Methodology for Debris Monitoring during At-sea Observation Programs in West Coast National Marine Sanctuaries

Peter Pyle, Michael Carver, and Lisa Etherington
Cordell Bank National Marine Sanctuary
Olema, California

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INTRODUCTION

To best protect the biological resources of West Coast National Marine Sanctuaries (WCNMS), information is needed on the diversity of vertebrate species that use associated waters, and how these species interact with each other, the planktonic environment, and the physical oceanographic parameters that characterize these waters. At-sea observational programs on birds and marine mammals currently provide a good source of data to obtain standardized density estimates by species, bioregion, and season. Many observational programs have been conducted from NOAA and other research vessels within WCNMS waters, often coincident with other marine investigative or sampling programs. Sampling has occurred both along standard transects developed specifically to collect observational data, and during passage between sampling stations for other purposes.

Recently, concern has been raised regarding the quantity of ocean debris in the Pacific Ocean and its detrimental effects on marine wildlife. For example, plastics ingested by albatross displace liquids needed for thermoregulation, resulting in dehydration and death (Aumon et al. 1997). Derelict fishing nets and gear entangles many species of wildlife, including endangered pinnipeds and birds (e.g., Hanni and Pyle 2000). Programs have subsequently been developed to survey and attempt to reduce the quantity of ocean debris (Ocean Conservancy 2007). To determine the effectiveness of these programs and to continue to assess the effects of ocean debris on wildlife, debris-monitoring programs are currently needed.

In 2004, Cordell Bank National Marine Sanctuary (CBNMS) started the Cordell Bank Ocean Monitoring Program (CBOMP) - an at-sea observational program initially developed to monitor marine birds and mammals as related to physical oceanographic parameters. In 2006, CBNMS received funding to develop protocols and implement at-sea monitoring of marine debris in conjunction with their on-going at-sea program CBOMP. Draft protocols for debris monitoring were developed and tested in 2006-2007 during CBOMP and off central California and during the *Stenella* Abundance Research (STAR) program operated by the Southwest Fisheries Science Center (SWFSC) in the eastern tropical Pacific. Methods were further tested during Gulf of the Farallones National Marine Sanctuary's at-sea program (Sanctuary Ecosystem Assessment Surveys (SEAS). This document provides final methodologies for debris monitoring during ocean observing programs, as based on refinement of original draft protocols following testing in the field.

GENERAL AT-SEA MONITORING

Survey Vessels and Observers

At-sea monitoring programs use vessels of various sizes as platforms. From one to four observers are stationed on the flying bridge to collect observational data on birds, marine mammals, and other organisms during daylight hours. Observations occur when a ship is underway and going at least 7 knots. Typically, a single observer is responsible for censusing birds, pinnipeds, turtles, fish, and invertebrates using strip-transect methodology in a 100- to 300-m strip on one side of the boat. A separate observer censuses cetaceans, boats, and perhaps albatross using either strip-transect methodology in a larger strip on both sides of the vessel (e.g., 1600-m strip, 800 m on each side) or using line-transect methodology. In addition, one to two observers record data (See Figure 1). The widths of strips used in strip-transect methodology are determined by the height of the vessel above sea level. In both the smaller and larger survey areas, each observation is further binned into 100-m strips (Fig. 1). With strip transect methodology, all observers usually assist each other in making observations; collective observation reduces biases associated with species identification, numbers observed, and distance estimation. Observers typically rotate after 2-hour shifts. See Pyle (2007) for more information on the use of strip and line transect methodology during observation programs in WCNMS waters.

Effort and Environmental Observations

Effort data recorded for each observation includes; cruise number, date and time (both local and Greenwich), position, sea state, visibility, ship's course, observation conditions (quality of observation code), observation side, and observer code. Date, position, ship course, and time data are often automatically entered into computer entry programs via a link to the ship's Global Positions System (GPS). Sea state is based on the single-digit Beaufort scale and visibility is the distance that can be assessed given environmental conditions. Four observation condition codes are typically used, equating to "poor," "fair," "good," and "excellent" conditions. These are quality assessments by the observer based on viewing conditions at the time and direction of observation, as affected by visibility, glare, sea state, swell size, cloud cover, and other variables. Many observational programs also record other weather and marine variables including wind direction, swell size, and cloud cover. These data can also be imported from buoy and other NOAA ocean-observation programs.

Vertebrate Observations

During strip-transect methodology, all vertebrates within the strip are recorded and assigned a behavioral code including direction of travel for transiting organisms. Each organism is placed into a 100-m strip within the area, according to distance of closest approach. Accurate distance estimation is prioritized. Range-finders (pencils) with lines indicating distances (e.g., 100, 200, 300, 400, 600, and 800 meters) for a given eye-height and reticular binoculars are used to estimate distance. Vertebrates and all other censused organisms are given a four-letter alpha code. Umbrella codes are used to record unidentified organisms.

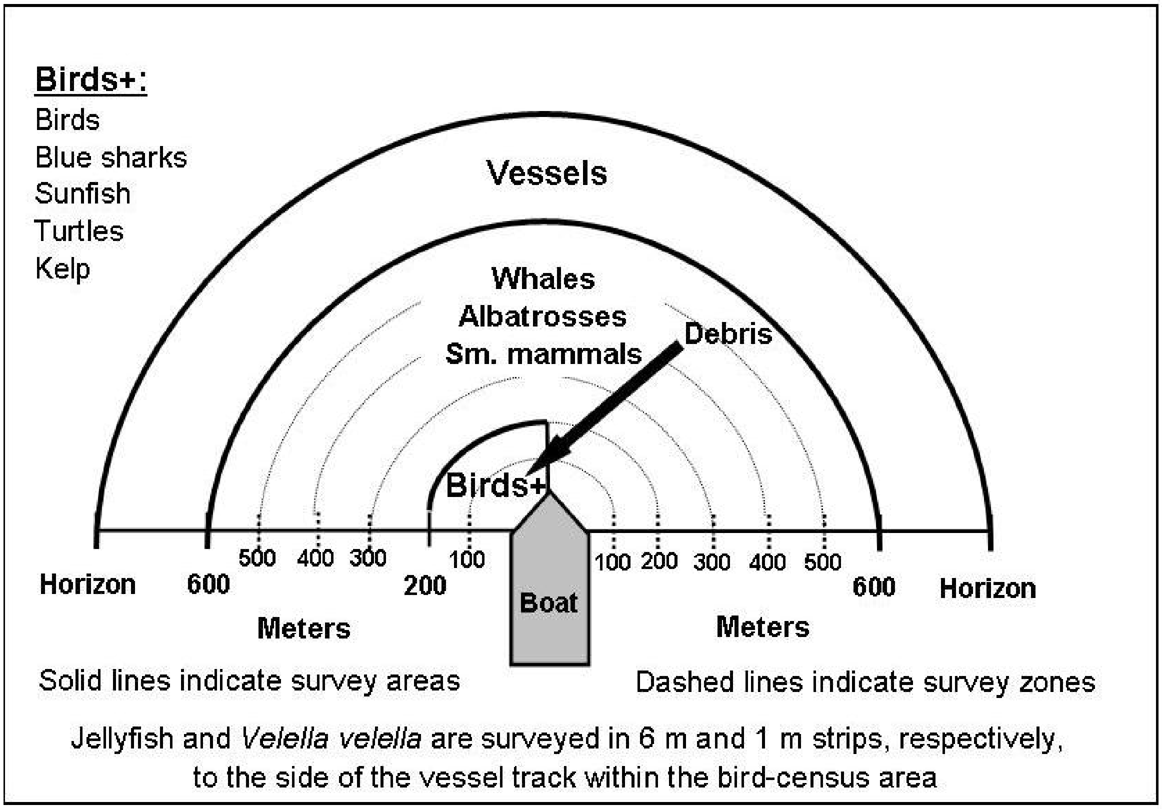

Figure 1. Survey areas and zones for recording birds, mammals, other organisms, debris, and boats, during the Cordell Bank Ocean Monitoring Program (CBOMP) using strip-transect methodology. For this program, most birds, pelagic fish, turtles, and most (smaller) debris items are sampled in a quartile-circular area (90° quadrant) to one side of the vessel; albatross, marine mammals and some (larger) debris items are sampled within 600 m in a semi-circular (180°) area in front of the vessel (resulting in a 1200-m strip); and boats are sampled to the horizon (hull visible at the water line) in front of the vessel. The bird and mammal areas are binned into 100-m zones. These distances were determined based on the height of the observers above the water, 3.8 m in this case. From survey heights $\geq$ 5 m it is recommended that the bird area-strip be 300 m and the mammal area-strip be 1600 m (800 m on both sides of the vessel).

MONITORING OF MARINE DEBRIS DURING OBSERVATIONAL PROGRAMS

Several documents have been produced that outline methods for assessing and monitoring debris, both on land and at sea (e.g., Ribic et al. 1992, Woodley 2002, UNESCO 2005, Ocean Conservancy 2007). Ribic et al. (2002) provides a comprehensive manual on marine debris survey techniques, including both beach and shipboard methods. In particular, these products have outlined categories for debris type and size. We built upon these established protocols to develop methods of assessing and monitoring floating debris within West Coast National Marine Sanctuaries as part of established, on-going at-sea monitoring programs.

Pre-existing ocean-observing programs have proven an effective and cost-efficient platform for the standardized monitoring of marine debris. Common strip widths for surveying floating debris are 50m and 100m; however the strip width used is dependent upon a particular study's objectives (Ribic et al. 1992). As most debris is small in size, it was determined that the most effective debris monitoring is performed using strip-transect methodology within the smaller (100- to 300-m) strips in which most birds are surveyed. Beyond 100 m, the only readily detectable items are larger, above-surface items, which can frequently be detected out to 300 m or greater. In areas of relatively high debris abundance, a 100-meter strip transect width is likely the maximum that can be effectively surveyed. We suggest that observations beyond 100m be grouped by 100-m bins so that the data can be truncated, if necessary, based on analyses of detectability. Larger debris can be monitored in larger strips (e.g., see Fig. 1), but most programs will probably find that the smaller strips are sufficient.

In areas of low-density of organisms and/or debris, a single observer assigned to monitor the smaller strip can effectively incorporate debris monitoring as one of their responsibilities. In areas of higher vertebrate and/or debris densities, a separate observer may be needed specifically for debris monitoring.

Categories and Codes for Debris

We used a data sheet developed by the Center for Marine Conservation for beach surveys (Ribic et al. 1992) as a template to develop categories of floating debris that would be likely to occur within the offshore environment, specifically along the west coast of the United States. These data sheets are used by multiple programs assessing debris on beaches (Woodley 2002, UNESCO 2005). From this document, we used the general debris categories of plastic, Styrofoam, glass, rubber, metal, paper, and wood, and then added the categories of organic, monofilament, and 'other'. Under each of these general categories, we included several types of specific debris. We developed four-letter codes for these debris categories (Table 1) in the same format as those used for biological observations. Sizes of debris were also defined.

Both anthropogenic and natural debris are classified into various types, recorded as four-letter codes in the same manner that birds and mammals are coded and recorded. Eleven general categories of debris and a total of 39 category/types of debris were identified, based roughly on those developed by the Center for Marine Conservation for beach clean up efforts (Ribic et al. 1992) and used by the UNESCO/Sandwatch program (UNESCO 2005) to assess debris on beaches (Table 1). Following the first season of field testing, it was determined that the codes developed for beach surveys were often too detailed for at-sea observations. Therefore, the codes were simplified to 11 general categories. These codes can also be used for unknown types of debris or when multiple types occur in abundances too large to record each item individually, as sometimes happens in the Eastern Tropical Pacific Ocean. Therefore, we are recommending that if conditions allow, debris should be coded to the highest level of detail, but recognize that broad categories of debris (e.g., plastic, glass, rubber, etc.) may be the only feasible option in many cases. Observers are encouraged to provide comments on all observations of other debris types not specifically categorized, or when abundances become too large to record items individually. Individual programs can come up with additional debris and other codes as appropriate, as long as the codes are well defined.

If conditions allow, additional information on size of debris should be recorded. The following size classes were taken from Ribic et al. (1992) and are generally based upon the size distribution of common items found on beaches. The upper limit of the small size class at 2.5 cm is based on the regulation that material released from ships be ground down to <2.5 cm.

Small – debris <2.5 cm (e.g., polystyrene pellets, fragmented plastic)
Medium – debris ≥ 2.5 cm and ≤ 10 cm (e.g., Styrofoam cups, bottle caps)
Large – debris > 10 cm and ≤1 m (e.g., balloons, crab pot floats, plastic bottles)
Extra Large – debris > 1 m (e.g., derelict fishing net, dock float, wooden pallet)

Data Entry and Analysis of Debris

Computer data-entry programs are currently used for most at-sea observation programs, with the *SeeBird/WinCruz* program developed by SWFSC being recommended for WCNMS observational programs. A notebook can be used if computer capabilities are not possible due to malfunction or high levels of activity during the survey. In all cases, debris items are recorded in the same manner as birds, mammals, and other organisms, using defined four-letter codes. Time, distance from observer, and size class should be recorded for each debris item or cluster of items. The *SeeBird/WinCruz* program has been set up to accept debris codes but to prompt observers if they enter an invalid code. Size class has yet to be been formally incorporated into this program (currently entered in comments section), but should be incorporated for an effective debris monitoring program.

Density of debris can then be calculated in the same manner as it is for birds and mammals, using sophisticated analytical programs already developed, that account for the effects of weather and observation conditions on densities of debris observed. Effective detection distances for each size class of debris can be calculated using data from the 100-m bins. An ultimate goal of the NMS program is to accumulate data from at-sea observation programs into a single database, from which maps, based on temporal and seasonal parameters within each NMS, can be developed and made available to sanctuary managers and the public. Densities of debris, by category, type, and overall, can easily be incorporated into this goal.

These methods of surveying marine debris can be applied to various objectives, including: 1) Identify types of floatable debris; 2) estimate densities of floating debris; 3) identify areas of low or high concentration of floating debris relative to other oceanographic features (e.g., currents, convergence zones); 4) relate floating debris to entanglement or other effects on animals; 5) detect temporal and spatial changes in the occurrence of floating debris (Ribic et al. 1992).

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Table 1. Categories and codes for debris

Debris Categories:
Size categories, based on longest dimension, are as follows:
Small: < 2.5 cm
Medium: ≥ 2.5 cm and< 10 cm
Large: ≥ 10 cm and < 1m
Extra Large: ≥ 1m
1) Organic (OROT – general code)
ORFI – Organic dead fish
ORBI – Organic dead bird
ORMA – Organic dead mammal
OROT – Other organic matter (not including kelp, jellyfish, or *Velella*; describe in comments)
2) Plastic (PLOT – general code)
PLFL – Plastic Float
PLBO – Plastic Bottle
PLSH – Plastic Sheet (including tarp)
PLST – Plastic Strap (including cargo straps)
PLBA – Plastic Bag
PLCL – Plastic cigarette lighter
PLOT – Other Plastic Item (describe in comments)
3) Wood (WOOT – general code)
WOLO – Wood log or branch
WOVE – Wood vegetation (land-based including eel grass, etc)
WOLU – Wood lumber or board
WOPA – Wood pallet or crate
WOOT- Other Wood item (describe in comments)
4) Monofilament (MOOT – general code)
MONE – Monofilament net (include all netting)
MOLI – Monofilament Line (include all ropes or tangles of ropes or fishing gear)
MOOT – Other monofilament item (describe in comments)
5) Glass (GLOT – general code)
GLBO – Glass bottle or jar
GLBU – Glass light bulb or fluorescent tube
GLFL – Glass fishing float (e.g., glass ball)
GLOT – Other glass item (describe in comments)
6) Rubber (RUOT – general code)
RUBA – Rubber balloon (includes all balloons)
RUME – Rubber medical or health item (including gloves, condoms)
RUTI – Rubber tire

RUOT - Other rubber item (describe in comments)
7) Metal (MEOT – general code)
MECA – Metal Can
MEDR – Metal drum (e.g., 55-gallon drum)
MEOT – Other metal item (describe in comments)
8) Styrofoam (STOT – general code)
STCO– Styrofoam food or beverage containers including cups
STFL – Styrofoam float
STPO – Styrofoam popcorn
STOT – Other Styrofoam Item (describe in comments)
9) Paper or cloth (PAOT – general code)
PASH – Paper sheet (including paper plate)
PACA – Cardboard or plasterboard
PAOT – Other paper or cardboard item (describe in comments)
10) Other, unidentifiable, or multiple items of different categories
DEOT – Other debris (describe in comments)