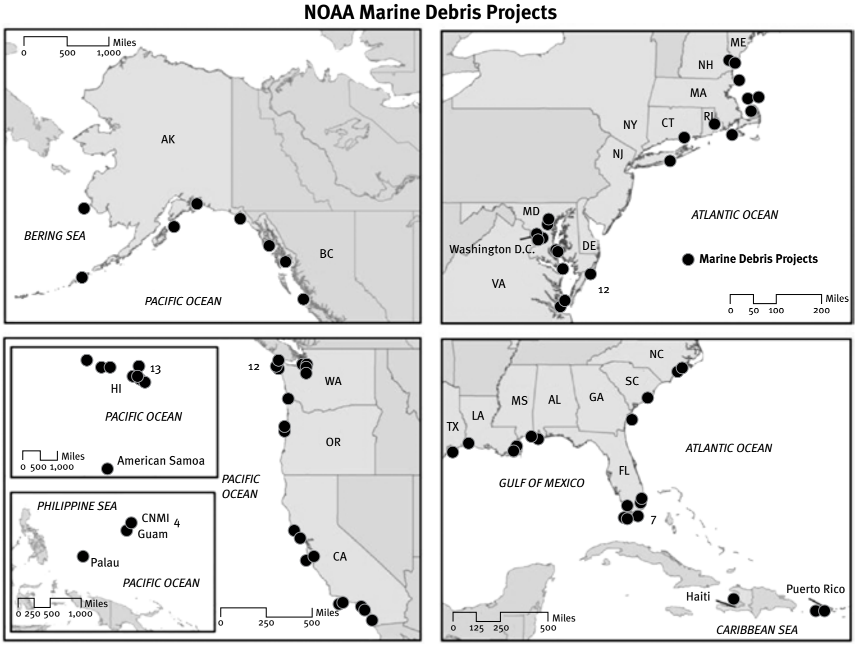

Figure 1. NOAA Marine Debris Program project locations by region. Numbers on the map depict the number of projects in that general area, as the dots overlap and a visual count is not possible. Projects that are not undertaken in the environment or have a national scope are not represented on the map.

hot spots may be identified as further research is completed. The hot spots are Alaska, Puget Sound, the Hawaiian Islands, Gulf of Mexico, southeast Florida (Atlantic), and Chesapeake Bay. Many of the projects funded through MDP funding opportunities have focused on these areas (Fig. 1).

The MDP is supporting research to assess the impacts of derelict blue crab pots in Chesapeake Bay on different species; supporting prevention activities by increasing the number of monofilament line recycling bins along our coastal beaches and piers; supporting marine debris assessment activities in several National Marine Sanctuaries and states, including Alaska; and teaming up with Ocean Conservancy annually to support International Coastal Cleanup (ICC) day. Multiple projects have been funded in Puget Sound to remove derelict fishing gear, assess its impacts to species and habitat, and train divers in safe removal techniques. Projects in California have focused on assessment and removal activities in several sanctuaries and around public piers. Port-specific projects in Hawaii, Washington, Massachusetts, and Rhode Island have provided free disposal bins for commercial gear, which is then recycled. Large shore removal projects, outside of ICC activities, have taken place in many states, including Florida, Washington, Hawaii, Alaska, and Rhode Island. Through projects like these, and by working with our partners, we will shed light on and better understand the sources and impacts of marine debris in our oceans and coasts, and contribute to the further development of solutions.

NOAA is also responsible for leading the Interagency Marine Debris Coordinating Committee (IMDCC), with the U.S. Environmental Protection Agency (EPA), to develop and recommend comprehensive and multidisciplinary approaches to reduce the sources and impacts of marine debris to the nation's marine environment, natural resources, public safety, and economy. Other federal agencies that are members include the U.S. Coast Guard, Department of the Interior, Department of State, Department of Defense, and Marine Mammal Commission.

Finally, a general list of the laws and international conventions that govern marine debris issues follow.

International

- International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), Annex V.
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972).

United States

- Marine Protection, Research, and Sanctuaries Act (1972).
- Clean Water Act (1977).
- Marine Plastic Pollution Research and Control Act (1987).
- Coral Reef Conservation Act of 2000.
- U.S. Ocean Action Plan (2004).
- Marine Debris Research, Prevention, and Reduction Act (2006).

Talking Trash in Kachemak Bay: The Kachemak Bay CoastWalk Program

Marilyn Sigman, Executive Director
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Center for Alaskan Coastal Studies, Homer, Alaska

The Center for Alaskan Coastal Studies (CACS), based in Homer, Alaska, is a nonprofit education organization founded in 1981. The mission of the organization is to foster responsible interactions with our natural surroundings and to generate knowledge of the marine and coastal ecosystems of Kachemak Bay through education, research, and stewardship programs. CACS has conducted educational programs in Kachemak Bay (Fig. 1) for more than 25 years, and currently serves more than 12,000 people annually at four educational facilities. Marine education occurs primarily at the Peterson Bay Coastal Science Field Station, accessible only by boat on the south side of Kachemak Bay. This residential facility has been the base of the Alaska Coastal Ecology school field trip program for more than 25,000 Alaskan students, teachers, and parent chaperones from Homer to Barrow. Field trips to rocky beaches, in an area where the tidal range is as much as 27 feet, are invariably the highlight of the excursion.

In 1984, CACS began to organize and support an annual Kachemak Bay CoastWalk to document and study the consequences of environmental changes (both natural and human-caused) occurring on the beaches and nearshore habitats of Kachemak Bay. Citizen volunteers, including school classes and youth groups, were encouraged to walk a stretch of the Kachemak Bay coastline and to survey biological communities, physical conditions, and evidence of human use and impacts. In keeping with the CACS mission of promoting active environmental stewardship, beach cleanup has been a feature most years and has resulted in the removal and disposal of tons of trash and marine debris.

At the "local" scale of Kachemak Bay communities, the Kachemak Bay CoastWalk program was developed as a program to increase awareness about the condition of specific areas on the shoreline and the overall health of

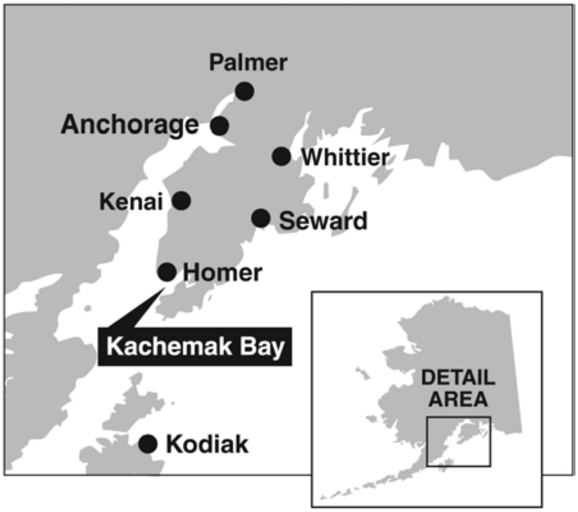

Figure 1. Location of the CoastWalk program in lower Cook Inlet, Alaska.

Kachemak Bay environments. It was designed as an annual snapshot of the shoreline, which proved especially important immediately following the 1989 *Exxon Valdez* oil spill.

Methods

The CoastWalk takes place over a three-week period each September. Kachemak Bay has been divided into 32 zones, many "adopted" by volunteers who have conducted CoastWalks on "their" beach for more than five years.

Volunteers are given garbage bags and data sheets, including a CoastWalk checklist to record general conditions and to record observations of birds, mammals, human uses and impacts, and unusual occurrences such a major erosion events or pollution discharges; a Marine Invertebrate Biodiversity Checklist; and, since 2001, the International Coastal Cleanup (ICC) data sheet. All forms and historic zone-specific data can be downloaded from the CACS Web site, http://www.akcoastalstudies.org/. GPS units and inexpensive cameras are available for checkout for additional documentation of unusual occurrences, and the location of large pieces of debris and sizable accumulations of debris. The CoastWalk zones and associated data are a georeferenced layer in the Kachemak Bay National Estuarine Research Reserve geographic information system (GIS). The GIS is the source of high-quality zone maps provided to the volunteers.

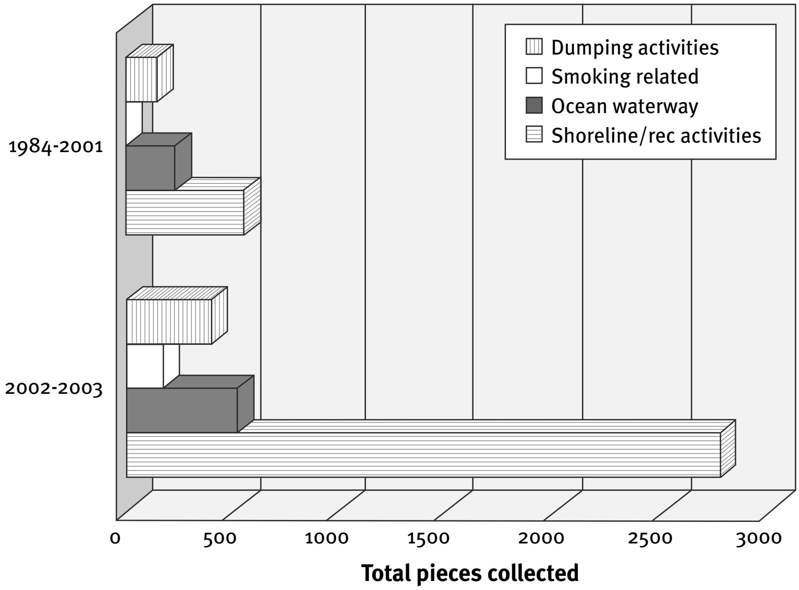

Figure 2. Composition of collected debris in Kachemak Bay from 1984-2001 compared to 2002-2003.

Surveys of plant and animal life and human activities and impacts have served as an "early warning" system for major changes (erosion, shoreline development) and for unusual events (e.g., large jellyfish blooms, mussel die-offs). The long-term survey has provided the basis to track areas near communities receiving heavy use and devise access and education efforts to minimize or avoid damage to biological communities.

Trends

Long-term trends on the quantity of marine debris removed are not possible because cleanups during the period 1984-2000 were not conducted every year and the amount removed was not always quantified. Beginning in 2001, the ICC data form was used consistently and the pounds of debris collected were estimated. CoastWalkers removed an average 1,000 lbs per year from Kachemak Bay during 2001-2005. In addition, removals of large debris like abandoned cars also occurred.

CACS has identified major trends in the types and sources of marine debris in Kachemak Bay. CACS has noted a significant increase in the amount of marine debris from shoreline/recreational activities in recent years (Fig. 2).

During the period 1984-2001, the top five items by quantity were (1) beverage cans, (2) plastic beverage bottles, (3) car parts, (4) buoys and floats, and (5) rope. During the 2002-2003 period, the top five items were (1) beverage cans, (2) fast food items, (3) plastic beverage bottles, (4) construction materials, and (5) caps and lids. As shown in the previous graph, this reflects a significant increase in the number of pieces of debris collected that came from shoreline/recreational activities (beverage cans and bottles, fast food items, and construction materials) compared to a smaller relative increase in the number of pieces from ocean/waterway activities (buoys, floats, and rope). This shift is likely a result of the reduction of commercial fishing inside the bay but could also reflect increased knowledge and compliance with MARPOL regulations related to ocean dumping by boaters. The significant increase in marine debris from shoreline activities has important implications for prevention strategies.

CoastWalk program constraints

Program constraints include

- Limited staff time (limited budget).
- Amount of equipment (e.g., cameras and GPS units) to temporarily lend to document accumulations for later pickup.
- Boat transportation to remote beaches on the south side of the bay.
- Sustaining and expanding volunteer commitment.
- Determination of beaches to estimate re-accumulation rates in addition to staff and logistical support.
- Coordination and targeting of prevention efforts.

Expansion of CoastWalk

In 2006, CACS expanded the CoastWalk program with the support of grant funds from the NOAA Community-based Marine Debris Prevention and Removal Grant Program. These additional financial resources were used to (1) increase the effectiveness of the Kachemak Bay CoastWalk cleanup, (2) expand prevention education efforts, and (3) expand the CoastWalk cleanup program to other Alaska communities.

Increase in effectiveness of the Kachemak Bay CoastWalk cleanup

With financial support for staff time to focus on the CoastWalk program, recruitment of volunteers and the amount of marine debris collected increased significantly in 2007 compared to the period 2004-2006 (Fig. 3). The number of miles of beach cleaned was limited by accessibility, but heavily used areas were cleaned more thoroughly with additional volunteer effort.

In 2007, 1,800 pounds of marine debris were removed, compared to the annual average of 1,000 pounds during the 2001-2005 period.

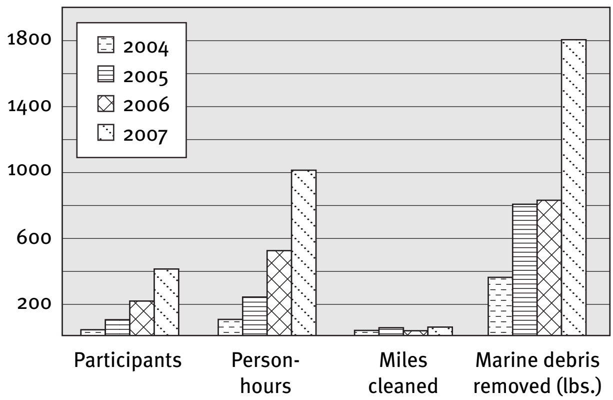

Figure 3. Number of participants, hours, miles cleaned, and pounds of debris removed during Kachemak Bay CoastWalk, from 2004 to 2007.

Expansion of prevention education efforts

Each year, the CoastWalk kicks off with a community education event around an annual theme and involves classroom presentations. During 2006 and 2007, CACS increased its focus on youth participation through classroom presentations focused on the marine debris issue, guided CoastWalk cleanups, and challenge grants to schools. Classroom presentations focused on understanding the origin of marine debris on Kachemak Bay beaches and individual choices to reduce plastic waste and avoid creating marine debris. In 2006, the theme of the CoastWalk kickoff program was the importance and recognition of youth volunteerism; in 2007, the results of the remote Gore Point "catcher beach" were presented first at the CoastWalk kickoff event and then at schools and college classes throughout the CoastWalk period. Bree Murphy presented her personal experience participating in the Gore Point cleanup using multilingual props illustrating the origin of the debris from many countries. The presentation incorporated North Pacific Ocean current patterns responsible for transporting international and domestic marine debris to Gore Point and into Kachemak Bay. CACS staff educated the public about the large scope of the problem with the intent to inspire participation in future cleanups by combining cleanup results with the science.

CACS has incorporated beach surveys and more intensive methods for monitoring change in biological communities into its K-12 school field trip programs. All Alaskan students can learn about marine science from an online Alaska CoastWatch curriculum at http://www.akcoastalstudies.org/Pdf/CoastWatchProgram.pdf. Teachers are able to use the beach field trip as a hands-on tool to teach aspects of science, geography, social studies, and environmental stewardship consistent with national and state standards. CACS staff facilitated incorporation of the CoastWalk beach survey and cleanup activities into the fifth grade unit of the statewide Alaska Seas and Rivers online curriculum in 2007, http://seagrant.uaf.edu/marine-ed/curriculum/.

CACS partnered with Cook Inletkeeper in 2006 to print and distribute statewide 300 Turning the Tide on Trash posters. In 2007 the partnership printed 5,000 Southcentral Alaska tide books with a multipage insert about marine debris regulations, impacts, and prevention messages for boaters.

Expansion of the CoastWalk cleanup program

CACS transferred the cleanup aspect of the CoastWalk program model to other Alaska communities through a challenge grant program, presentations at the statewide Alaska Forum for the Environment (AFE), and an Alaska Coastal Stewardship Conference. The challenge grant program passed through National Oceanic and Atmospheric Administration (NOAA) funds to support community-based cleanups with a substantial nonfederal match requirement that was lower than the 1:1 match required by the NOAA program. The conference was held in Homer, Alaska, in February 2007, immediately after the AFE. CACS leveraged travel funds from the National Fish and Wildlife Foundation and the World Wildlife Fund to increase participation in the conference, which also focused on the coastal issues of climate change and invasive, nonindigenous species in addition to marine debris.

Eleven challenge grants, totaling $15,500, were awarded to support participation in the conference and cleanups. Sixty people attended the conference, representing 15 Alaska communities. Challenge grants were awarded to the following groups:

- McNeil Canyon School, Homer
- Fireweed Academy School, Homer
- Homer Chamber of Commerce
- Seldovia Native Tribe, Seldovia
- Kenaitze Tribe, Kenai
- Kenai Watershed Forum, Soldotna
- Island Trails Network, Kodiak
- Resurrection Bay Conservation Alliance, Seward
- Takshanuk Watershed Council, Haines
- Gulf of Alaska Keeper, Anchorage (Gore Point cleanup)
- Alaska Sea Grant, Unalaska (support for conference travel, from World Wildlife Fund)

The reporting developed for the challenge grant program served to standardize reporting on marine debris cleanups. Based on these reports, the $14,000 from NOAA and National Fish and Wildlife Foundation leveraged

- $8,000
- 670[1] volunteers
- More than 2,100[1] volunteer hours
- 28 miles of beaches surveyed for marine debris in outer Kachemak Bay
- Removal of 11,000[1] pounds of marine debris from
    - 25 miles of beaches
    - 13 miles of streams
    - 7 acres of intertidal area at stream mouth

Summary

In Homer, Alaska, an annual community-based marine debris cleanup has been sustained for more than 20 years by nesting the cleanup within a series of community education events focused on appreciation, study, and concern related to area beaches. The types of marine debris have shifted from marine to land-based sources, which underscores the need for local prevention education. The program has recently emphasized youth as a target audience for prevention education and participation in cleanups.

Additional financial resources have made it possible to expand the program, increase its effectiveness, and successfully disseminate the program as a model and support marine debris assessments and removal.

[1] Numbers don't include results of the Gore Point cleanup, which required substantial additional resources for a major cleanup.

Derelict Fishing Gear in Alaska: Accumulation Rates and Fishing Net Analysis

Bob King, Marine Debris Program Coordinator
Marine Conservation Alliance Foundation, Juneau, Alaska

Background

The MCA Foundation (MCAF) is the nonprofit arm of the Marine Conservation Alliance (MCA), a fishing industry trade association whose members include fishermen, seafood processors, and fishing communities involved in the Alaska groundfish and crab fisheries. MCA began sponsoring marine debris cleanup work on St. Paul Island in 2003, and with funding from NOAA MCAF has continued the work since then. In 2006, the program was expanded to include Southeast Alaska, Prince William Sound, St. George Island, and Norton Sound, and 74.1 tons of debris were removed that year (Fig. 1). In addition, in 2006 surveys were conducted on Unalaska Island to assess debris accumulations. In 2007, cleanup work began in Unalaska, Gore Point, and Yakutat and continued in other locations. MCAF cleanup programs in 2007 collected 175.4 tons of debris (Fig. 1), and 2,100 miles of shoreline were surveyed to plan future cleanup efforts, in western Alaska from Cape Wales to Egegik and on the east side of Kodiak Island.

In 2008, MCAF plans to continue most of these cleanup projects and initiate new cleanups in Southeast Alaska, Kodiak, the Alaska Peninsula, Bristol Bay, and the Yukon Kuskokwim Delta.

Pribilof Island debris accumulation studies

In 2006, MCAF contracted with the St. Paul Island Tribal Ecosystem Conservation Office (Tribal ECO) to continue beach cleanup work; they focused efforts on 4 km of beach at the island's North Point. During a one-week period in May, 19,765 pounds of debris (8,965 kg) were removed from the beach (2,241 kg per km). In 2007 MCAF staff returned to North Point, where

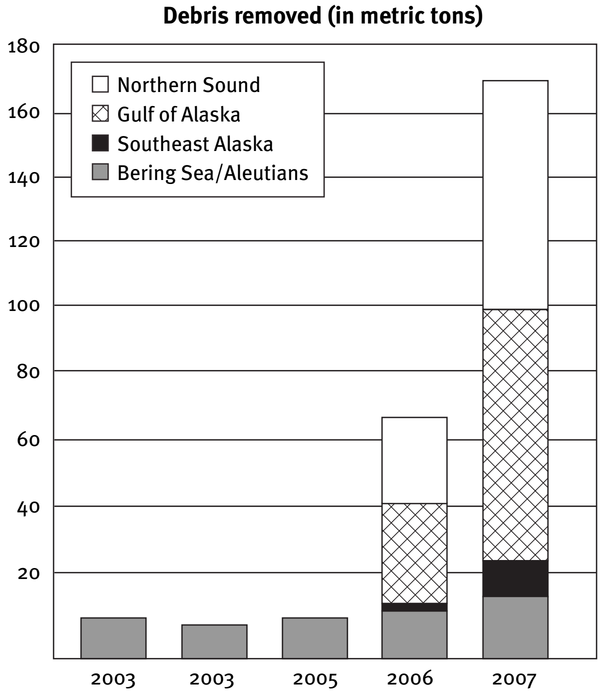

Figure 1. Mass of marine debris removed from selected Alaska coasts, 2003-2007.

they collected 822 pounds of debris on 1 km of beach that had been cleaned the previous year, an annual accumulation rate of 373 kg per km. Analysis of the debris revealed items related to the crab fishery, i.e., buoys and several tangles of line that accounted for 70.5% of the total. There were two small scraps of trawl net that weighed 13 pounds, or 1.6%. Much of the remaining debris was of marine origin: hawsers, tote covers, gloves, hard hats, and fish baskets. There were 52 plastic bottles made of polyethylene terephthalate (PETE), some with foreign labels. Less than 0.01% was locally generated.

On neighboring St. George Island, MCAF contracted with Kayumixtax ECO to clean 4.8 km of beaches including five fur seal rookeries and the village site. In 2006, 10,828 pounds (4,912 kg) of debris were removed or 1,023 kg per km. In 2007, the same beaches were cleaned again and 6,005 (2,724 kg) pounds of debris were removed, an annual accumulation rate of 568 kg per km. Debris identified from the crab and trawl fisheries accounted for only 35% of the total weight; of that, crab gear outweighed trawl web by a 4:1 ratio.

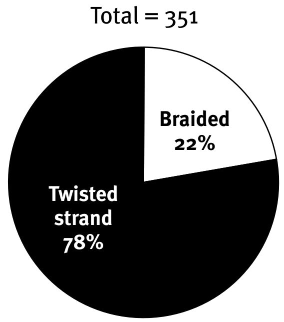

Figure 2. Percent of trawl twine types collected and sampled from Alaska cleanup projects in 2006 and 2007.

Discussion

Trawl net analysis

As part of MCAF's cleanup program, cleanup contractors are asked to provide samples of net collected during cleanup efforts, and more than 500 net samples were collected from across the state in 2006 and 2007. MCAF recorded the net samples based on protocols established by ghost-net identification programs in Australia and the northwest Hawaiian Islands. Samples were then shown to net design and construction experts for their analysis. The samples included trawl net, gillnet, seine gear, cargo netting, and mesh of undetermined use. Of the total number of net samples statewide, 351 were identified as trawl gear. Of these, 275 (78%) were constructed of twisted strand polyethylene (PE) twine and the remaining 76 (22%) were made of braided polyethylene (Fig. 2).

The domestic fishing industry almost exclusively uses nets made from braided, not twisted strand, polyethylene. Twisted strand polyethylene was the dominant twine type used by foreign and joint-venture fisheries prior to 1990 and it is unknown what percent of foreign fishing fleets use twisted strand today.

Mesh size

MCAF measured mesh size (distance between the centers of knots in stretched mesh) to identify the most likely fishery of origin for collected nets sampled in 2006 and 2007. Nets with very small mesh sizes, <50 mm, are likely shrimp trawls. Nets with mesh sizes of 50 to 100 mm are probably more than 20 years old, dating to when fishermen used a smaller mesh trawl to maximize the overall catch. Fishermen today use a larger, more selective mesh size to reduce the catch of juvenile fish and nontarget species. Netting with mesh sizes of 100 to

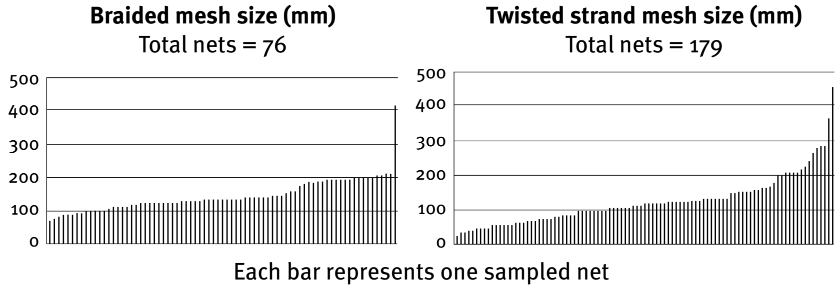

Figure 3. Representation of mesh sizes of twisted and braided strand nets sampled in 2006 and 2007.

150 mm is consistent with the pollock fishery, which accounts for one-half to three-quarters of the Bering Sea catch by weight. Mesh sizes of around 200 mm are used for larger groundfish such as flatfish and cod. Mesh sizes over 200 mm are probably from the outer wings of the nets.

Preliminary analysis indicates a significant amount of small mesh size gear (<100 mm) among the twisted strand samples (Fig. 3). Other net samples fall within the range of gear for pollock (100-150 mm) and flatfish (200 mm) and with several samples in excess of 250 mm. A similar pattern is apparent among the braided gear samples, although with less variation in mesh size at both extremes.

Relative age

Polyethylene is difficult to age, but five indicators of general condition help judge the relative age of the netting: chafing, fraying, color, stiffness, and the presence of marine growth. Some netting appeared obviously aged: (1) chafed knots, (2) frayed and stiff twine, (3) faded color, and (4) marine growth or detritus. Of samples of twisted strand mesh, 150 of 179 (83%) showed clear signs of age (i.e., all four signs of age). Of the 76 samples of braided gear, 38 or 50% showed clear signs of age and 20 samples or 26% showed no signs. The remaining 18 samples, 24%, fell in between with two or three signs of relative age. It is impossible to distinguish aging as a result of active fishing and movement in the nearshore zone.

Conclusion

The first year of MCAF's derelict fishing gear accumulation and identification program documented higher rates of accumulation in the Pribilof Islands than previously reported on the Bering Sea side of Amchitka Island. Located amid one of the world's richest fishing grounds, the Pribilof Islands are highly impacted by derelict fishing gear. Passage of the American Fisheries Act in 1998 "rationalized" the Bering Sea pollock trawl fishery, which resulted in a reduced fishing effort and ended the race for fish, factors that may reduce debris derived from domestic trawling. The Bering Sea crab fishery was similarly rationalized in 2005, resulting in a 60% reduction in effort. It will be interesting to see if rationalization results in a similar reduction in debris observed on the Pribilof Islands.

One year's data are very limited, however, and these studies will be continued and expanded to other parts of the Alaska coastline so we can get a better idea of accumulation rates. Identification of derelict fishing gear remains problematic. While it is difficult to positively identify the specific source of most nets, reasonable conclusions can be drawn about its country of origin and fishery use by examining the twine type, mesh size, and wear. The majority of the sampled trawl netting appears to be of foreign origin based on the predominance of twisted strand polyethylene collected. Ocean currents transport fishing floats and plastic bottles from Asia to Alaska. Additionally the Bering Sea and North Pacific have been intensively trawled for the past 60 years. Foreign trawlers operated in these waters for the first 30 years, followed by a decade of U.S./foreign joint ventures and two decades of exclusively domestic trawling. Significant derelict fishing gear accumulations were documented in the early 1970s, well before the start of the domestic fishery. It is hoped that further sampling and analysis may lead to more conclusive results.

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Debris via the Sea: St. Paul Island, Pribilof Islands, Alaska

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Ecosystem Conservation Office, St. Paul Island, Alaska

Cleanup of marine debris from St. Paul Island's shorelines took hold in 1994, planted and rooted by the hands of children in the Pribilof Islands Stewardship Program. By 1996-1997, the City of St. Paul refused to accept fishing debris in the local landfill due to the sheer amount and type of debris. A lack of alternate disposal sites illustrated a need for a more strategic effort. The Tribal Government of St. Paul took on the challenge of managing volunteer efforts beginning in 1999. Expanded cleanup efforts with financial support began in 2002 and continued through 2007. Debris removal from St. Paul Island shorelines has a 14-year history and will continue in 2008. The cleanup has become an annual one-week intensive effort that is synchronized to take place after winter's icy grip on shorelines is released and before the arrival of northern fur seals and seabirds, dependent on the cliffs and shorelines of the Pribilof Islands. Cleanup has happened as early as the end of April and as late as the first week of June. Cleanup methods, estimated amounts of debris, and challenges to cleanup are presented here.

History

St. Paul Island's youth began cleaning the shoreline of marine debris in 1994 through the Pribilof Islands Stewardship Program. Upon learning of the entanglement of fur seals, the youth were further motivated to clean beaches of fishing nets and other fishing debris. These cleanups were on a small scale, resulting in a few bags of debris. Adults working at the fish processors wanted to explore the island, and participated in a few cleanups. Adult volunteers were able to collect large items and amounts of debris beyond the capacity of the youth-only program.

Initially the debris was taken to and accepted by the local landfill. By 1996 the excessive amount of debris and its characteristics led the city to refuse fishing debris at the local landfill. The municipality's heavy equipment was becoming entangled in disposed nets, rope, and line, resulting in lost time and damage. In addition, there was concern over the space that debris was taking up in the small landfill on a small island. What to do with the marine debris was a decision that needed to be made.

Therefore, in addition to the children's concern for wildlife entanglement, the amount of debris coming off the shorelines led to the community's realization that there was a need for an extreme and strategic cleanup, removal, and disposal effort that was beyond the capacity of a youth-only program.

Why clean up marine debris?

On the Pribilof Islands, one can observe high concentrations of both marine wildlife and debris and the negative interaction between the two. Every year, hundreds of thousands of northern fur seals, a protected marine mammal, return to the many rookeries on St. Paul Island. Entanglement of individual seals in marine debris causes physical stress, energetic expense, social disruption, injury, infection, and even death. The negative impact of marine debris entanglement is not limited to the seal that is entangled. Our efforts to capture and disentangle an entangled seal can result in further disturbance to nearby fur seals, sometimes numbering in the hundreds. Fur seal entanglement can result in significant infections, and social interactions with other seals can be altered due to the wound's smell or other factors. Entanglement often leads to the death of the fur seal if measures are not taken to capture and disentangle it.

Cleanups also help reduce the chances of injury and deaths by entanglement or ingestion for some of the millions of seabirds that return each summer to the island's cliffs to breed and raise their young. Birding tourism, which brings visitors to witness the abundance and diversity of seabirds on the Pribilofs, has become an important economic factor. Thus, cleanups are necessary in this area to stay one step ahead of harm that can befall fur seals traveling to and from our shores, and to provide a healthy habitat for seabirds.

Methods and results

Due to the varied coastal terrain we have found manual labor is the only method to move debris from the coast inland to pickup trucks for transport to temporary storage. All-terrain vehicles provide access directly to some areas, but the majority are accessible only on foot. Shorelines range from flat sandy beaches, to cliffs, sand dunes, small cobble, and boulder beaches. Ingenuity and use of immediate resources are the best tools to remove debris with minimal impact to the habitat. In all the years we have been cleaning St. Paul Island's shores of marine debris, there was only one occasion when we were able to alleviate some of the backbreaking work with a piece of heavy equipment at the cleanup site.

We load all the collected debris into pickup truck beds to maximum capacity to reduce the number of trips. The number of trips is limited to alleviate damage to the tundra and trails. The truckloads are taken to a staging area approved by a local landowner. As mentioned earlier, the debris is no longer handled by the local landfill.

The window for conducting most of the marine debris removal is short and a moving target. Couched between periods when the shores are not being used by fur seals and when inclement weather makes collection hazardous, the window can be as short as one or two weeks when the work can be conducted. This means that work cannot be planned far in advance because no one knows when these opportune times will occur. The primary work must be conducted quickly by people on the island. Both factors increase logistical challenges and cost.

Over the years staging areas for collected marine debris and methods of handling marine debris have evolved. NOAA (National Oceanic and Atmospheric Administration) provided the first staging area close to town and on a main road where the public could see the sheer amount of debris coming off of St. Paul Island's shores. This pile was loaded into shipping vans and barged off the island. During following seasons, the local village corporation allowed for marine debris to be temporarily staged on their land a couple of miles away from the town and harbor, while interim plans for taking debris off the island were being developed. Heavy equipment was required to pick up the debris from the piles, and load it into trucks to move it. Old shipping vans were donated to the effort and filled prior to barging off the island. Shipping vans became an integral part of the marine debris cleanup process. To this date, marine debris collected from the shores continues to be loaded into pickup trucks, and then driven to the shipping vans and hand-loaded into them for storage prior to off-island disposal.

Results of annual cleanup efforts on St. Paul Island from 2003 to 2007 are as follows. Note that there have been changes in record-keeping over the years.

2003

- 20 people (combination of paid, volunteer, local, and nonlocal).
- 80,000-90,000 pounds (estimated) of debris removed from beaches.
- 17,000 pounds (estimated) disposed of in the same year.
- Primarily northern fur seal rookeries cleaned.
- Funded primarily by a grant from the Coastal Impact Assessment Program.

2004: April 29-May 4

- 7 local individuals.
- 1 off-island volunteer.
- 40,000 pounds (estimated) of debris.
- 6 locations: Antones Lake, Boulder Spit, Polovina Beach, Pier Point, Lukanin Beach, North Beach West.
- Funded primarily by Marine Conservation Alliance Foundation.

2005: June 9-14

- 385 paid staff hours.
- 250 volunteer hours.
- 2 miles of shoreline cleaned.
- 22,000 to 30,000 pounds of debris removed.
- 31 full-size pickup truckloads.
- Funded primarily by Marine Conservation Alliance Foundation.

2006: June 5-9

- 12 people.
- 332.50 regular and 35.00 overtime field hours.
- 50 volunteer hours expended in the field.
- 40+ hours of management and administration.
- Additional 5 people expended 41.25 hours to move debris stockpiled from previous cleanups and placed into shipping containers.
- 16 to 20 tons of marine debris.
- Approximately 2.5 mile stretch of shoreline.
- Funded primarily by Marine Conservation Alliance Foundation.

2007: May 29-June 1

- 444 regular and 91 overtime field hours.
- 25 volunteer field hours.
- 15,000-20,000 pounds of debris.
- 6.8 mile stretch of sandy beach.
- Ecosystem Conservation Office staff—additional 4.04 miles after June 1.
- Funded primarily by Marine Conservation Alliance Foundation.

Origin of debris

Fishing debris is a major component of the Pribilof marine ecosystem, and it degrades habitat and negatively impacts fish and wildlife. It is safe to say that 99% of marine debris on St. Paul Island's shores is fisheries-generated of non-local derivation.

Limits/constraints

Marine debris cleanup efforts are limited and constrained by various combinations of the following:

Weather
Occupation of shoreline by fur seals or birds
Funds
Timing
Equipment availability
Human resources

Next steps

Tribal Government of St. Paul Ecosystem Conservation Office recommendations:

- Evaluate and develop a fishing debris tax.
- Balance effort spent on cleanup with prevention.
- Evaluate the use of foreign-made nets and materials by U.S. fisheries, and the potential for mis-categorization of domestically derived fishing gear as foreign.
- Encourage the global fishing industry and shipping industry to work together to prevent marine and fishing debris that crosses international boundaries.
- Develop a process within domestic fisheries where marine debris prevention is rewarded.
- Define and develop who should be included in the prevention process, such as fisheries management councils.
- Strict and strong enforcement of MARPOL 73/78.
- Fisheries families and all their business connections should conduct and/or participate in the debris cleanups where their fishermen fish.
- Educate consumers and public of marine and fisheries debris problems in Alaska and the effect on marine environment.
- Establish consistent funding source, to allow preplanning for cleanups and purchase of equipment to efficiently conduct cleanups.

Marine Debris Remediation from Prince William Sound to Gore Point: Gulf of Alaska Keeper

Chris Pallister, President
Gulf of Alaska Keeper, Anchorage, Alaska

Gulf of Alaska Keeper (GoAK) has organized marine debris cleanups since 2002. The focus for the nonprofit organization is the remote areas of Prince William Sound (PWS). The organization works closely with NOAA, U.S. Forest Service, recreational boaters. and tourism industries to identify areas that are priorities for cleanup. GoAK applies for funding to remove debris from priority areas in Prince William Sound. Close ties with the boating community have been instrumental in allowing GoAK to access the remote outer coast beaches where very dense accumulations of debris aggregate.

We will highlight two years of cleanups by GoAK. In 2006, GoAK volunteers transported by boat were able to clean up more than 350 miles of extremely rugged and remote shoreline on the Knight Island archipelago. From this cleanup over 35 tons of debris were removed by hand and transported to the city of Whittier. In 2007, GoAK removed 40 tons from 110 miles of beach on 13 heavily inundated islands and islets in north-central PWS, and approximately 45 tons from the extremely fouled Gore Point–area beaches. Nearly 25 tons of marine debris came from just 2 miles of beach in Gore Point. The remaining 20 tons were from dense pockets of plastic marine debris on beaches along 70 miles of coast in Tonsina Bay, Port Dick, Qikutulig Bay, and Touglaalek Bay. During the 2007 cleanup, GoAK cleaned 180 miles of beaches, hauling approximately 85 tons of marine debris to local communities where tons of recyclable fishing gear was given away and the rest dumped into local landfills.

Most of the marine debris that GoAK removes from beaches is plastic. Debris comes from offshore locations and foreign countries. Large quantities of polystyrene foam (in both volume and number) and everyday household items are common.

In addition to cleanups, GoAK also surveys PWS to help direct cleanups in subsequent years. These surveys allow for estimations of marine debris accumulation rates as well as aid in planning efforts for future cleanups. Surveys have indicated that Montague Island is a priority area for future cleanups. Efforts are under way to revisit Gore Point to calculate the accumulation rate of debris at that location. Chemical analysis of plastic debris is also under way through a partnership with chemistry scientists from the University of Alaska Anchorage. The purpose of the chemical analysis is to determine possible toxicity and biological pathways between these plastics and marine life.

The main focus of GoAK is cleaning up debris from beaches, collecting data on re-accumulation rates, and examining plastic-related chemical pathways into the environment. This information will allow for improved marine debris efforts in the state. GoAK also does outreach and public education on the effects of marine debris and its prevalence in Alaska. GoAK has been featured in *Alaska* magazine, the *Anchorage Daily News*, the *New York Times*, a local TV news station, and various other media.

Challenges for GoAK include the annual collection and distribution of funds to conduct their work, finding locations that will accept the debris that they collect, and working on appropriate mechanisms for prevention when the majority of the debris that they encounter is foreign in origin.

Kodiak Archipelago Marine Debris Survey

Andy Schroeder, Executive Director
Island Trails Network, Kodiak, Alaska

Introduction

Island Trails Network (ITN) partnered with the Marine Conservation Alliance Foundation (MCAF) from June 15 to September 30, 2007, to conduct a survey of marine debris accumulations in the Kodiak Archipelago near Kodiak, Alaska. Marine debris is defined by NOAA as any man-made object discarded, disposed of, or abandoned that enters the coastal or marine environment. It may enter directly from a ship, or indirectly when washed out to sea via rivers, streams, and storm drains. For the purposes of this survey, we would add commercial fishing gear inadvertently lost at sea.

The results of the survey may be used for the purposes of designing, planning, and funding marine debris cleanups in the Kodiak archipelago. Results from this survey may also be used to estimate mass and volume of debris deposits and subsequent work required in other marine debris projects outside Kodiak. The survey is a joint product of both organizations, and is available at http://www.islandtrails.org/marinedebris.htm.

Background

Island Trails Network was established in 2006 to develop and maintain sustainable trail systems and promote responsible wilderness recreation throughout the Kodiak archipelago. ITN broadly defines trails as any recreational route over land or sea, for this island community with a rich maritime heritage (see http://www.islandtrails.org).

The Marine Conservation Alliance (http://www.marineconservationalliance.org) was established in 2001 by fishing associations, communities, Community Development Quota groups, harvesters, processors, and support sector businesses, to promote the sustainable use of North Pacific marine resources by present and future generations, based on sound science, prudent management, and a transparent, open public process. They seek practical solutions to resource use questions to both protect the marine environment and minimize impacts on the North Pacific fishing community. They also support research and public education about the fishery resources of the North Pacific.

Objectives

The objectives of this survey were to

1. Identify and prioritize seven significant marine debris deposits within a 10-mile radius of a population center on Kodiak (includes 1 each for Kodiak city and surrounding villages of Old Harbor, Akhiok, Port Lions, Ouzinkie, Karluk, and Larsen Bay).
2. Identify and prioritize seven significant deposits in areas deemed by ITN to have significant recreational value.
3. Identify all significant deposits (>1 ton) in Kodiak.
4. Identify the relative distribution of marine debris density in Kodiak, assigning each mile of coastline a value of 1-5 according to estimated density.

Voluntary reporting program

Phase I of the survey was to establish a voluntary reporting program for marine debris deposits. This element of the survey consisted of a mass-mailing of 458 surveys to Kodiak seine and set net permit holders, as listed in the online database of the Alaska Commercial Fisheries Entry Commission. Concurrently, 81 email newsletters went out to Kodiak charter boat operators, pilots, lodges, and hunting guides. Our toll-free marine debris "hotline" and online reporting form was advertised in the display advertisement in the *Kodiak Daily Mirror* weekly for 10 consecutive weeks, and local public radio station KMXT (once per day for 70 days). Feedback from this part of the survey was disappointing. Although there were a few inquiries asking if we were hiring vessels, only seven phone calls, emails, or conversations resulted in identifying an affected coastal area. The low levels of feedback from the voluntary reporting program suggest that marine debris is a low priority among the target audience, that the problem is perceived to be too pervasive to mitigate, or that we failed in our outreach effort.

Admittedly, the timing of the mailing was not ideal. The mailings were postmarked June 25, 2007, several weeks after the salmon fishing season was under way. Had the survey begun in the winter or spring, the mailing may have elicited more responses. The reporting guidelines were intended to be easy to understand; however, they may still have been overly precise and/or confusing. The locations and sources of voluntary reports we did receive are featured in the visual model of the survey.

Aerial survey

Phase II of the survey included collecting and analyzing aerial photographs of coastal areas to determine the extent of marine debris there. The area to be surveyed originally included the principal islands of Kodiak, Afognak, and Shuyak, as well as the Trinity Islands. There are 16 major islands in the archipelago, with a combined area of 4,500 square miles. Kodiak Island, the largest of the archipelago, has an estimated 900 miles of coastline with 1,400 miles of coastline in the archipelago.

Since flight hours did not permit adequate coverage of the full area, Kodiak and Afognak islands received higher priority than Shuyak and the Trinity Islands. Accordingly, the latter areas were not surveyed in 2007. Kodiak and Afognak received only partial surveys. In all, 1,639 data points covering 629.5 miles of coastline were collected. This makes up about 45% of the archipelago.

Objective 4 of the survey was to provide a visual model of Kodiak Island, assigning values (1-5) of relative marine debris density to different areas of the coast. This model is available from ITN and is viewable through Google Earth. Within the model, the user can manipulate the data, including sorting by score, by source, or by geographic region. Several overlays are also provided, including area villages with a 10 nautical mile radius, the Kodiak road system, public lands, and relevant easements. Perhaps most importantly, each of the raw data points is available for viewing by simply clicking on the red balloon pointing to the site. The photos have been resized for ease of downloading, but high-resolution files are available from ITN upon request.

The following explains how the visual model achieves the objectives of the survey, describes the scoring system, and explains how the photos were interpreted.

Marine debris in areas near population centers

Objective 1 of the survey intended to identify significant deposits within a 10-mile radius of a population center on Kodiak, including one each for Kodiak city and surrounding villages of Old Harbor, Akhiok, Port Lions, Ouzinkie, Karluk, and Larsen Bay. Some villages were only partially surveyed, and two (Larsen Bay and Karluk) not at all. In accordance with objective 3 significant deposits (more than 1 ton) in Kodiak will be given special attention and will be represented on the model.

The seven villages are shown in the model, with a radius of 10 nm drawn around each. These areas were deemed close enough to the village to launch a volunteer cleanup effort from the local population. The proposed cleanup sites may be shifted or re-prioritized once the entire coastline has been surveyed.

Marine debris in areas of significant recreational value

Objective 2 of the survey attempts to identify and prioritize seven significant marine debris deposits in areas of significant recreational value. Although we did not survey the entire archipelago because of logistical and weather delays, we did select seven sites based on the areas we did survey.

The recreational value of a coastal area is subjective, especially when compared to another area. All lands in the archipelago have some recreational value through hunting, fishing, wildlife viewing, hiking, boating, or camping. The areas most heavily used for recreation are commonly those most accessible. The Kodiak road system, available as a separate overlay in this model, is the most obvious access point for recreational sites. Areas accessible by foot or vehicle tend to see more human recreation than sites requiring vessel or aircraft transportation. Thus, marine debris sites on the road system were given some priority over those off the road system. One notable exception is Long Island, which is only minutes from town by skiff and frequently used for various types of recreation.

Beyond the road system, coastal areas are deemed to have significant recreational value if they are (1) owned by government entities and accessible to the public or (2) are privately owned but have guaranteed access by easement. Such public lands include state parks and recreation sites, national wildlife refuges, borough recreation sites, or simply state-owned or Bureau of Land Management (BLM) lands (Kodiak Island Borough Comprehensive Plan 2007).

Private and Native-owned lands throughout the archipelago also have recreational value, although land use fees sometimes discourage use. Still, private lands often have trail or campsite easements to allow public access. Listed on the survey are 45 one-acre campsites guaranteed access by public easement. Though more easements exist throughout the borough, those listed in this survey are situated in coastal areas and prone to be impacted by marine debris.

Scoring

Areas surveyed aerially and photographed were subsequently scored from 1 to 5 based on the observed or predicted accumulation and retention of marine debris. There is no correlation of a score of 3 to an “average” or typical beach. Although the overall study attempts to establish patterns in relative distribution of debris, individual data points were scored empirically based on evidence in the photo and not based on trends in other data points in the area. Scores are awarded to the photograph only, not to any coastline not photographed.

Efforts were usually made to photograph deposits of marine debris and sometimes the absence of deposits. Thus the photos are not a representative sample of the coastline, but favor the higher density accumulations of debris and areas "worst affected." However, some cliffs and capes where little or no debris exists were photographed to show that the area has been surveyed and no gap in the survey exists there.

Because of the variabilities of the elevation, elapsed time, and purpose in capturing individual data points, there is little use in averaging scores to achieve a median representative score for a larger area. With respect to objective 3 of the study, all data points receiving a score of "5" are considered to be "significant" and may hold one or more tons of marine debris.

Areas scored as very light density of debris (score = 1) were primarily steep capes and cliffs affording little to no "adhesion" of debris on the coast. Areas scored as light density of debris (score = 2) were low-energy sites sheltered from waves, wind, and tide; or possessed topographical characteristics that made adhesion unlikely; or both. Sometimes an up-close examination resulted in the identification of more debris than predicted from the aerial survey alone. Areas scored as having a moderate density of debris (score = 3) had substantial accumulations either spread out intermittently along a beach or in dense clusters with little vertical depth of debris. Areas scored as high-density accumulations of debris (score = 4) feature continuous, uninterrupted accumulations of marine debris, flotsam, and/or driftwood, often extending above storm-tide level. Surveyed areas scored as having very high density of debris (score = 5) consisted of large-scale, uninterrupted deposits that are long, wide, and deep in marine debris, flotsam, and/or driftwood.

Driftwood and marine debris

This survey assumes that some link exists between the presence of driftwood and the presence of marine debris. Undoubtedly some variation on this relationship exist. Debris able to be transported by wind above the intertidal zone will persist in areas where heavier driftwood, unable to be transported by wind, does not. Consequently, although the absence of driftwood does not indicate an absence of marine debris, the presence of driftwood usually means that marine debris is also present. This impacts scoring descriptions above. Other environmental factors may affect plastics more than driftwood, such as the effect of wind on the debris while it is at sea. Denser debris such as driftwood may be more affected by tidal influences than wind. Conversely, for debris of lower density such as Styrofoam or plastics, wind may be more influential than tide.

Many estimates in the survey were made based on the presence or absence of driftwood. Most driftwood logs have been stripped by force of the ocean of any bark or branches and are relatively smooth on their surface. Not all driftwood crosses the ocean. Some is flushed out of rivers and deposited in the adjacent delta, some timbers fall over an eroding cliff, and some are the byproduct of commercial logging. As a general rule, only driftwood without branches or bark, having a smooth appearance, and often possessing a bleached color was considered to have been deposited by ocean forces.

Particular care was taken near river deltas, eroding shorelines, and logging areas to distinguish between the two types of driftwood and only consider long-traveled logs in scoring. However, a higher incidence of the more recent driftwood, with bark and branches intact, become tangled with fishing web. Anything that by its shape is able to snag webbing has usually done so, suggesting that webbing has likely come in contact with other objects before its entangling marriage with a tree.

Summary and recommendations

Marine debris is a widespread phenomenon that has impacted shores on all sides of Kodiak Island. In Kodiak's case, more troubling than any one deposit of debris is how widely the phenomenon is spread. The findings of this survey are sufficient to identify several areas of particular concern along the east side of Kodiak and Afognak islands. The true distribution patterns will not be known until the west side of Kodiak and Afognak, as well as the Trinity Islands and Shuyak, are surveyed.

When additional marine debris resources for Kodiak become available, the following recommendations should be considered:

- Continue to survey the 55% of the coastline that has not had aerial surveillance.
- Collect samples of marine debris at sites ranging from 1 to 5, recording weight and volume of marine debris per given distance along the shore. Such sampling could be paired with a survey of relative distribution to estimate total mass and volume of marine debris and for planning site-specific cleanup operations.
- Continue a scaled-back public outreach campaign, but using different methods and/or timing.

Sunny Resurrection Bay: What's Happening on Our Beaches?

Tim Johnson, Cleanup Director
Resurrection Bay Conservation Alliance, Seward, Alaska

2005, first beach cleanup

- Two beaches were cleaned.
    - Tonsina Beach.
    - Fourth of July Beach.
- 10 volunteers walked to and from the sites.
- Collaborative effort was initiated with Alaska State Parks.

2006 Resurrection Bay cleanup

- Total of 11 beaches cleaned.
    - Tonsina Beach.
    - Fourth of July Beach.
    - Derby, Callisto, and north beaches.
    - South beaches of Caines Head State Recreation Area.
    - Sandspit Point State Marine Park (north beach) on Fox Island.
- 19 volunteers were shuttled to and from remote beaches on three volunteered "vessels" (two skiffs and a zodiac).
- Collaborative effort with Alaska State Parks and National Park Service.

2007 Resurrection Bay cleanup

- Total of 17 beaches cleaned.
    - All the beaches from previous cleanups.
    - All the beaches of Thumb Cove.
    - Humpy Cove beaches.
    - Sandspit Point of Fox Island (north and south of lagoon).
    - Sunny Cove and other beaches on Fox Island.

- 44 volunteers were shuttled on five volunteer boats.
  - Alaska State Parks landing craft.
  - Alaska SeaLife Center's landing craft and Avon rigid hull inflatable craft.
  - Two privately owned skiffs.
- Collaborative efforts were expanded greatly throughout the community.
  - Alaska Waste, NOAA, Alaskans for Litter Prevention and Recycling (ALPAR), local water taxi, and multiple restaurant/coffee shop support.
- All volunteer collection on beaches with shuttling back to "tending" vessels.
- Debris is cataloged on the International Coastal Cleanup data cards (Ocean Conservancy).
- Disposal through Alaska Waste (donated dumpster).

We've grown every year in volunteer numbers and community/business support.

Composition of debris collected

- Mix of both local (piles of polystyrene dock sections) and nonlocal (Asian cases, bottles, etc.) sources noted.
- Both fishery (nets, lines, and floats) and non-fishery (bottles, bags, toilet seats, etc.) origins noted.
- Approximately ⅔-¾ of total debris volume was polystyrene blocks in various sizes.

Constraints on the program

- Costs of transporting and feeding volunteers and debris disposal.
- Weather and time constraints (single day vs. boat-based event).
- Transportation capacity of available vessels.

Cleanup of Marine Debris on Unalaska Island

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NOAA Office of Response and Restoration, Seattle, Washington

On December 8, 2004, the freighter *Selendang Ayu* ran aground between Skan Bay and Spray Cape on Unalaska Island, Alaska. The freighter subsequently broke in two, releasing most of the heavy intermediate fuel oil and diesel fuel on board. Surveys for marine debris on Unalaska Island, Alaska, were conducted in conjunction with surveys for oil spilled from the freighter, and provided useful data on location and extent of marine debris. The data were consolidated in a database, which provided site-specific maps, GPS coordinates, photos, and description of the marine debris found.

Marine debris sites were prioritized, and after an archeological and cultural review was completed and permits were obtained, cleanup of the debris was conducted for four days in September 2005. A tender boat and skiff shuttled the cleanup team to the beaches and back. Approximately 15,000 lbs of marine debris, mostly derelict fishing gear, was collected and brought to Dutch Harbor. Some reusable items were recycled, but most of the debris was disposed of at the local landfill.

In 2006 the Marine Conservation Alliance Foundation (MCAF) conducted additional surveys north of Dutch Harbor, in areas where the survey was inadequate in the previous year, and found areas with large concentrations of marine debris. In September 2007 MCAF led a cleanup team that, in an operation similar to the previous marine debris cleanup, removed an additional 15,000 lbs from two locations: Constantine Bay and Southeast Cove. Due to weather, this cleanup operation halted after two days.

A number of important lessons were learned from this project: (1) Surveys for spilled oil can, and should be leveraged for marine debris data collection, where feasible, but needs to be consistent and high quality throughout. (2) A database and maps generated from the survey for marine debris proved very useful. (3) Excellent cooperation among federal agencies, state agencies, MCAF, Alaska State Historic Preservation Office, and Magone Marine, the removal contractor, was a major benefit to all involved. (4) More science is needed for source identification, accumulation rates, standard survey methods, and priority areas based on sensitive habitats. (5) Marine debris cleanup in Unalaska should be integrated with other Alaska marine debris efforts.

Norton Sound Economic Development Corporation Clean Water Program

Wes Jones, Fisheries Biologist
Norton Sound Economic Development Corporation (NSEDC), Unalakleet, Alaska

The Norton Sound Economic Development Corporation Clean Water Program aims to clean debris from waterways and beaches of Norton Sound that may be harmful to area fish resources. This program consists of two components: the marine debris and the freshwater debris cleanup operations. The marine debris component is funded by the Marine Conservation Alliance Foundation and NSEDC. The freshwater component is solely funded by NSEDC.

NSEDC is one of the six Community Development Quota groups. NSEDC is the northernmost group and made up of the 15 communities in the Bering Strait, Norton Sound, and St. Lawrence Island region.

The Clean Water Program was initiated by NSEDC after board members expressed concern over debris around area waters. Eastern Norton Sound members spoke of abandoned nets in the river that needed to be removed. Western members spoke of the large nets and other plastics along the ocean beaches in the western part of the region. The members generally agreed that the problems had increased in the last two decades.

The Clean Water Program started in 2006 with the main mission to clean beaches and rivers of debris that may be harmful to our fish resources. The secondary objective is providing employment in a region that has high unemployment. There is an emphasis on hiring people who have not had jobs before and are attending college or trade schools.

The marine debris portion focuses on cleaning Norton Sound coastline and associated ocean floodplains adjacent to our member communities. In 2006 a cleanup was started near Unalakleet, and some Norton Sound coastline was surveyed for debris. In 2007 the Unalakleet cleanup was completed and a cleanup was conducted near Shaktoolik. Also the entire Norton Sound coastline was surveyed for debris. More cleanups are planned for the Norton Sound region in the coming years.

The freshwater cleanup portion aims to remove debris from Norton Sound rivers and from camps along rivers before it enters the water. The first freshwater cleanup was conducted in 2007 by White Mountain along the Fish River.

The program aims to clean up coasts adjacent to each member community within three years. Subsequent plans are to begin more remote coastal cleanups and follow-up cleanups along coasts with high re-accumulation rates.

NSEDC programs work closely with the Marine Conservation Alliance Foundation (MCAF). Within the region we try to work with the city governments and IRA councils in each community (IRA councils are organized under the Indian Reorganization Act of 1934). The groups within each community bring the knowledge of the area immediately around a village. Many have already done some small cleanups or have documented high concentrations of debris.

To date, our cleanup crews have ranged in size from six to twelve. The main tools of the NSEDC cleanups are four-wheelers with trailers and open skiffs (18-20 feet). In many cases this small equipment is used to gather the debris and bring it to a central location. Then, large equipment is contracted to haul it to the local dumps. In the White Mountain cleanup, some debris was stacked on driftwood during the main cleanup. After freeze-up and when there was a small amount of snow, snowmobiles were used to haul the debris back to the local landfill. Being flexible and waiting to remove the debris with snowmobiles saved many hours of labor and equipment wear. When old boats are found on the floodplain, they are moved to the water's edge and filled with debris. They are then towed to a location where they can be loaded directly into a truck to be hauled to the landfill.

As we move forward and expand to more remote locations we will face some significant logistics problems. So far, all local communities have accepted the debris collected in cleanups that are nearby, but many do not want debris from locations farther away. For the remote cleanups we will likely have to use large vessels to transport the debris and then find a disposal location.

Common items that have been removed in our cleanups are skiffs, gillnets, 55-gallon drums, propane tanks, insulated sewer pipes, four-wheelers, snowmobiles, PVC pipes, household trash, plastic bottles, tarps, polystyrene foam, plastic buckets/lids, and oilcans.

Unmanned Aerial Systems and Buoy Technologies for Locating and Tracking Marine Debris in the High Seas

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Airborne Technologies, Inc., Wasilla, Alaska

The concept of locating and removing derelict fishing gear from the high seas before it impacts the nearshore environment is not new. Until recently, though, the technologies available did not make at-sea removal a cost-effective and viable option. The GhostNet project (www.highseasghost.net) was started in 2001 with the purpose of determining if satellite and airborne remote sensing could be used to locate and track marine debris in the high seas. The project has proven the concept to be viable and has provided tools to aid in debris removal efforts. A satellite-derived product, called the DELI (debris estimate likelihood index) map, highlights areas of potential convergence in the ocean where derelict fishing gear is likely to gather. Low-cost satellite-tracked drifter buoys were designed and built for tracking debris movement. They are deployed by vessels of opportunity and tagged to derelict fishing nets. These nets are tracked and their movement correlated to the convergence areas. The buoys allow for bidirectional communications via a simple web interface. When a recovery vessel is near the location transmitted by the buoy, the buoy can be interrogated to turn a strobe light on and send an immediate position report in order to aid in recovery of the net.

A small ship-launched unmanned aircraft system (UAS) was built to be deployed from debris recovery vessels that are directed into the convergence zones by the DELI map. The identified zone can be searched systematically for debris using the UAS and visual observations from the ship. The UAS can be directed to fly over specific targets such as a reported buoy location. The UAS is “marinized” for sea operations and is launched from the vessel either by hand or using a simple catapult launcher. The UAS can be programmed to follow a dynamic route based on the moving ship's current location. Real-time video and telemetry data are fed back to the ship where software evaluates the video for nets and allows the UAS operator to monitor or control the UAS via a computer/radio modem interface. Upon completion of the flight, the UAS lands in the water near the ship. It is recovered and ready for flight again in less than 15 minutes.

These new tools are providing a cost-effective means for identifying, tracking, and removing derelict fishing gear while still on the high seas, thereby eliminating the damage done by these nets when they impact our coastlines.

Nature and Sources of Chemicals in Marine Plastic Debris

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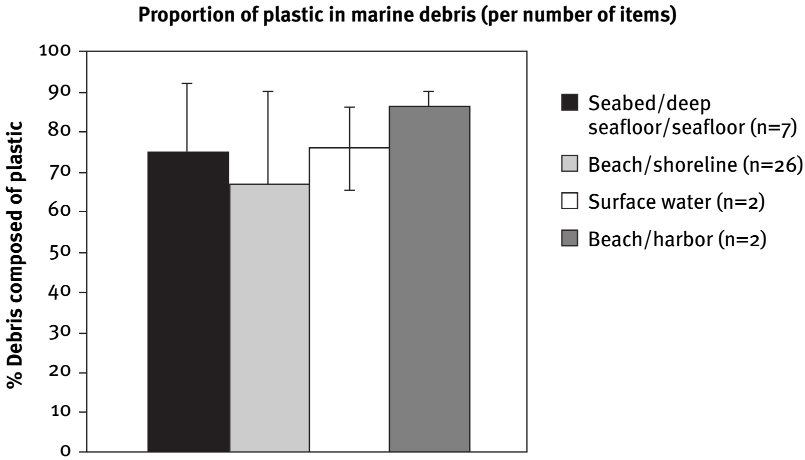
The pollution of the marine environment by plastic debris has been reviewed recently (Derraik 2002). It is clear that this human activity is among one of the major threats to marine life and biodiversity. Unfortunately the impact of plastics on the marine environment has been ignored for a long time. Although reliable estimates of the amount are not obtainable, it has been determined that plastics make up the largest observable portion of the marine debris when surveyed as a percent of the items counted (Fig. 1)

Plastic debris is a hazard to many organisms due to entanglement and ingestion. Several hundred species of fish, seabirds, turtles, and marine mammals have been documented victims of these two exposures (Laist 1997). Many species of marine organisms accumulate large numbers of plastic particles in their gut. The results of several studies in marine birds indicate plastic ingestion hinders formation of fat deposits, blocks gastric enzyme secretion, diminishes feeding stimulus, lowers steroid hormone levels, delays ovulation, and causes reproductive failure (Azzarello and Van Vleet 1987, Ryan 1988).

Very limited information is currently available about the chemicals present in marine plastic debris. The chemicals that may impact marine organisms have at least two possible sources. One source is the synthetic chemicals present in the polymers, and the other is the hydrophobic persistent organic pollutants (POPs) absorbed at sea from the air and water (Ryan et al. 1988). The fact that little information is available is due to the large variability in polymer



	Average	Max	Min	STD
Seabed/deep seafloor/seafloor (n=7)	75%	92%	52%	13%
Beach/shoreline (n=26)	67%	90%	32%	16%
Surface water (n=2)	76%	86%	65%	15%
Beach/harbor (n=2)	86%	90%	83%	20%

Figure 1. Proportion of plastics among marine debris worldwide by location (Derraik 2002).

composition and the challenge of evaluating contaminant transfer. Analytical analysis of the constituent composition and the contaminants absorbed into such a complex matrix is challenging.

POPs have increased in concentration throughout the marine food webs and tend to increase with increasing trophic level. These compound classes (PCBs, pesticides, and polybrominated diphenyl ethers) generally mimic natural hormones, lead to reproductive disorders, and appear to increase the risk of disease (Ryan et al. 1988, Lee et al. 2001). There is some evidence that PCBs in seabirds and sea turtles originate from ingested plastic particles (Ryan et al. 1988, Bjorndal et al. 1994). In addition to persistent organic pollutants, plastic debris is a source of fuel-based compounds, polynuclear aromatic hydrocarbons (PAH) produced by combustion, and other contaminants such as the constituent plasticizers (Mato et al. 2001, Teuten et al. 2007, Rios et al. 2007). These components have been observed in a small number of samples collected from Gore Point, Alaska, and analyzed by gas chromatography with mass spectral detection (Fig. 2).

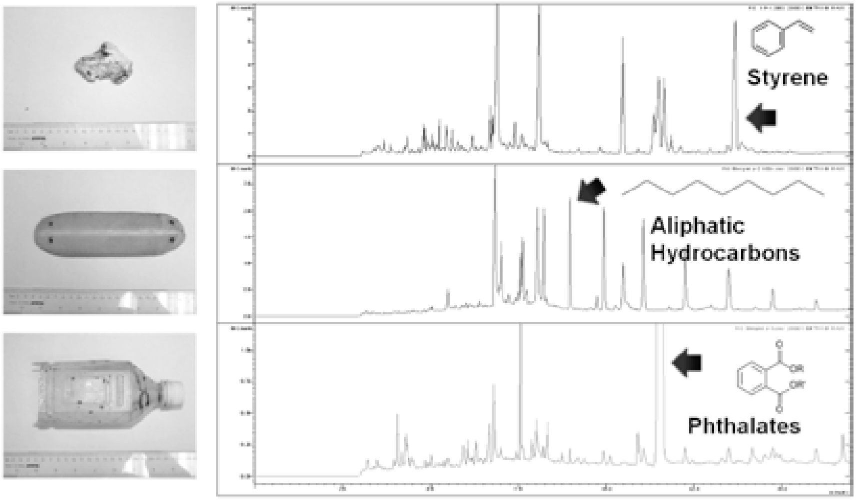


Figure 2. Chromatograms of compounds extracted from selected plastic debris collected from Gore Point, Alaska, in summer 2007.

Although significant research has been completed on the effects of POPs and PAH on marine species, no studies have been completed on the toxic effects of constituent compounds from plastic debris. There is a need to characterize the uptake, distribution, metabolism, and cellular response to these components in marine organisms. In mammalian studies of plasticizers in laboratory animals, toxicities have been shown to vary by specific phthalate, and can disrupt endocrine function, cause cancer, cause fetal death, and mutate cells. These studies demonstrate a clear need for directed studies of the effects on marine species and the chemical components of debris as they degrade in the marine environment.

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Seabirds Indicate Plastic Pollution in the Marine Environment: Quantifying Spatial Patterns and Trends in Alaska

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Seabirds and plastic debris: global perspective

As far-ranging and upper-trophic predators, seabirds are valuable biological indicators of climatic and human-related perturbations of marine food webs, including the incidence of pollutants (e.g., Furness and Camphuysen 1997, Burger and Gochfeld 2004). In particular, seabirds have proven sensitive indicators of trash in oceanic systems because they often ingest debris resembling their prey (Van Franeker and Meijboom 2002, Nevins et al. 2005). However, studies to date have largely focused on documenting the incidence and type of plastic ingestion. The available research has documented global marine debris distributions (Ayre 2006, Weiss 2006) and pervasive plastic ingestion in seabird populations worldwide (Collins 2005, Edwards 2005), from the tropics to subpolar regions.

Seabirds and plastic debris: local perspective

Seabirds are an integral and conspicuous component of the Alaska marine ecosystem, with large breeding populations (~29 million seabirds belonging to 35 species) nesting in the Gulf of Alaska and the Bering Sea each spring/summer and large populations of seasonal visitors (~20 million), including migratory species from the western Pacific and the Southern Hemisphere (Hunt et al. 2000, Stephensen and Irons 2003). Because seabirds eat the same zooplankton, fish, and squid prey consumed by commercially valuable fish species (e.g., salmon), they provide valuable information about the pollutant loads of marine resources consumed by humans (e.g., Burger and Gochfeld 2004, Blais et al. 2005). In fact, the subsistence harvest of seabirds and their eggs by indigenous inhabitants of Alaska potentially transfers pollutants directly from these upper-trophic marine predators to human consumers (e.g., Denlinger and Wohl 2001, Vander Pol et al. 2004).

Herein, we review published information on plastic ingestion by Alaska seabirds, offer suggestions for the establishment of standardized time series to quantify this phenomenon, and discuss future research needs to develop an understanding of the ecological impacts of plastic ingestion on seabirds.

Current knowledge

One of the key ecological factors influencing the incidence of plastic ingestion by seabirds is feeding mode. Surface feeding species that feed opportunistically are most susceptible to ingesting floating marine debris. In particular, several tubenose seabirds (order Procellariiformes) are characterized by a high degree of plastic ingestion, with 62-84% of fulmars and 100% of albatross examined in recent studies containing plastic (Nevins et al. 2005).

To date, only three studies have quantified temporal trends in plastic debris ingestion by Alaska seabirds. A colony-based survey of multiple species revealed species-specific differences in the incidence of plastic ingestion among Alaska breeding seabirds. Overall, 62.5% (15 out of 24 species, n = 1,799 individual birds) had ingested plastic debris (Robards et al. 1995). Of the 4,417 plastic items examined, 76% were industrial preproduction pellets, 22% were fragments of user plastic, and 2% were unidentified. Although most seabird species ingested marine debris, this study highlighted the differential incidence of plastic ingestion among feeding modes; surface-feeding species showed a greater rate of plastic ingestion than diving species (86% vs. 47%), and took a relatively greater proportion of user plastics. Furthermore, Robards et al. (1995) compared plastic ingestion in the 1970s and the 1980s, and documented a higher prevalence (incidence and magnitude) and an increase in the number of breeding Alaska seabird species affected by plastic ingestion. For example, the plastic ingestion rate for the northern fulmar (*Fulmarus glacialis*) increased from 58% (1969-1977) to 84% (1988-1990).

The second study addressed the long-term (decadal) trends in the amount and the types of plastics ingested by a far-ranging seasonal visitor from the Southern Hemisphere, the short-tailed shearwater (*Puffinus tenuirostris*). Vlietstra and Parga (2002) documented a change in the types of ingested debris, with a shift from industrial pellets (1970-1978) to user plastics (1997-2001), but no change in the overall incidence (86%) of plastic ingestion by this species in the southeastern Bering Sea.

More recently, the third study quantified the amount of plastic ingested by northern fulmars washed up dead along the west coast of North America during the winter of 2003-2004 (Nevins et al. 2005). Plastic fragments occurred in 71% of the 190 fulmar stomachs examined in central California, with an average of nine post-consumer fragments (range = 1-41), two industrial preproduction pellets (range = 1-8), two polystyrene foam fragments (range = 1-10), and two other pieces of debris (range = 1-6; including rubber bands, party balloons, fishing line, lure fragments, plastic film, artificial sponge fragments). The mean (± SD) size of the user plastic fragments ingested by fulmars was 5.7±2.8 mm (n = 733).

Knowledge gaps

The results of these three studies underscore the need for standardized time series of plastic ingestion by Alaska seabirds, designed to capture regional patterns in the type (e.g., plastic, Styrofoam, fishing line), the amount (e.g. incidence, number, mass), and the source (e.g., industrial, user) of the ingested debris. Such seabird monitoring programs are already under way in the European Union (Van Franeker and Meijboom 2002, Van Franeker 2004).

The tendency of seabirds to reproduce in large aggregations at predictable localities, and the broad geographic distributions of many species, will facilitate regional and basin-wide comparisons of plastic ingestion in breeding populations (Stephensen and Irons 2003, Vander Pol et al. 2004). In particular, comparisons of widespread species (e.g., storm-petrels, fulmars) in different regions (e.g., Gulf of Alaska, Bering Sea) and ocean basins (e.g., North Pacific, North Atlantic) will provide valuable information for assessing spatial and temporal trends.

Comparative studies involving diverse perspectives (e.g., colony-based studies during the breeding season, at-sea sampling in the winter range) will also facilitate regional and seasonal comparisons of plastic ingestion rates. Nevertheless, monitoring programs for Alaska seabirds will need to address the different migration patterns and foraging grounds of locally breeding and migratory seabirds. The interpretation of these data will be constrained by the spatial scales of the foraging movements of the different seabird species.

For instance, while northern fulmars forage close (tens to hundreds of kilometers) to their colonies in summer, after the breeding season they migrate widely and disperse to the west coast of North America (Hunt et al. 2000, Nevins et al. 2005).

Next steps

We advocate the development of research and monitoring programs designed to (i) identify those species more susceptible to plastic ingestion and therefore better suited to serve as bio-sensors of marine debris; (ii) develop standardized metrics to quantify the regional and temporal patterns of plastic ingestion by Alaska seabirds; and (iii) enhance public awareness about this pervasive problem by applying the research and monitoring results in outreach and educational materials. Moreover, using seabirds as biological samplers of marine debris distributions will require identifying those life history and ecological traits that influence the ingestion of plastic debris, characterizing those physical processes that concentrate and make marine debris accessible to foraging seabird, and quantifying short-term and long-term health effects (lethal and sublethal) on seabird populations from the ingestion of plastic debris.

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Somebody Untangle Me! Taking a Closer Look at Marine Mammal Entanglement in Marine Debris

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Marine debris can entangle marine mammals resulting in injury and mortality. Both active and derelict fishing gear are responsible for marine mammal entanglements. Marine mammal entanglement is difficult to assess quantitatively, and to respond to safely. Laist (1997) reports that 23 species of marine mammals (47% of all marine mammal species) have been observed entangled in marine debris. Here we provide details from entanglements and disentanglement response for three Alaska species: humpback whales, northern fur seals, and Steller sea lions.

Humpback whales

Entanglements in fishing gear are a source of human-caused injury and mortality for endangered humpback whales. The marine mammal stranding program database of NOAA Fisheries, Alaska Region, has recorded 97 humpback whale entanglement incidents between 1997 and 2007. Much of the gear involved in these interactions has not been identified to a specific fishery (22% unknown, 2% unknown net); however, a significant amount appears related to pot fishing

(22% attributed to unidentified pot gear, 18% to crab pot gear, and 9% to shrimp pot gear). Other humpback whale entanglements have occurred involving gillnet (14%), trawl net (6%), seine net (5%), and longline gear (2%). In some cases, Alaska gear has been found on humpback whales in Hawaii during the winter months. Six humpbacks in Hawaii have been reported to carry Alaska gear; five of these cases represent commercial pot gear. The mean straight-line distance that whales have carried this gear is 1,200 nautical miles; the maximum known straight-line distance is 2,350 nm (entangled west of the Pribilof Islands).

In many cases, it appears that humpback whales are capable of self-release and they survive their entanglements. Analysis of humpback whale photos from northern Southeast Alaska indicated at least 52% (95% CI: 45-60%) of the whales surveyed (n = 180) displayed caudal peduncle entanglement scars (Neilson 2006, Neilson et al. 2007). Males had a significantly higher entanglement rate (82%) than females (54%).

Response to whale entanglement incidents occurs under permit no. 932-1489-10 of the NOAA Fisheries Marine Mammal Health and Stranding Response Program. Response involves case-by-case authorization after careful evaluation of the entangled whale's condition, which involves answering the following questions: Is the animal a candidate for disentanglement? Is the situation life-threatening for the animal? What is the likelihood for success? Are resources, gear, and a standby vessel available? What are the risks to responders? Personnel safety is of paramount concern when undertaking an at-sea disentanglement, and specialized training is required.

In 2005, a partnership to provide classroom training and on-the-water exercises was initiated between the NOAA Fisheries Alaska Region office and NOAA's Hawaiian Islands Humpback Whale National Marine Sanctuary, to address large whale entanglements. The national disentanglement procedure currently in use was first established by the East Coast Disentanglement Network. Entanglement response is ideally conducted from a maneuverable rigid-hulled inflatable boat. It involves attaching inflated poly buoys to slow and keep the entangled animal at the surface, in order to facilitate release from gear using equipment specifically designed for this purpose. NOAA Fisheries and partners maintain equipment caches in numerous Alaska communities to respond to events. Technology such as telemetry buoys are also used to attach to trailing gear, to track entangled whales by satellite.

Northern fur seals

Northern fur seals were first observed entangled in 1923 (Proctor 1923); since then Pribilof residents, scientists, and managers have observed and responded to entanglements. Scientists led more comprehensive research on northern fur seal entanglement in the 1970s and 1980s, as observations of entangled northern fur seals increased and the use of plastics became common. Scientists determined that, relative to non-entangled fur seals, those entangled have longer foraging trips, spend less time resting while on land, have reduced pup growth, and ultimately suffer higher mortality (see review in Fowler 2002).

Previously entangled fur seals have lower survival than similar-aged seals never entangled (Fowler et al. 1990). Subsequent population modeling (Fowler 1982, Reed et al. 1987, French et al. 1989, Reed et al. 1989, French and Reed 1990), and a measurable decline (York 1990), indicated that fur seal entanglement in marine debris could be having population level effects. The northern fur seal population is currently listed as depleted (NMFS 2007). Fowler (1987) estimated that up to 15% of juvenile fur seals (grouped from weaning to 4 years old) may be entangled in all sizes of marine debris each year. To further illustrate, in August 2003 there were approximately 159,000 individuals in the juvenile fur seal category; 15% would represent about 23,000 entangled juvenile fur seals in all sizes of debris.

Scientists reinitiated studies of juvenile male northern fur seal entanglement in the mid 1990s. The estimates of entangled juvenile northern fur seals seemed to be similar or lower than those from the 1980s. Subsequent estimates were continued by the Tribal Government of St. Paul Island (see most recently Zavadil et al. 2006). In 2003, with funding from the Prescott Stranding Grant Program, the juvenile male entanglement study was reinitiated (Williams et al. 2004). Williams et al. showed that to detect a 50% change in the proportion of juvenile males entangled in debris with 80% power, approximately 20,000-30,000 animals would need to be sampled. Sample sizes from 1998 to 2003 were well below 20,000, suggesting that suspected changes in the proportion of juvenile males observed entangled in small debris (less than 1 kg) were not detectable.

Northern fur seals can self-release from debris, as observed with humpback whales. Subtle changes in sampling methods, behavioral changes of entangled fur seals (e.g., attendance and foraging trip duration), and the unknown probability of entanglement in large debris (i.e., greater than 1 kg) further confound interpretation and synthesis of studies. Out of the estimated 160,000 northern fur seals under 4 years old, a minimum of 300-500 are annually entangled in debris weighing less than 1 kg. It is unknown how many more are entangled in heavier debris and are not observed by land-based entanglement studies.

Steller sea lions

The Steller sea lion is currently listed as an endangered species west of Cape Suckling, Alaska (144°W) and as threatened in the eastern portion of their range (Southeast Alaska to California). The western population has experienced a decline in excess of 80% over the last 30 years, while the eastern population has increased about 3.1% per year (Loughlin et al. 1992, Trites and

Larkin 1996, Sease et al. 2001, Pitcher et al. 2007). Although the reasons for these trends are unknown, entanglement in fishing gear and marine debris is known to contribute to Steller sea lion mortality (Perez 2006, Angliss and Outlaw 2007).

From 2000 to 2007, Steller sea lion entanglements were documented throughout Southeast Alaska and northern British Columbia concurrent with other field studies. During this period, a minimum of 386 entangled individuals were photographed and observed (Raum-Suryan et al., unpublished). Entanglements affected both sexes and all age classes. Most entanglement types fall into one of two categories: approximately half of entangled animals had debris encircling their neck and the other half were entangled with fishing gear (e.g., hook/line, salmon flashers) in or around their mouths (Fig. 1; Raum-Suryan et al., unpublished). Although 190 sea lions were observed with neck entanglements, the entangling material on most of the animals (n = 146) could not be identified because the material was embedded in the skin and blubber. The identifiable neck entanglements (n = 44) included packing bands (54%), large rubber bands (30%), rope (7%), net (7%), and monofilament line (2%). Neck entanglements can lead to lacerations, infection, reduced feeding ability (and eventual starvation), and strangulation. Hook/mouth entanglements included salmon fishery flashers (lures, 80%), longline gear (12%), hook and line (4%), spinners/spoons (2%), and bait hooks (2%). Ingested hooks may perforate the esophagus or stomach lining, leading to catastrophic infection and/or organ damage, and the presence of gear may impair feeding ability, leading to starvation.

The number of entangled Steller sea lions has likely been underestimated for several reasons. First, the likelihood of observing all entangled individuals is low. In Southeast Alaska and northern British Columbia (north of 50°N), sea lions use eight rookeries and over 40 major haul-out sites (more than 50 animals) during the breeding season, as well as numerous (more than 50) other sites during the nonbreeding season. Second, sea lions may die at sea as a result of their entanglement and not be available to be recorded. Third, because of reduced survivorship and increased time at sea due to the drag created by an entanglement (Bengtson et al. 1989, Fowler et al. 1990), entangled individuals are not likely to be sighted and resighted onshore as reliably as individuals that are not entangled (Fowler 1987, Page et al. 2004, Boren et al. 2006). Finally, external evidence of entanglement may not exist or may be lost over time. For example, some fishing gear may be swallowed entirely and therefore not visible; and when a salmon flasher breaks off a line swallowed by a sea lion, the hook may still be embedded inside the sea lion's esophagus or stomach, potentially causing internal injuries or death, but not visible to observers. Entanglement of Steller sea lions in marine debris is likely a greater problem than previously realized, and additional effort to document entanglements should be included during future field research.

In 2007, the Alaska Department of Fish and Game was awarded a Prescott Grant to reduce entanglements of live stranded Steller sea lions in Alaska. The primary objectives of this grant were to develop methods and equipment to disentangle Steller sea lions and to increase awareness of the problem through education and outreach. Work toward these goals has included adapting capture methods and equipment to target entangled sea lions, as well as production and presentation of education materials, including a video, to educate the public, fishers, and agencies about sea lion entanglement in marine debris.

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A Tangled Web: The Mystery, Math, and Mechanics of Net Recycling

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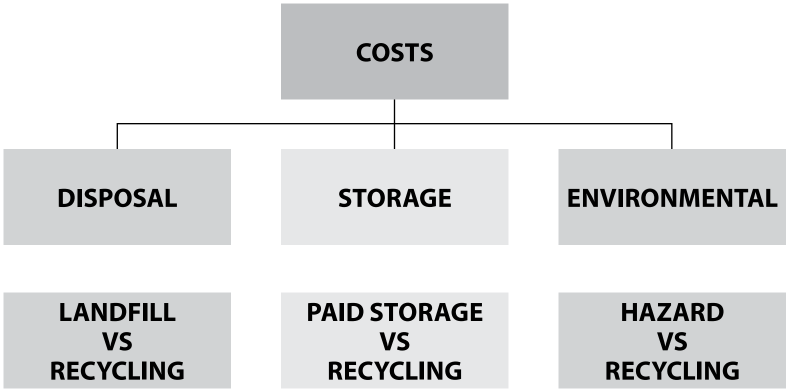
The recycling of used fishing net has been called a tangled web

- Why all the mystery?
- What is the math behind the costs of dealing with old nets?
- What are the mechanics of handling recycling?

The mystery

- Fish nets contain multiple plastic resins such as nylon, polyethylene, and polypropylene.
- Each resin has a different value on the recycling market.
- Mixed resins can be accepted, but usually for a fee.
- Sorted resins have value that recyclers may pay for.
- Contamination also affects the market value.
- Contamination is any nonplastic material that degrades the value of the product.
- This includes polystyrene foam, cork, wood, metal (including lead line), buckets, buoys, and polyvinyl chloride.
- Contamination also includes any biomass (fish or vegetation).



The math behind the costs of dealing with old nets

What are the costs of different options for used fishing web?

Disposal costs

- Landfill tip fees are $100 per net ton.
- Labor cost to handle and package.
- Freight to landfill.
- Taxes needed to subsidize landfills.
- History tells us more taxes will be needed to clean up old landfills.

Storage costs

- Monthly land storage fees.
- Hidden cost of space occupied, even if it's your backyard.
- Lower property values, fines, etc.
- Inflated costs when disposal eventually occurs.
- Cost in time and resources to handle materials for storage and again at disposal.

Environment costs

- Community health hazards.
- Loss of habitat for regeneration of new plant and animal life.
- Regulatory restrictions on fishing industry.
- Piles that attract other debris.
- What is the cost of destroying your livelihood?
- What is the cost to "poop in our own nest"?

Recycling costs

- Recycle fees $0-$75+ per net ton.
- Clean, sorted resins have a greater value.
- Labor cost to handle and package.
- Freight to the facility and the market.

Recycling benefits

- Recycling avoids landfill tip fees and reduces the need for expansion.
- Recycling avoids cost of paid storage.
- Recycling avoids cost of repeated handling during temporary storage.
- Recycling avoids fines and health hazards.

The mechanics of recycling—adding value for the recycler

- Separating non-contaminated materials by resin.
- Baling resins to compact the materials for easier transportation.

Conclusion

- Recycling turns discarded items into a renewable resource.
- Markets exist in Asia for these resins that are converted back into plastic pellets.
- The cost of handling becomes an environmental credit when conservation of natural resource occurs and/or when reduction in environmental impact preserves our future.

Summary

- Fish net web can be recycled.
- Net web is more valuable when free of contamination.
- Clean web is more valuable when sorted by resin.
- Sorted resins are more valuable when compacted.
- Logistical questions remain for remote sources: the who, what, when, and where of collection and handling.
- Skagit River Steel and Recycling is in the business of plastics recycling and can work with you to address these logistical concerns.

Summaries of Marine Debris Workshop Breakout Discussions

Introduction

The steering committee for the Marine Debris in Alaska workshop identified seven questions for open discussion, during which workshop participants would advance optimum strategies for resolving challenges related to the questions. The questions were (1) Where and how accessible are regional shore-cast marine debris accumulations? (2) Is standardized marine debris data collection possible? (3) What can be done with collected marine debris? (4) How can we prevent and reduce marine debris sources through education and outreach? (5) How can emergent programs for marine debris removal and prevention be developed? (6) How does marine debris affect wildlife and the environment? (7) What criteria should be applied to prioritizing marine debris cleanups in Alaska?

The open discussions were led and coordinated by two workshop participants identified in advance by the steering committee. The discussions were guided by identifying a series of relevant sub-questions that the leaders would use to promote productive dialogue, while still allowing new ideas from participants. After the discussions were complete, each group summarized key points of discussion, certainty and uncertainty of data, and next steps to be taken with the entire group. The workshop participants decided questions 1-4 would be discussed in groups of 8-15 people during the morning session, and questions 5-7 would be discussed in similar-sized groups in the afternoon session. Participants signed up for a particular question in the morning and afternoon sessions. After the workshop, group leaders reviewed the notes and prepared the following summaries with minor editorial revision.

Question 1: Where and How Accessible Are Regional Shore-Cast Marine Debris Accumulations?

Discussion leaders and summary preparers:
Nir Barnea and Tim Veenstra

I. Statement of the issue

Managers and cleanup crews must evaluate the most effective means for reducing marine debris in the environment. Identifying and removing the largest concentrations of debris make the most sense; however, accessibility and site safety are major considerations that are often poorly understood at remote sites. Regional areas of marine debris accumulation may be inaccessible due to a variety of factors. Uninhabited coastal areas may have large unknown debris accumulations with significant unknown risks associated with access and removal of debris. Can regional accumulations of marine debris be identified, and the accessibility to those accumulations be evaluated prior to commitment of cleanup crews and resources?

II. Introduction

Why is this an issue and describe the relevance to Alaska

Alaska is a big state, with thousands of miles of shoreline. Marine debris is a persistent and significant problem in Alaska, one that needs to be addressed to reduce marine debris impact on the environment. A key component in addressing marine debris is to know where it is and how to access it in order to assess, prevent, or remove it. Funding limitations and size of the state necessitate the need to optimize efficient use of marine debris resources.

Marine species in Alaska face many threats from commercial and recreational fisheries, as well as changes in their marine environment. As the marine environment is fouled, its ability to sustain healthy fisheries and marine mammal stocks decreases and can cause lower production and ultimately reduce commercial, recreational, and subsistence opportunities. Debris accumulations both along the shorelines and offshore kill fish, mammals, birds, and invertebrates that are already under stress, aggravating their situation and contributing to the threat of extinction.

History of the problem

Alaska is sparsely populated, and while its communities generate their share of trash and debris, local contribution is minimal compared to the overall marine debris problem present in Alaska. Historical and current fishing activities conducted by the domestic and foreign fleets generate much of the marine debris currently observed on Alaska's shores. A significant amount of the marine debris found and removed in Alaska is derelict fishing gear (see King 2009, this volume). The expansion of fishing activities in recent years, and the composition of the gear—almost exclusively made of plastic and metal and not degradable—makes the problem worse. Packaging materials have evolved over the years and are now made up mostly of nonbiodegradable plastics (e.g., packing straps, shrink wraps, etc.), polystyrene foam, and treated and preserved wood products. The lifetime of these objects in the marine environment is unknown but is assumed to be extremely long.

Debris is also generated by other marine activities, such as marine transportation and the tourist industry, including beachgoers, cruise ships, and recreational boating. Efforts are made to control and limit the disposal of debris into the ocean, but inadvertent (and sometimes intentional) discharge of debris occurs, and adds to the overall marine debris burden in Alaska waters and along shorelines.

Much of the marine debris ending up on Alaska shorelines and in its waters is generated many miles away, in fishing operations or North Pacific shipping. Foreign language labeling, and foreign net types and other fishing gear, indicate that the source can be foreign fishing fleets, which currents and wind bring to Alaska from thousands of miles away.

III. Discussion topics

Causes of marine debris accumulation

A number of factors influence marine debris transport and accumulation, including currents, wind, waves, and tides. High energy such as high wind, waves, and storm surge may toss marine debris such as nets, floats, lines, and even large objects such as crab pots and small vessels far inland, where they remain. Shipping lanes, fishing, and other commercial activities are the sources of marine debris and influence the overall quantities of marine debris, especially derelict fishing gear (DFG).

Coastal topography influences the accumulation and adhesion of debris at predictable locations. Debris is brought into the funnel-shaped bay and pushed toward the head of the bay, where it gets entangled and immobilized by logs, rocks, and shifting sand.

Adhesion describes the extent by which debris stays at the place where it is deposited. Flat, sandy beaches and the presence of logs increase the tendency of marine debris, especially derelict fishing gear, to accumulate. Beach sand will trap and bury debris and log piles entangle debris. Crevices of rocky shores tend to retain plastic bottles, Styrofoam pieces, and small debris items, as well as nets and larger items such as crab pots. Forested areas retain marine debris of all kinds.

Interesting point

Participants came to a consensus on the relationship between beach logs and marine debris: There is strong correlation between logs on the beach and the presence of marine debris, especially derelict fishing gear. It seems that both marine debris and logs are transported by the same mechanism. Also, nets and line entangle logs, get stuck, and have a high persistence rate after log entanglement. This point is useful because at times those who make aerial surveys for marine debris or opportunistic sightings of marine debris cannot get close enough to the beaches for an accurate view of the debris. It has been suggested that log piles can be used as a proxy for identification of plastic debris due to the high correlation between the two. When this relationship was presented to the larger group, it was determined that the correlation often holds true in areas where logging has occurred and where currents are favorable to log deposits, but it is not applicable to all areas. Thus some communities may differ in their aerial surveys and identifiers for marine debris accumulations.

Surveying for marine debris

The different elements of survey for marine debris were discussed:

Local knowledge: Local knowledge is critical for assessing marine debris location and concentration in an area. People who fish, recreate, and visit areas have intimate knowledge of what is present there, and should be approached and consulted as a first step before other expensive surveys are done.

Aerial survey: Aerial surveys are useful to cover large areas and serve as a screening tool to survey marine debris. Nets, line, and smaller debris may be difficult to identify from the air if they are obscured by logs, beach grass, or rocks, or are partially buried in the sand. Logs can be seen relatively easily and can indicate the likely presence of debris in some areas. Fishing buoys are also generally easy to see from the air.

Land survey: On the ground surveys are very useful to validate aerial surveys, to make a conclusive determination of the presence of marine debris, and to determine on the ground logistics such as safe moorings and where to send cleanup crews. Ground surveys can also be conducted in subsets of the aerial survey to ground truth the findings from the aerial surveys.

Vessel survey: Vessel surveys are not useful because they are expensive for the amount of area covered, the visibility from the bridge of the vessel is not sufficient to cover large areas, and accessibility of vessels to remote areas is often limited by sea state, bottom depth, and marine obstructions (rocky outcrops), tides, and currents.

Satellite/remote sensing: Currently satellite/remote sensing is not quite suitable to replace aerial surveys, but may be more useful in the future when resolution improves. Also, satellite/remote sensing may be able to help correlate numbers of buoys with other marine debris.

Accessibility: factors and challenges

A number of factors play a major role in and present challenges to accessing marine debris on the shoreline.

Weather, tides, swells: Weather has a strong influence on a cleanup crew's ability to access marine debris. The productive season to conduct marine debris cleanup is limited to a window between snowmelt and the end of August. For aerial surveys, the window is snowmelt to late May. Once grass begins to grow, it obscures underlying debris from view. The use of multispectral, hyperspectral, or infrared sensors may help observers see debris that would otherwise be hidden to the human eye or to a standard color camera.

Proximity to population centers: The proximity of marine debris accumulations to population centers can play a large role in the ability to conduct a successful cleanup. These factors include knowledge that the debris exists, infrastructure such as road access, disposal into a maintained landfill, and availability of people to conduct the cleanup. The logistical challenges in all of these factors typically increase as the location of the debris is farther away from population centers.

Equipment and resources: Due to the short outdoor working season in Alaska, marine debris projects must compete with commercial, recreational, and scientific users for boats, aircraft, people, and other resources.

Logistics: Logistical support of cleanup operations is extremely important:

- Transportation and housing: Need to be able to bring people to the cleanup site, house them, and feed them.
- Transport debris out of the sites—by vessel, helicopters, or by foot. Remote areas may incur high cost of removal.
- Disposal and/or recycling of marine debris: who and where?

Permits and consultation: Presence of natural resources or toxic materials may require permits to conduct cleanup activities, and their presence may prevent cleanup activity at least some of the time. Archeological assets would also be a concern and necessitate consultation with the Alaska State Historic

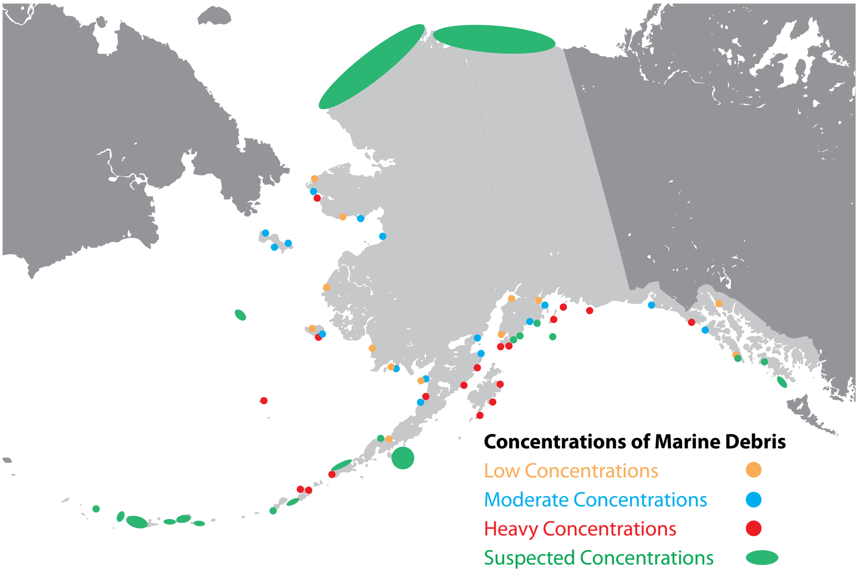


Figure 1. Locations of marine debris on Alaska's coast, representing opinions of breakout session participants. Red = heavy concentrations of marine debris; blue = moderate; and yellow = low. Green designates areas where marine debris problems are likely. Locations with heavy concentrations, east to west: Lituya Bay, Kayak I., Outer Hinchinbrook I., Box Pt. (outer Montague I.), Gore Pt., Chugach Is., Outer Spruce I. (Kodiak), Outer Sitkalidak I. (Kodiak), Sitkinak I., Port Heiden (Bristol Bay), Cape Sarichef (Unimak I.), Priest Rock (Unalaska I.), Driftwood Bay (Unalaska), Nunivak I. (SE corner), Northeast Pt. (Pribilof Is.), Lost River (N of Port Clarence).

Preservation Office. Another factor is access to state and national parks and wildlife refuges. Other factors affecting access are private ownership of the land and the necessity to gain owners' approval for access, and military zones where access may be prohibited or limited.

IV. Critical elements

Map

Participants in the work group placed colored dots on a map to represent areas where marine debris is heavy, medium, light, and suspected, based on their surveys or personal expertise (Fig. 1). While useful as a general guideline, it would be more practical to generate a GIS-based map of Alaska, with all the areas marked and prioritized.

Survey

The discussion covered the major elements of a statewide survey for marine debris. It is agreed that a survey is a necessary and critical component for response by identifying the location and quantity of marine debris. Subsequent to a survey, crews must determine accessibility, and estimate level of effort and cost. Surveys for marine debris have been conducted in several locations in Alaska, but without coordination and uniform data collection and presentation (see data gaps below). The importance of a survey and the critical need to present survey results justify developing survey standards and methodologies.

Survey experts/regional points of contact

Wes Jones: Western Alaska
Andy Schroeder: Kodiak
Chris Pallister: Gore Point
Tim Veenstra: ATI Aerial Survey, Bristol Bay
Bill Zentner: Turning the Tides, survey of Southeast Alaska/Juneau
Rob Wolotira: NOAA Restoration Center

Access

The main factors affecting access to marine debris are the topography (whether the location is easily accessible from air, land, or sea); the proximity to population centers; weather; and logistics (e.g., housing, feeding, transporting staff). A second important aspect is administrative: the necessity to obtain permits and conduct consultations. The main action item for the accessibility issue is to share what works and what doesn't, and provide guidelines to share among the different entities involved with marine debris in Alaska. Experience and lessons learned by one can be shared with many.

V. Data gaps

A number of data gaps were identified.

Survey areas

Surveys for marine debris have been conducted in some areas, but not in others. To obtain a comprehensive picture of the distribution of marine debris in Alaska and its environmental impact, representative areas should be surveyed. To provide some understanding of areas of marine debris accumulation, each member of the breakout group was asked to place colored dots on a map of Alaska, based on their personal knowledge: red for heavy accumulations, blue for moderate, and yellow for light (Fig. 1). A green dot was also provided to identify assumed areas of accumulation, based on anecdotal information. It was obvious that there were three regions where little direct knowledge is available: the northern Alaska coast, the entire Aleutian Island archipelago, and the outer coast of Southeast Alaska. This may be related to the participant's experience and the steering committee's inability to identify residents from these little-known areas to attend the workshop.

Survey methodologies

A big gap was identified in the classification of marine debris. What is described as "heavy" for one is "light" for another. How can we come up with a standard naming and presentation of marine debris? One idea is to use Shoreline Cleanup Assessment Technique (SCAT) methodology as a guideline to develop standardized ways to estimate and convey marine debris type and density.

Access

What areas are accessible and to what type of transportation? A map or description to assist with access could be useful.

Logistics

Nonlocal people are disconnected on what is and is not available statewide. There is a need to document what material (e.g., reports, equipment, risk analysis, insurance needs, etc.) is available, and assemble a summary of information: aircraft, recycling points of contact, sources of volunteer groups, support marine vessels, best practices and procedures, and a mechanism for an ongoing information exchange among entities involved with marine debris. Contingency plans for oil spill response may provide a model template to develop regional marine debris prevention and removal strategies.

Reference

King, B. 2009. Derelict fishing gear in Alaska: Accumulation rates and fishing net analysis. In: M. Williams and E. Ammann (eds.), Marine debris in Alaska: Coordinating our efforts. Alaska Sea Grant, University of Alaska Fairbanks. (This volume.)

Question 2: Is Standardized Marine Debris Data Collection Possible?

Discussion leaders and summary preparers:
Sarah Morison and Lauri Jemison

I. Statement of the issue

Successful prevention and outreach for marine debris requires accurate identification and quantification. The composition of marine debris within Alaska can vary more widely than debris found in other parts of the United States, where standardized data forms have been developed. Can a standardized data form be created for marine debris collected in Alaska?

II. Introduction

Data collection, through cleanup surveys, has been done throughout Alaska using a variety of techniques and data recording forms. From these surveys, it is known that the types of marine debris impacting Alaska vary widely, and general survey forms often do not allow surveyors to adequately record what is observed. Debris sources stem from both land-based and ocean-based activities, which influence what debris is found at sea or on shore. In some areas, eroding historic dumps are the main source of marine debris. In others, derelict fishing gear is the most common type. Considering the debris differences across Alaska, is it feasible to undertake standardized data collection, and if so, how might the survey form and methodology be developed?

III. Discussion topics

The breakout session discussion focused on several key questions related to standardized data collection, as discussion participants agreed early on that **the answer to the initial question "Is standardized data collection possible?" was "yes."** The developing questions asked were

- Why collect data to begin with?
- How can the data be collected and reported using standard techniques?
- How can the data be used?
- How can data be made accessible to all interested parties?

The responses to each of these were intertwined with the others; therefore, the discussion is not separated out by question in the Critical elements section below.

IV. Critical elements

Several critical elements were raised in addressing the above questions. Some of the purposes of data collection, and the associated ways to use the data, include to

- Determine if cleanups and prevention activities are reducing the amount of debris in the environment.
- Identify debris sources.
- Identify where to focus cleanup efforts.
- Evaluate the economics of cleanups.
- Evaluate environmental impacts.
- Target prevention activities.

A note was made that if results are to be used for analytical purposes, surveys need to be standardized (area, hours spent, etc.) to determine if the amounts of debris are really changing over time, or if effort is changing.

For each point, discussion took place on land-based debris versus ocean-based, location of the survey/removal location in Alaska, and the relative amounts of debris being found. In directly linking these points to the initial question of standardization, many opinions were raised. Most agreed that standardization is the key, and can potentially be achieved through agreed-upon survey techniques that would be developed considering as many debris types and circumstances as possible, as well as database development. To ensure that collected data be analyzed in a quantitative manner, it would be extremely beneficial to have a statistician provide input on survey techniques and data recording. The participants who felt that standard data collection at a detailed level was not feasible are constrained by time windows for removal activities, where data collection would take time away from actual debris removal. Suggested techniques for data collection included counting individual items, estimating coverage area, measuring final weight, and developing a standard sampling protocol, where trained experts would sample debris collected after a cleanup event. The importance of establishing monitoring sites across the state, for use in establishing hot spots, debris trends, and the geographic distribution of different types of debris, was also discussed.

A central database, both as a place to house data and a place to mine data, was seen as inextricably linked to standardized data collection. To develop a survey, survey techniques, and a database would require agreed-upon methods for measuring marine debris based on type. For example, Styrofoam may be estimated by weight or area coverage, instead of individual pieces being counted. Guidance on how to estimate would need to be developed. Derelict fishing gear may need to be itemized for optimum use in prevention activities. Debris resulting from landfills may be estimated en masse instead of individual items being counted. Mining data in the recorded surveys would allow the issues in the bulleted list above ("The developing questions asked were . . .") to be addressed. This led back to the issue of a survey form that would list all possible debris types found in Alaska and how it would be developed, along with associated methodology.

Participants agreed that Alaska needs a "super survey" form, which would be the top tier of a tiered data collection system. **The super survey form would contain debris type fields, and survey and recording methodology (as appropriate) for every type of marine debris found within Alaska.** For each area to be surveyed, the survey/cleanup coordinator would pull the most appropriate debris fields for that particular area from the super survey into a local survey form (the second tier of the data collection system). This would allow each survey form to be tailored to the needs of the area, without room being taken up by fields that would never be needed. In theory, this also allows more space on the survey form to be used for gathering detailed information, as appropriate. By using the super survey form as the base for creating local survey forms, data collected will be in the correct format to be entered into the statewide database, and allow for debris collected across Alaska to be compared. Development of the super survey would need to take into account the time required to follow the methodology, and the type of person doing it (paid surveyor or debris remover; marine debris volunteer; or volunteers or researchers surveying marine debris in addition to other, more primary, survey activities). The third tier of the data collection system would be the forms used for data collection at established monitoring sites. The EPA's National Marine Debris Monitoring Program, whose five-year report was just released (http://www.oceanconservancy.org/site/PageServer?pagename=mdm_debris), was mentioned as a possible model for establishing monitoring sites.

V. Current needs

The major needs for acquiring useful information on marine debris are a central database and super survey form, with a collective body or lead group to actually create them. The developers would need an understanding of debris types around Alaska, local issues, research needs and methodologies, and database development. **Therefore, participants in this breakout session strongly suggested the creation of a statewide marine debris coordinating body, the "Alaska Marine Debris Alliance" (AMDA).** As discussion continued on the possible roles and abilities of this group, it was generally felt that many of the issues raised within the overall workshop could benefit from AMDA, including not only the development and implementation of a super survey form and database, but also best methods for removal, identifying experts to fulfill needs, providing links to non-debris activities, coordinating outreach and education, and in general ensuring Alaska marine debris activities are coordinated, are represented within national marine debris activities, and do not reinvent items within every local community. The idea of a statewide marine debris coordinator was also raised. Marine Conservation Alliance Foundation representatives spoke to the idea of a statewide coordinator, saying they felt this was part of their role. Also, MCAF is in the process of developing a database that might serve as a basis for the database advocated by the breakout discussion group.

Notes: In post-breakout group discussions, the co-leads realized that it was never clarified within the group whether the term "data collection" meant during cleanup activities, or during pre- or post-removal survey efforts (by land or air). This issue would need to be addressed in the super survey development group. In this report the terms "cleanup" and "removal" are used interchangeably.

Question 3: What Can Be Done with Collected Marine Debris?

Discussion leaders and summary preparers:
Bob King and Lois Young

I. Statement of the issue

Hundreds of metric tons of marine debris are collected in cleanup programs in Alaska every year, but landfill space is limited in many parts of the state and sometimes not available. Costs for shipping collected debris out of state are expensive. How can marine debris groups better take advantage of recycling and waste-to-energy technology? What other options exist for the future disposal of collected marine debris?

II. Introduction

Marine debris is part of a broader issue of solid waste disposal, a worldwide problem with unique aspects in Alaska. Landfill space is at a premium in rural parts of the state and expanding or relocating them is difficult and expensive due to habitat, terrain, and other environmental considerations. In small rural Alaska communities, marine debris disposal can become a large part of the solid waste disposal problem.

Statewide most marine debris is plastic, which is relatively low weight and high volume. Lois Young of Skagit River Steel and Recycling reported that plastics account for approximately 10% of the weight in a landfill and 20% of the volume. The problem is historic. Much debris remains from past fishing activity and prior to passage of the **International Convention for the Prevention of Pollution from Ships** (MARPOL 73/78) in Alaska, and new debris is added every day. The problem is international and local in scope with debris originating from Asia as well as Alaska. The potential for more local contributions increases with litter and coastal erosion. For example, erosion at Port Heiden is undercutting an old landfill and returning solid waste to the marine ecosystem. Similar erosion problems were reported in Kivalina.

Ways in which collected debris have been disposed of vary widely around the state. In 2006, it cost $13,000 to transport and dispose of 9 metric tons (t) of debris from the Pribilof Islands to a landfill in Roosevelt, Washington. In Sitka, it would cost $1,800 to dispose of a similar amount of debris at the local transfer facility that ships all its waste to the same landfill. Many communities support debris programs by waiving landfill fees, but as volume increases, they are reconsidering even accepting debris due to limited space and operations. The City of Unalaska landfill is burdened with over 10,000 tons of plastic, mostly old nets. The city briefly stopped accepting such material last year until fees were increased and requirements for accepting it were tightened. A fisherman who retrieved a several-ton section of cod end from the Bering Sea was told it would cost $10,000 to dispose of in Unalaska. The net was ultimately taken by backhaul to the Seattle area and accepted for free by a local recycler.

Short-term options include taking steps to increase the reuse and recycling of debris. Longer-term solutions include better coordination with regional efforts to address the broader solid waste issue, and looking at other options including waste-to-energy technology that is becoming economically feasible. Other options such as fees were also discussed.

III. Discussion topics

- How is Alaska debris currently disposed of?
- How is debris disposed of elsewhere?
- Transportation issues/options
- Recycle
- Waste to energy
- Reuse
- Other discussion items
    - Short-term plan needs
    - Long-term plan needs
    - Data gaps

IV. Critical elements

How is debris currently disposed of?

Marine debris collected by different cleanup programs is disposed of in a variety of ways. Debris collected by the Marine Conservation Alliance Foundation (MCAF), mostly derelict fishing gear (DFG), was often deposited in local landfills, often for free. This may not continue to be an option. Concerned by the increasing volume, the City of Unalaska recently increased disposal fees and St. George Island said it would no longer accept this material. St. Paul Island requires all marine debris—little of which originates locally—be shipped to an outside landfill. This is very expensive. In 2006, a stockpile of 157,000 pounds of debris was shipped to a landfill in Washington for $114,000. In 2007, 20,000 pounds of debris from St. Paul intended for the Washington landfill was given instead to a Washington recycler, an option that was less expensive than landfilling, but transportation costs were still high.

Sitka has a transfer facility for all its solid waste and charges $0.09 per pound, but will not accept metals. Sand Point has an incinerator. Regional groups such as SWAMC (Southwest Alaska Municipal Conference) and the Southeast Conference are looking at regional options for solid waste disposal and recycling. Some marine debris is scuttled: trawlers that inadvertently snag lost crab pots often return them to the sea, usually in areas designated for pot disposal.

How others dispose of marine debris

Hawaii disposes of much of its solid waste including derelict fishing gear in a high-tech, clean-burning incinerator that produces electric energy. Sand Point uses a small-scale incinerator and reports successful results and no emissions problems. Others (Unalaska, MCAF) have studied this option but found that compliance with environmental permitting issues would be cost prohibitive. In Skaegen, Denmark, plastic is shredded, melted, and used in other products. This shred and sell program is also an option for the City of Unalaska, but no action has been taken.

Shipping options

There was discussion of various options for shipping debris. Barges are most often used to take containerized debris to Seattle for landfilling or recycling. Some airlines offer attractive backhaul rates from rural communities that could link in with recycling efforts in Anchorage. The option of trucking debris from Alaska to Seattle is often overlooked. Regardless of the means, there is need for a defined logistical chain so containerized debris does not accumulate within the shipping system. Options were discussed for direct shipment to Asia markets but concerns were raised about possible federal laws/tariffs that may affect this. The current weak dollar may also affect this, as greatly increased U.S. exports are using most container space.

Recycling

Skagit River Steel and Recycling in Burlington, Washington, will accept plastics either for a fee in the case of unsorted debris or for free for sorted materials. Sorting increases the value and Skagit will pay for certain sorted materials such as nylon, polyethylene, and polypropylene. Payment will not fully defray shipping costs from Alaska, but elimination of landfill fees alone is significant.

Sorting debris in the field can be challenging, but would help in marketing the material and reducing costs. A simple and easy sort would involve sorting plastics from nonplastics such as wood and metal (including lead line). Other hard plastics such as fishing baskets, totes, Polyform, and hard plastic buoys are acceptable in the plastics. A more detailed sort also would segregate Styrofoam (including foam fishing floats) and PVC pipe. A more detailed sort would segregate different materials (such as netting, buoys, and high-value materials such as nylon gillnets) in different parts of the container.

Transportation costs can be reduced through densification of the material through baling. Fully loaded containers of debris (20 foot), hand-loaded by MCAF, ranged from 2 to 8 t and averaged 5 t. Each are charged the same to ship. The same container can contain 10 t of similar materials when they are baled. Baling increases handling costs and may require the use of forklifts.

Skagit has trucks regularly in the Seattle area to pick up plastics. Coordination of shipping and transportation schedules is important to reduce costs. All containers today are screened for radioactivity, and concern was raised about certain valves and regulators that are used to measure temperature and pressure that contain low levels of radioactivity, which may set off detectors.

Recycled plastics are sent to Asian markets where they are processed, pelletized, and later used to make different plastic products.

Another recycling option in Alaska is Total Reclaim in Anchorage. Recycle Tech in California is said to have equipment that can densify Styrofoam for recycling.

Waste to energy

There was considerable interest in options to convert plastics back to oil and use as a fuel source. Ambient Energy of Bellingham, Washington, and the Plas2Fuel Company in Kelso, Washington, are working together on plastic-to-fuel technology that would convert plastics including derelict fishing gear into synthetic crude oil. This is a distillation (not incineration) process. Shredded plastic is placed in a sealed container and heated by a propane or natural gas burner. The plastic melts and then gasifies. The gaseous plastic is pulled by vacuum through a water tank where it converts back to its original constituent form—oil—that floats on the water and is skimmed off to a holding tank. Ambient and Plas2Fuel claim a 65% recovery rate of oil that can be converted to synthetic diesel. About 25% of the volume is non-condensable gases (i.e., propane and methane) that can be directed back to the burner. The remaining 10% is inert solid carbon and sludge and can be landfilled. The technology is not new, but has recently become profitable given the current rise in the price of oil.

Ambient and Plas2Fuel are developing a pilot project near Salem, Oregon, that would convert agricultural wastes, which are similar to types of marine debris found in Alaska. These projects indicate the feasibility of using 10,000 tons of landfilled plastic fishing nets in Unalaska. A successful prospect would require access to the landfilled material and an available market to use the end product. The product would be a synthetic diesel capable of mixing with regular diesel and used for electric generation. Some fish processing plants in Dutch Harbor currently mix fish oil with diesel as a biofuel and it is assumed they could also accept this synthetic diesel mix.

The Unalaska concept is very preliminary and may use four shredded plastic-to-fuel converters operating together. The process would operate 24 hours per day for cost efficiency. It would require 5,000 square feet of space, a shredder machine such as those used in Skaegen (estimated cost = $300,000), and tanks for the fuel.

The four converters would consume a maximum of 10 tons of plastic per day. At this rate the project would create about 1,800 gallons of oil per day. The stockpiled material currently in the Unalaska landfill could be converted in three years. It is possible that Unalaska eventually would not be able to support this equipment at its maximum capacity if landfill deposits remain consistent with today's rates. However, it is assumed that with lower disposal rates (possibly even rebate incentives to fishermen) debris disposal would increase and other fishing communities such as Akutan may even bring debris. Once operational the Unalaska plant could be a regional collection point for debris from other Alaska communities. Already Kodiak residents have expressed an interest in the idea.

The plastic to fuel proposal has much promise to address Alaska plastic issues. There are several economic challenges to this proposal, but interested companies are currently examining them.

There was discussion among the breakout group about the possibility of a mobile platform, whether on a barge or vessel (e.g., former crabber) that could take this technology or other recycling machinery from community to community as needed.

Reuse

Some reuse of collected marine debris takes place, although on a limited scale. Good fishing buoys are often reused. On St. Paul Island, these are collected in a "buoy corral" and are available for free to anyone. Buoys collected in Prince William Sound are placed in a container where they are available for tourists to take as souvenirs. Cleanup crews in the Aleutians have been known to salvage hawsers and netting for use as cargo nets, etc. Community members in Homer were invited to sort through the 45 tons of debris collected at Gore Point before it was taken to the landfill, and a dozen or more truckloads were salvaged. One local artist took several truckloads of buoys and floats for various uses. On Nunivak Island, residents weave nylon netting into purses and other handicrafts. The Carpenteria Bay Ghost Net program in Australia reported that local aboriginal tribesmen make artworks from nets.

Other discussion items

The breakout group discussed a variety of other items to encourage the reuse/recycling and proper disposal of debris. These include

- Return refund: instituting an appropriate fee on plastic bottles, nets, and crab buoys that would be collected by individual cleanup programs when the item is returned for recycling. This would encourage recycling, as do refund fees on glass bottles in other states.
- Statewide logistical planner: a state official is needed to better coordinate the complex logistics of handling collected debris and recycling and waste-to-energy options.
- A tax on nets and other frequently found items to fund cleanup efforts.
- Barcoding of nets and buoys for better source fishery identification.
- Involve the North Pacific Fishery Management Council on derelict fishing gear issues.
- Increased partnering with federal, state, and local governments, as well as NGOs and private industry, to address the broader marine debris issue.
- Possible use of correctional labor for sorting. The Alaska Department of Corrections has not been interested in the use of correctional labor for cleanups, but sorting is a possibility.

Suggested planning items

Short term

1. Continue to investigate recycling options for plastic debris and other community solid waste.
2. Determine cost/benefit to on-site sorting if debris is being shipped to a recycler that offers payment for certain materials. This group was split on when and where it is beneficial to sort in the field. Other considerations include cost of workforce for sorting, availability of a sorting and bailing facility, availability of interim storage, and other infrastructure factors.
3. Increase banding, baling, or shredding of debris to densify materials for better return and reduced transportation costs.
4. Investigate transportation options and reduced backhaul rates, and encourage increased use of fishing vessel backhauls to Washington.

5. Investigate corporate sponsorships and other revenue options to encourage cleanup work and recycling.

Long term

1. *Regional coordination.* Work with other regional or statewide groups to address the broader issue of solid waste and coordinate removal of plastics from landfills to be recycled. Possible regional partners include Southeast Conference, Southwest Alaska Municipal Conference, Community Development Quota and Alaska Native Claims Settlement Act corporations, and nonprofits.
2. *Economic argument.* Research and report the true costs of landfills and the economic benefits of recycling and waste-to-fuel options.
3. *Technological opportunities.* Continue to monitor progress of waste-to-energy options offered by Ambient Energy, Plas2Fuel, and others.
4. *Logistical planning.* Work for improved options for transportation of collected debris to reduce cost.
5. *Funding.* Continue to look for alternate funding sources to facilitate recycling and waste-to-fuel options.

V. Data gaps

1. Economic feasibility of plastic to fuel technology.
2. Status of backhaul tariff or other federal legal issues.
3. Status of past recycling efforts in Alaska (United Cook Inlet Driftnet Association, Western Alaska).
4. Other recycling companies such as Total Reclaim and Rabanco, and how they may fit into the waste stream.
5. Is the use of correctional labor for sorting a possibility?
6. Is alternate funding available through Minerals Management Service (MMS), Coastal Impact Assistance Program (CIAP), others?

Question 4: How Can We Prevent and Reduce Marine Debris Sources through Education and Outreach?

Discussion leaders and summary preparers:
Bree Murphy and Jerry Dzugan

I. Statement of the issue

"The most effective way to clean up marine debris is to keep it out of the water in the first place. . . . By educating the public on and around the water, we keep dangerous debris in its place and out of the water," said retired Navy Vice Admiral Conrad Lautenbacher while serving as the Undersecretary of Commerce for Oceans and Atmosphere. In this quote he clearly stated the value of marine debris education and outreach as a technique for prevention. Diverting debris from entering the environment negates the need for constant beach cleanups.

The final report of the U.S. Commission on Ocean Policy, published in 2004, also supported education and outreach as an important marine debris preventive technique stating, "Because comprehensive monitoring and enforcement of individual behavior would be impractical and undesirable, people need the knowledge, training, and motivation to voluntarily change their behavior." This point is intensified in Alaska, which represents one-third of the U.S. coastline, where the majority of human interactions with the marine environment occur in remote areas. Monitoring and enforcing of marine debris laws is unrealistic with Alaska's large expanse and dispersed populations. Therefore, prevention and reduction of new sources of marine debris will largely rely on voluntary compliance.

II. Introduction

With more than 75% of Alaskans living on the coast, effective marine debris education and outreach programs could greatly benefit Alaska residents whose livelihood and lifestyles are deeply connected to the marine environment. There are vibrant marine subsistence and recreational lifestyles in Alaska, including fishing, hunting, and harvesting marine invertebrates and algae. In addition, the Alaska economy is strongly linked to the marine environment through a variety of industries, including fishing/seafood processing, tourism, oil/gas extraction, and shipping.

Surges of seasonal workers and tourists provide a prime opportunity to educate people about the negative impacts of marine debris and the importance of prevention. According to the Alaska Department of Commerce, Community and Economic Development, an estimated 1.7 million out-of-state visitors traveled to Alaska in 2007 between May and September. Sixty percent of these guests experienced Alaska on the water by traveling by cruise boat. During 2005, Alaska Department of Labor and Workforce Development reported that 39% of fish harvesters were nonresidents, while 67% of the seafood processing workers were nonresident. Public support of marine debris as a significant statewide issue could be greatly enhanced if transient workers and tourists were informed of the importance of marine debris prevention during their time in Alaska, and if they took the message back to their home communities.

History of marine debris education and outreach in Alaska

In 1987, U.S. administration and congressional leaders charged the National Oceanic and Atmospheric Administration (NOAA) with forming a federal task force on marine debris. The 12-agency task force published *The Interagency Task Force on Persistent Marine Debris* in May 1988. Among its recommendations was "Vigorously implement all laws related to marine debris," specifically, the Marine Plastic Pollution Research and Control Act of 1987. The NOAA Office of the Chief Scientist asked Alaska Sea Grant to create a public summary of the task force report. The illustrated booklet, *Persistent Marine Debris: Challenge and Response*, was published in 1988 and widely distributed in Alaska and across the nation.

The Alaska Marine Debris Action Group (AMDAG) was formed in 1989, a coalition of state and federal agencies, citizens, and industry. Governor Cowper endorsed May 1989 as statewide marine cleanup month. In 1989, Alaska Sea Grant published *A Guide to Cleaning Up Marine Debris in Alaska*, for organizers of local beach cleanups, *Marine Debris in Alaska?*, an informational brochure, and produced in collaboration with Saltwater Productions, *Trashing The Oceans*, a video funded by the Marine Entanglement Research Program.

At the same time, the Pacific States Marine Fisheries Commission in Newport, Oregon, conducted a marine debris project in Alaska, led by Fran Recht. Recht worked closely with Alaska harbormasters and other local officials to establish dockside refuse facilities to receive derelict and discarded fishing nets, as required by new MARPOL Annex V regulations that were going into effect at the end of 1989.

Other Alaskans who worked heavily on the marine debris issue in the late 1980s included Ketchikan harbormaster Doug Ensley, National Park Service, Southwest Alaska Municipal Conference, Kodiak Fishermen's Wives Association, Women in Fisheries Network, and the Alaska Coastal Management Program.

Although the state has a history of marine debris education and outreach, a unified strategic comprehensive effort is needed. There are a limited number of programs in the state, and the majority of efforts are directed toward four groups: (1) school children, (2) commercial fishing, (3) the general public, and (4) boat owners.

The Center for Alaskan Coastal Studies (CACS) and the Alaska Maritime National Wildlife Refuge (AMNWR) have long-standing marine debris education programs targeting school children. However, the bulk of the marine debris education programs they provided occur on the lower Kenai Peninsula. In 2004, CACS also produced a curriculum, *Gulf of Alaska CoastWatch*, for teachers interested in teaching about and monitoring coastal change (http://www.akcoastalstudies.org/resourcescoastalcomm.htm). The marine debris activities were recently excerpted from this curriculum by Alaska Sea Grant during the process of revising their Sea Week educational activities, now called *Alaska Seas and Rivers Curriculum* (http://seagrant.uaf.edu/marine-ed/curriculum/). The 5th grade unit is focused on human impacts on the ocean and beach cleanups. *Understanding Sustainability Curriculum* is another recently released educational activity guide. It was sponsored by the Marine Conservation Alliance Foundation (MCAF) and the National Oceanic and Atmospheric Administration (NOAA) and has a lesson on marine debris for Alaska middle school teachers. NOAA also has an educational marine debris Web site, *Marine Debris 101*, with several pages dedicated to teachers and students (http://marinedebris.noaa.gov/marinedebris101/welcome.html).

The Alaska Marine Safety Education Association (AMSEA) works with commercial fishermen, boaters, and children and delivers training and educational materials to these groups. MCAF funded AMSEA to develop a 15-60 minute lesson and PowerPoint presentation on why it is in fishermen's best interest to not discard trash at sea. This presentation will be delivered in all of AMSEA's Emergency Drill Conductor courses in 2008. In addition posters, stickers, and fliers have been produced that will help educate fishermen about the hazards of throwing trash at sea. AMSEA plans to reach several hundred Alaska fishermen with their marine debris prevention message. Also, at the end of 2008, a video will be produced targeting commercial fishermen and explaining the risks of throwing trash and losing fishing gear at sea.

Education and outreach efforts targeting the Alaska general public have been broad and have included a variety of methods, such as posters, special events, and cleanups. For several years Cook Inletkeeper has produced the *Turn the Tide on Trash* poster, which is displayed in harbors, visitor centers, conferences, special events, and fairs. Some of the best ways to share information about the impacts of marine debris and encourage prevention is through the media. In 2007, the Gulf of Alaska Keeper organized a large-scale cleanup at Gore Point. The project drew media coverage from the local to state level and brought to light the presence of the marine debris problem in "our backyards" for many Alaskans. A local reporter with the *Homer News* covered the story as a volunteer. On the state level, Alaska's KTUU Channel 2 television covered the cleanup, as did *Alaska Magazine*. This media coverage raised the issue of marine debris in Alaska, and the resulting impact was that more than 100 people called to volunteer for the next Gore Point cleanup.

Recreational boaters have been another target group for education. In 2007, Alaska Sea Grant focused an issue of their *Alaska Seas and Coasts* series on clean boating (http://seagrant.uaf.edu/bookstore/pubs/M-72.html). It outlines boating best management practices that protect the environment. The Cook Inletkeeper created inserts about the effects of marine debris in the tide table booklets they produce annually for the Cook Inlet and Southcentral Alaska region. MCAF created posters on marine debris outreach and reporting for harbormaster bulletin boards. In 2004, the *Alaska Best Management Practices for Harbor, Marina and Boat Operations* manual was updated with a table identifying sources of marine debris and recommendations for personal actions taken by boaters for marine debris prevention (www.alaskaharbors.com/resources/HarborBMPmanual.pdf).

III. Discussion topics

Target audience and themes in marine debris education

A marine debris education and outreach program in Alaska will need to have a full-spectrum approach that targets a variety of groups, as there is no one single source for the marine debris that reaches Alaska's beaches. Effective programs will establish marine debris as an important conservation issue and develop a sense of accountability. Effort should be made to make the education programs and outreach messages relevant to the audience and regionally appropriate; therefore themes in marine debris education will be dynamic.

The importance of a targeted campaign goes back to 1987 when the Ocean Conservancy (OC), developed a series of public service announcements (PSAs) about the effects of marine debris. The OC identified six major groups to direct their education efforts: commercial fishing, merchant shipping, plastics industry, recreational boaters and fishermen, and the general public. The major campaign effort was a series of PSAs with the same message, but framed differently for each group. For example, the PSAs for merchant shipping had a picture of a garbage bag and said, "When it's done holding your ship's garbage, it could hold death for some marine animals." The PSA for recreational fishermen was, "This discarded line is done fishing. But it's not done killing." The PSAs for the industries were placed in trade journals and regional publications, and the recreational PSAs were placed in boat journals, marinas, and bait shops.

Efforts in Alaska should be made to expand the programs offered to the existing target audiences, and add new groups including, but not limited to, the following: tourists, tourism industry, shipping, seasonal residents, charter boat crew, recreational fishermen, subsistence harvesters, city and tribal governments, sections of the retail industry, and consumers.

Currently spearheading marine debris education and outreach in Alaska is a blend of federal organizations, such as NOAA and the AMNWR, and nonprofits like CACS and AMSEA. A cohesive Alaska marine debris education and outreach program could be developed if these organization were coordinated and they were joined with state representatives from the Coast Guard, the Environmental Protection Agency, the Alaska Department of Natural Resources Coastal Management Program, the tourism industry, local governments, retail industries, harbormasters, and boat operators.

Statewide coordination

Effective marine debris education and outreach are achieved through a coordinated statewide program. Currently, there are isolated regional efforts that need to be tied together for efficiency, cohesion in message, and a more widespread impact. Additionally, there is a need for a statewide presence to promote marine debris as a marine conservation issue. Schoolteachers, community groups, and other organizations are more likely to support and help develop a coordinated education program. Due to the diverse nature of the communities and the marine debris issue across the state, it will be important to have regional input incorporated into a statewide effort.

Coordinated tools and events could involve a range of tactics, including an annual statewide meeting on marine debris, listservs, an Alaska marine debris mascot, state government recommendations, and a traveling marine debris display. An Alaska marine debris education Web site would be useful as a clearinghouse for resources, including signs, brochures, films, school curricula, and other information and resources. Statewide coordination could also develop campaigns and strategies for addressing especially problematic marine debris such as plastic bags, derelict fishing gear, plastic water bottles, and balloons.

An Alaska beach cleanup day could be an effective tool in creating awareness and community involvement on the impacts of marine debris across the state. The efforts of several Alaska communities to connect with the International Coastal Cleanup (ICC) have been unsuccessful, largely due to Alaska's unique marine debris problem. Primarily, the ICC's annual September cleanup date is late in the "weather window" for safe and reliable Alaska beach cleanups. In addition, the ICC data sheets do not adequately capture the types of marine debris found in Alaska (see Question 2. Is standardized Marine Debris Data Collection Possible?). A coordinated statewide cleanup campaign would create media attention and public awareness.

Statewide coordination and representation of the marine debris issue could help nest these efforts in the context of other marine issues in the state. Currently, there are several working groups focused on other coastal issues (e.g., marine invasives) that are also trying to solve these issues also through education and outreach in Alaska. There is tremendous potential for working with other marine oriented efforts.

Statewide templates

It is impractical to have one statewide model for community marine debris education, because Alaska communities, and the marine debris problem itself, are diverse culturally, geographically, socially, and economically. There are, however, techniques that have proven helpful in some communities across the state.

Effective outreach of educational messages for rural and remote communities can be done through community bulletin boards, public radio, and VHF communication. Weaving information into church services, governmental meetings, and other community events can also be an effective technique to share information.

Fishing industry has an emerging template for educating fishermen through the Alaska Marine Safety Education Association (AMSEA). Marine debris has been integrated into their boating safety education program. There is a significant need for similar training programs offered in close association with coastal industries such as seafood processors and shipping. Although there have been some isolated training sessions for employees within the tourism industry there is potential for growth in this area. Charter boat captains and crew, kayak and other guides, lodge owners, and water taxis should be trained in marine debris prevention messages and have outreach information at their offices for customers. Furthermore, the cruise ship industry could provide a prime opportunity to educate passengers and lead a publicized example of marine debris prevention.

Some of the most successful models for education and outreach to the general public have involved conducting beach cleanups during Earth Day and the 4th of July, art exhibits, promoting the use of cloth bags, and lecture series. Creativity has provided effective ways for reaching the public. Unalaska raised a great deal of awareness about the effects of marine debris by having a marine debris fashion show. Another example of creative outreach came from a parade in the Pribilof Islands that featured a float with a mythical creature, called "Marina Debris," which was constructed of nets, line, and other items collected off the beach.

There are various models in education and outreach for school groups. Programs and curricula that tightly link to science and math standards are crucial for teachers who are making sure their programs are aligned with state requirements. One example is the Center for Alaskan Coastal Studies' CoastWalk program, which involves an in-class visit followed by students participating in beach cleanups. Involving students in cleanups can be a powerful tool for fostering stewardship, and it provides an opportunity for students to learn science and math when debris items are counted, summarized, and studied for their impacts on the environment.

IV. Critical elements

There are several critical elements in education and outreach that need to be addressed to sustain and expand marine debris education in Alaska. These elements break down into funding, monitoring, and coordination.

While some financial support for marine debris cleanups exists, it is much harder to find financial assistance for education and outreach programs on marine debris prevention. For the healthy development of education and outreach programs in Alaska, funding for both cleanup and prevention is needed.

Education and outreach specialists need specific information about where the marine debris is coming from when it washes up on Alaska's shores, to justify funding requests and target the audience for each campaign. There is a distinct lack of comprehensive data in Alaska on the types and amounts of marine debris. Monitoring and understanding marine debris and its sources are essential to developing effective education programs.

Currently, the marine debris education efforts and resources are scattered across the state. For marine debris prevention efforts to be successful, there is a need for a coordinated effort to collect resources and promote marine debris as a state issue. Additionally, a cohesive marine debris campaign could increase marine debris awareness across Alaska. This statewide coordination would promote a unified and integrated approach when groups are working with marine transportation, marine fisheries, and coastal communities.

V. Current needs

Cleanups and enforcement of pollution laws can minimize the effects of marine debris, but a key to stopping future sources lies in effective public education and outreach. Alaska's long and mostly remote coastline presents tremendous challenges in enforcing marine debris laws. With the majority of our coastline being inaccessible, cleanups are often expensive and logistically challenging. The foundation of marine debris prevention will, therefore, largely rely on educated, voluntary compliance.

This point was echoed by First Lady Laura Bush when recently speaking in Mississippi about the 2007 Marine Debris Research, Prevention, and Reduction Act. She noted the value of beach cleanups in the marine debris issue when she said, "But one of the most important parts will be to make sure people are educated about marine debris and what they can do about it. Successful conservation really depends upon informed citizens." She concluded her speech by urging people to participate in marine debris prevention through a variety of ways. "These efforts will preserve a cleaner, healthier ocean for everybody," she said.

Question 5: How Can Emergent Programs for Marine Debris Removal and Prevention Be Developed?

Discussion leaders:
Chris Pallister and Philip Zavadil

Summary preparer:
Erika Ammann

I. Statement of the issue

Are there key elements that are shared by successful marine debris programs around the state? Would these key elements be useful to emergent marine debris programs in order to allow them to be sustainable? In this session leaders from various communities discussed and compared their programs.

II. Introduction

Why is development of emergent programs an important Issue?

Development of emergent programs is important to generate appropriate assistance based on regional coverage or statewide priorities. It is important to understand the program purpose, community needs, and perspective of different organizations involved in marine debris work in order to adequately support these organizations.

What are reasonable goals for local marine debris programs, and what measurable outcomes can be reported from these programs? How can principal investigators and reviewers ensure that productive work is performed and a reasonable measurement of success is understood? Where and when can cooperation and partnerships reduce the cost and effort expended on marine debris work?

Relevance to/in Alaska

The vastness of Alaska's coastline, in addition to the isolation of coastal and rural communities, results in a lack of communication and knowledge sharing between various marine debris programs. Communities interested in starting and completing a marine debris removal project face an incredibly diverse set of challenges. These challenges can lead to setbacks or an inability to initiate or complete a project. Where possible we would like to provide a list of "lessons learned" in order to prepare new organizations to avoid potential pitfalls.

Alaska also has diverse stakeholders including local, state, tribal, and federal governments; industry (including fishing, shipping, tourism, mining, and oil and gas); Native corporations; military; subsistence users; scientists; and environmentalists. The different points of view of these stakeholders can affect how programs develop, what resources are available, how the work is conducted, and how success is defined.

History of the issue

Organizations have been conducting marine debris work in Alaska for more than twenty years. This work includes on-the-ground cleanups, education programs, and scientific study. During the two-day Marine Debris in Alaska workshop, people from many organizations met for the first time with others who had been performing similar work in the state. Information sharing between these groups improves marine debris work in the state. Future marine debris workshops should continue this communication and information sharing as a statewide priority.

III. Discussion topics

There is no single template that describes marine debris programs in Alaska. Due to differences in sources of marine debris, level of isolation in communities, funding sources, landowners, and stakeholders, programs formed in different areas have different purposes and therefore different goals. These different goals necessitate different metrics to calculate achievements. A community that faces mostly land-based debris may find it is of upmost importance to concentrate their efforts on landowner and land user stewardship education. In contrast, communities that are inundated with debris not locally generated may need to concentrate on cleaning sensitive habitat or subsistence areas. Table 1 lists the different variables influencing marine debris programs in Alaska.

Table 1. Variables influencing marine debris programs in Alaska.

Funding sources:	Government	Tribes	Industry	Nonprofits/ foundations	
Labor source:	Volunteer	Paid	Seasonal	Full time	
Debris source:	Fishing	Tourism	Local/recreation	Land based	Shipping
Immediate results:	Public knowledge	Volunteer hours	Pounds of debris collected/ miles of coast cleaned	Source/ type data collection	Temporarily clean beaches
End results:	Prevention of further marine debris	Improved environment	Less entanglement/ other interaction	Legal basis for enforcement	Legislation passed (i.e., MARPOL)

IV. Critical elements

Statewide coordination

While not all programs share the same needs and goals due to factors unique to each community, it was apparent that consistent statewide coordination would be beneficial. Duplication of effort could be avoided by coordinated debris removal from remote locations, prepared education packets, and database management. A dedicated coordinator would promote the stability, viability, and success of programs. Interaction between statewide marine debris groups also allows for sharing best practices for removal, disposal, education resources, and funding opportunities. A statewide organization will likely be more successful at describing the problems and developing solutions to appropriate management, policy, and funding organizations.

Long-term planning/financial stability

The ability to plan is essential for cost-effective marine debris programs. This is especially true in Alaska where major constraints include a short weather window, inaccessible locations, small labor force, and unavailable cleanup tools. Organizations receiving small levels of funding must develop and apply for matching funds to promote program longevity. The insecurity of applying for grants, as well as the short time period in which to expend grant funds, do not always ensure long-term viability for programs to deal with the marine debris problem effectively.

International efforts

Alaska communities must engage the international community to truly prevent loss and illegal dumping at sea because of the sheer volume of foreign-origin marine debris. Policy and enforcement efforts should receive guidance from the communities that repeatedly deal with the effects.

V. Data gaps

Net guide/source identification

Prevention is the ultimate goal of all marine debris work. Cleanups will go on indefinitely without effective prevention. One important element to direct prevention is determining the source of debris. Without source identification responsible groups cannot be effectively reached, and appropriate methods cannot be developed to prevent marine debris.

Available technology for disposal

Knowledge of new technologies available for disposal and recycling of marine debris is an urgent need across the state. Marine debris disposal can discourage communities that are not on the road system, have limited landfill space, or have limited recycling opportunities, from starting or continuing a marine debris removal program. Preliminary investigations have been made on reception sites in Washington, as well as incineration opportunities in the state, but more information and feasibility studies are needed.

Database

A statewide database that contains information on areas cleaned, accumulation rates, source of debris, makeup of debris, and wildlife/environmental impacts would allow the marine debris response community to better develop programs to respond to and prioritize marine debris projects. The database should be publicly accessible and incorporate data from organizations throughout the state.

Question 6: How Does Marine Debris Affect Wildlife and the Environment?

Discussion leaders and summary preparers:
David Hyrenbach and John Kennish

I. Problem statement

Is marine debris just an eyesore or are there effects that will cause harm to the environment, economy, or human beings? In this session we explored and defined the effects of marine debris on the environment and coastal users. These answers inform prevention, outreach, and education efforts and should be tailored to varied audiences from the public to lawmakers.

II. Introduction

Why is this an important issue?

Debris from marine and terrestrial sources, including lost/discarded fishing gear and consumer plastics, litters marine and nearshore habitats across the globe. This debris impacts numerous organisms directly (through entanglement and ingestion) and indirectly by damaging marine habitats (smothering, physical damage to shorelines and sessile flora and fauna). Another possible impact relates to the introduction of invasive species transported by marine debris into Alaska marine ecosystems.

In addition to these "mechanical" impacts, the chemical composition of marine debris poses a threat to wildlife. For instance, high concentrations of hydrophobic organic contaminants have been measured on plastic marine debris collected from the environment, but the toxicological effects and the fate of these contaminants (e.g., phthalates, fire retardants) are poorly understood. Moreover, the role of bioaccumulation through the food web, the potential absorption of other pollutants (e.g., persistent organic pollutants, POPs) by marine debris, and the synergistic interactions of these various compounds are critical and poorly understood aspects. As plastics are mechanically or chemically degraded into smaller and smaller particles, are there additional impacts on lower trophic levels in the food web?

Relevance to/in Alaska

Marine debris is a very important environmental, economic, and possibly human health concern in Alaska for the following reasons:

1. Alaska's vast coastline, ocean currents, and geography make the state a sink for marine debris originating from local fisheries and throughout the North Pacific. Ocean currents transport marine debris originating from distant sources, throughout the North Pacific basin.
2. Alaska is the source of 54% of the seafood landings in the United States, with critical economic value to the state and the nation. Alaska led all states in volume with finfish and shellfish landings of 5.3 billion pounds, a value of $1.5 billion, in 2007 (National Marine Fisheries Service Office of Science and Technology; http://www.st.nmfs.noaa.gov/st1/fus/fus07/).
3. Tourism is critical to the economy in Alaska, with over 1.8 million visitors spending approximately $1.7 billion during the 12 months prior to April 2007 (Alaska Visitor Statistics Program; http://www.commerce.state.ak.us/oed/toubus/research.htm).
4. Local residents of the state rely heavily on marine resources through subsistence harvests and commercial fisheries.
5. Large populations of upper-trophic marine predators (i.e., marine mammals and birds) breed or seasonally migrate to Alaska. Many of these populations are harvested by subsistence hunters.
6. The high volume of shipping through the great circle route (west coast of North America to Asia) and the potential opening of a northern passage route through the Bering Strait to the Atlantic increase the potential debris sources and vessel interactions with debris.

History of the marine debris problem in Alaska

Marine debris has been reported at sea and on beaches throughout the North Pacific since the 1970s (reviewed in Derraik 2002), with the number of published reports and studies increasing in the 1980s and 1990s (e.g., Wong et al. 1974, Day and Shaw 1987). Entanglement and ingestion by wildlife has been reported in a wide range of marine taxa, including fish, birds, turtles, and mammals (reviewed in Laist 1997). While there are few time series of the abundance and types of marine debris over time, longitudinal studies suggest an increasing trend. For instance, deposition rates on beaches on the Pribilof Islands indicate accumulation rates higher than previously reported in other areas of the Bering Sea (see King 2009, this volume)

Time series of biological impacts are also revealing trends of increasing ingestion rates by locally breeding seabirds (from 1969-1977 to 1988-1990; Robards et al. 1995), and a shift from "industrial" to "consumer" plastics in stomach contents (Vlietstra and Parga 2002). Entanglement is another particularly difficult wildlife impact to study. Fowler (1987) found a reduction in juvenile male northern fur seal entanglement by the late 1980s on St. Paul Island, but investigations do not have the power to detect recent changes in the proportion of juvenile males entangled if any have occurred (Williams et al. 2004). Recent research on St. George Island (Zavadil et al. 2006) corroborates previous findings (Delong et al. 1988, Kiyota and Fowler 1994) that the rate of entanglement among female fur seals increases with the arrival of young females from late July through September. Similarly, data for northern fur seal pups during two consecutive years on St. George Island show a mean entanglement rate of 0.06-0.08%, with a potential maximum rate of up to 0.11% in October prior to weaning (Zavadil et al. 2006). These studies indicate that the rate of entanglement among adult females and pups may be higher than previously estimated (e.g., Fowler 2002).

III. Discussion topics

Major concepts

To organize the information in a coherent fashion, we considered the following five components.

1. Habitats:
   Intertidal (e.g., beaches, mud flats, rocky shorelines).
   Subtidal (e.g., kelp beds, continental shelf, canyons).
   Deepwater (e.g., coral beds, seafloor).
2. Living marine resources (fish, mammals, birds).
3. Commerce (fisheries, tourism, shipping).
4. Traditional/subsistence harvest, livelihoods.
5. Ecosystem (including issues relating to pollutants, toxins, invasive species).

For each component listed above, we addressed four knowledge areas:

a. Currently known—direct (i.e., effects on individuals).

b. Currently known—indirect (i.e., emergent effects on populations and food webs).

c. Theories on impacts (i.e., physical, biological, economic, social).

d. What is unknown (next steps) (i.e., research needs, methods to test theories listed above).

1.a. Habitats, known direct effects.

Current understanding focuses on "high use" habitats, defined herein as those of high subsistence, economic, and recreational value to humans, yet the ecology and potential impacts on many other habitats are not well understood.

We acknowledge that any review of marine debris impacts should recognize these biases and avoid falling into the "out of sight, out of mind" trap. In particular, we identified four poorly known habitats potentially impacted by marine debris:

- Seamounts/offshore banks (important foraging and spawning areas; open or closed to fishing).
- Subtidal (debris resuspension and transport may affect submerged areas adjacent of beaches).
- Canyons (important fish habitat, and onshore-offshore transport; potentially a path and site of aggregation for sunken debris).
- Seafloor (ghost fishing and entanglement on deep-sea corals).

1.b. Habitats, known indirect effects.

- Characterize impacts where debris accumulates (e.g., smothering of the habitat in the high tide zone).
- Investigate whether marine debris can destroy the different habitats, by altering their structure/function permanently, or whether the impacts vanish once the debris is removed.

1.c. Habitats, theories on impacts.

- Impacts of marine debris on intertidal communities: latitudinal differences (i.e., tropical vs. temperate vs. subarctic).
- Return time after disturbance longer in Alaska due to slower regeneration. Debris degradation time shorter/longer in Alaska (e.g., waves, sunlight, temperature).
- Resuspension/transport of debris (e.g., high-energy beaches, winter storms).

1.d. Habitats, unknown.

- Fate of debris on beaches (e.g., deposition, resuspension, loss, degradation).
- Effects of debris on beaches (e.g., plastic pellets/fragments incorporated into sediments, smothering of flora and fauna, physical/chemical changes).
- Role of seasonal changes/events (e.g., temperature/rain variability, movement of debris by winter storms, seasonal ice).

- Can habitat be destroyed by marine debris?
- Invasive species transported by marine debris? (If so, how far, what are the sources?) (e.g., northwestern Hawaiian Islands study involving marine debris and invasives).
- Time series needed to assess status and trends:
  - Baselines: archived samples, "memory" (oral history traditional ecological knowledge, photos).
  - Start new time series: shore zone mapping (Prince William Sound Regional Citizens' Advisory Council photos 2007).
- Evaluate existing resources for marine debris monitoring (e.g., photos, "environmental sensitivity maps").
- Characterize extent of marine debris impact (e.g., depth in sediment, transport inland by wind, wildlife, storms).

2.a. Living marine resources (fish, mammals, birds), known direct effects.

- Mechanical damage/smothering of intertidal and deep-sea organisms (e.g., corals).
- Entanglement pervasive (e.g., mammals, birds).
- Plastic and hook ingestion (e.g., zooplankton, fish, mammals, birds)—secondary marine mammal plastic ingestion (Eriksson and Burton 2003) and anecdotal salmon ingestion.

2.b. Living marine resources (fish, mammals, birds), known indirect effects. Contaminant loads in organisms: When should they reflect ingested debris? Consider other mechanisms for transfer of this pollution (e.g., food webs).

2.c. Living marine resources (fish, mammals, birds), theories on impacts. Entanglement and ingestion cause individual injuries, but it is difficult to estimate mortality at sea. Theories for assessing impacts are thus limited by reliable extrapolation to the entire stocks or populations.

2.d. Living marine resources (fish, mammals, birds), unknown.

- Use existing samples and monitoring programs (e.g., diet and stomach content analysis from fish, seabirds, and marine mammals from research, recreational, commercial, or subsistence harvests).
- Entanglement/ingestion data from various sources (e.g., fish, plankton, sportfishing: salmon, halibut, and herring).
- Need to develop reliable and accurate bio-indicators. Consider previous heavy metal study organisms, and species involved in trophic transfer in the food web and subsistence/commercial harvests.

- Explore correlation studies between ingested plastics and pollutant loads.
- Develop controlled studies with animals: plastic ingestion, pollutant absorption. (Note: fish may be suitable model organisms.)
- Evaluate links to human health through commercial/subsistence harvests/uses.

3.a. Commerce (fisheries, tourism, shipping), known direct effects.

- Ghost fishing/bycatch (undetectable, may affect species targeted by Endangered Species Act).
- Gear/vessel damage.
- Damage to "high-value" tourism resources and habitat.

3.b. Commerce (fisheries, tourism, shipping), known indirect effects.

- Economic loss to entire fishing-based economy.
- Recycling marine debris to create "new" fishing gear.
- Incentive for tourism and fishing industry to recycle (avoid landfills).

3.c. Commerce (fisheries, tourism, shipping), theories on impacts.

- Cost/benefit analysis of "green" practices (e.g., Puget Sound commission study on fish loss due to ghost fishing).
- Consider established modeling frameworks:
  - Contingent valuation analysis.
  - Benefit transfer analysis.

3.d. Commerce (fisheries, tourism, shipping), unknown.
Research needs will focus on obtaining the required cost/benefit data for the modeling discussed above.

4.a. Traditional/subsistence harvest; livelihoods, known direct effects.
We considered these "indirect" impacts on the harvested populations.

4.b. Traditional/subsistence harvest; livelihoods, known indirect effects.

- Fur seals/sea lions (e.g., entanglement).
- Ghost fishing reducing resource availability.
- Eggs, seabirds, sea ducks, mammals, fish, and invertebrates may constitute an indirect impact due to public health concerns from contaminants associated with debris breakdown.
- The indirect effects mentioned above can also affect other terrestrial organisms consuming contaminated marine organisms. For instance, black-tailed deer in Kodiak consume kelp.

- Invasive species introductions mediated by marine debris may modify the habitat and compete with native species.

4.c. Traditional/subsistence harvest; livelihoods, theories on impacts.

- Bio-accumulation in harvested organisms.
- Food web magnification, especially of upper-trophic organisms.
- Trophic level and longevity of the resources (e.g., mammals, birds, rockfish).

4.d. Traditional/subsistence harvest; livelihoods, unknown.

- Evaluate pollutants in resources used by subsistence harvests (beware of indirect effects).
- Model pathways of bio-accumulation and food web magnification.
- Review traditional ecological knowledge (TEK) with elders and communities to evaluate resource use, reliance on different resources, and potential direct and indirect impacts.

5.a.b. Ecosystem (pollutants, toxins, invasive species), known direct and indirect effects.

We considered direct/indirect effects together because the ecosystem inherently involves direct/indirect processes.

- Alaska beaches are a sink of marine debris transported from the North Pacific.
- Evidence of invasive species arriving in Alaska is lacking, yet potential links with marine debris transporting invaders or modifying the habitat are unknown.
- Changes in physical/chemical conditions when large marine debris is deposited on beaches (e.g., sediments going anaerobic).

5.c. Ecosystem (pollutants, toxins, invasive species), theories on impacts.

- Loss or reduction of ecosystem function from marine debris.
- "Alternate states" hypothesis may lead to persistent ecological effects from marine debris.
- Climate change, may alter marine debris sources/magnitude/effects:
  - Currents influence source/amount/location of debris deposition.
  - Alaska more benign to invasive species under a warming scenario.
  - Increased shipping through Bering Sea after arctic ice loss.
- Role of high-energy beaches (e.g., resuspension, faster mechanical degradation).

5.d. Ecosystem (pollutants, toxins, invasive species), unknown.

- Characterize how currents and wind transport/concentrate debris and relate marine debris deposition on beaches to currents (e.g., subsurface debris accumulations/transport, "small-scale" eddies).
- Investigate how much debris originates from the ocean versus the rivers/erosion of coastal landfills.
- Evaluate physical/chemical conditions on beaches with marine debris deposition.
- Compare Alaska patterns with other ocean basins/U.S. regions/North Pacific.
- Do chemicals leach out of marine debris (e.g., into water, sediment, organisms)?
- Consider other "non-fishing" debris, including terrestrial sources (e.g., toxic/treated wood, consumer plastics).

Interesting points

1. Alaska is unique and different from other regions of the United States and the world. Regional/international comparisons may help us understand how Alaska residents, wildlife, fisheries, and ecosystems will be affected by marine debris.
2. Due to the large coastline, the low population density of the state, and the input of marine debris from the North Pacific, fishing-related and other marine sources of debris comprise the vast majority of marine debris found in Alaska.
3. Wind circulation patterns transport airborne pollutants north, making Alaska a global sink for these pollutants. It is critical to consider the ability of plastic debris to absorb and concentrate these pollutants as well.
4. Large subsistence user community in the state extracts resources directly from the marine environment. Rural residents may be particularly susceptible to toxic effects of marine debris and direct losses of wildlife populations and ecosystem functions.

IV. Critical elements

Marine debris is not just an eyesore—the available time series of debris deposition, collection, removal, and the incidence of impacts on wildlife (e.g., entanglement, ingestion) indicate the incidence and magnitude of these effects are increasing over time. Yet, while there is mounting quantitative evidence that individual organisms are impacted by marine debris, it is inherently difficult to evaluate potential effects at the population level (primarily due to mortality at sea) and to extrapolate these impacts to the entire ecosystem. Identifying the synergies and pathways involved in these indirect effects, and quantifying the magnitude and spatial/temporal variability of these factors, are critical information gaps and research needs.

Quantifying societal and economic effects on commercial fisheries, tourism, recreational fisheries, and subsistence harvests will also require considering direct/indirect effects and a variety of modeling approaches. These approaches will require data on the resources used by different groups, and the associated costs/benefits of ongoing and future losses due to marine debris.

V. Data gaps

Short term—key components that need to be addressed before moving forward:

- Fate of debris on beaches (e.g., deposition, resuspension, loss, degradation).
- Develop time series needed to assess status and trends of marine debris in Alaska.
- Baselines: archived samples, "memory" (oral history, traditional ecological knowledge, photos).
- Start new time series: shore zone mapping (e.g., Prince William Sound Citizens' Advisory Council photos 2007).
- Evaluate existing resources for marine debris monitoring (e.g., photos, "environmental sensitivity maps").
- Characterize extent of marine debris impact (e.g., depth in sediment, transport inland by wind/ocean, wildlife, storms).
- Use existing stomach collections and diet monitoring programs from commercial, subsistence, and recreational harvesting to evaluate direct and indirect plastic ingestion.
- Use existing stomach collections and diet monitoring programs from commercial, subsistence, and recreational harvesting to evaluate correlations between pollutant loads and direct and indirect plastic ingestion.
- Assess entanglement data from various sources (e.g., marine mammals, seabirds, fish, plankton, sportfishing—salmon, halibut, herring, subsistence harvest).
- Review traditional ecological knowledge (TEK) with elders and communities to evaluate resource use, reliance on different resources, and potential direct and indirect impacts.
- Evaluate pollutants in resources used by subsistence harvests (beware of indirect effects).
- Expand scope of marine debris research by considering other "non-fishing" debris, including terrestrial sources (e.g., toxic/treated wood,

consumer plastics, and terrestrial inputs via rivers).

Long term—components that need to be addressed to obtain full understanding of marine debris impacts:

- Effects of debris on beaches (e.g., plastic pellets/fragments incorporated into sediments, smothering of flora and fauna, physical/chemical changes).
- Investigate whether marine debris changes the physical/chemical conditions on beaches. Do chemicals leach out of marine debris? (e.g., into water, sediment, organisms).
- Role of seasonal changes/events/climate change (e.g., temperature/rain variability, movement of debris by winter storms, seasonal ice).
- Invasive species transported by marine debris, now and in the future? (If so, how far, what are the sources?)
- Need to develop reliable and accurate bio-indicators. Consider previous heavy metal study organisms, and species involved in trophic transfer in the food web and subsistence/commercial harvests.
- Develop controlled animal studies (e.g., plastic ingestion, pollutant absorption) using bio-indicators.
- Evaluate links to human health through commercial, recreational, and subsistence harvests/uses.
- Model pathways of bio-accumulation and food web magnification.
- Compare Alaska patterns with those from other U.S. regions/North Pacific areas/ocean basins.
- Evaluate conceptual models of marine debris impacts and collect long-term data to assess whether marine debris can destroy Alaska habitats and impact its marine ecosystems.

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Question 7: What Criteria Should Be Applied to Prioritizing Marine Debris Cleanups in Alaska?

Discussion leaders and summary preparers:
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I. Statement of issue

As marine debris issues are better understood, we need a priority list of criteria to develop focused effort in Alaska. To distribute limited funds and to assess where future funds should be spent, we need to develop a framework through which resources can be allocated.

II. Introduction

Alaska's coastline is extensive, variable, and logistically challenging to access. Though Alaska is perceived as pristine, its coastline is littered with thousands of tons of marine debris. Alaska is also unique in that it receives debris from international and domestic sources throughout the Pacific. In determining the relative importance of responding to marine debris accumulations, funders and decision-makers need a structure to base evaluations upon when prioritizing marine debris proposals across the state.

Alaska's marine environment is home to many threatened and endangered species, valuable and abundant seafood resources, and unique coastal habitats and endemic species. Some of the most ancient indigenous cultures of the United States are found here, and shorelines contain numerous sites of significant historical and cultural relevance. Many of Alaska's coastal areas are important spawning grounds for fish and invertebrate species, nursery grounds for many commercially important species, as well as haulout, breeding habitat, and important migratory stopovers for marine mammals and birds. Much of the state's coastline is protected as wilderness areas, wildlife refuges, national and state parks, and wetland/estuarine reserves. Marine debris threatens the ecological integrity and wilderness character of many of these significant resources.

III. Discussion topics

Major concepts

- Established a list of criteria to be prioritized.
- Discussed challenges and focus areas within criteria.
- Defined criteria with bulleted list of examples or clarifying descriptions.
- Prioritized criteria using all of the workshop participants.

Criteria for prioritizing cleanup projects

Ecological importance

- Where are the threatened/endangered species located? Are they affected by marine debris?
- How is marine debris impacting the ecosystem?
- Magnitude of impact.

Cost effectiveness/efficiency

- Will the project result in additional or future funding?
- Is it an efficient use of time and funding?
- What is the source of the funding?
- In what time frame does the funding need to be spent?
- Getting the most bang for your buck—some beaches will rate higher because of where they are and because they are more visible or higher public use.
- How can it make a convincing argument on a national level to provide long-term funding? You have to convince a taxpayer in Ohio why their tax dollars go toward marine debris prevention or removal.

High accumulation

Identify high accumulation locations before beginning to work on it. Find the areas of high accumulation and the problem areas that need to be addressed.

Community support/volunteers

- Are there community support and resources within the community?
- The first MCAF (Marine Conservation Alliance Foundation) cleanup program was on St Paul Island. St. Paul was chosen because they recognized the northern fur seal entanglement problem and high density of debris. It was within the operation where they worked, and they had ties there. There was an existing community program and they felt they were able to enhance that program.

- How many local volunteers and in-kind contributions do you have?
- Is there a way to bring the information back to the community?

Realistic
Is the applicant's proposal realistic/doable?

Risk factor
Low-risk beaches or at least an assessment of risks is being addressed.

Human use
- High recreational use.
- Culturally important.

Long-term sustainability
- How do you keep a long-term interest?
- How do you sustain the effort?

Prevention/outreach strategies
- Opportunities for targeting prevention.

Innovation/technology/program change
- Is the program/project using the best available technology? Or a new use of existing technology? What type of technology will be used?
- Future research needs.

Transferability
- Do models or pilot projects have applications in other places?
- Can cleaning up marine debris be cross-cutting (addressing other conservation and management issues as well)?

Measurable outcomes
- What is the best measure of success?
    - Miles cleaned.
    - Pounds removed.
    - Bags of debris removed.
    - Volunteer hours.
- Is there a measurable outcome?
- What type of debris is being removed?
- What are the logistics involved?
- Where will the debris be disposed of/recycled?

- Does the cleanup project help solve the root of the marine debris problem?
- Will it make a change in the program? Will it affect how cleanups are done in the future?

Public visibility

- Will the cleanup project get publicity? Publicity influences the politicians and citizens to act.
- What is the strategy for outreach?
- Will the results be published? If so, where?
- Aesthetics.
- Will it clean up a highly visible coastline, from the tourist point of view?

Partnerships

- What partnerships are there? Is it a collaborative effort?
- Is another organization or agency already doing the work?
- In-kind support

Culturally relevant

- Is it important from the standpoint of Alaskans?
- Cultural relevance to tribes, corporations, communities?
- Can you access the land legally?

Meet needs of funders

- What are the objectives for using the money?
- Avoid, minimize, and mitigate the damages. It will affect the funding for the project. The things you cannot minimize, you mitigate for the effects.
- Do you have the expertise to complete the proposed idea?
- Does the area have a baseline established?
- How many of the above criteria does it meet?

Interesting points

- Funder's expectations/intent.
- Regional priorities.
- Volunteer buy-in, motivation, and longevity.
- Gore Point example: large media coverage draws public attention and increases potential future funding.

- How to measure cost effectiveness.
  - St. Paul—10 miles, 10 tons, $45,000, match of $45,000, local labor, trucks to access sites.
  - Prince William Sound—110 miles, 40 tons, $120,000, remote beaches, vessels to access sites, local and nonlocal labor, disposal fees waived.
  - Yakutat—11 miles, 7.6 tons, $56,000.
  - Homer—25 miles of shoreline, 13 stream miles, 17.5 tons, $14,000, $8,000 match, 9 communities.
- Scenario—what would you do with $500,000 in one year?
- Spread the funds regionally on place-based focuses (MCAF).
  - For Southeast Alaska distribute through community grants.
  - For GOA go with a proven group with community support, publicity, and dedicated personnel.
  - For Pribilofs—high wildlife value, willing/proven workforce.

IV. Critical elements

Workshop attendees were instructed to choose their top four priority criteria for directing future marine debris projects. Votes were tallied for each criterion and ranked. The number of votes is shown in parentheses after each criterion.

Top five criteria to use as decision-making factors in allocating marine debris funds:

1. Ecological importance (23).
2. Prevention/outreach strategies (17).
3. Human use (9).
4. High accumulation (8).
5. Long-term sustainability (8).

Other priorities voted upon

Cost effectiveness/efficient (6)
Realistic (6)
Measurable outcomes (6)
Partnerships (6)
Public visibility (5)
Innovation/technology/program change (4)
Community support/volunteers (3)
Risk factor (1)
Political impact

Transferability
In-kind support
Culturally relevant
Meet needs of funders

V. Data needs

- Lacking baseline information on Arctic, Western Alaska, outer Southeast Alaska coastline, areas of Cook Inlet and Aleutians.
- Aerial surveys to determine extent of marine debris accumulation (northern passage opening?)
- Impacts of efforts in watersheds (i.e., how far up the watershed needs to be cleaned?).
- Disaster response (i.e., oil spills, hurricanes, tsunamis).

When considering these data needs, the challenges associated with determining effective criteria for the entire state of Alaska are as vast as the number of miles of Alaska coastline. This priority list of criteria is a starting point only in determining when, why, and how to deal with current funding limitations and to potentially direct future funding, people, resources, and effort. Much more input is needed by a larger array of Alaska stakeholders, but the results of this effort may be an effective guide for future planning.

There are many external factors that drive criteria priorities. The "requirements (time and effort) of the funding organization" and "high priority/exposure scenarios," such as endangered species interactions or human health issues, are baseline tenets that must be met; but determining criterion that will guide future efforts will further refine prioritization of funding allocation. Challenges in determining criteria need to take into account the geographic diversity of Alaska and the high likelihood of developing regional priorities weighted by statewide guidance.

Though current response to marine debris is reactive, there are several proactive steps to consider in the future, including underrepresented/unobserved areas like the Arctic and the Aleutian Islands, new technologies that may aid in cleanup efficiency, and cross-cutting outreach efforts that educate communities on how to keep their local areas unspoiled by marine debris.

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