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GhostNet marine debris survey in the Gulf of Alaska – Satellite guidance and aircraft observations

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ABSTRACT

Marine debris, particularly debris that is composed of lost or abandoned fishing gear, is recognized as a serious threat to marine life, vessels, and coral reefs. The goal of the GhostNet project is the detection of derelict nets at sea through the use of weather and ocean models, drifting buoys and satellite imagery to locate convergent areas where nets are likely to collect, followed by airborne surveys with trained observers and remote sensing instruments to spot individual derelict nets. These components of GhostNet were first tested together in the field during a 14-day marine debris survey of the Gulf of Alaska in July and August 2003. Model, buoy, and satellite data were used in flight planning. A manned aircraft survey with visible and IR cameras and a LIDAR instrument located debris in the targeted locations, including 102 individual pieces of debris of anthropogenic or terrestrial origin.

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1. Introduction

The NOAA Marine Debris Program (http://marinedebris.noaa.gov/) defines marine debris 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." Fishing debris, especially derelict fishing gear, is widely recognized as a serious threat to vessels at sea (i.e., collision or prop entanglement) as well as to fish, sea birds, marine mammals and turtles (i.e., entrapment and drowning). Ubiquitous in the marine environment, marine debris, especially long-lasting plastic debris, has become a global problem (Atlantic Ocean: Law et al., 2010; Gulf of Mexico: Barnea et al., 2009; Mediterranean Sea: Aliani et al., 2003; Indian Ocean: UNEP, 2009; Southern Ocean: Barnes et al., 2010; Pacific Ocean: Morishige et al., 2007). In addition, grounded debris, particularly fishing nets, can cause physical damage to reef and beach environments and continue to entangle and kill reef and surf/beach inhabitant species. In particular, young Hawaiian Monk Seals, an endangered species, and Northern Fur Seals, a depleted species, are particularly vulnerable to entanglement in nets and plastic debris (Donohue and Foley, 2007; Fowler, 1987; Henderson, 1990; Zavadil et al., 2007).

The GhostNet Project, a research collaboration of Government, academia, and industry, was conceived in 2000 with the goal of developing instrumentation, remote sensing techniques, and a search and recovery strategy to cost-effectively detect, track, and eventually remove marine fishing debris in the open ocean. It was postulated that extracting derelict nets at sea would

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contribute to (1) preventing "ghost fishing;" i.e., continuation of net entrapment of living species by lost or abandoned fishing gear, (2) decreasing derelict net damage to reef and beach ecosystems, and (3) reducing the cost of removing nets from reefs and beaches. NOAA uses small boats and divers to cut nets off of the coral reefs of the Northwestern Hawaiian Islands (Dameron et al., 2007). During the period 1996–2009, 671.45 metric tons of derelict fishing gear were extracted from the reefs of the Northwestern Hawaiian Islands (NOAA Marine Debris Program, 2011). After studying the historical reports of marine debris distribution in the North Pacific (Mio et al., 1990), the GhostNet project targeted the Gulf of Alaska, the Southeastern Bering Sea, and the North Pacific Subtropical Convergence Zone (STCZ) north of Hawaii as areas that could benefit from at-sea detection and removal efforts. The Gulf of Alaska was the first region surveyed (in 2003), and served as the prototype for subsequent field programs in the North Pacific. The second and third field programs targeted the STCZ north of Hawaii in 2005 and 2008 and have been documented in Pichel et al. (2007) and McElwee and Morishege (2010), respectively. The Gulf of Alaska (GoA) pilot survey, documented herein, (1) provided information on marine debris in a region which has not been extensively surveyed, (2) served to develop and refine techniques for detection of possible convergent areas and for observing marine debris, and (3) provided practical experience concerning which satellite and aircraft sensors were the most useful for marine debris surveys. The techniques developed in the GoA field program are quite generally applicable for marine debris surveys in other ocean areas from the tropics to high latitudes.

The GoA field program consisted of a series of nine aircraft flight legs crossing portions of the GoA during the period July 20, 2003 to August 2, 2003. These flights were the culmination of 2 years of study of historical debris distribution, extensive project planning, development of a buoy system for marine debris tracking, aircraft remote sensing instrumentation testing, tailoring of an ocean geographic information system (GIS) for environmental analysis and debris tracking, analysis of historical and current satellite remote sensing data, and flight planning and preparation. This paper will (1) describe what was known historically of the distribution of marine debris in the GoA, (2) present satellite observations of likely debris convergence zones, (3) describe the aircraft survey, (4) detail the results of the survey flights and describe the debris that was found and its distribution, and (5) detail the lessons that were learned in this initial survey which paved the way for subsequent GhostNet surveys.

2. Methods

The following strategy was adopted for the marine debris surveys conducted by the GhostNet Project: (1) Locate general ocean areas of probable debris accumulation by researching historical studies, running circulation models and analyzing wind and current information to determine areas of convergence. (2) Track drifting buoys, either those already available or those deployed by GhostNet, to validate convergence, track actual nets at sea (i.e., those tagged with buoys), and determine local ocean circulation patterns. (3) Develop methods of analyzing co-located buoy, satellite, and meteorological data within a GIS environment to develop and refine the flight plan and help in the interpretation of survey results. (4) Observe identified areas of probable debris accumulation using satellite remote sensing imagery and measurements to observe ocean features indicative of convergent processes. (5) Test and refine sensor systems, observation strategies, and analysis/charting systems to determine an effective method of accurately observing and recording debris by aircraft survey. (6) Just prior to field debris surveys, consult weather and ocean forecasts and satellite wind and cloud data to verify that weather conditions are conducive to debris survey operations; i.e., cloud ceiling is higher than flight altitude, minimal sun glint, winds have been light (or at least less than 12 m/s) for the past 24 h, winds are forecast to be light (or at least less than 12 m/s) for the survey region during the survey times, waves are small to moderate (root-mean-square slope less than about 0.2 with few breaking waves), and there is sufficient illumination for visual observations (solar zenith angle less than 60 degrees). Determine the regions with the best viewing conditions and adjust the flight plan accordingly. (7) Fly manned instrumented aircraft over areas of ocean convergence with weather and ocean conditions conducive to aerial surveys, and observe and document individual debris objects and the general distribution of debris in the targeted areas. (8) Develop a system using a debris recovery ship and an unmanned aerial system (UAS) that could be used to cost-effectively locate and retrieve debris at sea on an operational basis.

The first 7 elements of the above strategy were followed for the GoA survey and are detailed below. Number 8 has been a focus for GhostNet development subsequent to the GoA survey, but was not an activity of the GoA survey.

2.1. Historical debris and oceanographic studies and drift model data

Activities within the current NOAA Marine Debris Program and the GhostNet Project to study marine debris distribution are recent efforts built on marine debris studies which have been underway sporadically for a number of decades. Some of these surveys were detailed in a series of marine debris conferences held in Hawaii in the 1980s (Shomura and Godfrey, 1990; Shomura and Yoshida, 1985). In the late 1980's, the Japanese Government conducted marine debris surveys of the North Pacific and Alaska waters (Mio et al., 1990). This was an extensive study of the North Pacific utilizing 32 vessels over a period of 2 years, surveying a total of 165,288 nautical miles. In 1987, 46,706 debris sightings were recorded with the distribution given in Table 1.

Debris density was high in coastal regions and in the region bounded by 25°N to 30°N latitude and 130°W to 170°W longitude. Unfortunately, the GoA was not well surveyed, so no firm conclusions can be drawn as to debris density there. Debris observations in the vicinity of the Aleutian Islands and in the Bering Sea were predominately floating seaweed. Dahlberg and Day (1985) found 10 objects in one transect of the Gulf of Alaska, predominately at 55°N (a transect length and width estimated by Ribic and Bledsoe (1990) to be approximately 1240.8 km long and 50 m wide). In a study of benthic debris in the waters around Kodiak Island, Alaska (Hess et al., 1999), marine debris obtained in 625 research bottom trawls during 1994–1996 were analyzed and summarized. Fishery-related items (most commonly plastic fishing line, bait jars and crab pots) made up between 38% and 46% of the total debris items recovered; however, more metal cans were recovered than any other type of debris. Debris densities within inlets and bays,

Table 1
Type of marine debris and percent of total debris observed by shipboard observers in the North Pacific during the year 1987.[a]

Description of object	Percent of total (%)
Fishing net debris	0.7
Other fishing gear	5.9
Styrofoam	14.0
Other plastic products	18.3
Drifting logs or lumber	7.9
Floating seaweed	42.7
Other (principally glass products and empty cans)	10.5

[a] Data for Table 1 taken from Mio et al. (1990).

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