NOAA Marine Debris Shoreline Survey Field Guide

Sarah Opfer, Courtney Arthur, and Sherry Lippiatt

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Response and Restoration
Marine Debris Program

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This shoreline protocol was developed and tested by the NOAA Marine Debris Program. This document is a revised version of the August 2011 field guide, and should be treated as a draft protocol that may be altered in the future. Further testing is currently underway to develop a statistically robust survey design that will recommend the frequency of sampling, number of transects, and sampling unit size at site, location, and regional spatial scales.

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Introduction

Marine debris has become one of the most widespread pollution problems in the world's oceans and waterways today. The NOAA Marine Debris Program (MDP) serves as a centralized marine debris resource within NOAA, coordinating and supporting activities within NOAA and with other federal agencies. The MDP uses partnerships to support projects carried out by state and local agencies, tribes, non-governmental organizations, academia, and industry.

Marine debris monitoring programs are necessary to compare debris sources, amounts, locations, movement, and impacts across the US and internationally. Monitoring data can be used to evaluate the effectiveness of policies to mitigate debris and provide insight into priority targets for prevention. Thus, the NOAA MDP has developed standardized marine debris shoreline survey protocols to facilitate regional and site-specific comparisons. This document provides a standard data sheet and two different methods for shoreline monitoring and assessment.

Types of Shoreline Surveys

The objectives of your study will determine how you monitor for marine debris. There are two main types of shoreline surveys: accumulation and standing-stock surveys.

- Accumulation studies provide information on the rate of deposition (flux) of debris onto the shoreline. These studies are more suited to areas that have beach cleanups, as debris is removed from the entire length of shoreline during each site visit. This type of survey is more labor-intensive and is used to determine the rate of debris deposition (# of items per unit area, per unit time). Accumulation studies can also provide information about debris type and weight. These surveys cannot be used to measure the density of debris on the shoreline because removal of debris biases the amount of debris present during subsequent surveys.
- Standing-stock studies provide information on the amount and types of debris on the shoreline. Debris within discrete transects at the shoreline site is tallied during standing-stock surveys. This is a quick assessment of the total load of debris and is used to determine the density (# of items per unit area) of debris present. Debris density reflects the long-term balance between debris inputs and removal and is important to understanding the overall impact of debris.

Table 1. Salient characteristics of standing-stock and accumulation surveys.

CHARACTERISTIC	STANDING-STOCK	ACCUMULATION
Debris removed during surveys?	No	Yes
Time required per survey	Less	More
Length of shoreline site	100 m	100 m or longer
Is a set survey interval required (e.g., once per week or per month)?	Yes	Yes
Types of data that can be collected	• Debris density (# of items / unit area) • Debris material types	• Debris deposition rate (# of items / unit area / unit time) • Debris material types • Debris weight

We suggest that users give careful consideration to which type of survey best suits their goals and objectives. Table 1 provides important information to take into account when deciding how to monitor. Once a survey type is chosen, meaningful data can be collected through regular monitoring. The following sections describe how to choose survey sites and conduct surveys.

How to Pick Your Site

To select your sampling site(s), follow these steps:

1. The first step is to choose an appropriate shoreline location based on the objectives of your study. For example, if you wish to examine the impact of land use, you should select locations in watersheds with various land use types. Next, categorize the various areas within your location (it may help to use an aerial photo or map, as shown below). For example, your location may cover a span of shoreline 1 km long. Within that 1 km, there may be an area with heavy recreational use and another area where an urban stream mouth is located. Identify any barriers to shoreline access or offshore structures that may affect nearshore circulation (e.g. jetties).

2. Select shoreline sites (where you will sample) according to the characteristics below. If your location includes different use areas (for example, an area with heavy recreational use and a more remote area), it is preferable to select a site within each use category.

Shoreline sites should have the following characteristics:

- Sandy beach or pebble shoreline
- Clear, direct, year-round access
- No breakwaters or jetties
- At least 100 m in length parallel to the water (note that standing-stock surveys require a 100-m shoreline site)
- No regular cleanup activities

These characteristics should be met where possible, but can be modified.

Before You Begin Your Surveys

Before any data collection begins, the Shoreline Characterization Sheet should be completed for each shoreline site. On this data sheet you will note:

- GPS coordinates in decimal degrees at the beginning and end of your shoreline site, or at the site's four corners if the width of the beach is > 6 m;
- Shoreline characteristics (e.g. tidal range and substrate); and
- Surrounding land-use characteristics that may influence the delivery of land-based debris to the site (e.g., farmland 5 km from a small town or urban parkland 50 m from a river mouth).

The Shoreline Characterization Sheet needs to be completed only once per site per year unless major changes occur to the shoreline.

Shore IDs (on the Shoreline Characterization Sheet) should be created based on the initials of the shoreline name (e.g., Fort Smallwood = FS). This will make it easier to keep track of multiple sampling sites.

The Shoreline Characterization Sheet and Debris Density Data Sheet were adapted from Cheshire et al. (2009)[1].

You will need the following supplies in order to complete your surveys:

- Digital camera
- Hand-held GPS unit
- Extra batteries for GPS and camera (we recommend rechargeable batteries)
- Surveyor's measuring wheel - *for standing-stock surveys only*
- Flag markers or stakes
- ~100′ fiberglass measuring tape
- First aid kit (including sunscreen, bug spray, drinking water)
- Work gloves
- Sturdy 12″ ruler
- Clipboards for data sheets
- Data sheets (on waterproof paper)
- Pencils
- Trash bag or bucket - *for accumulation surveys only*

Safety is a priority. Do not touch or lift potentially hazardous or large, heavy items. Notify your local officials if such items are encountered.

All of the data collection forms you will need are included in Appendix A at the end of this document. The same data collection forms are used for accumulation and standing-stock surveys.

- Shoreline Characterization Sheet (pp. 8–9)
- Debris Density Data Sheet (pp. 10–12)

[1] Cheshire, A. C., E. Adler, et al. (2009). UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter, UNEP Regional Seas Intergovernmental Oceanographic Commission**:** 132 pp.

Accumulation Surveys

If you decide to conduct accumulation surveys, follow this protocol:

1. BEFORE arriving at the site, check local tide tables and plan to arrive at your site during low tide.

2. ONCE ARRIVED, begin filling out the Debris Density Data Sheet's Additional Information section. Mark the beginning and end of your shoreline site, perhaps with flags or stakes. (Remember to pick up these markers at the end of your survey to make sure they do not become marine debris!) The back of the shoreline is where the primary substrate (e.g., sand) changes (e.g., sand becomes gravel) or at the first barrier (e.g., vegetation line).

3. In order to cover the entire site from water's edge to the back of the shoreline, decide whether you will traverse the survey area parallel or perpendicular to the water. See Appendix B for walking pattern schematics. If more than one surveyor is available, the survey area should be divided evenly with clearly specified areas assigned to each individual. Surveyors should traverse the survey area in a pre-determined walking pattern until the entire site is cleared of marine debris.

4. Record on your Debris Density Data Sheet counts of debris items that measure over 2.5 cm, or 1 inch (~bottle cap size), in the **longest** dimension (see Figure 1). If any part of the item is within the survey area, count the item. Record large debris items, anything bigger than 1 foot (~ 0.3 m, typical forearm length from palm to elbow) in the large debris section of the Debris Density Data Sheet.

5. Take photos of your shoreline site and some of the debris items!

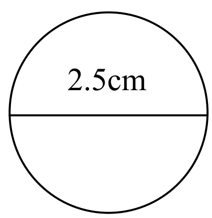


Figure 1. Minimum debris size to be counted. **This size is required to keep surveyors counting the same size items and to help keep the survey results uniform.*

Standing-stock Surveys

If you decide to conduct standing-stock surveys, follow this protocol:

1. Sketch your 100-m shoreline site and divide the 100 m into 5-m segments. There should be 20 of them. Number each section (left to right) from 1 to 20. Each 5-m segment should run from the water's edge to the back of the shoreline (Figure 2). The back of the shoreline is where the primary substrate (e.g., sand) changes (e.g., sand becomes gravel) or at the first barrier (e.g., vegetation line).

2. BEFORE arriving at the site, select four numbers from the Random Number Table (Appendix C) by first choosing a number between 1 and 5, and then a number between 1

and 4. The corresponding number in the table (1–20) is one of the four transects you will survey. Complete this exercise four times to choose four random transects (each transect can be used only once per survey). These numbers correspond to the 5-m segments you drew on your sketch and are called transect ID numbers (see Debris Density Data Sheet). You should fill out one Debris Density Data Sheet per transect. On any sampling day, 20 m of your 100-m shoreline site is analyzed (i.e., 20% coverage of the area). In addition, check local tide tables and plan to arrive at your site during low tide.

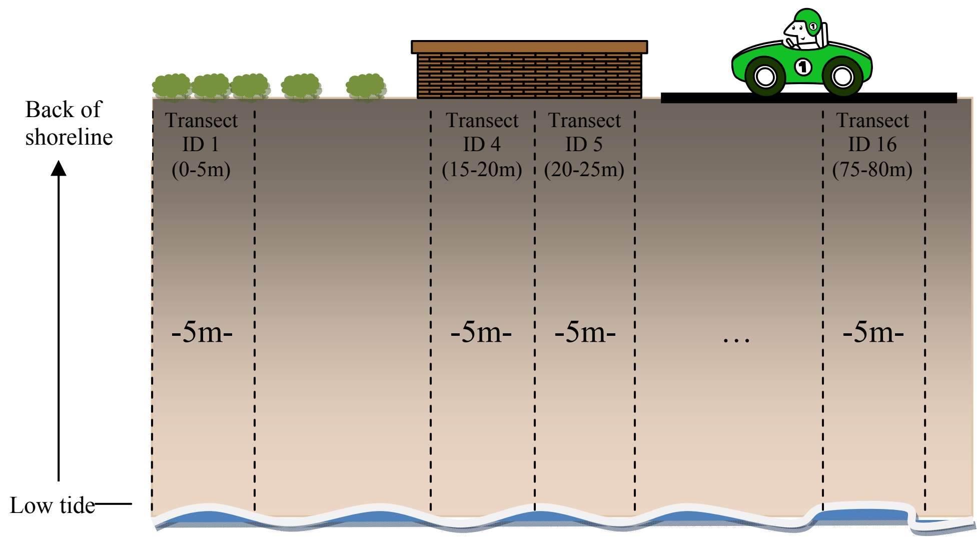


Figure 2. Shoreline section (100 m) displaying perpendicular transects from water's edge at low tide to the first barrier at the back of the shoreline section.

3. ONCE ARRIVED, begin filling out the Debris Density Data Sheet Additional Information section. Using your measuring wheel, begin at the start of your shoreline section and mark the four selected transect boundaries with flags according to the distances provided in the Transect ID table (for example, transect 12 covers 55 to 60 m from the start of your shoreline section).

4. Measure the width of each transect from water's edge to the back of the shoreline. Record GPS coordinates for each transect in decimal degree format. For shoreline segments that are less than 6 m wide from the water's edge to the back of the shoreline, GPS coordinates should be taken at the center (Figure 3). For shoreline segments that are over 6 m wide, take GPS coordinates at two spots—one nearer the back of the shoreline and one nearer the water.

5. Walking each transect from water's edge to the back of the shoreline, record on your Debris Density Data Sheet counts of debris items that measure over 2.5 cm, or 1 inch (~bottle cap size), in the **longest** dimension (see Figure 1). If any part of the item is within the sample transect, count the item. *Remember that for standing-stock surveys, debris is not removed from the shoreline.* Record large debris items, anything bigger than 1 foot (~ 0.3 m, typical forearm length from palm to elbow) in the large debris section of the Debris Density Data Sheet.

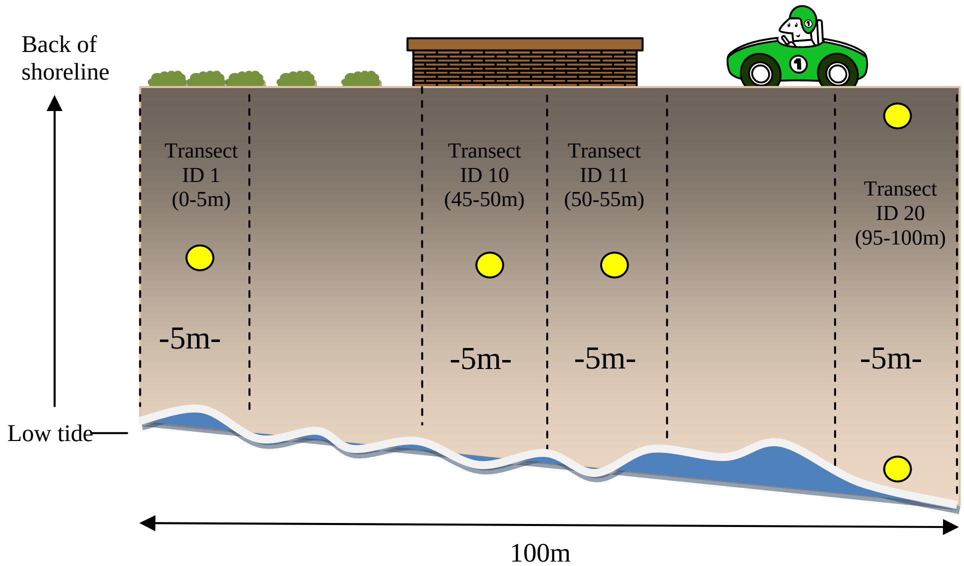


Figure 3. Example of a shoreline section (100m) with yellow circles indicating marked GPS coordinates. Width determines location of GPS coordinates.

6. Take photos of each transect and some of the debris items!

Submitting Your Shoreline Debris Data to NOAA

Marine debris monitoring groups should plan to compile and analyze their own survey results. The NOAA MDP will have periodic calls for data from monitoring groups. If you would like more information on data analysis or to be included in data calls, please send an email to MD.monitoring@noaa.gov.

Appendix A: Data Forms

SHORELINE DEBRIS **Shoreline Characterization Sheet**	Organization		Name of organization responsible for collecting the data
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form **ONCE** for each site location	Date		Date of this survey

SAMPLING AREA

Shore ID			Unique code for the shoreline
Shoreline name			Name by which the section of shoreline is known (e.g., beach name, park)
State/County			State and county where your site is located
Coordinates at start of shoreline section	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees) at start of shoreline section (in both corners if width > 6 meters)
Coordinates at end of shoreline section	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees) at end of shoreline section (in both corners if width > 6 meters)
Photo number/ID			The digital identification number(s) of photos taken of shoreline section

SHORELINE CHARACTERISTICS – from beginning of shoreline site

Length of sample area (should be 100 m if standing-stock survey)		Length measured along the midpoint of the shoreline (in meters)
Substratum type		For example, a sandy or gravel beach
Substrate uniformity		Percent coverage of the main substrate type (%)
Tidal range		Maximum & minimum vertical tidal range. Use tide chart (usually in feet).
Tidal distance		Horizontal distance (in meters) from low- to high-tide line. Measure on beach at low and high tides or estimate based on wrack lines.
Back of shoreline		Describe landward limit (e.g., vegetation, rock wall, cliff, dunes, parking lot)
Aspect		Direction you are facing when you look out at the water (e.g., northeast)

LAND-USE CHARACTERISTICS – within shoreline location

Location & major usage	Urban		Select one and indicate major usage (e.g., recreation, boat access, remote)
	Suburban		
	Rural		
Access			Vehicular (you can drive to your site), pedestrian (must walk), isolated (need a boat or plane)
Nearest town			Name of nearest town
Nearest town distance			Distance to nearest town (miles)
Nearest town direction			Direction to nearest town (cardinal direction)
Nearest river name			If applicable, name of nearest river or stream. If blank, assumed to mean no inputs nearby
Nearest river distance			Distance to nearest river/stream (km)
Nearest river direction			Direction to nearest river/stream (cardinal direction from site)
River/creek input to beach	YES	NO	Whether nearest river/stream has an outlet within this shoreline section
Pipe or drain input	YES	NO	If there is a storm drain or channelized outlet within shoreline section
Notes (including description, landmarks, fishing activity, etc.):			

SHORELINE DEBRIS **Debris Density Data Sheet**	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form during **EACH** survey or transect (if standing-stock) per site visit	Email address		Email contact for surveyor
	Date		Date of this survey

ADDITIONAL INFORMATION

Shoreline name			Name for section of shoreline (e.g., beach name, park)
Survey Type	Accumulation ☐	Standing-stock ☐	Type of shoreline survey conducted (check box)
Transect ID # (N/A if accumulation survey)			Transect ID (include shoreline ID, date, and transect #)
Coordinates of start of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at water's edge.
Coordinates of end of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at back of shoreline.
Width of beach			Width of beach at time of survey from water's edge to back of shoreline (meters)
Time start/end	Start	End	Time at the beginning and end of the survey
Season			Spring, summer, fall, winter, tropical wet, etc.
Date of last survey			Date on which the last survey was conducted
Storm activity			Describe significant storm activity within the previous week (date(s), high winds, etc.)
Current weather			Describe weather on sampling day, including wind speed and % cloud coverage
Number of persons			Number of persons conducting the survey
Large items	YES	NO	Did you note large items in the large debris section?
Photo ID #s			The digital identification number(s) of debris photos taken during this survey.

Notes: Evidence of cleanup, sampling issues, etc.

DEBRIS DATA: (continued on back)

ITEM	TALLY (e.g., ~~IIII~~)			TOTAL
PLASTIC				
Plastic fragments	Hard	Foamed	Film	
Food wrappers				
Beverage bottles				
Other jugs or containers				
Bottle or container caps				
Cigar tips				
Cigarettes				
Disposable cigarette lighters				
6-pack rings				
Bags				
Plastic rope/small net pieces				
Buoys & floats				
Fishing lures & line				
Cups (including polystyrene/foamed plastic)				
Plastic utensils				
Straws				
Balloons				
Personal care products				
Other:				
METAL				
Aluminum/tin cans				
Aerosol cans				
Metal fragments				
Other:				
GLASS				
Beverage bottles				
Jars				
Glass fragments				
Other:				

ITEM	TALLY (e.g., ~~IIII~~)	TOTAL
	RUBBER	
Flip-flops		
Gloves		
Tires		
Rubber fragments		
Other:		
	PROCESSED LUMBER	
Cardboard cartons		
Paper and cardboard		
Paper bags		
Lumber/building material		
Other:		
	CLOTH/FABRIC	
Clothing & shoes		
Gloves (non-rubber)		
Towels/rags		
Rope/net pieces (non-nylon)		
Fabric pieces		
Other:		
	OTHER/UNCLASSIFIABLE	

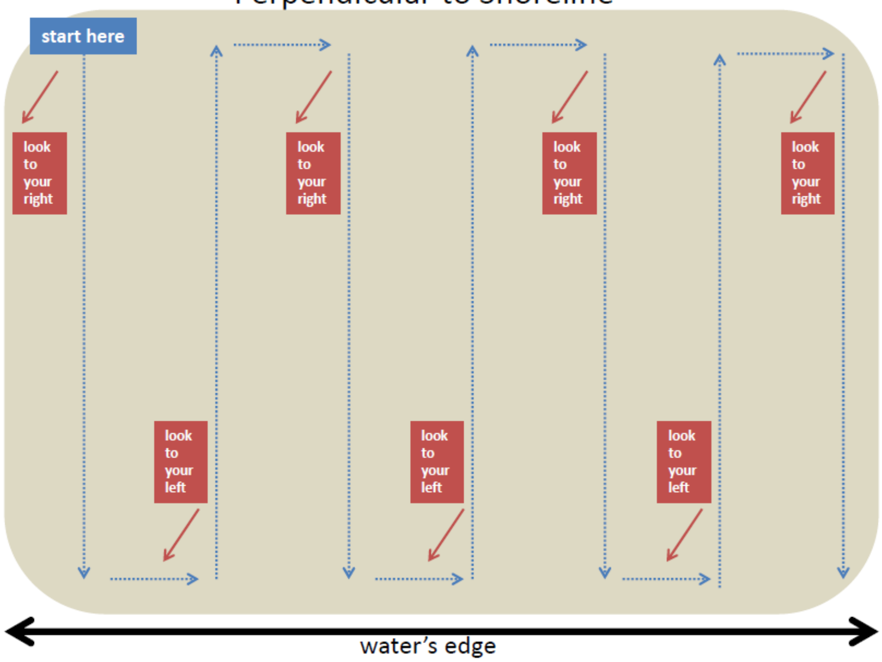
***LARGE DEBRIS ITEMS* (> 1 foot or ~ 0.3 m)**				
Item type (vessel, net, etc.)	Status (sunken, stranded, buried)	Approximate width (m)	Approximate length (m)	Description / photo ID #

Notes on debris items, description of "Other/unclassifiable" items, etc:

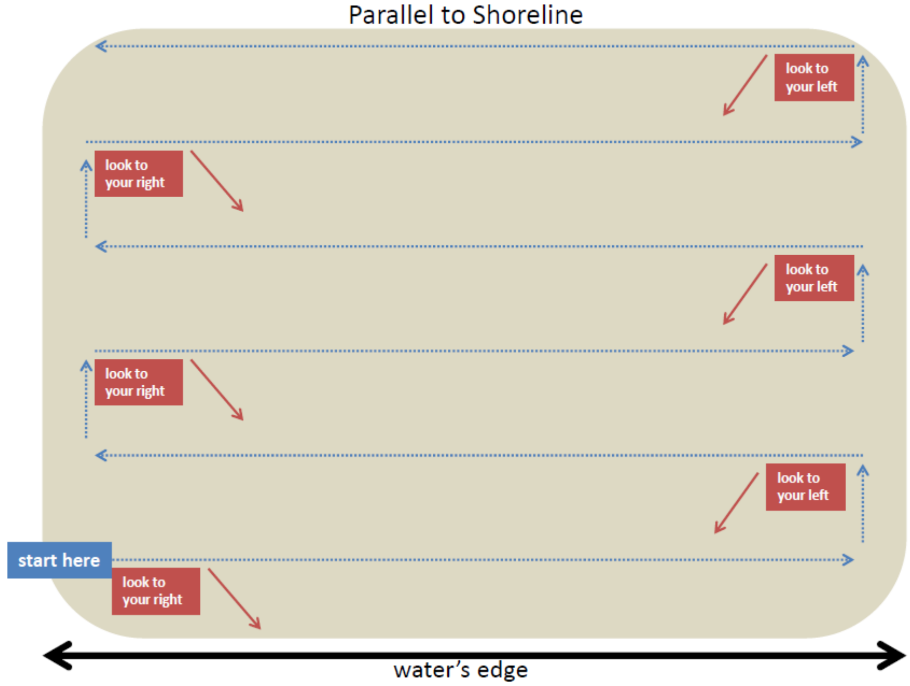
Appendix B: Shoreline Walking Patterns

The schematics below are potential survey walking patterns to ensure that the entire shoreline site or transect is covered. Suggested distance between walking lines is approximately one meter.

Walking Pattern #1:
Perpendicular to Shoreline



Walking Pattern #2
Parallel to Shoreline



APPENDIX C: RANDOM TRANSECT SELECTION

If you are conducting a standing-stock survey, use these tables to select transects. BEFORE arriving at the site, select four numbers from the Random Number Table, by first choosing a number between 1 and 5, and then a number between 1 and 4. The corresponding number in the table (1–20) is one of the four transects you will survey. Complete this exercise four times to choose four random transects (each transect can be used only once per survey).

Random Number Table

	1	2	3	4	5
1	4	8	17	9	1
2	7	19	2	12	20
3	18	14	6	16	11
4	3	5	15	10	13

Transect ID and distance along shore from start of 100-m shoreline section (see Figure 2 above)

Transect ID	Meters	Feet and inches
1	0–5 m	0–16' 4"
2	5–10 m	16'4"–32'9"
3	10–15 m	32'9"–49'2"
4	15–20 m	49'2"–65'7"
5	20–25 m	65'7"–82'
6	25–30 m	82'–98'5"
7	30–35 m	98'5"–114'9"
8	35–40 m	114'9"–131'2"
9	40–45 m	131'2"–147'7"
10	45–50 m	147'7"–164'
11	50–55 m	164'–180'5"
12	55–60 m	180'5"–196'10"
13	60–65 m	196'10"–213'3"
14	65–70 m	213'3"–229'7"
15	70–75 m	229'7"–246'
16	75–80 m	246'–262'5"
17	80–85 m	262'5"–278'10"
18	85–90 m	278'5"–295'3"
19	90–95 m	295'3"–311'8"
20	95–100 m	311'8" - 328'1"

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An analysis of marine debris in the US

Drawing on decades of experience in marine and coastal pollution research, Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) undertook a collaborative project with Ocean Conservancy (OC) and the National Oceanic and Atmospheric Administration Marine Debris Program (NOAA MDP) to better understand marine debris within the United States.

NOAA
Ocean Conservancy

How much marine debris is there on US shores?

We estimate there are somewhere between 20 million and 1.8 billion pieces of plastic along the coastline of the United States, with the number likely at the upper end of the range.

These estimates are based on data from the NOAA MDP Marine Debris Monitoring and Assessment Project (2009 - 2016), the OC's International Coastal Cleanup (ICC) data (2010 - 2015) and CSIRO's own assessment (2016).

There are a number of variables that affect the amount of debris found at a site. Some of these include the level of urbanization, land use type, back-shore vegetation, accessibility to the site, population density, socio-economic status, and inputs from local watersheds.

We included these variables in our statistical models to better understand the patterns in the data. We also incorporated additional variables to remove sampling bias.

Sampling bias can include: the number of people that carried out the survey, the size of the survey area, and how long people spend searching for debris. For example, surveys with six people participating may find more litter than surveys with four people, but this may not necessarily mean there is more litter at that site. Our standardization takes this information into account to get a 'true' representation of the amount of debris at each site.

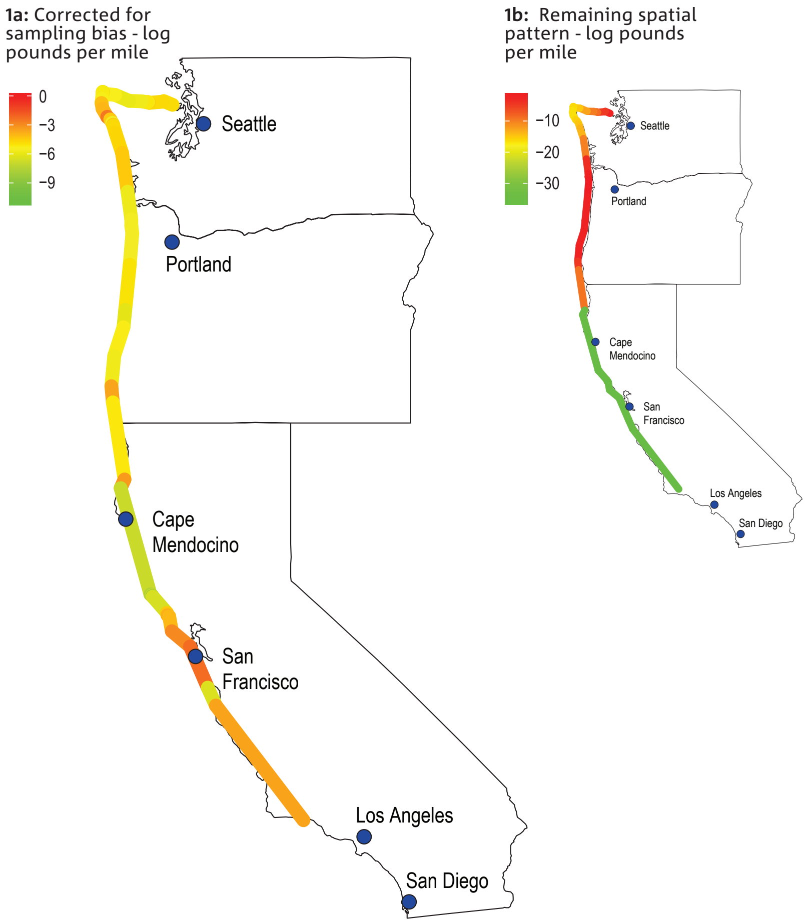
What do the data tell us?

Figure 1a (next page) shows the pattern of debris density data for the west coast, based on NOAA MDP's accumulation dataset and correcting for sampling bias.

We expected to find high debris loads near major urban centres, and indeed, San Francisco has significantly higher debris than less-populated regions such as Washington state and the northern coast of California.

To determine what debris patterns would look like without the influence of large population centers and other drivers (e.g. land use, socio-economic status), we incorporated these variables into our modelling. We see the leftover spatial pattern in the data in the ribbon plot in Figure 1b. Areas to the north of Cape Mendocino have noticeably higher debris loads, while in most areas south of the California/ Oregon border we see relatively low debris loads.

The California Current is the dominant ocean current system, and moves north to south along the west coast of the United States. Interestingly, the sites with less debris than expected (south of Cape Mendocino), have a slightly south-westerly orientation, while the coastline with higher loads (north of Cape Mendocino) has a north-westerly orientation. Given the strong component of northerly winds on the west coast, these differences could be influenced by onshore transport driven by both the coastal orientation and wind direction.



Figures 1a and 1b: Shoreline debris load based on NOAA MDP accumulation data. The ribbon on the left shows the relative amount of debris after accounting for sampling bias, while the ribbon on the right shows the remaining levels of debris after accounting for sampling bias, population density and other drivers, possibly indicating a greater offshore component to the debris north of Cape Mendocino.

Where are the national hot spots?

The International Coastal Clean-up (ICC) (Figure 2 below) shows us that Texas, Idaho, Illinois and many of the urbanized mid-Atlantic states stand out as having particularly high debris loads, along with several states on the Gulf coast.

In some states, such as Texas, this is driven by the coastal portion of the state. In other cases, there is a significant contribution from inland waterways and lakes.

The coastal current in the Gulf of Mexico may move material from the US Gulf coast south-westerly along the coast and onto the Texas coastline.

These marine debris transport explanations could be a good focus of future investigation.

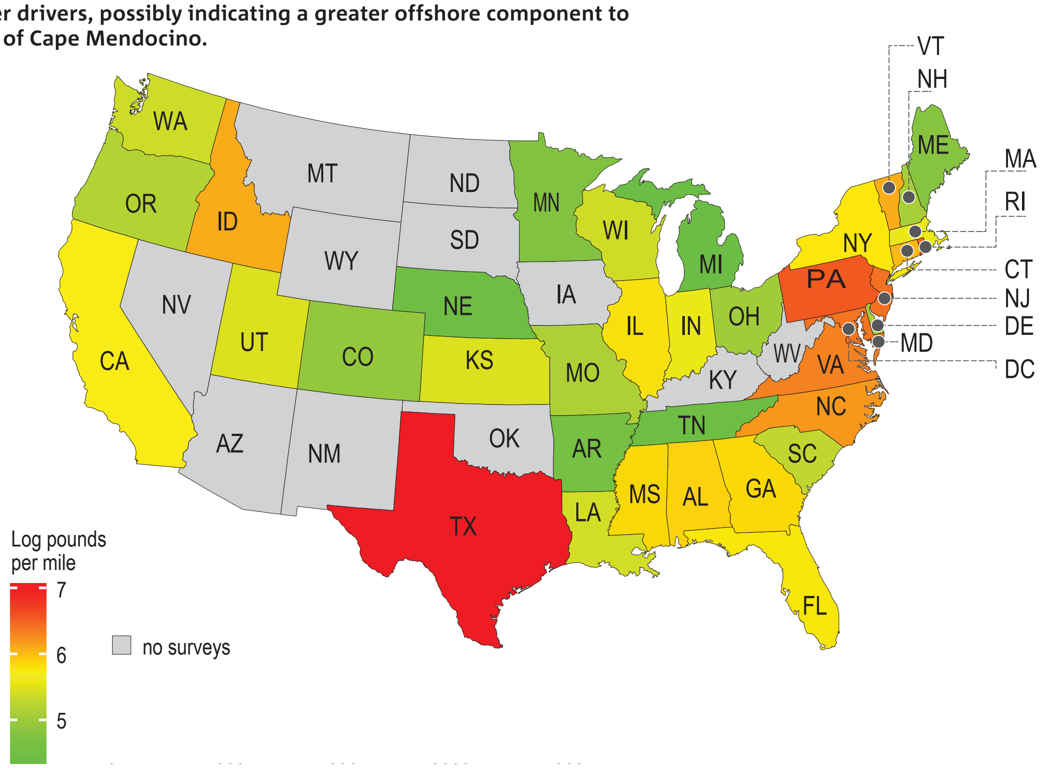


Figure 2: Statewide debris load based on ICC data after correcting for sampling bias. Values represent the average weight of debris per mile for all debris surveys across each state

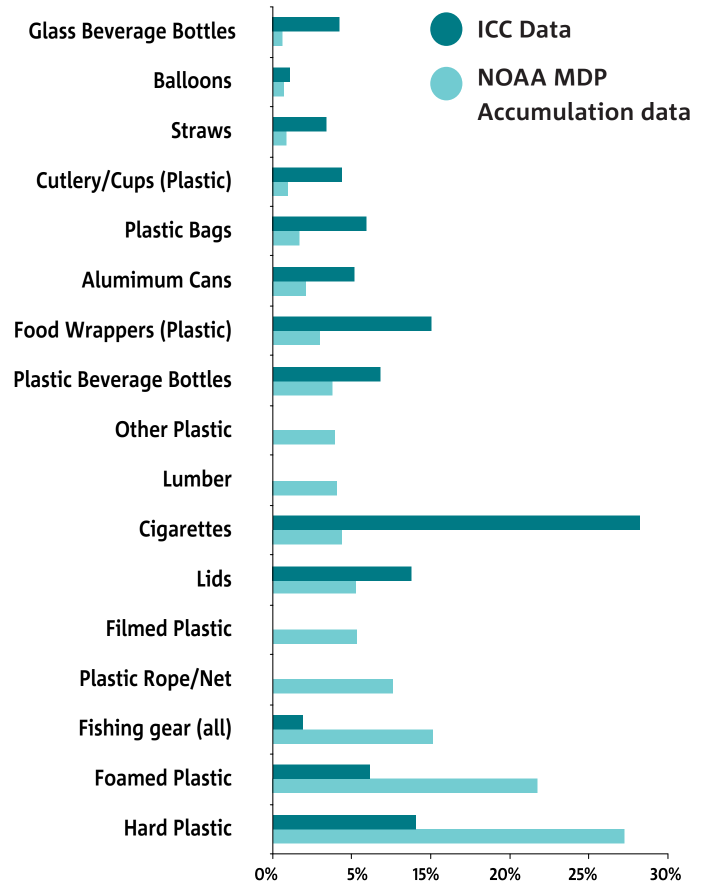
Which items were most abundant?

Using the NOAA MDP Accumulation and ICC data, we calculated the most common items in each survey.

Cigarette butts, food wrappers, plastic beverage bottles, and lids are all very common items in both the NOAA MDP and ICC datasets. However, there are distinct differences in relative abundance, with cigarette butts reaching nearly 25% of all items in the ICC data, while they are only 6% in the NOAA MDP data. The most abundant items in the NOAA MDP data set are fragments of hard plastic, filmed plastic, foamed plastic and plastic rope.

Why the NOAA MDP and ICC results do not match

There are a number of differences in how surveys are carried out including where data are collected (sample site), survey protocol, and survey effort (number of people participating and how much of an area is surveyed).



Which items pose the most risk to wildlife?

Based on recent CSIRO and OC research, fishing gear, plastic bags, balloons, plastic beverage bottles, and cigarette butts were most harmful to sea birds, marine mammals, and turtles.

In this study we found that fishing gear was particularly common on the coast of Texas, the northern Atlantic, southern Florida and the northern part of the Pacific.

We found balloon litter was fairly constant across the whole of the continent.

Cigarette butts were relatively high along the coastal eastern US, and the southern and northern ends of the US west coast.

Plastic bags were relatively common across the country, but we found the most in Texas and southern California.

The greater number of litter icons displayed, the higher the occurrence of that litter, except for beverage containers and balloons which were found across the continent.

Ballons were found across the continent.

Beverage containers made up a smaller percentage of debris collected in states that had Container Deposit Legislation (CDL) (see next page).

How effective is legislation?

Do bottle bills work?

Based on NOAA MDP's data, beverage containers made up a smaller percentage of the debris collected in states that had Container Deposit Legislation (CDL) – California, Hawaii and Oregon – compared to states that do not provide a cash incentive for recovery of beverage containers – Alaska, Virginia and Washington.

Maybe people in certain states are thirstier?

We also calculated the ratio of lids to containers. Many beverage containers (with the exception of aluminum cans) are produced with lids, so this means that both lids and containers are able to enter the waste stream. CDL is based on returning containers, not lids, so the ratio of lids to containers left behind can also shed light on the effectiveness of container deposit legislation.

Overall, our findings provide very strong evidence that CDL reduces the chance of beverage containers becoming marine debris.

PROPORTION OF CONTAINERS

PROPORTION OF LIDS

States without CDL   States with CDL

Understanding the different sampling methods

NOAA MDP implements a comprehensive sampling regime across a relatively small set of representative beaches, at regular time intervals. Trained volunteers collect trash and quantify the debris type per unit area.

In contrast, OC's International Coastal Cleanup is an annual citizen science event held at thousands of sites each year (typically in September). People with no formal training clean up an area of shoreline over the course of a 1.5-2 hour community participation event and count individual items of trash collected.

CSIRO's approach differs again, focusing on stratified designed surveys conducted by trained professionals at sites selected by a random sampling design.

While it is possible to use data from any of these monitoring programs to understand debris baselines, drivers, and changes, combining them was a challenge.

Surveys using CSIRO's method found much higher debris densities. One major difference is that CSIRO surveys include items as small as 1-2mm where as NOAA MDP and OC do not record any items smaller than an inch (25mm).

The differences between the data sets at shared locations suggest that thorough survey design is important to reduce variability among survey approaches and locations.

This balance is key for engaging participants, but implies some compromises from a survey design and data quality perspective.

Due to the large area of the United States, finding a balance between rigorous scientific research and citizen science participation is key.

Recommendations and next steps

1. **DEVELOP A NATIONAL BASE-LINE**
   A survey incorporating recommendations presented by CSIRO would require relatively little time and cost, and would provide a useful baseline on which to build.

2. **CONTINUING COASTAL CLEAN-UPS**
   Although it is time consuming to compile data on types of items collected during volunteer clean-ups, these data provide a rich source of information. Volunteer data helped us identify the effectiveness of policies, hotspots for items that have a large impact on wildlife, and areas to prioritize engagement with industry and consumers. Clarifying some potential biases, such as how sites are chosen, and how volunteers search during a clean-up will significantly improve the value of volunteer efforts.

3. **INVESTIGATE THE CAUSES OF MARINE DEBRIS**
   Socioeconomics, site accessibility, population density, and other factors affect local marine debris loads. Further analysis would provide useful information for both understanding how these factors influence debris loads on the coast and inland waterways, as well as targeting specific actions such as clean-ups, outreach, incentives, and regulation.

4. **UNDERSTANDING THE LINKS BETWEEN LAND-BASED ACTIVITIES AND MARINE DEBRIS**
   Most marine debris originates from land-based litter. By combining the available coastal data with our knowledge of how debris is transported on land, we can gain a better picture of the important processes and possible intervention points before litter becomes marine debris.

5. **ESTABLISH A NATIONAL MONITORING PROGRAM**
   Designing a national monitoring system would allow NOAA MDP to periodically re-survey the coastal US for debris, with a clear idea of the likely person-hours required, the expected data structure and sampling design. This would be supported by a pre-existing analytical design and data management system. This approach would deliver cost-effective monitoring and result in an interpretable data set, despite potentially using different providers over time.

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Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment

NOAA Marine Debris Program
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Technical Memorandum NOS-OR&R-46
November 2013

Photo taken by U.S. National Park Service, Kenai Fjords National Park

Marine Debris Monitoring and Assessment

Recommendations for Monitoring Debris Trends in the Marine Environment

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Contents

EXECUTIVE SUMMARY

Marine debris is defined by the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard (USCG) 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 (33 USC 1951 et seq. as amended by Title VI of Public Law 112-213). Marine debris has become one of the most recognized pollution problems in the world's oceans and waterways today.

In recent years, research efforts have significantly increased knowledge of the topic of marine debris. However, the field as a whole has not adopted standardized monitoring procedures or debris item categories. Standard methodology and reporting is necessary in order to compare marine debris source, abundance, distribution, movement, and impact data on regional, national, and global scales.

The NOAA Marine Debris Program (MDP) has developed standardized, statistically valid methodologies for conducting rapid assessments of the debris material type and quantity present in a monitored location. The monitoring guidelines in this document focus on abundance, types, and concentration rather than analyzing by potential source, as in many cases it is very difficult to connect a debris item to a specific debris-generating activity. These techniques are intended to be widely applicable to enable comparisons across regional and global scales.

This document includes guidelines for estimating debris concentrations on shorelines, in surface waters, during visual surveys at sea, and in the benthos. Background information is provided for each environmental compartment (i.e., shorelines, surface waters, and the seafloor), in addition to guidelines for survey design, required equipment, the survey techniques, and study implementation considerations. The appendices include a brief literature review for each compartment, survey data sheets, a debris item photo guide, frequently asked questions for shoreline surveys, and a summary of work completed by Versar, Inc. to test the methodologies.

The techniques described in this document were developed over the course of a number of years, based on a review of the literature, discussions with experts, and field testing by the MDP and contractors. For shoreline monitoring, the MDP benefited from feedback from partner organizations who implemented these methods prior to the official publication of these guidelines.

The guidelines in this document are intended for use by managers, researchers, citizen scientists, and other groups conducting marine debris survey and assessment activities, especially those requiring a rapid assessment. Monitoring and assessment of marine debris is essential to understanding the problem and being able to mitigate, prioritize, and prevent the most severe impacts. The effort to develop this document was rooted in the need to standardize methodologies and facilitate comparisons across time, space, and environmental compartments. These guidelines are provided to the marine debris community at large in order to guide the development of integrated monitoring programs nationwide.

1.0 INTRODUCTION

Marine debris, in some form, has been addressed by NOAA since the early 1980s and officially recognized as a problem by the federal government since the passing of the Marine Plastic Pollution Research and Control Act (MPPRCA) in 1987 (Public Law 100-220, Title II). This legislation was one of the first to provide research prioritization and authorize federal funding for marine debris in the United States. The NOAA Marine Debris Program (MDP) was initiated as a program in 2005 within the National Ocean Service's Office of Response and Restoration and was legally established by the Marine Debris Act (33 U.S.C. 1951 et seq., as amended by Title VI of Public Law 112-213). The act provides specific mandates to the program including mapping, identification, impact assessments, removal and prevention activities, research and development of alternatives to gear posing threats to the marine environment, and outreach activities.

Standardized marine debris monitoring and assessment can be used to evaluate the effectiveness of policies to mitigate debris, such as recycling incentives or extended producer responsibility measures, and provide insight into priority targets for prevention and mitigation (NRC 2008). For example, in the Gulf of Alaska, the NOAA Alaska Fisheries Science Center conducted shoreline monitoring prior to and following the implementation of the International Convention for the Prevention of Pollution from Ships (MARPOL); results indicated a significant decrease in the abundance of derelict fishing gear debris, in the form of nets from ships (Maselko and Johnson, 2011). Similarly, debris monitoring in Washington DC and other areas with recently-enacted policies on single-use shopping bags are indicating fewer plastic bags in rivers and in riverine "trash traps" (e.g., Anacostia Watershed Society, unpublished data).

The complicated nature of the distribution of marine debris in the environment calls for a clear and defined approach to characterizing and assessing the problem. Marine debris enters the marine environment through many pathways, and the extensive size of the ocean, patchiness in the distribution of debris, and spatial and temporal variability in the drivers of debris add to the complex life cycle of marine debris (Ryan et al., 2009, Cole et al., 2011, Doyle et al., 2011). This document updates and expands upon marine debris assessment guidelines developed by the NOAA Marine Entanglement Research Program in 1992 (Ribic et al., 1992). The guidelines outlined here incorporate modern technologies and sampling equipment and focus on standardization of data and reporting for a statistically robust analysis which can address all types of debris. Guidelines are included for estimating debris concentration on shorelines, in surface waters, during visual surveys at sea, and in benthic surveys. The shoreline survey technique described here is available in a user-friendly version in the *NOAA Shoreline Survey Field Guide* (Opfer et al., 2012).

1.1 Objectives and Method Development

The guidelines in this document are intended to serve as a basis for nationwide monitoring and assessment of marine debris, and were designed with four main objectives in mind:

- Estimate the quantity of debris at local and regional levels according to land use or other correlating parameter
- Determine types and concentration of debris present by material category (plastic, metal, glass, rubber, paper/processed lumber, cloth/fabric, other)
- Examine the spatial distribution and variability of debris
- Investigate temporal trends in debris types and concentration

This report includes guidelines for four survey techniques developed and/or modified by the MDP:

- Shoreline techniques: Guidance for assessing debris concentration on shoreline segments, including both macro- (> 2.5 cm) and meso-debris (5 mm–2.5 cm)
- Surface water techniques: Guidance for assessing floating debris concentration, including macro-debris (>2.5 cm), meso-debris (5mm–2.5cm) and micro-debris (≤ 5 mm in length)
- At-sea visual techniques: Guidance for conducting ship-based visual surveys of floating macro-debris (> 5cm or 2 in)
- Benthic techniques: Guidance for evaluating debris concentration on the seafloor

The methods detailed in this report take into consideration lessons learned from studies listed in Section 7.1. Additionally, shoreline methods were developed with input from an established advisory group. The advisory group consisted of established researchers in the debris monitoring field, other federal agencies involved in marine debris efforts, and internal NOAA MDP staff (Section 7.2).

The techniques for shorelines, surface waters, and at-sea visual surveys were tested and refined by NOAA MDP staff during a pilot project in summer and fall 2009 - 2010 in the Chesapeake Bay (Arthur et al., 2011). In 2011, the refined techniques were used during monthly surveys in various tributaries of the northern Chesapeake Bay to test the hypothesis that debris concentration is correlated with land-use (Lippiatt et al., 2012). Additionally, rigorous bi-weekly shoreline and surface water sampling completed by Versar, Inc. from July through December 2011 at two sites in the mid-Atlantic informed statistical considerations described in Sections 2.0 and 3.0 of this document. The shoreline technique was also extensively used and tested by regional and local groups along the U.S. west coast, Alaska, and Hawaii to monitor for the arrival of marine debris generated by the 2011 Japanese tsunami.

In 2009, the United Nations Environment Program (UNEP) published a debris assessment framework with the major goal of management and integration of debris monitoring activities across broad geographic regions (Cheshire et al., 2009). The UNEP framework includes a set of survey methods for beach, benthic, and floating debris assessment based on existing techniques used in the Oslo and Paris Convention for the Protection of the Marine Environment of the

North-East Atlantic (OSPAR), the Northwest Pacific Action Plan (NOWPAP), Australian Marine Debris Status (AMDS), and the National Marine Debris Monitoring Program (NMDMP) (Cheshire et al., 2009). The approach taken in this document is modeled after UNEP's framework with a few key differences: NOAA techniques focus on item count and concentration (in units that count debris items per square meter of shoreline, # items/m^2) rather than both count and weight information; NOAA shoreline survey techniques focus on assessment of debris standing-stock rather than flux rate (however, the NOAA shoreline survey can be adapted for accumulation surveys, see discussion in section 2.0, below); and the debris classification systems vary between the two methods.

The application of these guidelines to discrete studies will be most informative when study design and site selection address clearly stated objectives.

1.2 Debris Classification

Although previously published guidelines have focused on documenting the primary source of debris (e.g., Sheavly, 2007), the methods described here emphasize material type.

Debris source information is an excellent educational tool, however many debris items are difficult to identify as either land- vs. sea-based or industrial- vs. consumer-based debris. The source of a piece of debris found in the open ocean cannot necessarily be attributed to the manufacturing origin or country of consumption. Even when the debris has markings that can be used to identify where it was produced, the exact point of loss to the environment is unknown. Original sources of floating marine debris in the oceans can be difficult to identify, given the persistence and potential for long-range transport of lightweight buoyant materials (Ryan et al., 2009).This makes it difficult to evaluate controls on the land- or ocean-based sources of marine debris. Guidelines in this document take a tiered approach whereby every piece of debris is recorded according to material category and then by specific item or product (as recommended in Ribic et al., 1992). The material categories included are plastic, metal, glass, rubber, paper/processed lumber, cloth/fabric, and other or non-classifiable debris. There is also the allowance of "other" items that are locally important and may not be currently listed on the data sheets. Further, these items can be catalogued and tracked in the www.md-map.net online database (see Section 2.6). In this way, these guidelines allow for regional customization of important debris items. Information on debris source can be obtained during data analysis if indicator items are identified (e.g., plastic fishing floats are assumed to be sea-based debris). Furthermore, this approach enables analysis of variability in the composition and quantity of debris over time and space. The NMDMP effort (described in further detail in section 2.0), which collected information on specific indicator items, was designed to evaluate debris trends on a regional scale and was not suitable to local-scale assessments of spatial and temporal variability in debris types and quantities (Sheavly, 2007, NRC 2008, Ribic et al., 2010, Sheavly, 2010, Ribic et al., 2011, Ribic et al., 2012).

The methods described here do not include debris weight information. Debris weight can be challenging to measure and dependent on water content; reporting in units of debris counts (e.g.,

#items/m^2 of shoreline or #items/m^3 of water) provides more reliable and consistent data and techniques that are more accessible to organizations that may not have means of accurately weighing debris. Other programs that are not meant to be part of a rapid response technique or wish to factor in how physical properties such as weight, density, and form affect debris hydrodynamics and fate, may want to collect weight data.

Debris items encountered during these surveys is differentiated based on size class. Both the shoreline and surface water sampling strategies distinguish between large (>30cm) and small debris items (<30cm). Large debris items have a larger surface area and therefore have a greater potential to disturb valuable habitat. Additionally, large debris items may be less mobile in the environment and may be encountered more than once in reoccurring surveys. Having a record and location of these items will limit the potential errors in duplication. Figure 1, below, indicates the debris size ranges sampled by the techniques described here.

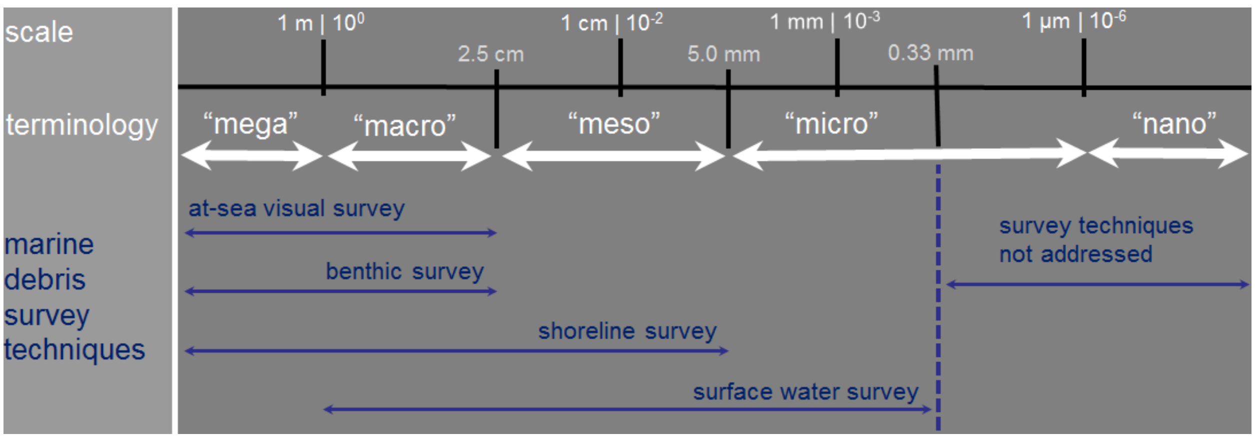

Figure 1. Size ranges sampled by the techniques suggested in this document.

1.3 Safety

Safety should be the number one priority during any survey activity. Because this work is carried out in the field, there are inherent hazards associated with these techniques. Use caution and follow general safety guidelines. The safety tips below are provided as general guidance, but it is imperative that project leads understand all risks associated with survey activities, always use caution, and conduct an operational risk assessment for the specific marine debris survey activity and location. Operational risk assessments should include resources (e.g., equipment, boats, communication, support, personal protective equipment), environmental hazards or considerations (e.g., remoteness, surf zones), personnel (experience, training, physical and mental fitness), weather, and mission complexity.

- Follow the buddy system when conducting shoreline surveys and other field operations.
- Let someone know where you are and when you expect to return.
- Carry a means of communication for emergencies, for example a cell phone or radio. If there is no reception use a GPS emergency responder or personal locator beacon.

- Always carry a first aid kit. The kit should include an emergency water supply and sunscreen, as well as bug spray.
- Understand the symptoms of heat stress and actions to treat it. For more information, see the OSHA website (https://www.osha.gov/SLTC/heatstress/heat_illnesses.html). Make sure to carry enough water.
- Be prepared for the weather and tides. Do not conduct field operations in severe weather and when tides could impede the survey area or block an access route.
- Wear appropriate clothing. Be sure to wear close-toed shoes and gloves when handling any non-hazardous debris as there may be sharp edges.
- Be aware of your surroundings and be mindful of trip and fall hazards.
- While on a vessel, always wear your life jacket and make sure it fits correctly.
- Large, heavy objects should be left in place. Do not attempt to lift heavy debris objects as they may have additional water weight and lifting them could result in injury.
- If you are conducting surveys in the United States and you come across a potentially hazardous material (e.g., oil or chemical drums, gas cans, propane tanks), contact local authorities (a 911 call), a state emergency response or environmental health agency, and the National Response Center at (1-800-424-8802) to report the item with as much information as possible. Do not touch the material or attempt to move it.
- When in doubt, don't pick it up! If unsure of an item, do not touch it. If the item is potentially hazardous, report it to the appropriate authorities.

2.0 SHORELINE METHODS

Marine debris monitoring on shorelines has become an increasingly common undertaking for academic, government, and environmental organizations. Shoreline surveys are usually more accessible, inexpensive, and straight-forward than monitoring in other environmental compartments. Often the highest debris concentrations are found on shorelines, which facilitates data analysis and trend assessment.

In addition to lessons learned from the studies listed in Section 7.1 and described below, these methods were developed with input from an established advisory group. The advisory group consisted of researchers in the debris monitoring field, other federal agencies involved in marine debris efforts, and NOAA MDP staff (Section 7.2). Data sheets modified here (Section 7.5) were adapted from UNEP and the Intergovernmental Oceanographic Commission (UNEP/IOC) debris monitoring guidelines (Cheshire et al., 2009).

2.1 Debris Assessment Methods

Numerous marine debris monitoring programs exist throughout the world. Most programs have unique objectives and employ a variety of region-specific methodologies, making across the board comparisons of debris estimates difficult (e.g., Barnes et al., 2009). For shorelines, some studies report number (or weight) of debris items per unit length of shoreline (e.g., Bowman et al., 1998, Barnes and Milner, 2005) or strandline (e.g., Velander and Mocogoni, 1999) while others report number (or weight) of items per unit area of shoreline (e.g., Acha et al., 2003).

In addition to the NOAA Marine Entanglement Research Program guidelines mentioned above (Ribic et al., 1992), lessons learned from previous marine debris monitoring efforts were considered during development of these guidelines. One key long-term, large scale monitoring program, the National Marine Debris Monitoring Program (NMDMP), was developed by an interagency working group consisting of the U.S. Environmental Protection Agency, NOAA, National Park Service, and United States Coast Guard following the ratification of MARPOL Annex V and the passage of the MPPRCA. NMDMP was designed to assess the magnitude of the marine debris problem in the U.S. and evaluate any regional or temporal trends according to a statistically valid design and sampling plan (Escardó-Boomsa et al., 1995). The NMDMP study, which consisted of monthly surveys conducted by trained volunteers at randomly selected sites along the U.S. coastline, used indicator items to identify the major sources of debris (Sheavly, 2007). Monitoring occurred from 1996 to 2006 and an analysis of data from a five year time period (2001 – 2006) is provided in Sheavly (2007). The five year analysis showed no statistical change in the prevalence of the indicator items for the nation as a whole (regional data analyses are found in Ribic et al. (2010), Ribic et al. (2011), and Ribic et al. (2012)).

This NOAA shoreline survey technique is designed as a rapid, quantitative beach assessment for collection of standardized and consistent data that can be applied to address policy and management needs at various spatial scales. The UNEP framework mentioned above (Cheshire et al., 2009) provides two different beach survey techniques – comprehensive and rapid beach assessments. This NOAA shoreline technique is designed to be useable by trained community volunteer organizations while simultaneously providing data that can be used to address key management questions. Table 1 provides a comparison of the two survey techniques.

	UNEP	NOAA
Removal of shoreline debris?	Yes	No/Yes*
Report item count or weight?	Both	Count only
Shoreline site length	100 – 1000 m	100 m sections
Site characterization included?	Yes	Yes
Minimum debris size	2.5 cm	2.5 cm
Recommended survey frequency	At least every 3 months	Every 28 days +/- 3 days
Smaller item protocol?	10-m wide transects	Sieve protocol
Large items recorded separately?	Yes	Yes
Specialized equipment required?	Scale for weight	No

Table 1. Comparison of NOAA and UNEP shoreline survey guidelines.
* NOAA standing-stock techniques can be adapted for shoreline cleanup efforts. See Section 2.3, below.

2.2 Standing-stock surveys

The shoreline technique described in this document is designed as a standing-stock assessment survey. Standing-stock surveys are used to measure the load or concentration of debris at a shoreline site over time. Each survey event is a snapshot of the concentration of debris at the site, and a series of these snapshots over time provides information on changes in the baseline concentration of debris. Knowing the concentration of debris (in units of #items/m^2 of shoreline) at various shoreline sites is necessary in evaluating the cumulative impact and conducting impact or risk assessments of debris at a given site and on a regional scale. In standing-stock surveys, the measured debris concentration reflects the long-term balance between inputs (land and sea based) and removal (through export, burial, degradation, etc.). An understanding of how the abundance of debris changes over time facilitates analysis of the drivers of debris deposition (e.g., weather, tides, tourism, prevention efforts).

In order to obtain a valid time-series of debris concentration, the natural flux of debris onto and off of the shoreline should not be altered by the survey activity. Integrity of the sample design should be maintained by not removing debris from the site during standing-stock surveys. If debris is removed from the shoreline site during a survey, the overall abundance of debris may be underestimated at subsequent surveys. Exceptions should be considered if an item poses a threat to human health or is potentially hazardous.

The standing-stock and residence time of marine debris on a given shoreline will vary with characteristics of the debris itself, deposition from land- and sea-based sources, local climate and seasonal weather patterns, and characteristics of the beach itself. Shoreline geomorphology, substrate, exposure, and coastal current patterns are some of the factors that will affect whether a given site tends to accumulate or capture debris.

2.3 Accumulation surveys

The shoreline survey technique described here can be modified for accumulation surveys (see Opfer et al., 2012). During accumulation surveys, marine debris is removed from the shoreline site. Accumulation studies require initial removal of all debris from the site followed by regular surveys to record and remove all debris. Because debris is removed from the site, the data collected over time provides an estimate of the flux of debris onto the shoreline (in units of #items/m^2/time), as opposed to the concentration or standing-stock of debris. Both types of data are useful for developing models of the life cycle and movement of debris among environmental compartments. Accumulation survey data indicate the *net* flux of debris onto the shoreline, and assume that the rate of debris accumulation is uniform between sample events. Debris flux data can be used to assess changes in at-sea debris loads, but cannot be used to evaluate the debris load or cumulative impacts of debris. Compared to standing-stock surveys, accumulation studies require more time and money as they are more thorough, require debris removal, and need to be conducted on a more frequent basis.

Accumulation survey frequencies must be identical for comparison between studies (Ribic et al., 1992). Shoreline sites may have a relatively rapid debris turnover rate, so in order to accurately estimate debris flux onto a shoreline site it must be sampled frequently. There is growing evidence that accumulation rates are underestimated by typical survey frequencies. Eriksson et al. (2013) found that daily accumulation rate measurements (i.e., surveys conducted on a daily basis) were an order of magnitude higher than those measured during monthly surveys, and Swanepoel (1995) suggested that daily accumulation rates were 100-600% higher than weekly accumulation rates. Eriksson et al. (2013) further suggested that 12 days of consecutive sampling at a given site may be more informative than monthly surveys over the course of one year. However, Ryan et al. (2009) argue that longer intervals between sampling events reduces variability in measured accumulation rates.

It is difficult to differentiate between factors that result in the deposition of debris onto the shoreline. Depending on the timing of sampling events (e.g., just prior to or following a storm event), the calculated net accumulation rate will likely vary. A debris marking study by Williams and Tudor (2001) found that "old" debris can reappear on the shoreline following strong wind events. Debris can become buried soon after deposition; in reality, accumulation studies are measuring the accumulation rate of visible debris items (Ribic et al., 1992). Accumulation data may also be affected by the lateral influx of debris from adjacent shoreline sites. Thus, conducting shoreline surveys may not be a suitable proxy for estimating debris loads in the ocean.

Given these considerations, accumulation studies may be appropriate based on study objectives. For example, accumulation surveys can be used to look for a spike in debris deposition from a major debris-generating event or variations due to climactic events (e.g., El Niño Southern Oscillation; Morishige et al., 2007). Debris flux measurements are important to understanding the life cycle of marine debris, and accumulation surveys will provide information on the relative abundances of different debris types. To reduce the impacts of marine debris in critical habitats, the benefit of more invasive accumulation surveys (with removal of debris) versus less intrusive standing-stock surveys should be considered in these locations.

2.4 Survey Design

Previous studies have shown that varying amounts and types of marine debris accumulate on shorelines depending on geographical location, oceanographic and meteorological conditions, climatological patterns (such as El Niño), and proximity to land-based or ocean-based sources (Morishige et al., 2007, Sheavly, 2007). To provide a more statistically relevant dataset, monitoring sites should be randomly selected from appropriate strata (e.g., land use, commercial and recreational fishing activities, political boundaries or management areas, storm water or sewage outfalls). Because there are various factors affecting debris deposition on shorelines, some studies have not detected significant differences in debris abundances between sites based on stratifying parameters. For example, van Cauwenberghe et al. (2013) found that sedimentary regime (i.e., accretion versus erosion) and tourism did not account for the debris loads they found on Belgian shorelines. Further, Versar, Inc. (2012) did not find differences in debris loads based on watershed land use.

The amount of sampling necessary to assess debris concentrations within a given region is dependent on the spatial variability in debris concentrations and the desired level of detection (i.e., in order to detect a smaller change in debris load, more sampling is required). Versar, Inc. (2012) used a nested survey design to test the utility of the shoreline and surface water survey techniques described here, which were developed based on a 100-m length of shoreline. At the coarsest level, two regions in the coastal mid-Atlantic United States were selected based on land use (urban vs. rural). Within each region, three 1000-m locations (stretches of shoreline) were identified. Locations were required to meet all site selection criteria (listed below) and were separated by at least 1200 m. Within each location, three 100-m shoreline sites were systematically selected and remained fixed for the duration of the study. Surveys at the site level were conducted on a bi-weekly basis for a period of six months in accordance with the standing-stock technique described below. Results of the study indicated that there was more variability (higher relative standard error) in debris concentrations among sites within a given location compared to the variability between locations at the regional level. This suggests that in order to decrease error in reported debris concentrations, shoreline surveys should be designed to assess debris at the scale of a 1000-m location (i.e., random selection of transects within a 1000-m location).

However, this technique was designed to be widely applicable, and it is recognized that in some cases it is not possible to find a suitable 1000-m stretch of shoreline for location-level assessment. Further, the European Union / Joint Research Centre Marine Strategy Framework Directive (MSFD) recommends a study design that includes more than one 100-m site on a given stretch of shoreline, or two sections of 50-m on heavily littered shorelines (MSFD, 2013). The technique explained below is based on assessment of debris at one 100-m site, but it should be noted that a study that includes more than one site on a given shoreline will provide more statistically powerful results.

2.4.1 Site Selection

An assessment of the impact of marine debris surveys on the local environment should be completed prior to commencement of any monitoring activities. In particular, monitoring should not be conducted where there is the potential for impacts to endangered or protected species or habitats. Organizations wishing to engage in marine debris monitoring activities are encouraged to contact local land owners or managers and wildlife authorities during the site selection process.

Shoreline survey sites should have the following characteristics:

- Sandy beach or pebble shoreline
- Clear, direct, year-round access (or seasonal access depending on physical conditions of the site)
- No breakwaters or jetties that affect local circulation and accumulate or inhibit debris deposition
- A minimum of 100 m in length parallel to the water (measured along the waters' edge)
- No regular cleanup activities. Sites do not need to be precluded solely because of annual or semi-annual cleanup events, but activities need to be tracked and noted in data analysis

These characteristics should be met where possible, but should be analyzed on a case-by-case basis and modified if appropriate for a particular region/location or shoreline type. The minimum length of shoreline was selected based on UNEP recommendations for rapid assessment (Cheshire et al., 2009). UNEP and MSFD (2013) suggest selecting shoreline sites that have a low to moderate slope (15 – 45º). Shallow tidal mudflat areas can be very wide at low tide, and marine debris is typically not very common in the intertidal. However, low-slope sites may still be appropriate for surveys.

2.4.2 Sample Frequency

Biweekly testing in the coastal mid-Atlantic indicated that in most instances, individual sampling events closely tracked monthly averages (Section 7.3). This finding suggests that sampling once every 28 days provides an accurate snapshot of debris concentration for the month. Following on recommendations from the National Marine Debris Monitoring Program (Sheavly, 2007), surveys should occur within a three-day window of the scheduled sampling event (i.e., shoreline standing-stock surveys should occur once every 28 ± 3 days).

2.5 Equipment

The following items are suggested for shoreline standing-stock assessments:

- Digital camera
- Hand-held GPS unit
- Extra batteries (suggest rechargeable batteries)
- Surveyor's measuring wheel
- Flag markers/stakes

- 100-foot measuring tape (fiberglass preferred)
- First aid kit (to include sunscreen, bug spray, drinking water)
- Work gloves
- Sturdy 12-inch ruler
- Clipboard for each surveyor
- Data sheets (printed on waterproof paper)
- Pencils
- For meso- and microdebris assessment:
  - 5-mm stainless steel sieve
  - Stainless steel tweezers/forceps
  - 32-ounce (~1 L) amber glass sample bottles with lids
  - Wide-mouth funnel (stainless steel) to fit glass bottles
  - Plastic bucket
  - Quadrat kit (1 m^2)
  - Small folding shovel
  - Waterproof paper for labels
  - Permanent markers

2.6 Pre-Survey Shoreline Characterization

Before any sampling begins, shoreline characterization should be completed for each 100 m site. Each survey site should be measured and marked for accuracy and repeatability using a surveyor's measuring wheel. This includes recording GPS coordinates in decimal degree format (DDD.DDDD N/W) at the start and end of each 100 m segment (note that locations in the southern or western hemispheres will have negative latitudes or longitudes). If the shoreline width is greater than 6 m, GPS coordinates at all four corners of the shoreline section should be recorded where possible. Additionally, a shoreline ID name should be created and used for the duration of the study (this name will be used for reference in the www.md-map.net database[1]).

Shoreline characteristics and surrounding land-use characteristics (*e.g.* primary land use, nearest town, nearest river, etc.) should also be recorded on the data sheets prior to survey activity. Shoreline characteristics include identification and uniformity of the primary substrate type (sand, cobble, etc.), the tidal range and distance (if applicable), a description of the first barrier at the back of the shoreline section (dunes, vegetation, etc.), and the aspect of the shoreline. It is important to record the distance to outfalls, rivers, and other potential sources of marine debris as well as local current patterns which can affect debris deposition. Digital photographs should be taken to document the physical characteristics of the monitoring site. Unless major changes occur to the shoreline, shoreline characterization only needs to be completed once per site per year. As mentioned above, changes in beach morphology (e.g., as a result of storm activity) may result in changes in debris deposition.

[1] At the time of publication, the NOAA MDP online database for shoreline survey data is housed at www.md-map.net. The database allows users to create custom debris items within the existing NOAA datasheet framework and facilitates data export and analysis. For information or access to the database, email MD.monitoring@noaa.gov.

2.7 Shoreline Survey Methodology for Macro-Debris (>2.5 cm)

In order to analyze the maximum width of the shoreline section during a relatively rapid beach assessment, sampling should be conducted within three hours of low tide. This constraint is made for the following reasons:

- Basing surveys on tides provides a consistent starting point at the waters' edge. Wrack lines are inadequate reference points as they move and change throughout the year.
- Some shoreline sites are inaccessible at high tide.
- Low tide heights typically exhibit less variability than high tides, which allows for a larger window of time to conduct surveys.
- Surveys conducted just prior to high tide may miss debris deposited on the wrack line at high tide.
- Surveying the entire shoreline (including the intertidal) at all sites facilitates comparisons of debris concentrations across sites. Data is representative of the entire shoreline site and is not biased by a small sample size (Rees and Pond, 1995; Burnham et al., 1985).
- Low tide provides a simple gauge of area surveyed. If a survey team does not have the ability to measure beach width at a given survey, it may be a valid assumption that approximately the same area of shoreline is being surveyed (we highly suggest testing this for a given shoreline site prior to accepting this assumption).

Before arriving on site, select four numbers from the random number table (Section 7.4) to eliminate any bias from visual inspection of the shoreline section. These four numbers correspond with four transects of 5 m in length within the shoreline section that will be sampled at this particular survey. The number of transects chosen for each sampling event correspond with a 20% coverage of the shoreline section. Thus, on any sampling day 20 m of the 100 m shoreline section is analyzed for debris.

Transects run perpendicular to the shoreline section from water's edge, at the time of sampling, to the back of the shoreline (Figure 2). The back of the shoreline is defined as the location of the first barrier or primary substrate change. There might be a change in substrate within the intertidal zone; in this instance the back of the shoreline should be defined such that it extends to at least the high tide wrack line. Further, if there is evidence that storm or wave action is pushing debris beyond the back of the shoreline, surveyors may be interested in recording these debris items separately (e.g., in Alaska debris is commonly found in the wooded region behind the shoreline). In this case, debris beyond the back barrier is recorded on a second data sheet and tracked separately from debris on the shoreline.

Upon arrival at the site at low tide, use the surveyor's measuring wheel to mark the selected transects with flags and record transect GPS coordinates in decimal degree format. Depending on the width of the shoreline section, the coordinate information can be recorded either at one point in the middle of each transect (shoreline width <6 m or < ~19.5 ft) or at both the water's edge and back of each transect (shoreline width >6 m or ~19.5 ft; Figure 2). This designation is due to the error associated with the operation of handheld GPS units. The GPS coordinates of each transect are recorded for quality assurance and to track any changes of beach morphology over the course of the study. For surveys conducted at high latitude locations, include information on the GPS datum used in the notes section of the data sheet. In addition to GPS locations, record ancillary data prior to the debris survey, which includes the length of each transect from water's edge to first barrier, the time, season, and date of last survey, description of recent storm activity, current weather conditions, and the number of individuals conducting the transect survey. If these characteristics are consistent between transects on a given survey event, they only need to be recorded on one data sheet.

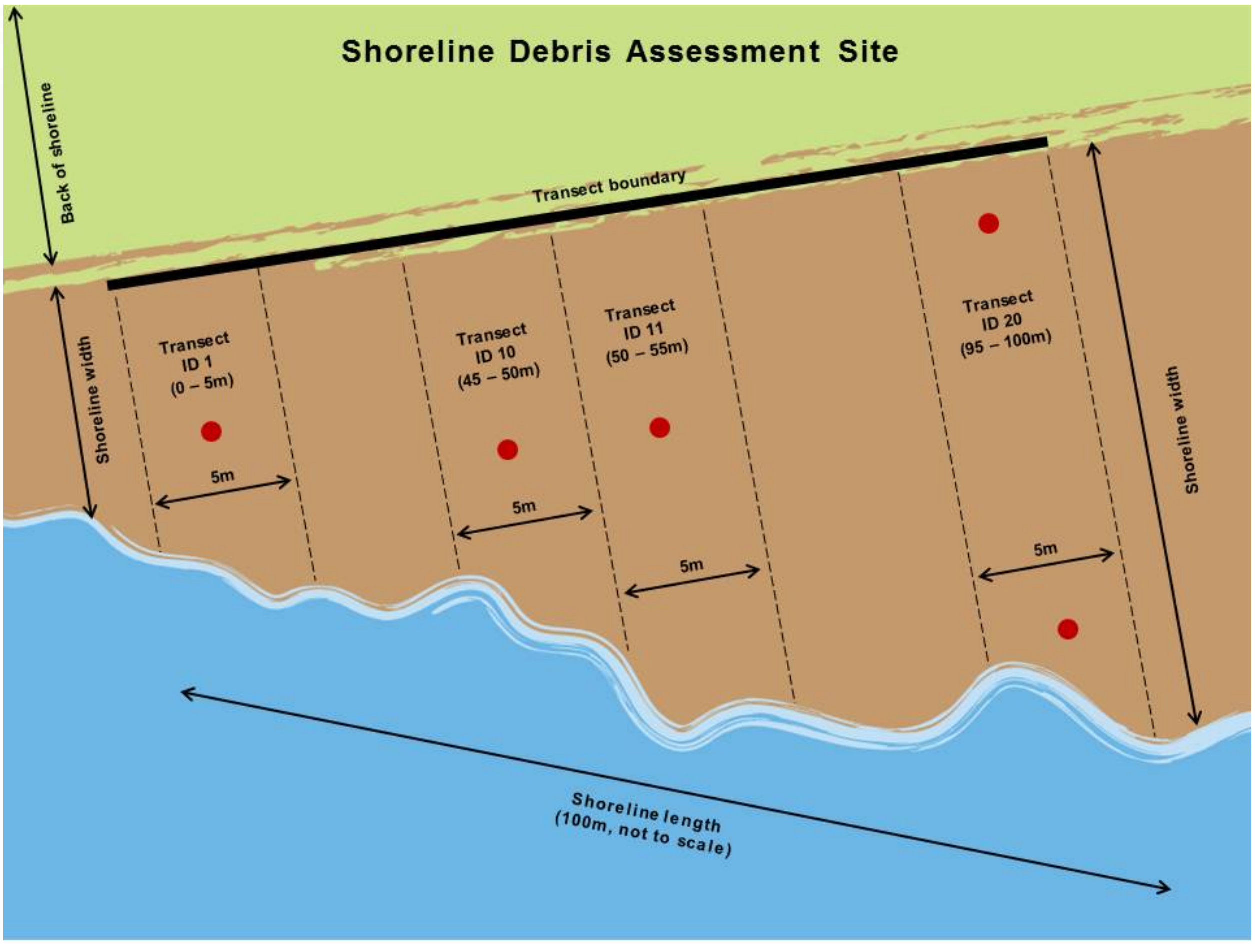

Figure 2. Shoreline section (100 m) displaying perpendicular transects from water's edge at low tide to the first barrier at the back of the shoreline section. Red circles indicate marked GPS coordinates. Shoreline width determines location and number of GPS coordinates. Figure not to scale.

Once ancillary data are recorded, surveyors should walk each transect tallying debris items according to material type and subcategory (see data sheets in Section 7.5). Debris items should only be recorded if they are at least 2.5 cm in size on the longest dimension (Figure 3). This standard length (approximately the diameter of a typical beverage bottle cap) was chosen to ensure that the same size items are counted across surveys and to maintain consistency in survey results. Data on debris < 2.5 cm has limited accuracy due to its small size compared to the transect area. In practice, surveyors will inevitably miss a significant fraction of debris below this size cutoff. This size cutoff for macro-debris surveys has also been adopted by UNEP (Cheshire et al., 2009) and the MSFD (MSFD, 2011, MSFD, 2013). Recognizing that small items represent an important size fraction of marine debris that may pose an even greater threat to marine life (e.g., through ingestion), this technique suggests the use of subsampling within transects for the assessment of meso- and micro-debris. The challenges with this approach, given the variability in small debris concentrations within a shoreline transect, are discussed below.

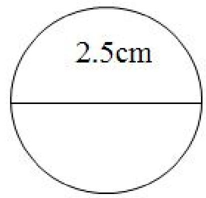

Figure 3. The minimum debris size to be counted is 2.5 cm.

Large macro-debris items (> 30 cm or about 1 ft) are recorded on a separate section of the debris data sheet. Large items should only be recorded in the large items section. Information recorded should include the debris type, the status of the large item (sunken, stranded, or partially buried), the latitude and longitude of the item, and the approximate debris size. This information is important in determining the footprint of large debris items.

Any item that is partially within a transect should be tallied (however, items should not be tallied twice if randomly selected transects are adjacent). If an item is blown into a transect mid-survey, it is tallied only if the surveyor has not yet surveyed the section of the transect where the item is located. Multiple fragments of what may have originally been a whole item should be tallied separately. Capturing information on the total number of fragments present is a better reflection of the debris impacts and effort required for cleanup. If one fragment is recognizable as a specific item, for example a remnant of a plastic beverage bottle, it should be recorded as such provided that the remnant is at least 50% of the original item (Tangaroa Blue Foundation, 2012).

Items that do not fall under a specific subcategory can be entered into the "other" category at the end of each material section. In order to ensure that these standardized methods are widely applicable, NOAA's online shoreline survey database allows users to create custom debris categories[1]. This allows researchers to track locally-relevant debris items within a nationally-standardized format.

If a surveyor is unsure of an item's material type, it is tallied in the other/non-classifiable category at the end of the data sheet. Include a brief description of the item in the notes section for clarification. Items that are composed of multiple material types should be recorded according to the most abundant material that makes up the surface of the item. For example, a tire with a metal rim would likely be recorded as a large rubber item. A debris item photo guide is included in Section 7.6. Digital photographs should be taken of unidentifiable items, as well as other debris items or markings of interest. Place a lined ruler next to the debris item to establish a size reference. It is also a good practice to take a photo of each transect surveyed, and record photo ID numbers on the data sheet.

The macro-debris item concentration (number of debris items/m^2) per transect is calculated as follows:

$$C = \frac{n}{(w \times l)}$$

C = concentration of debris items (# of debris items/m^2)
n = # of macro-debris items observed
w = width (m) of shoreline section recorded during sampling (i.e, transect width)
l = length (m) of shoreline sampled = 5 m

Note that the shoreline width that is measured at each transect is essential for calculating debris concentrations. For a given sampling event:

1. Calculate debris concentrations for each individual transect surveyed (a minimum of four per survey).
2. Take the mean of the concentrations at each transect to calculate an overall site concentration (± standard deviation) for that date.

The previously mentioned online database exports survey data (counts) and concentrations per debris item category, material type, large debris, and total debris.

2.8 Sampling for Meso- (5 mm – 2.5 cm) and Micro-Debris (≤5 mm)

Random samples can be collected from sandy beach locations for analysis of meso- and micro-debris. For random sampling within a shoreline segment, use a random number table (Section 7.4) to select the placement of a 1-m^2 quadrat. The placement of the number on the random number table determines the location of the sample. For example, if random number seven was chosen, the placement of the quadrat would be on the right side of the transect in the wrack line.

Because shoreline meso- and micro-debris concentrations are very patchy, random quadrat placement may not always be the preferred method. During field testing in the coastal mid-Atlantic, meso-debris was very rare in randomly selected samples (meso-debris occurred in only 2-3% of sample events; Versar, Inc. 2012). Therefore, depending on study objectives, it may be appropriate to focus meso-debris sampling on sections of the shoreline where small debris is more likely to accumulate. Previous studies have suggested sampling along the wrack line, where less re-suspension and thus higher debris concentrations are expected to occur, and to avoid the effect of tidal height on the deposition of debris of various sizes and densities (Browne et al., 2010). Van Cauwenberghe et al. (2013) found significantly higher concentrations of microplastic at the high-water mark compared to the low-water mark on Belgian shorelines. However, if samples are collected in a non-random fashion (i.e., focused on the wrack line), results cannot be extrapolated over larger spatial scales.

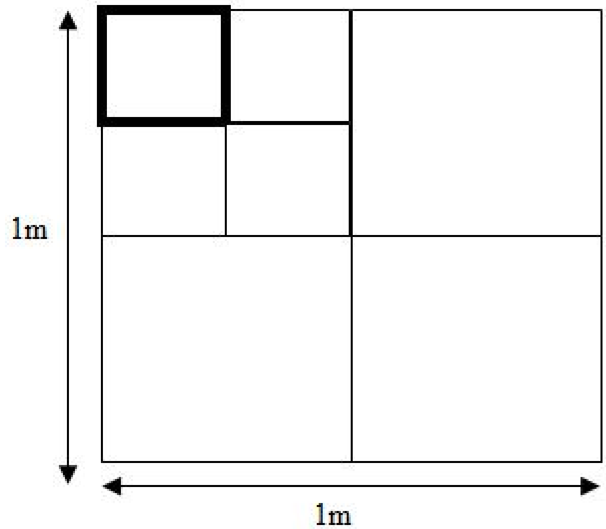

Figure 4. Randomly placed 1 m^2 quadrat with area of sand to be sieved (0.0625 m^2) in bold.

Once the quadrat placement is selected, remove any pieces of debris from the surface that are larger than 2.5 cm (and should have been counted in the macro-debris survey). Use a small stainless steel shovel to collect the top 3 cm of sand from 1/16 of the quadrat (0.0625 m^2). This is done by dividing the quadrat into fourths and then dividing one of the quarters into fourths (Figure 4). Sieve the collected sand through a stainless steel 5 mm mesh sieve above a bucket or funnel and sample jar. If the sand is wet, use a water rinse to facilitate the sieving process (seawater that has been sieved through a 0.33-mm screen is sufficient for this purpose). Transfer the sieved micro-debris samples to labeled amber glass bottles for further analysis back in the lab (Baker et al., 2013). If it is not possible to properly identify meso-debris items (> 5 mm) in the field they should be collected and analyzed back in the lab. Repeat this process for each of the four transects that were sampled for macro-debris.

Meso- and micro-debris item concentration (# of debris items/m^3) is calculated as follows:

$$C = \frac{n}{(a \times h)}$$

C = concentration of debris items (# of debris items/m^3)
n = # of debris items observed
a = area sampled = 0.0625 m^2
h = depth of sample = 0.03 m

Provided that samples are collected randomly, meso- and micro-debris concentrations for a given sampling event can be calculated according to the same approach as for macro-debris (Section 2.7).

2.9 Quality Control

To ensure that all of the appropriately sized debris items within a transect are recorded, quality control estimates should be conducted by a second surveyor before the collection of the meso- and micro-debris sample. The second surveyor should assess 20% of the total number of transects sampled per site over the course of the study (e.g., one site visited monthly will have a total of 48 transects and 10 quality assurance / quality control samples). Quality assurance sampling should be distributed among different sampling events and include consideration of debris classification.

2.10 Considerations

Shoreline surveys are the most accessible and cost-effective mode of marine debris monitoring and assessment. Depending on study objectives, additional data collection needs may be identified, for example debris location on the shoreline, number of beach visitors, or information on debris biofouling. This information can be included in the notes section of the data sheets or on a separate form. Surveys can be conducted by appropriately trained and managed volunteers to reduce costs, but as with any citizen-science effort, volunteer coordination is a major (and often overlooked) task. Site selection, proper debris classification, and survey schedule often prompt questions from new volunteers. A frequently asked questions document is provided in Section 7.7.

As mentioned above, care should be given to avoid threatened or endangered species and habitats during site selection and while conducting surveys. While removal of debris from the environment is an important endeavor, it is not a long-term solution. The distinction between standing-stock and accumulation surveys, and the information gleaned from each, is important. Leaving debris on the shoreline allows surveyors to assess the variation in debris loads over time, which is essential information for quantifying the impacts of debris on the marine environment and making the case for increased prevention and mitigation efforts.

3.0 SURFACE WATER METHODS

Floating marine debris has been noted by research and other vessels since 1971 (Carpenter et al., 1972; Carpenter and Smith, 1972). However, few systematic quantification surveys have been conducted throughout the oceans to develop a cohesive understanding of the extent and degree of pollution from floating marine debris.

Reported debris concentrations range from less than 1 piece/km^2 to 20,328 ± 2324 pieces/km^2 in the subtropical Atlantic Ocean (Law et al., 2010), to potentially higher concentrations in the North Pacific Ocean (NRC 2008; see Section 7.1). In addition to a lack of standard sampling methodologies, metrics vary by study objective which complicates debris concentration comparisons. Weight and number of items are used to measure debris items, while area and volume measure the matrix sampled (Section 7.1).

This section provides rigorous, standardized methodologies for assessing the amount and type of floating anthropogenic debris and guidance for the development of a robust survey design for coastal and offshore waters. Guidelines were developed to be flexible enough to conduct both coastal and offshore assessments. A goal for these guidelines is to increase the amount of surface water marine debris data that can be leveraged from tangentially-related organizations and projects that routinely conduct surface trawling. Data collected can facilitate comparisons to assess where floating debris is most prevalent and contribute to assessments of the eventual fate and risk posed by the debris.

3.1 Floating debris survey techniques

Floating marine debris and debris suspended in surface waters has been documented across the world in the open ocean and in coastal waters. In general, efforts to monitor oceanic marine debris have been informal, with many anecdotal reports, few scientific expeditions that included floating debris sighting surveys, and even fewer scientific expeditions dedicated to collection and quantification of floating marine debris samples. Early marine debris sampling was often conducted with pelagic plankton sampling. Methods have varied over the years to include oblique plankton tows (Carpenter et al., 1972) and Neuston nets towed across surface waters (Colton et al., 1974, Yamashita and Tanimura, 2007). In the North Atlantic Ocean, the Sea Education Association used Neuston nets towed by a sailing vessel in a standard procedure to produce a 22-year data set (Law et al., 2010). Moore et al. (2001b, 2002) published some of the first reports that demonstrate the use of a manta net in conducting debris trawls. Brown and Cheng (1981) note an advantage of the manta net is the two paravanes that attach to the frame and allow the net mouth to skim the surface of the water. Thompson et al. (2004) determined plastic fragment concentrations in archived samples collected with a continuous plankton recorder.

Variability in the physical construction of nets, towing conditions, and overall technique make it difficult to interpret temporal and spatial trends of floating debris concentrations. These studies demonstrate a large variability in the physical construction of nets used in surface water debris surveys, in terms of aperture, mesh size, and net length. Towing conditions, such as tow speed and trawl length, vary depending on the overall study objective (Section 7.1). Reported mesh sizes have ranged from 150 to 947 μm (NRC 2008) and though studies have not yet targeted floating nano-sized debris particles, it is possible that these could be sampled with various whole-water sampling techniques. Marine debris was investigated in new and archived surface water plankton tow samples from the CalCOFI program (Gilfillan et al. 2009, Doyle et al. 2011), which uses a manta net equipped with a flowmeter and 0.505 mm mesh for 15 minutes at a speed of approximately 1.0-1.5 knots. These methods have been employed in standard plankton tows for decades, and proved effective for sampling debris in surface waters.

We evaluated the methodology from published literature to develop the guidelines presented in this document, which are heavily influenced by the California Cooperative Ocean and Fisheries Investigations (CalCOFI). The surface water debris sampling technique and study design described in this section were tested in a pilot sampling effort conducted in the Chesapeake Bay, as well as in a more rigorous testing of nearshore coastal waters in the Delmarva Peninsula (Versar, Inc. 2012).

3.2 Survey Design

Few studies have repeatedly sampled an area for marine debris using a standardized technique; often measurements are tangential to primary study objectives and debris data are not published. Even when long-term data exist, the patchiness of debris distribution may obscure expected trends (Law et al., 2010).

To test the utility of the surface water guidelines described here, Versar, Inc. developed a nested survey design (Versar, Inc. 2012; see Section 7.3). As discussed in Section 2.4, at the coarsest level, two regions in the coastal mid-Atlantic United States were selected based on land use (urban vs. rural). Within each region, three 1000-m locations (stretches of shoreline) were identified. Adjacent to each location, nine surface water sampling stations were selected and remained fixed for the duration of the study. To avoid tow direction bias, direction of the tow was randomly assigned for each trawl. Surveys were conducted on a bi-weekly basis for a period of six months in accordance with the sampling technique described below. Results of the study indicate that floating macro-debris abundances in urban and rural locations did not differ significantly, but differences among locations and temporal trends were detected using this survey design.

Given the widely variable debris concentrations noted by published reports and during testing by Versar, Inc., it is difficult to provide strict recommendations about survey design. Survey design should consider the following suggestions while tailoring the study to address specific questions about floating marine debris.

3.2.1 Site Selection

The coastal sampling design presented here pursues a regional perspective on floating debris and its relationship to shoreline debris. Additional considerations for offshore sampling include oceanographic conditions; known currents, eddies, convergence patterns, mixing, and seasonal fluctuations therein; known or potential sources of marine debris; shipping lanes; and the bathymetry and geomorphic structures that may influence the generation and eventual fate of floating debris. Groups conducting offshore sampling are strongly encouraged to conduct surveys in conjunction with ongoing marine research and/or water quality assessments.

To provide a statistically robust dataset, selected sites for coastal surface water sampling should be stratified based on appropriate parameters, for example land use (e.g., urban, rural) associated with nearby shorelines, fishing activities, or storm water or sewage outfalls. Random site selection from each stratum (stratified random sampling) is a useful tool to assess temporal and spatial variability while controlling for some of the expected variability and reducing sampling error. In order to compare shoreline and adjacent surface water debris concentrations, shoreline site selection should occur before any surface water site selection takes place.

Additionally, sites should have the following characteristics:

- Direct, seasonal or year-round access, depending on location
- Located within one nautical mile from shore for comparison to shoreline debris loads
- No stationary or transient in-water barriers to ship transect path
- Preferably areas that have not seen recent changes or manmade alterations to hydrographic patterns

These characteristics should be met where possible, but should be analyzed on a case-by-case basis and modified if appropriate for a particular region/location. This technique may be adapted or modified to monitor riverine, coastal, and offshore locations.

3.2.2 Sample Number and Frequency

In addition to standardizing the technique and equipment used, it is equally important to complete enough sampling to account for heterogeneity in debris concentration (e.g., Pichel et al., 2007). Depending on study objectives, detecting significant trends or making regional comparisons may require an infeasible sample size (Ryan et al., 2009, Versar, Inc., 2012). It may be advantageous to conduct surveys initially more frequently to understand the spread of the data and factors affecting variability (MSFD, 2013). To increase confidence in debris concentration estimates, balance spatial distribution of sampling and the number of floating debris transects within a location with the amount of replication required at the shoreline site level (Versar, Inc., 2012).

Once location is determined, at least ten transects are identified, plotted in mapping software, and randomly numbered. Three numbers are selected from a random number table to determine which transects are evaluated on a sampling event. At least three transects should be completed within two nautical miles parallel to the adjacent shoreline site and within one nautical mile perpendicular to the shore (Figure 5). We suggest surveyors pair the surface water sampling frequency with adjacent shoreline assessments. And, where possible, groups are encouraged to conduct surveys in conjunction with ongoing marine research and/or water quality assessments.

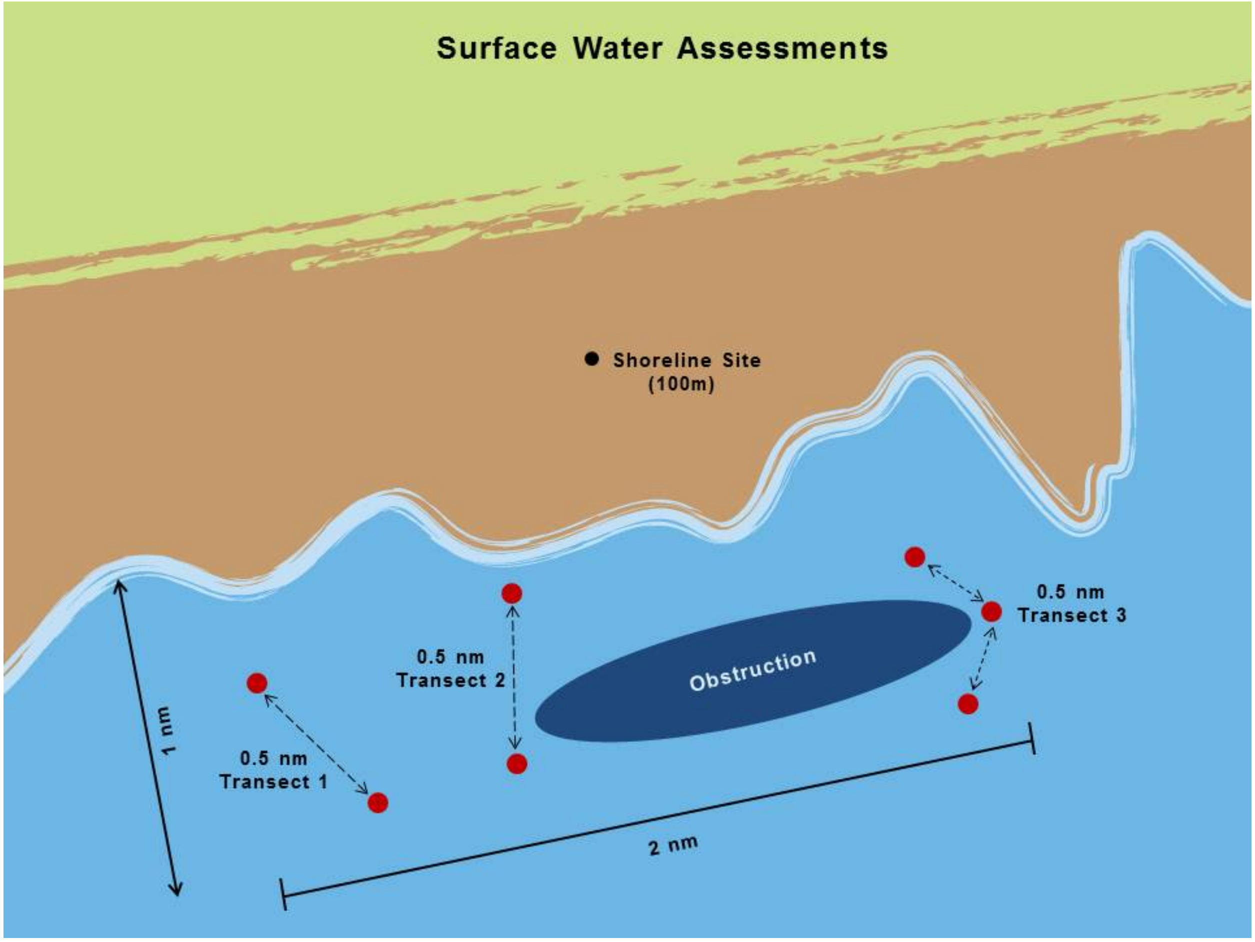

Figure 5. Shoreline and pelagic sampling should be coordinated so that the pelagic trawl transects occur within two nautical miles of the shoreline assessment sites (here, denoted as a single 100 m section of beach). Three trawls, each approximately 0.5 nm, will be conducted at each site. Red circles represent points at which to note GPS coordinates. If obstructions are present, it is necessary to take GPS coordinates whenever the vessel changes heading and not only at the beginning and end of each trawl transect.

3.3 Equipment

The following equipment is suggested to perform surface trawls for floating marine debris:

- Nautical charts
- Digital camera
- Hand-held GPS unit
- Extra batteries (suggest rechargeable batteries)
- Manta net
- Detachable cod end (+ one spare)
- Bridle for manta net
- Weights to attach to frame, if in offshore or choppy waters
- Flowmeter
- Stopwatch

- Squirt bottles
- Plastic buckets with handles (two 5-gallon)
- Stainless steel sieves (5-mm and 0.30-mm mesh)
- Calipers
- First aid kit (including sunscreen, bug spray, drinking water)
- Work gloves for hauling the net
- Latex gloves (or appropriate alternative) for handling the sample
- Stainless steel forceps, 6-inch, angled tip, for picking out larger debris items
- 32-ounce (~1 L) amber glass sample bottles with lids
- Wide-mouth funnel (stainless steel) to fit glass bottles
- Clipboards
- Data sheets (on waterproof paper)
- Waterproof labels for jars, pre-labeled and affixed to jars prior to trawls
- Pencils
- Permanent markers
- White trays, 12-inches square (or equivalent) for sorting debris
- Stainless steel spatula, ~8-inches in length, with tapered and rounded ends for sorting debris
- Sealant to repair net holes
- Bags for large debris items
- Instrument to measure water quality parameters (optional)

3.4 Pre-Survey Site Characterization

Before completing floating debris surveys, shoreline characterization is completed for each 100 m site. See Section 2.0 of this document for the methodology.

For surveys of coastal waters adjacent to shoreline sites, current bathymetric maps should be obtained for the area within two nautical miles of the chosen shoreline site. Several potential sites for trawls are chosen based on ease of access and strata described in the survey design section. It is ideal to complete a survey of the surrounding surface waters before any sampling begins. For studies with concurrent shoreline surveys, any pertinent information on hydrography, bathymetry, and in-water barriers is also described in the "notes" section of the shoreline characterization data sheet.

Select transects prior to arrival at the site. Each data sheet captures ancillary data and data pertaining to a single trawl event. Ancillary data may be recorded before arrival at the site.

Each trawl transect has a unique identification in this suggested format:

Site ID_year-month-day_transect #

An example is [MD-MR_2010-01-07_T1] for a trawl completed in Maryland's Middle River on January 7, 2010 along the first transect (identified as T1 in mapping software).

3.5 Surface Water Trawl Survey Methodology (> 0.30 mm)

3.5.1 Trawling technique

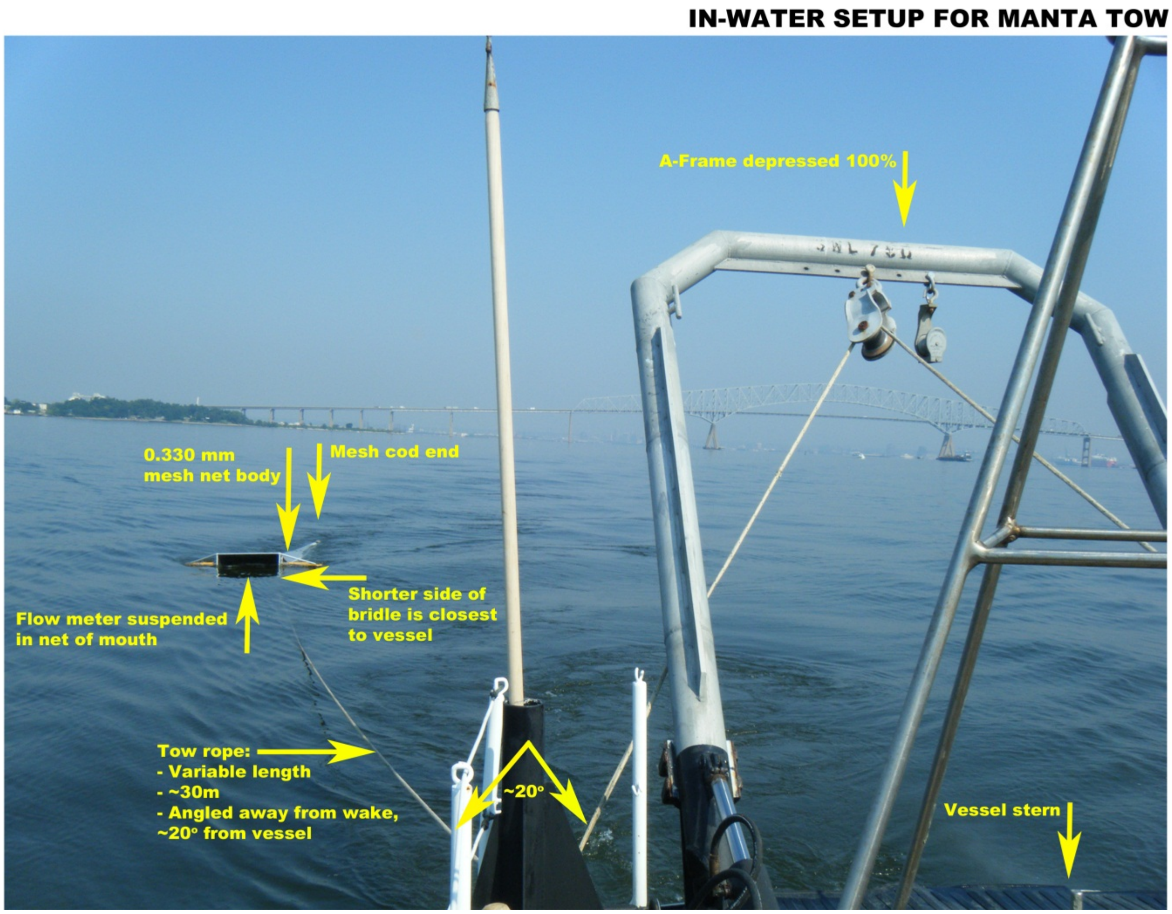

Figure 6. In-water setup for a manta tow. The vessel shown has an A-frame at the stern that is fully depressed, which supports a tow rope that is cleated to achieve and angle of ~20° between the vessel and the net to minimize interaction with the vessel's wake. The shorter side of the bridle should be closer to the vessel to help facilitate avoidance of sampling the wake.

All transects follow the same trawling technique. A manta net, with a body composed of 0.330 mm nylon mesh and measuring approximately 3 m in length, is towed horizontally at the surface (Figure 6). Depending on sea state, weights are added to the bridle to ensure balanced positioning and coverage of the surface waters. Alternately, weights may be added to a tow line that connects the bridle to the winch line. A swivel connects the tow rope to the manta net bridle, which is offset so that one side is slightly longer to encourage a towing angle that samples waters outside of the vessel's wake. A buoy is attached to the net for safety and retrieval purposes.

A digital or analog flowmeter is attached to the net frame and suspended in the center of the net mouth. An initial flowmeter reading is taken prior to deployment of the net apparatus; this reading should not change before placement in the water. The net is deployed from the back or the side of the vessel, with enough slack to allow the net to smoothly skim the surface of the water and avoid the vessel's wake. The side paravanes of the manta net should be on the water's surface. An angle of approximately 20 degrees between the line of the vessel and the net is desirable for minimizing interaction with the vessel wake. The shorter side of the bridle should be closer to the vessel to obtain the required towing angle (Figure 6).

The trawl is deployed for approximately 0.5 nautical miles at a speed of 1-3 knots, an approximately 15 minute duration. When noting the in-water time, include time for deployment and retraction when the net is submerged in the water and the flowmeter is recording volume. During the trawl, vessel speed and tow rope length may be adjusted to ensure the net is properly skimming the surface away from the vessel wake. One person watches the net and notes any large debris items that may be initially funneled into the net mouth. These should be detailed on a large debris data sheet.

GPS coordinates are recorded in degree decimal format at the beginning and ending point of each trawl transect. This can be done with a handheld GPS unit or by marking coordinates of the vessel's transect path in mapping software. If obstructions are present in the area and require alteration of the original transect, GPS coordinates should be recorded when the vessel changes heading (Figure 5).

3.5.2 Sample Processing

The flowmeter reading is recorded as soon as the net is recovered. Contents of the net are gently washed with natural seawater from the outside, into the cod end. If possible, ambient seawater is filtered through a 0.333 mm mesh sieve to remove particles that could bias the sample. The cod end is detached and its entire contents are rinsed with seawater. Digital photos document the process throughout, especially the cod end contents at the end of each trawl.

Samples may be processed on the vessel or transferred to labeled sample jars for laboratory processing. Any obvious large debris items, >30 cm, are counted on a separate large debris data sheet, rinsed to collect any small attached particles, photographed, and then stored in bags or discarded appropriately. Large natural items can be discarded but should be rinsed to collect any small attached particles; items may be recorded on the data sheet and photographed depending on study objectives.

When processing samples on the vessel, the remaining sample from the cod end is rinsed into stacked stainless steel sieves (5 mm and 0.333 mm) to separate debris items into two size fractions, ($x > 5$ mm) and (5 mm $> x >$ 0.333 mm). Proper rinsing with squirt bottles filled with ambient seawater is essential to collect all natural and anthropogenic particles that may be attached to debris items and natural contents (e.g., floating leaves, woody stems, pine needles, jellyfish). Rinsing is important if samples will be analyzed for microplastic concentration; in that case, the study design may consider using deionized water for rinsing to decrease potential bias. Debris items larger than 5 mm are sorted by material category and tallied on debris data sheets. Macro-debris may then be discarded appropriately or archived depending on study objectives.

The size fraction smaller than 5 mm, composed of micro-debris, is carefully rinsed into glass sample bottles and stored frozen to prevent any sample degradation.

If samples are not processed on the vessel, steps are taken to condense the sample by minimizing rinsing and cataloging any large debris items. Large items are processed as described above and removed from the sample. Trawl contents are rinsed into glass sample jars for sieving in the laboratory, following the sieving technique described above. Samples are processed as soon as possible to avoid the need for initial freezing or chemical preservation.

Analytical methods are available for processing water, sediment, and sand samples to quantify microplastic debris (Baker et al., 2013). When applicable, archiving frozen samples for further analyses is suggested.

3.6 Data analysis

Volume of water filtered during each trawl is calculated based on the flowmeter used. In general, distance is calculated per trawl by subtracting the initial and final readings of the flowmeter and applying a correction factor specific to the flowmeter. Distance is then multiplied by the area of the net mouth to determine a volume of water filtered. The concentration (#items/m^3) of macro-debris items is calculated as follows:

$$C = \frac{n}{V}$$

C = concentration of debris items (# of debris items/m^3)
n = # of debris items observed
V= volume of water filtered (m3) = [(net mouth width) × (net mouth height) × d]
d = distance traveled = (flowmeter final – flowmeter initial) × correction factor

For a given sampling event:

1. Calculate debris concentrations for each individual transect surveyed (a minimum of three per survey) using the equation above
2. Take the mean of the three concentrations to calculate an overall site concentration (with a standard deviation) for that date

3.7 Quality Control

Quality control procedures increase the efficiency, accuracy, and precision of floating debris assessments. Safety and data management plans should be in place before sampling begins. For accuracy in positioning of trawl transects, develop a survey design before sampling begins and use a GIS to label all potential transects. Naming conventions should be standardized for notation on sample labels and data sheets.

Consistently following a standardized procedure is essential. Trawling and processing techniques should be monitored for consistency. During trawling, watch the manta net to ensure that it is properly skimming the water's surface without creating excessive splashing of water in the net mouth that influences water sampling. If the manta net is not skimming properly, vessel speed (or other parameters) should be tweaked to provide appropriate positioning and water flow through the net. Debris counts should be confirmed by two individuals if possible; at least 20% samples should be analyzed separately by two people for quality assurance. Debris samples should be saved for additional testing if material type is not determined. For studies investigating micro-debris, rinsing standards are important and the suggestions listed here may be appended with additional controls such as using deionized or filtered water for rinsing, and conducting all rinsing within a controlled laboratory environment. Sieves and equipment should be thoroughly rinsed between trawl events. All instruments should be calibrated and cleaned regularly. Equipment and rigging should be cleaned and inspected after each sampling event.

3.8 Considerations

Assessing floating debris quantity and composition presents challenges and confounding factors. The recommended technique for floating debris surveys is meant to be robust to slight modifications depending on study objectives, and this has been noted in the text. This section presents additional considerations for employing the floating debris survey technique.

3.8.1 Survey design

As discussed in Section 1.2, debris sources and points of input are often impossible to determine. Several categories have been identified, including (1) larger pieces from land-based runoff or actual release; (2) larger pieces from ocean-based dumping or accidental release; (3) smaller pieces that result from the degradation of larger marine debris in the environment; and (4) small debris, for example, micro- and nano-plastics used in consumer products (e.g., plastic beads used as an exfoliant in soaps) that enter the waste stream from regular use and are likely discharged with wastewater (Fendall and Sewell 2009). Programs that seek to understand the source of debris should heavily consider survey design in terms of both selecting appropriate sites to monitor and adding enough replication to constrain the variability in debris concentrations attributed to environmental conditions.

Local weather, runoff, other potential point sources of debris, and oceanographic conditions will be important to consider in the study design. Where possible, groups are encouraged to conduct surveys in conjunction with ongoing marine research and/or water quality assessments. This may necessitate adjustment to the suggested study design, but more important is standardizing the techniques used to collect and process the floating debris samples, as well as the metrics used to report debris concentrations.

3.8.2 Technique

Note that, as a general rule, faster tow speeds and larger mesh sizes will exclude smaller particles and will bias the sample toward larger particles. The techniques recommended here provide an overview of the amount and type of debris present in surface waters at a given location, but due to operational constraints will not sample the entire water column or obtain all debris. Particles smaller than 0.33 mm (the suggested mesh size) will escape during trawling. Trawl transect lengths may be optimized based on local conditions. For example, during a phytoplankton bloom the mesh may become clogged and will not filter effectively. Techniques that diverge from the standard transect length or standard tow speed are especially encouraged to measure flow volume per trawl, in order to account for varying flow volumes in calculated concentrations.

Depending on study objectives, samples may be processed in a clean laboratory environment with slight changes to sieving technique such as a more thorough washing with deionized water, a more detailed sorting based on additional size classes (e.g., additional sieving through a 1-mm screen), drying the total sample, and weighing debris items. All visible debris items may be measured with calipers.

If study objectives involve correlating debris loads and water quality, parameters such as dissolved oxygen, pH, temperature, etc. should be recorded at the beginning and end of each transect.

3.8.3 Data analysis

The reporting unit is extremely important when making comparison to other comparable studies.

For macro-debris, count (debris pieces) per volume (water filtered) provides an accurate measurement. This is a departure from most historic and present-day conventions, but is commonly used in marine plankton studies, is fairly simple to obtain, and allows for comparison of macro-debris concentrations in other matrices such as sand and sediments. Volumetric measures of surface water debris are useful because debris, especially plastic debris, can be neutrally buoyant and exist at depth in the water column due to wind-driven mixing (Kukulka et al., 2012). In the future, it may be possible to use measurements of floating marine debris to integrate a measurement through the water column; and thus providing an estimate for the amount of water filtered in each trawl would enhance parameterization.

In some cases it may be useful to obtain mass measurements to estimate debris density within a given parcel of water (g/m^3). This measurement is informative for macro-debris, but is especially important for micro-debris particles that may not be easily counted. In addition, density estimates of micro-debris may be compared to density estimates of natural material in a given size class which provides an easily understood ratio of debris to the naturally occurring particles. Density is easily compared to whole water samples, benthic sediment grabs, and plankton abundance measurements that may be obtained in the same study. For very small particles (<1 mm), mass measurements will likely be more accurate than count.

3.8.4 Relevance

Given the high variability in floating debris concentration, it may not be cost-effective to conduct enough sampling to accurately compare locations or regions, or to understand which environmental variables most influence debris concentration (Versar, Inc., 2012). To address this reality and strive for relevance with these techniques, this document stresses the benefits of completing floating marine debris surveys in conjunction with ongoing marine research and/or water quality surveys for increased efficiency in data collection. In addition, these techniques sample both macro- and micro-debris. Particles smaller than 5 mm have been documented in many water samples that did not contain macro-debris. Understanding the factors that affect the size distribution and particle concentration of debris in the ocean is important to advance the state of the science regarding debris movement, distribution, and degradation. These floating debris assessment techniques may be applied to address additional research questions beyond those posed at the beginning of this section.

4.0 AT-SEA VISUAL SURVEY METHODS

4.1 Background

Ship-based visual surveys are a relatively easy, cost-effective method for crowd-sourcing open ocean marine debris sightings (i.e., from vessels of opportunity) and can provide useful information on the types of debris commonly encountered and spatial and temporal variability of floating debris. The accuracy of reports generated from ship-based debris sightings is affected by environmental factors (e.g., weather conditions, sea state) and variation between observers (Ryan et al., 2009) and vessel size and speed (Rees and Pond, 1995). On larger vessels, observers are typically situated higher above the water surface and farther from the bow (e.g., on the bridge), which causes items very close to the bow to go undetected (Thiel et al., 2011). To account for the likelihood of surveyors missing some debris items located on a transect (Ryan 2013) apply a correction factor to measured debris counts based on item size and distance. Line transect sampling methods (where the perpendicular distance to each item is recorded) may reduce bias (Burnham and Anderson, 1984), but is not recommended for novice observers. It is important to recognize that although the majority of debris floating on the ocean surface is from the smaller size fractions (e.g., Law et al., 2010, Doyle et al. 2011, van Cauwenberghe et al., 2013), visual sightings will be skewed toward larger debris items. Further, unlike surface water trawls which will capture debris just beneath the surface (i.e., debris that has been subjected to wind mixing), visual surveys will only account for debris that is visible at the surface. Visual survey data should be interpreted as a low-end estimate of the total concentration of floating debris.

A number of confounding factors must be taken into consideration for accurate comparisons of floating debris concentrations across time and space. Similar to marine debris in other environmental compartments, there is a lot of variability and patchiness in the abundance of floating debris. Large-scale convergence zones (e.g., the North Pacific High Pressure Zone), as well as small and meso-scale circulation features, may concentrate floating debris and create ephemeral debris patches. Areas of concentrated debris (which often also include natural debris) can be difficult to quantify from a moving vessel. One data analysis technique is to pool sightings from very long transects to account for debris patches (e.g., Ryan 2013 used 50 km transect lengths).

Quantitative comparisons of different visual survey efforts noted in the literature are difficult to make due to the differences in reporting units (e.g., #items/km or #items/km^2), minimum debris size (studies have varied from 1.5 – 10 cm (Section 7.1)), and transect width (up to 100 m; e.g., Morris, 1980, Shiomoto and Kameda, 2005). Relative to debris classification systems used for other types of marine debris monitoring, a simplified data sheet should be used for visual surveys as it is difficult to collect detailed and accurate information on debris types from a ship-based observer. Thus, the visual survey data sheet provided in Section 7.5 does not cover the same level of detail as data sheets for shoreline sampling and surface water trawls. Given the uncertainty in detection and patchiness of large debris items, data collected through visual surveys may be most useful for qualitative assessments of the types and relative abundances of floating debris.

4.2 Survey Design

Cheshire et al. (2009) provides methods for setting up a prescribed visual survey pattern in a given area and also for transect sampling. Given the widely variable debris concentrations noted by published reports, it is difficult to provide strict recommendations about survey design. Survey design should consider the suggestions put forth in the surface water trawl technique (Section 3.2), while tailoring the study to address specific questions about floating marine debris. Visual surveys may complement surface water trawl surveys and shoreline surveys. A survey design that includes visual surveys of floating debris conducted in conjunction with other survey types will lead to a more robust data set. Where possible, groups are encouraged to conduct surveys in conjunction with ongoing marine research and/or water quality assessments. This may include vessels of opportunity as well as structured studies that monitor at standard intervals. When vessels of opportunity are used as the platform for visual debris surveys, a structured study design is unlikely. This must be stated when data and results are reported (Ribic et al., 1992).

4.3 Equipment

The following equipment is suggested to perform visual surveys of floating marine debris:

- Clipboard
- Pencil
- Survey forms printed on waterproof paper
- GPS unit
- Binoculars
- Digital camera

4.4 At-Sea Visual Survey Technique

Visual surveys should be conducted along strip transects at least 0.5 nm in length. Ancillary data, including environmental conditions and GPS locations of transect beginning and end points should be recorded on the visual survey form (Section 7.5). Any changes in heading during individual transects should be recorded in the space provided. If possible, two surveyors should conduct surveys from the bow of the vessel, and data from the port and starboard sides can be pooled from two separate data sheets. If only one surveyor is available, the surveyor may want to conduct the survey from the glare-free side of the vessel (Ribic et al., 1992). Each surveyor is responsible for visually scanning the sea surface and recording all debris > 2.5 cm that passes either the port or starboard side of the vessel (Figure 7). MSFD (2013) recommends that visual surveys not be conducted when environmental conditions are such that this minimum debris size cannot be detected, and provides suggested transect widths (ranging from 3 to 15 meters) based on vessel speed and height of the observer above the water (reproduced in Table 2). It is important to note that these suggested transect widths need to undergo further testing, and should be used only as a starting point. Binoculars may be used to verify the identity of items.

Observer height above water	Ship Speed		
	2 knots	6 knots	10 knots
1 m	6 m	4 m	3 m
3 m	8 m	6 m	4 m
6 m	10 m	8 m	6 m
10 m	15 m	10 m	5 m

Table 2. Suggested visual survey transect widths based on observer height above water and ship speed. Adapted from MSFD (2013). Note that these suggestions are preliminary and will be further reviewed by the MSFD.

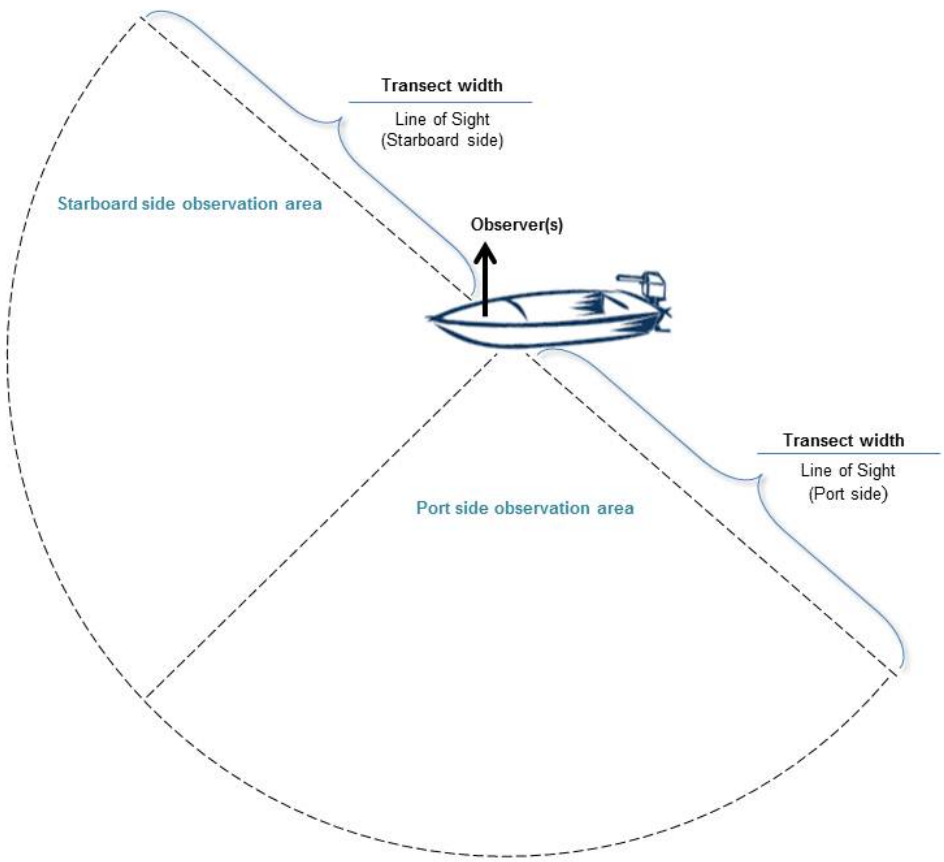

Figure 7. During visual surveys, observers are responsible for visually scanning the sea surface on either the port or starboard side of the vessel, within a defined transect width.

Visual survey data should be reported in terms of # items/km^2, based on the transect width and length (determined from latitude and longitude of transect start and end points). To get an understanding of variability in detection from different observers, quality control surveys should be conducted on 20% of survey transects, by a second visual observer on the same side of the vessel. Quality control surveys should be distributed among different sampling events and include consideration of debris classification and total count.

4.5 Considerations

As discussed above, ship-based debris observations can provide useful information on the abundances and types of debris floating at the sea surface. However, given the patchiness of surface water debris and uncertainty in debris classification during visual surveys, researchers must give careful consideration to survey design and standardization between observers and platforms in order to develop robust estimates of floating debris concentrations.

5.0 BENTHIC METHODS

The information provided in this section is intended to guide development of benthic surveys to ensure that data and results can be integrated with surveys in other environmental compartments. Integration and standardization of survey efforts between shorelines, surface waters, and the benthos is important to understand and model the life cycle and behavior of debris. We suggest that groups interested in developing a benthic survey program follow the guidelines below and refer to more detailed protocols provided by the MSFD (MSFD, 2013).

5.1 Background

Historical methods for detection and survey of benthic debris vary according to vessel capabilities and available equipment, target debris type and size, location, personnel (e.g., availability, skill level, training, technical abilities), and environmental conditions (e.g., depth, water clarity, current strength). Benthic monitoring efforts are often cost-prohibitive and more logistically challenging than some other types of marine debris monitoring (namely, shoreline monitoring), and there is often a lot of spatial variability in benthic debris concentrations. However, the seafloor is recognized as a potentially significant debris sink that should not be ignored.

MSFD (2013) provides suggested methods based on depth, divided between shallow (< 20 m; SCUBA), shelf (up to 800 m; trawls), and deep sea floor environments; the sections that follow provide a general overview of the MSFD (2013) suggested approach. It is recognized that there is no single technique that will work across survey efforts in diverse environments and with different objectives and available resources. The guidelines presented here should be used as a guiding framework during the planning process, during which operation-specific protocols and safety measures will be developed.

Benthic debris items should be catalogued according to the same classification system used for other environmental compartments. That is, debris should be tallied according to the material types and item categories captured on shoreline and surface water data sheets (Section 7.5). Further, to ensure comparability with data collected on shorelines and in surface waters, the focus should be on debris abundance (count and concentration) rather than weight. However, from a management perspective it might be informative and efficient to concurrently collect volume, size, and/or weight estimates. In instances where debris is not collected during surveys, there will be a lower degree of confidence in accurate item classification (e.g., diver or submersible surveys). A list of the benthic marine debris survey literature reviewed is provided in Section 7.1. Side scan sonar is not considered here given that it is only feasible for detection of large debris items, for example derelict crab pots (Stevens et al., 2000; Morison and Murphy, 2009).

Although assessment of micro-debris (< 5 mm) is not a focus of this document, it is worth noting that concurrent sampling of this small size fraction during macro-debris assessment requires the use of sediment grabs or trawls with a fine mesh size (e.g., Cole et al., 2011).

5.2 Survey Design

5.2.1 Site Selection

Survey locations are dependent on accessibility, study objectives, and available resources and equipment. Sensitive habitats or species and underwater hazards should be avoided. This includes sites that may contain unexploded ordinance or have features that may pose an entanglement hazard to divers or gear. Given the patchiness of benthic debris, sampling should focus on areas where debris is suspected to accumulate and may be stratified by factors such as land use, proximity to river mouths, substrate, tourism, fishing pressure, or oceanic current patterns. Bathymetry and hydrodynamics should be considered during site selection as there is growing evidence of their influence on benthic debris accumulations (e.g., Galgani et al. 1996; Keller et al. 2010). Acha et al. (2003) show that salinity fronts associated with river mouths tend to trap debris and may be common accumulation areas.

5.2.2 Sample Frequency

Survey frequency for benthic debris assessments should be determined based on study objectives, available resources, and expected seasonal or annual variability. In the Bay of Biscay (France), Galgani et al (1995a) found a greater abundance and more spatial variability in benthic debris trawls during the winter / early spring compared to other times of the year when debris concentrations were more uniform. The authors suggest that this variation may be due to seasonal changes in coastal currents and water levels. Quarterly or biannual sampling may be appropriate in regions that exhibit less seasonality (e.g., tropical regions with wet / dry seasons) and sampling may be further restricted by weather conditions and accessibility in high latitude areas.

5.3 Shallow Environments (< 20 m)

Based on proximity to source, shallow nearshore regions are more likely to accumulate seafloor debris. In areas where there are strong bottom currents or intense storm activity, debris may be pushed farther out on the continental shelf, accumulate around rocky ledges or outcrops, or be deposited in offshore canyons or other depressions (e.g., Galgani et al., 1996, Bauer et al., 2008, Kendall et al., 2007, Wei et al., 2012, Schlining et al., 2013).

Dive surveys along line or strip transects are often the preferred method for assessment of seafloor debris in shallow or coastal environments. The ability to detect debris is a significant concern during underwater visual surveys, and the dimensions of each sampling unit (e.g., transect length and width) should be based on estimated debris concentration, detectability, and environmental conditions. Diver experience may also affect the degree of detection (Ribic et al., 1992). MSFD (2013) provides a range of transect lengths (20 – 200 m) and widths (4 – 8 m) based on environmental conditions and debris concentration (based on Katsanevakis, 2009; see

Table 3). In order to double the areal coverage of surveys, the UNEP survey technique employs a pair of divers, one on each side of the transect line (Cheshire et al., 2009). Further, MSFD recommends the use of a distance sampling method, where divers record the distance of each debris item from the line so that a degree of detectability can be applied during debris concentration calculations. A minimum debris size must be identified prior to any survey activities. The minimum debris size should be based on study objectives but should not be smaller than the lower limit of detection (Donohue et al., 2001, Timmers and Kistner, 2005); ideally all items > 2.5 cm are detectable. Selecting a smaller minimum debris size cut-off will require more time and resources. Results of dive transect surveys are expressed in terms of #items/m^2.

Debris Density	Environmental Conditions	Sampling Unit (length x width)
0.1 – 1 items / m^2	Low turbidity & high habitat complexity	20 m x 4 m
0.1 – 1 items / m^2	High turbidity	20 m x 4 m
0.01 – 0.1 items / m^2	In every case	100 m x 8 m
< 0.01 items / m^2	In every case	200 m x 8 m

Table 3. Suggested dive survey transect lengths and widths based on environmental conditions and debris concentration. Adapted from MSFD (2013) and Katsanevakis (2009).

To ensure that all of the appropriately sized debris items within a transect are recorded, quality control estimates should be conducted by a second surveyor on 20% of the total number of transects sampled per site over the course of the study. Quality assurance sampling should be distributed among different sampling events and include consideration of debris classification.

Both SCUBA and snorkel free-dive techniques have been used for shallow water benthic debris assessments (e.g., Donohue et al., 2001, Bauer et al., 2008; see Section 7.1). Existing biological monitoring programs that employ diver surveys may provide an opportunity for collaboration. Debris surveys would be more economical and efficient if combined with existing benthic ecology or other monitoring efforts.

For any diving activities or other use of compressed gas as a breathing medium (e.g., surface supplied air), safety is the number one priority and divers must be trained to a level commensurate with the type and conditions of the diving activity being undertaken. Project leads are responsible for understanding all aspects of dive safety regulations and required trainings (e.g., OSHA distinctions between scientific and commercial diving) and must ensure that their organization has the capacity to oversee all planned diving activities (e.g., appropriate insurance, safety policies, etc.).

5.4 Continental Shelves (up to 800 m)

In locations where it is too deep for dive surveys, debris assessments can be combined with ongoing trawl surveys, for example benthic ecology studies or fish stock assessments (e.g., Keller et al., 2010). Although debris loads are likely underestimated with trawls, not all debris is captured and debris may be lost while the net is returned to the vessel; (Spengler and Costa, 2008), trawl surveys can provide an idea of the relative types and abundances of benthic marine debris, which is informative at a local or regional level. It should be noted that trawling activities are largely limited to smooth and flat areas of the seafloor, which are not indicative of typical debris accumulation areas (Galgani et al., 1995a). Ribic et al. (1992) point out that variability in the vessel, crew, net type (including footrope), depth sampled, and weather will affect the accuracy of measurements.

UNEP (Cheshire et al., 2009) provides a benthic trawl survey design. The suggested approach is to select a 5 km by 5 km survey area, create a grid of 25 km^2, randomly select three sub-blocks of 1 km^2, and conduct five parallel trawls of 800 m each within each selected sub-block. Trawls should be separated by at least 200 m and data from all transects should be aggregated to report an overall debris concentration. Trawl equipment should have a fixed mouth width (e.g., otter trawls) such that debris concentrations can be reported in units of #items/km^2 based on the distance trawled.

To ensure that all of the appropriately sized debris items within a sample are recorded, quality control assessments should be conducted by a second individual on 20% of the total number of samples per site over the course of the study. Quality assurance sampling should be distributed among different sampling events and include consideration of debris classification.

It is important to consider the impacts of any trawling activity on benthic ecosystems, and sensitive or protected habitats and species should be avoided. Marine debris trawl surveys are more affordable and less destructive if combined with existing sampling programs. Van Cauwenberghe et al. (2013) applied the UNEP trawl survey design on the Belgian continental shelf and argue that the trawls were an inefficient use of time and resources.

5.5 Deep Sea Floor

There is a paucity of data available on debris in the deep sea, particularly in areas where trawling is not a viable option. Debris is expected to accumulate in relatively calm areas with high sedimentation rates, and studies have shown that debris tends to accumulate near outcrops and in offshore canyons or channels (e.g., Galgani et al., 1996, Kendall et al. 2007, Wei et al., 2012, Schlining et al. 2013). In regions of the seafloor with varying topography (e.g., outcrops, canyons, steep slopes), submersibles are the only viable option for marine debris surveys. Remotely operated vehicles (ROVs) and manned submersibles have previously been used for debris surveys (Section 7.1), but are restrictively expensive in many cases. Detectability is a significant concern for surveys that employ submersibles, and in some cases the vehicle may purposely avoid debris due to entanglement hazards. Further, the color, size, shape, fouling, and degree of burial in sediments will affect detectability (Ribic et al., 1992). In Monterey Bay, CA a 22-year archive of ROV video footage was recently analyzed for marine debris sightings (Schlining et al., 2013). The study added to our understanding of typical accumulation regions but no estimation of debris concentration was provided.

5.6 Considerations

Benthic debris has been shown to inflict negative impacts on marine species and habitats, particularly corals (e.g., Schleyer and Tomalin, 2000, Bauer et al., 2008, Yoshikawa and Asoh, 2004). Thus, it may be worthwhile to identify relationships between bottom communities and marine debris in various environments (Bauer et al., 2008). Benthic debris typically has a very patchy distribution, so surveys may be a necessary first step to prioritize debris cleanup efforts, but considerable effort is required in order to cover large regions of the seafloor (Galgani et al., 1996). As mentioned above, although the benthos is likely a significant sink for marine debris, surveys are often prohibitively expensive and logistically complicated compared to other types of monitoring.

When designing a study, it is important consider and report the lower size limit for detection, which will be based on the equipment used, habitat type, and in some cases water clarity. In addition, information on the depth range over which sampling occurs and total area of seafloor sampled is important (Spengler and Costa, 2008). Regardless of the benthic survey technique employed, #items/unit area is the suggested basic reporting unit.

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This section contains references cited within the main text of this document and in literature review tables (see Section 7.1).

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7.0 APPENDICES

7.1 Literature Review Tables[2]

Shoreline survey literature reviewed:

Citation	Location	General Metrics
Alkalay et al. 2006	Israel	Debris count, concentration
Cauwenberghe et al 2013	Belgian shelf and shoreline	Debris concentration, weight
Edyvane et al. 2004	Anxious Bay, Australia	Debris count, weight, source, and entanglement
Eriksson et al 2012	Two islands south of Australia	Debris concentration/day
Frost & Cullen 1997	New South Wales, Australia	Debris concentration, weight, source
Jambeck et al., 2009	New Hampshire, USA	Debris count, source, entanglement
Kusui & Noda 2003	Sea of Japan (Japan & Russia)	Debris count, weight, and source
Liu et al. 2013	Taiwan - southwest coast	Debris concentration
Moore et al., 2001a	Orange County, California	Debris concentration, weight, source
Morishige et al. 2007	Northwest Hawaiian Islands	Climate/weather, Debris count
Oigman-Pszcsol & Creed 2007	SE Brazil	Debris count, concentration
Rees & Pond 1995	United Kingdom	Debris count, source
Ribic et al 2010	Nationwide USA	Debris count, source, entanglement
Ribic et al 2011	Caribbean and Gulf of Mexico	Debris count, source, entanglement
Ribic et al. 1994	Nationwide	Debris count, source
Rosevelt et al 2013	Monterey Bay, California	Debris concentration
Sheavly 2007	Nationwide USA	Debris count, source, entanglement
Thiel et al., 2013	North-central Chile	Debris concentration

Visual survey literature reviewed:

Citation	Location	Transect width (distance from ship)	Metric
Day et al 1990	North Pacific	50 m	items / km^2
Matsumura and Nasu, 1997	Japan	no limit	items / km^2
Ryan, 2013	Bay of Bengal / Straits of Malacca (Indian Ocean)	50 m	items / km^2
Shiomoto and Kameda, 2005	nearshore Japan	100 m	items / km^2
Thiel et al 2003	SE Pacific (near Chile)	10 m	items / km^2
Thiel et al 2011	German Bight, North Sea	20 - 70 m	items / km^2

[2] These publications were reviewed during development of NOAA survey techniques, and do not necessarily represent an exhaustive literature review.

Surface water trawl literature reviewed:

Citation	Location	Depth Range	Method	Metrics
Carpenter et al., 1972	coastal North Atlantic Ocean	surface to unspecified depth	oblique plankton net using 0.33-mesh	$\#/m^3$
Carpenter and Smith, 1972	Sargasso Sea	surface	neuston net tows using 0.33-mm mesh at 2 knots	$\#/km^2$ and g/km^2
Colton et al., 1974	North Atlantic Ocean Caribbean	surface	neuston net tows using 0.947-mm mesh at 5 knots	$\#/km^2$ and g/km^2
Day et al., 1990	North Pacific Ocean, Bering Sea, Japan Sea	surface	ring net or Sameoto net tows with 0.50-mesh	$\#/km^2$ and g/km^2
Day and Shaw, 1987	North Pacific Ocean	paper?		
Doyle et al., 2011	Bering Sea; California Current	surface (10-15 cm) and subsurface (California) to 212 m	Sameoto neuston net tows using 0.505-mm mesh at 1.5-2.0 knots; manta net using 0.505-mm mesh; subsurface cruises used Bongo nets with 0.505-mm mesh	$\#/m^3$ and mg/m^3
Gilfillan et al., 2009	California Current	surface	manta net tows using 0.505-mm mesh at 0.5-0.75 m/s	$\#/m^3$ and mg/m^3
Goldstein et al., 2012	North Pacific Ocean	surface	ovoid and rectangular plankton net tows using 0.505-mm mesh at 2 m/s; manta net tows using 0.333-mm mesh at 0.7-1 m/s	$\#/m^3$ and mg/m^3
Lattin et al., 2004	California Current	surface to 5m	neuston net tows (manta) using 0.333-mm mesh; bongo net tows using 0.333-mm mesh; both at 1.0-2.3 m/s	$\#/m^3$ and g/m^3
Law et al., 2010	North Atlantic Subtropical Gyre	surface	neuston net tows using 0.335-mm mesh at 2 knots	$\#/km^2$
Moore et al., 2001(b)	North Pacific Ocean	surface	manta net tows using 0.33-mesh at 1 m/s	$\#/km^2$
Moore et al., 2002	coastal North Pacific Ocean; California Coastal Current	surface	manta net tows using 0.33-mesh at 1 m/s	$\#/m^3$ and g/m^3
Moret-Ferguson et al., 2010	North Atlantic Ocean	surface	neuston net tows using 0.335-mm mesh at 2 knots	average count (#), size (mm), mass (g), density (g/mL)
Ogi et al., 1999	coastal Japan	surface	neuston net tows using 0.3-1.8 mm mesh at 2 knots	$\#/km^2$ and g
Ryan et al., 2009	review	comprehensive	n/a	n/a
Thompson et al., 2004	North Sea; North Atlantic Ocean	10m	continuous plankton recorder using $127mm^2$ aperture onto 0.280-mm mesh	$\#/m^3$
Yamashita and Tanimura, 2007	North Pacific Ocean; Kuroshio Current	surface	manta net tows using 0.33-mm mesh at 2 knots	$\#/km^2$

Benthic survey literature reviewed:

Citation	Location	Depth Range	Method	Metrics
Donohue et al 2001	Northwestern Hawaiian Islands	> 10 m	snorkel	items / km^2
Bauer et al 2008	Grey's Reef, South Atlantic Bight, USA	16 - 20 m	SCUBA	# items / 100 m^2
Chiappone et al 2004	Florida Keys	< 8 m	SCUBA	# items / 100 m^2
Acha et al 2003	Rio del la Plata, South America	6 - 23 m	trawl	items / km^2
Cauwenberghe et al 2013	Southern North Sea, Belgium	not reported	trawl	items / km^2
Galgani et al 1995a	Seine Bay and Bay of Biscay, France	0 - 100 m	trawl	# items / hectare
Galgani et al 1995b	Northwestern Mediterranean	up to 750 m	trawl	# items / hectare
Galgani et al 1996*	Gulf of Lions, France	100 - 1600 m	trawl	# items / hectare
Galgani et al 2000*	European Seas	at least 2200 m	trawl	# items / hectare
Hess et al 1990	Kodiak Island, AK	not reported	trawl	items / km^2
June 1990	Oregon and Bering Sea	7 - 675 m	trawl	items / km^2
Keller et al 2010	US West Coast	55 - 1280 m	trawl	items / km^2 and kg / km^2
Lee et al 2006	East China Sea and South Sea of Korea	not reported	trawl	kg / km^2
Stefatos et al 1999	Ionian Sea, Greece	not reported	trawl	items / km^2
Wei et al. 2012	Gulf of Mexico	359 - 3724 m	trawl	# items / hectare
Galgani et al 1996*	offshore Marseille and Nice, France	40 - 1448 m	manned submersible	# items / 100 m
Galgani et al 2000*	European Seas	50 - 2700 m	manned submersible	# items / km
Watters et al 2010	Monterey Bay and Southern California	20 - 365 m	manned submersible	# items / 100 m
Schlining et al 2013	Monterey Bay, CA	25 - 3971 m	ROV	# items (normalized debris counts - relative abundance)

* Studies listed twice because they employed more than one survey method.

7.2 Shoreline Survey Advisory Group

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7.3 Versar, Inc. Executive Summary

The text below is the executive summary of the final report compiled by Versar, Inc. (Versar, Inc., 2012) based on comprehensive testing of the shoreline and surface water survey techniques presented in this document. The complete report can be accessed at www.clearinghouse.marinedebris.noaa.gov.

> Developing standardized protocols to quantify marine debris is critical for the protection of natural resources and for evaluating debris removal programs and policies designed to reduce marine debris. The National Oceanic and Atmospheric Administration (NOAA) Marine Debris Division (MDD) developed a suite of sampling protocols to quantify marine debris on coastal shoreline habitats and in nearshore pelagic surface waters. We developed a large scale pilot project to test the ability of the protocols to quantify marine debris, monitor changes in debris density, and assess factors correlated with changes in debris density on short and long-term timescales. The overall goal of the pilot project was to provide feedback to the MDD on the level of sampling effort required to implement the protocols in a larger assessment program. Two sampling regions representing urban and rural land use in the coastal zone of the mid-Atlantic Bight were chosen to conduct the pilot project. Within the urban and rural regions, three locations consisting of three sampling sites each were sampled for marine debris along the shoreline and in the ocean using visual shoreline transect surveys and pelagic net sampling methods designed by the MDD. Each region was sampled bi-weekly from June 27th to December 08th, 2011 for a total of 12 sampling events per region over the 24 week survey.
>
> MDD sampling protocols were successfully employed to sample debris and make estimates of debris densities. Debris was more common in the shoreline compared to the pelagic portion of the survey for each size class of debris. Plastic was the most common form of debris observed. Shoreline macrodebris varied over time and at each level of spatial resolution except for the region level. The urban and rural region had similar debris densities. Differences among shoreline locations were best explained by the sampling event on which the location was sampled, the number of people per site, and the total debris density. Shoreline macrodebris was weakly correlated with densities of people and the week of sampling. Both debris density and the number of people decreased over the course of the survey. Relative standard errors for shoreline macrodebris at the region, location, and site levels indicate that reasonably precise estimates were made (RSE<=30% in most instances). Pelagic macrodebris varied among locations but was similar between regions, among transects, and over time. Pelagic macrodebris was positively correlated with surface water temperature. Differences among pelagic locations were best explained by the sampling event during which the location was sampled and the surface water temperature. Relative standard errors for pelagic macrodebris at each spatial resolution indicate that estimates are imprecise due to high spatial and temporal variability of debris in the water. Sample size analyses indicate that sample size would have to increase exorbitantly to distinguish urban from rural due to the high degree of similarity between regions. Overall we found the sampling protocols employed in this survey are consistent and repeatable and based on our assessment would have the flexibility to serve as a guide for standardized methods for quantifying marine debris in small or large scale marine debris monitoring and assessment surveys. To further enhance these sampling protocols and future surveys we recommend (1) that a critical evaluation be conducted to determine the value of comparing differences in marine debris

between land use types, (2) additional protocol testing be conducted in other shoreline habitat types, (3) readily available GIS and location specific data from U.S. regions be identified and compiled into a comprehensive GIS, and (4) that shoreline sampling continue in the location of the current pilot survey using a stratified random sampling rather than fixed sampling approach.

7.4 Random Number Tables

Transect Selection Random Number Table					
	1	2	3	4	5
1	4	8	17	9	1
2	7	19	2	12	20
3	18	14	6	16	11
4	3	5	15	10	13

Micro-Debris Random Number Table					
	1	2	3	4	5
1	6	2	14	17	19
2	8	10	13	5	9
3	16	18	15	4	7
4	1	3	20	12	11

5m

Each column represents 1m of transect width. Rows represent zones of a shoreline section.

white = above the wrack line (closer to the first barrier)
light gray = at the wrack line
dark gray = below the wrack line (closer to the water)

Transect ID # from start of 100 m shoreline section		
1	0-5m	0-16'4"
2	5-10m	16'4"- 32'9"
3	10-15m	32'9" - 49'2"
4	15-20m	49'2" - 65'7"
5	20-25m	65'7" - 82'
6	25-30m	82' - 98'5"
7	30-35m	98'5" - 114'9"
8	35-40m	114'9" - 131'2"
9	40-45m	131'2" - 147'7"
10	45-50m	147'7" - 164'
11	50-55m	164' - 180'5"
12	55-60m	180'5" - 196'10"
13	60-65m	196'10" - 213'3"
14	65-70m	213'3" - 229'7"
15	70-75m	229'7" - 246'
16	75-80m	246' - 262'5"
17	80-85m	262'5" - 278'10"
18	85-90m	278'5" - 295'3"
19	90-95m	295'3" - 311'8"
20	95-100m	311'8" - 328'1"

7.5 Data sheets

7.5.1 Shoreline data sheets

SHORELINE DEBRIS **Site Characterization Sheet** **Standing-Stock Surveys**	Organization		Name of organization responsible for collecting the data
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form **ONCE** for each site location	Date		Date of this survey
SAMPLING AREA			
Shoreline name			Name or ID by which this section of shoreline is known (e.g., beach name, park)
State/County			State and county where your site is located
Coordinates at start of shoreline section	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees) at start of shoreline section (in both corners if width > 6 meters)
Coordinates at end of shoreline section	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees) at end of shoreline section (in both corners if width > 6 meters)
Photo number/ID			The digital identification number(s) of photos taken of shoreline section
SHORELINE CHARACTERISTICS			
Length of sample area (usually 100 m)			Length measured along the midpoint of the shoreline (in meters)
Shoreline slope (°)			Slope above horizontal (between 0 – 90°)
Substratum type			For example, a sandy or gravel beach
Substrate uniformity			Percent coverage of the primary substrate type (%)
Tidal range			Max & min vertical tidal range. Use tide chart (usually in feet).
Tidal distance			Horizontal distance (in meters) from low- to high-tide line. Measure on beach at low and high tides or estimate based on wrack lines.
Back of shoreline			Describe landward limit (e.g., vegetation, rock wall, cliff, dunes, parking lot)
Aspect			Direction you are facing when you look out at the water (e.g., northeast)

LAND-USE CHARACTERISTICS			
Location & major usage	Urban		Select one and indicate major usage (e.g., recreation, boat access, remote)
	Suburban		
	Rural		
Access			Vehicular (you can drive to your site), pedestrian (must walk), isolated (need a boat or plane)
Nearest town			Name of nearest town
Nearest town distance			Distance to nearest town (miles)
Nearest town direction			Direction to nearest town (cardinal direction)
Nearest river name			If applicable, name of nearest river or stream. If blank, assumed to mean no inputs nearby
Nearest river distance			Distance to nearest river/stream (km)
Nearest river direction			Direction to nearest river/stream (cardinal direction from site)
River/creek input to beach	YES	NO	Does nearest river/stream have an outlet within this shoreline section?
Pipe or drain input	YES	NO	Is there a storm drain or channelized outlet within shoreline section?
Notes (including description, landmarks, coastal hydrography, offshore barriers, etc.):			

SHORELINE DEBRIS **Survey Data Sheet**	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form during **EACH** transect	Email address		Email contact for surveyor
	Date		Date of this survey
ANCILLARY INFORMATION			
Shoreline name			Name for section of shoreline (e.g., beach name, park)
Transect # and photo ID			Transect # (1-20) and digital photo number of transect
Coordinates of start of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at water's edge.
Coordinates of end of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at back of shoreline.
Width of beach			Width of beach at time of survey from water's edge to back of shoreline (meters)
Time start/end	Start	End	Time at the beginning and end of the survey
Time of low tide			Time of the most recent or upcoming low tide.
Season			Spring, summer, fall, winter, tropical wet, etc.
Date of last survey			Date on which the last survey was conducted
Storm activity			Describe significant storm activity within the previous week (date(s), high winds, etc.)
Current weather			Describe weather on sampling day, including wind speed and % cloud coverage
Number of persons			Number of persons conducting the survey
Large items	YES	NO	Did you note large items in the large debris section?
Debris behind back barrier?	YES	NO	Is there debris behind the back barrier of the site (if yes, do not include it in tallies below)
Photo ID #s			The digital identification number(s) of debris photos taken during this transect.

Notes: Evidence of cleanup, sampling issues, etc.

DEBRIS DATA: (continued on back)

ITEM	TALLY (e.g., ~~IIII~~)			TOTAL
	PLASTIC			
Plastic fragments	Hard	Foamed	Film	
Food wrappers				
Beverage bottles				
Other jugs or containers				
Bottle or container caps				
Cigar tips				
Cigarettes				
Disposable cigarette lighters				
6-pack rings				
Bags				
Plastic rope/small net pieces				
Buoys & floats				
Fishing lures & line				
Cups (including polystyrene/foamed plastic)				
Plastic utensils				
Straws				
Balloons				
Personal care products				
Other:				
	METAL			
Aluminum/tin cans				
Aerosol cans				
Metal fragments				
Other:				
	GLASS			
Beverage bottles				
Jars				
Glass fragments				
Other:				

ITEM	TALLY (e.g., IIII)	TOTAL
	RUBBER	
Flip-flops		
Gloves		
Tires		
Rubber fragments		
Other:		
	PROCESSED LUMBER (no natural wood)	
Cardboard cartons		
Paper and cardboard		
Paper bags		
Lumber/building material		
Other:		
	CLOTH/FABRIC	
Clothing & shoes		
Gloves (non-rubber)		
Towels/rags		
Rope/net pieces (non-nylon)		
Fabric pieces		
Other:		
	OTHER/UNCLASSIFIABLE	

LARGE DEBRIS ITEMS (> 1 foot or ~ 0.3 m)

Item type (vessel, net, etc.)	Status (sunken, stranded, buried)	Approximate width (m)	Approximate length (m)	Description / photo ID #

Notes on debris items, description of "Other/unclassifiable" items, etc:

7.5.2 Trawl data sheets

PELAGIC DEBRIS **Trawl Data Sheet**	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form during **each** trawl	Email address		Email contact for surveyor
	Date		Date of this survey

ANCILLARY INFORMATION				
Body of water, location				Name of the water body and the approximate location of the trawl (sketch map below)
Date of last survey				Date on which the last survey was completed
Current weather	Wind	Cloud cover	Sea state	Describe current weather including wind speed, % cloud cover, sea state
Storm activity				Describe significant storm activity in previous week (e.g., date, high winds)
Number of persons				Number of persons conducting trawl
Latitude/longitude start	Latitude	Longitude		Record as XXX.XXXX at start of the sample transect (decimal degrees)
Latitude/longitude end	Latitude	Longitude		Record as XXX.XXXX at end of the sample transect (decimal degrees)
Time	Start	End		Record as HH:MM. Record when flowmeter starts / stops turning.
Time (adjusted)	Start	End		Any adjustments to the actual trawl time, in seconds, based on eployment/recapture of net.
Flowmeter	Start	End		Flowmeter reading (xxxxxx) before and after trawl
Average ship speed				Record in knots
Photo ID #s				The digital identification number(s) of debris photos taken during this transect.

<u>Map:</u> Space provided below for sketching a map of the site, including important bathymetric or hydrographic features.

DEBRIS DATA:

ITEM	TALLY (e.g., IIII)	TOTAL
PLASTIC		
Plastic fragments	Hard / Foamed / Film	
Food wrappers		
Beverage bottles		
Other jugs or containers		
Bottle or container caps		
Cigar tips		
Cigarettes		
Disposable cigarette lighters		
6-pack rings		
Bags		
Plastic rope/small net pieces		
Buoys & floats		
Fishing lures & line		
Cups (including polystyrene/ foamed plastic)		
Plastic utensils		
Straws		
Balloons		
Personal care products		
Other:		
METAL		
Aluminum/tin cans		
Aerosol cans		
Metal fragments		
Other:		
GLASS		
Beverage bottles		
Jars		
Glass fragments		
Other:		
RUBBER		
Flip-flops		
Gloves		
Tires		
Rubber fragments		
Other:		
PROCESSED LUMBER (no natural wood)		
Cardboard cartons		
Paper and cardboard		
Paper bags		
Lumber/building material		
Other:		

ITEM	TALLY (e.g., IIII)	TOTAL
CLOTH/FABRIC		
Clothing & shoes		
Gloves (non-rubber)		
Towels/rags		
Rope/net pieces (non-nylon)		
Fabric pieces		
Other:		
OTHER/UNCLASSIFIABLE		

***LARGE DEBRIS ITEMS* (> 1 foot or ~ 0.3 m)**				
Material type (e.g., plastic)	Item type (e.g., net)	Approximate width (m)	Approximate length (m)	Description / photo ID #

Notes on debris items, description of “Other/unclassifiable” items, etc:

<u>Sea state</u>: BEAUFORT WIND FORCE SCALE: Specifications and equivalent speeds for use at sea

FORCE	EQUIVALENT (miles/hr)	SPEED (knots)	WAVE (m)	DESCRIPTION	
0	0-1	0-1	0	Calm	Sea like a mirror
1	1-3	1-3	.1	Light Air	Ripples with the appearance of scales are formed, but without foam crests.
2	4-7	4-6	.2	Light Breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break.
3	8-12	7-10	.6	Gentle Breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.
4	13-18	11-16	1	Moderate Breeze	Small waves, becoming larger; fairly frequent white horses.
5	19-24	17-21	2	Fresh Breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray.
6	25-31	22-27	3	Strong Breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.
7	32-38	28-33	4	Near Gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.
8	39-46	34-40	5.5	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.
9	47-54	41-47	7	Severe Gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	55-63	48-55	9	Storm	Very high waves with long over-hanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The 'tumbling' of the sea becomes heavy and shock-like. Visibility affected.
11	64-72	56-63	11.5	Violent Storm	Exceptionally high waves (small and medium-size ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.
12	73-83	64-71	14+	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.

PELAGIC DEBRIS Large Debris Data Sheet	Organization		Name of organization responsible for collecting the data
	Surveyor Name		Name of person responsible for filling in this sheet
	Phone Number		Phone contact for surveyor
Completed for large items collected OR lost (excluded) from net tows	Date		Date of this survey
	Body of water, location		Name by which the body of water is known

Large Debris Data:

Item Type (vessel, net, etc.)	Status (CAPTURED in net vs. EXCLUDED from net in ship path)	Trawl #	Trawl Latitude (nnn.nnnn N)	Trawl Longitude (nnn.nnnn W)	Approximate Area		Photo ID/#	Description
					Length (ft)	Width (ft)		

7.5.3 Visual survey data sheets

This data sheet is also available on the NOAA website.
http://www.corporateservices.noaa.gov/~noaaforms/eforms/nf75-103.pdf

Shipboard Observation Form for Floating Marine Debris

DIRECTIONS:

1. Determine transect width based on observer height above water and ship speed (see Table)
2. Record ancillary data and start and end lat/long and time.
3. Log debris (> than 2.5 cm) spotted on one side of the vessel (port or starboard) within transect width.

Date: Month/Day/Year	**Vessel Name:**
Observer Name:	**Vessel Speed:**
Height of obs. above water (m):	**Transect width:**

Transect line START: Time (01:00-24:00 UTC): ___________ Heading: ________°

Latitude: _______°____.____' N Longitude: _______°____.____' W

Transect line END: Time (01:00-24:00 UTC): ___________ Heading: ________°

Latitude: _______°____.____' N Longitude: _______°____.____' W

Did your heading change between your start and end time? ☐ YES (Note heading changes below) ☐ NO

Heading change #1: Time of change (01:00-24:00 UTC): ___________ Heading: _____________°

Heading change #2: Time of change (01:00-24:00 UTC): ___________ Heading: _____________°

Heading change #3: Time of change (01:00-24:00 UTC): ___________ Heading: _____________°

Observer height above water	Ship Speed		
	2 knots	6 knots	10 knots
1 m	6 m	4 m	3 m
3 m	8 m	6 m	4 m
6 m	10 m	8 m	6 m
10 m	15 m	10 m	5 m

Observations from PORT or STARBOARD side?	Fishing/Boat Gear				Plastics						Glass		Other	Wildlife			SPEED / WEATHER / SEA STATE					NOTES	Did you take any photos? File naming: VesselName_Date_PhotoNumber
	Buoys/ Floats	Misc Line	Misc. Nets	Other Fishing Gear	Plastic Fragment	Bags, Sheeting, Tarp	Bottles (Beverage)	Jugs/ Buckets	Styrofoam	Other Plastic Item	Glass Bottle	Other Glass Item	*Describe **(e.g., processed lumber)**	Turtles? (Y or N)	Jellyfish? (Y or N)	Seabirds? (Y or N)	Avg wind speed (knots)	Avg boat speed (knots)	Weather (describe)	Cloud cover (% of the overhead sky covered in clouds)	Avg sea state (describe)	**Include info on:** Any disruption, stops, changes in speed, dense patches of debris, etc.	
P	*I*	*0*	*0*	*0*	*III*	*0*	*I*	*0*	*I*	*0*	*II*	*0*	*--*	*N*	*N*	*N*	5	*10*	*sunny/ clear*	*5%*	*calm*	*No stops or disruptions; straight course*	*Y - buoy*

7.6 Marine Debris Survey Photo Manual

NOAA Marine Debris Program
Marine Debris Monitoring and Assessment Project

www.MarineDebris.noaa.gov
Keep the sea free of debris

Marine Debris Survey Photo Manual

Plastic

Plastic fragments will have a similar texture to their original condition, but may be more deteriorated due to exposure to the environment. Polystyrene (PS) can be hard or foamed, but may change with exposure to the environment. Pieces of plastic film or sheeting can be found shredded into strips.

Hard Plastic:

Foamed Plastic:

Plastic Film:

Plastic Film:

Food wrappers come in a variety of types and sizes. Food packaging can be made of polypropylene (PP), polystyrene (PS), or polyethylene (PE). Food wrappers are distinguished from plastic films by identifiable labels.

Beverage bottles for soft drinks, water, juice, sports drinks, and beer. Made in a variety of sizes (e.g. 6 oz. to 2 L), colors vary (translucent, green, brown, light blue, etc.). Usually made of polyethylene terephthalate (PET or can be made of PETE).

Other jugs/containers include a variety of packaging types ranging from the common milk jug to a food container to an oil lube bottle to cleaner bottle to a 5-gallon bucket. Most are made of polyethylene.

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Bottle & container caps come in various sizes and colors. Caps and closures for beverage bottles are usually made of polypropylene (PP) and high density polyethylene (HDPE) with other container lids being made of low density polyethylene (LDPE) or linear LDPE (LLDPE).

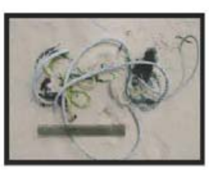
Cigar tips are provided on a few brands of cigars and are considered disposable filters.

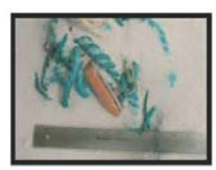
Cigarettes/cigarette filters can be hard or fibrous (both are made of a synthetic polymer – cellulose acetate); some cigarettes may not have filters and are composed of only tobacco and paper.

Disposable cigarette lighters have a casing made of a rigid plastic (usually with a metal top). May or may not contain fluids.

Bags (film) used for dry cleaning, newspapers, bread, frozen foods, bulk ice, fresh produce, household garbage, etc. Bags are usually made of HDPE or LDPE

Plastic rope & small net pieces are composed of synthetic material rather than cloth or fabric. Net pieces can be distinguished from rope pieces if knots are present. Plastic rope and net is composed of polypropylene and/or nylon.

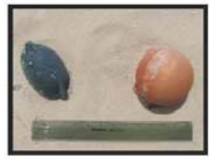




www.MarineDebris.noaa.gov

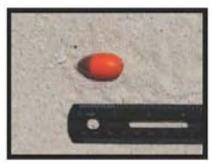
Buoys & floats are usually associated with fishing and boating activities. A buoy floats at the surface and is moored to the bottom. Floats (some are also called bobbers) can 'float' at various depths or rest at the surface. These come in various sizes, shapes and colors. Most mooring buoys are made from HDPE. Rope floats are made of compression molded polyvinyl chloride (PVC). Some floats can be made of rigid polystyrene (PS-foamed plastic).






Fishing line & lures can be found in a variety of forms based on fishing type. Fishing lures come in a variety of shapes, sizes and materials dependent on their function. Modern types are made of plastic with metal hooks and eyes for line. Fishing line types are mostly available in three varieties – monofilament, braided and fluorocarbon. Fishing line is usually made of nylon or PET/PETE, with monofilament being the most popular.






Cups (including polystyrene) are usually made of either PP or foamed plastic / PS. However, some cups have been made of HDPE and PET, with most paper cups being coated with a plastic film.

Straws come in various sizes ranging from shorter ones (~ 4 inches) used in cocktail drinks to a variety of beverage types (~8-10 inches). Straws that are made of paper will deteriorate faster, even if wax-coated. Straws found on the beach or floating on the water will most likely be made of polypropylene (PP).

Balloons (mylar balloons) have a seam and are made of a metal (foil) coated plastic such as polyethylene or nylon.

Personal care products is a very broad plastic debris category. This includes various products including health and beauty aids ranging from deodorants (usually with a roller-ball applicator as most aerosol containers are made of metal) to suntan or body lotion bottles to combs/ brushes to toothbrushes. This debris can be "left" at the beach or is deposited from storm water drainage or washed in from offshore sources. This debris is usually made of polypropylenes and polyethylenes (including HDPE).






Pellets (for use in pelagic and microdebris analysis) Resin pellets are raw plastic material used to produce plastic products. They come in a variety of basic shapes (e.g. round, cylindrical, ovoid), can be translucent or may be in color, but are usually white, black or clear. Once the pellets have been exposed to the environment, their color will change. Most pellets are less than 5 mm in size.




Metal

Aluminum/tin cans are used for beverages (sodas, juice, beer) and food stuffs. Exposure to the environment will cause these containers to deteriorate – aluminum cans become brittle over time and collapse. If dumped at sea, they will most likely sink out before being deposited on the shore. Tin cans can rust when exposed to the environment. These are usually associated with household trash, but larger cans (6 inch diameters or larger) are usually related to ship galley food products.



Aerosol cans have an outer shell of metal (aluminum or steel) and compressed contents. The spray valve will be made of plastic and the cap is also usually plastic. The spray valve and cap will most likely not be attached to the canister.


Metal fragments can vary in size and may be located with a metal detector. Metal pieces that have been exposed to the environment may rust depending upon their material.

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Glass


Beverage bottles are used for sodas, water, liquor, beer, and wine and come in assorted colors (clear, green, brown, blue, and other colors). Most glass beverage bottles have metal caps.



Jars for condiments and other foods can be made of glass. This type of debris is usually associated with household waste (land) or galley waste (ocean). The lids are usually metal. If these are dumped at sea without their lid, they most likely will sink.


Glass fragments care should be taken in collecting this debris. Use gloves and/or use a slotted scooper to remove pieces of glass.

Rubber

Flip-flops/shoes found as debris may consist of the entire article or part of it, such as the bottom of a flip flop or the sole of a shoe. Shoes may be made of leather, canvas or nylon. Boots used for fishing operations and are usually rubber with heavy soles and steel toes.






Gloves are used for numerous water-related activities (both recreationally and commercially). Work gloves used for fishing may be made of natural rubber latex, Nitrile (synthetic rubber compound), neoprene (polychloroprene), polyvinyl alcohol (PVA), polyvinyl chloride (PVC), polyurethane (PUR), or butyl rubber (synthetic). NOTE: In some geographic areas, evidence of sea turtles attempting to feed on discarded gloves can be seen with diamond-shaped bites in the gloves.

Tires can come in various sizes (trucks, cars, trailer, bicycle, recreational vehicles, lawn mower, etc.) and may have the wheel rim still attached (metal), hub cap (metal) covering lug nuts (metal). If an inner tube is found, it will be made of rubber but will be from a much dated vehicle as current styles do not use inner tubes.

Rubber fragments may not feel like "rubber" due to their degradation when exposed to the environment. Due to oxidation, rubber may even feel brittle.

Balloons are traditionally made of a liquid rubber (natural latex). NOTE: Most toy balloons are made of natural latex, but some are made from a synthetic polymer and are therefore considered plastic.

Processed lumber/paper

Cardboard cartons will begin to deteriorate the longer they are exposed to the environment. They absorb moisture and the layers that form the walls will start to fall apart, resulting in the box collapsing. The longer the cardboard carton is exposed, the faster it will deteriorate.

Paper & cardboard will consist of newspapers, magazines and books that may have been left on the beach or have been blown onto the beach or into the water. Cardboard might be left behind as packaging for a case of beer cans or allowed to blown onto a beach from a waste bin. Both materials will most likely be deteriorated due to exposure to the environment.

Paper bags may have been left behind by a beach-user or allowed to blow on the beach or into the water. These may be the result of fast food that was consumed near or on the beach. The bags will begin to deteriorate the longer they are exposed to the environment. As bags absorb moisture the paper will fall apart.

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Building material may include a variety of material types depending upon the use and source. Plywood and lumber pieces can float and will be carried to other areas by the wind and waves. Other potential types of building materials could include PVC piping (polyvinyl chloride), rebar (metal) and polystyrene insulation.

Cloth/fabric


Clothing is usually left behind (lost) by beach goers or fishermen. Shorts, tops and often underwear have been collected.

Gloves (non-rubber) made of fabrics are most likely not used on boats or fishing activities.

Towels/rags have various sources based on usage. Towels are usually left behind by beach goers and rags might be used on boats for working with equipment and maintenance (cleaning) activities


Rope/net pieces that are not made of nylon can be identified by a "softer" feel in most cases. Natural rope material can also be tested using the flame of a lighter where the synthetic rope will melt when exposed to the rope fibers, natural fibers will ignite (provided they are relatively dry). Large (very thick) natural ropes are often used as mooring lines for ships when in port.

Fabric pieces are identified when the original object is no longer distinguishable due to deterioration. Fabric pieces usually tear when pulled on.

7.7 Frequently Asked Questions for Shoreline Surveys

Shoreline Survey Frequently Asked Questions

General

Q: Our volunteers cannot make the regularly scheduled survey. How should we reschedule the survey?

Q: How many photos should be taken at each survey?

Q: How do I keep track of the date on which photos were taken?

Q: My GPS is giving me lat/longs in the wrong format, how do I change it to decimal degrees?

Shoreline Characterization

Q: If my shoreline is greater than six meters wide, I need to record GPS coordinates at all four corners of survey site. How do I take GPS coordinates at the water's edge when waves are washing in and out?

Q: How do I determine the tidal distance?

Q: My shoreline site is longer than 100 m. How do I select a 100 m segment?

Q: How do I determine the back of the shoreline?

Survey Protocols

Q: I found an item of debris smaller than 2.5 cm in the longest dimension. Why can't I record it on the data sheet?

Q: I found an item that could become a large item (> 30 cm) if it became unraveled / unwound. How should I record it?

Q: Do surveys always need to be conducted at low tide?

Q: Why do we need to measure beach width at every survey?

Q: How do you record the width of the site if the back of the shoreline is not parallel to the water (e.g., a U-shaped site)?

Q: What should I do if I cannot determine the debris material type?

Q: I found a piece of natural driftwood. Should I record this on the survey sheet?

Q: I found an item that is coated in one material type, and composed of another. How do I record it?

Q: I found multiple pieces of a larger piece of debris. Should I record it as one item or multiple items?

Q: There is debris beyond the first barrier or change in substrate at the back of the shoreline. Can I record those items?

Q: What should I do if I find debris fouled with what might be invasive species?

Q: What should I do if I find a piece of hazardous debris?

Q: What should I do if I find a derelict vessel or other large object that may become a hazard to navigation?

Q: What should I do if I find an item that may be a valuable or significant memento?

Q: I am completing standing-stock surveys. Why do I need to take GPS coordinates of all four transects at every survey?

Q: I am completing standing-stock surveys, and at multiple surveys I have been encountering the same item. Should I tally this item at each survey (assuming it is in one of the random transects)?

Data Entry and Submission

Q: How do I get access to the NOAA MD-MAP database?

Q: How often should I upload data to the NOAA MD-MAP database?

General

Q: Our volunteers cannot make the regularly scheduled survey. How should we reschedule the survey?

A: Surveys should be conducted on a regular, every 28 day schedule. If you need to miss a survey it should be made up within a three day window of the original survey date (i.e., 28 days ± 3 days). That gives you a seven day window for completing the missed survey.

Q: How many photos should be taken at each survey?

A: Taking a photo of the entire site from the beginning and end points at each survey is a good way to visually capture changes in shoreline topography and other characteristics that may affect debris deposition. You may also want to take a photo of each individual transect. In addition, please take photos of interesting, unidentifiable, or fouled debris (organisms growing on or attached to debris).

Q: How do I keep track of the date on which photos were taken?

A: You should download the photos to your computer following each survey. Change the filename of the photos to include a date, location, and photo # (e.g., 06-10-2012_LongBeach#01.jpg). You can also write comments about the photos you've taken in the notes section of the data sheet.

Q: My GPS is giving me lat/longs in the wrong format, how do I change it to decimal degrees?

A: The lat/long units can be usually be changed in the general settings of the GPS. There are also many online tools to convert between units.

Shoreline Characterization

Q: If my shoreline is greater than six meters wide, I need to record GPS coordinates at all four corners of survey site. How do I take GPS coordinates at the water's edge when waves are washing in and out?

A: When you conduct your initial shoreline characterization it is important to arrive at the site at low tide so that you can capture the entire width of the beach. In order to record GPS readings at the water's edge, watch the breaking waves to try to determine the shoreward extent of the water. Record coordinates at that point. If a portion of the shoreline site is underwater at subsequent surveys do not try to enter the water to survey. Only survey the exposed area of the shoreline.

Q: How do I determine the tidal distance?

A: Tidal distance is the horizontal distance on the beach between the average low and high tide lines. Arrive at your site at low tide and measure the distance from the water's edge to the high tide wrack line. This measurement is different from the total width of the shoreline, which is measured from the waters' edge to the back barrier.

Q: My shoreline site is longer than 100 m. How do I select a 100 m segment?

A: Select your 100 m segment based on areas with relatively low public usage, little evidence of debris from day use (picnic debris), and areas that are not immediately adjacent to an obstruction to nearshore circulation (e.g., breakwater, point of land). Also consider landmarks or permanent features to assist in returning to the same segment at future dates. You may want to consider randomly selecting multiple 100 m segments within a larger shoreline site.

Q: How do I determine the back of the shoreline?

A: The back of the shoreline is defined here as the first major change in substrate, which may be a vegetation line, cliff, or other barrier. If you are interested in also monitoring debris that may be pushed back into vegetation behind the beach during storms, that debris should be tallied on a separate data sheet so that it's not included in the calculated debris standing-stocks. Data entered into the NOAA database should only reflect the debris to the first change in substrate. If the back of the shoreline is only a partial barrier, for example a patch of vegetation behind which there is more beach, then survey up to the first continuous barrier (include that vegetation patch and the area behind it). In some cases, shoreline sites may be too complex to clearly delineate a maximum landward limit where debris might be deposited. These types of sites, and shorelines that are very high energy or dominated by sedimentary deposits, may not be good shoreline survey candidates. For the same reason, barrier islands and other shifting substrates are not likely to be ideal survey locations.

Survey Protocols

Q: I found an item of debris smaller than 2.5 cm in the longest dimension. Why can't I record it on the data sheet?
A: The 2.5 cm size cutoff (about the size of a bottle cap) is used as a standard metric because it is the smallest size that can reliably and consistently be detected with the human eye.

Q: I found an item that could become a large item (> 30 cm) if it became unraveled / unwound. How should I record it?
A: Items should be recorded according to how they're found at the time of the survey. For example, if a circular strap or band is found enclosed and is < 30 cm in all dimensions it should be recorded as a regular-sized item, but if it is opened / detached and is longer than 30 cm, it should be recorded as a large item.

Q: Do surveys always need to be conducted at low tide?
A: The NOAA protocols ask for surveys to be conducted at low tide so that the entire area where debris may be deposited is surveyed. However, in some areas where tidal ranges are measured in 10's of meters, it may not be practical to survey at low tide when large mud flats or wave-cut platforms are exposed. If it becomes apparent that the vast majority of debris in the intertidal is ultimately pushed up to the high tide wrack line, surveyors may decide that it is valid to survey at times outside of the suggested window. However, this decision should be made carefully, backed up with data, and revisited on a regular basis.

Q: Why do we need to measure beach width at every survey?
A: Knowing the width of the shoreline allows NOAA to report debris densities in units of # of items per square meter of shoreline. NOAA asks for the shoreline width at each survey in order to evaluate the variability in shoreline width over the course of the project. Ideally, you could note the shoreline width at the average lowest tide of the day (tidal height 0' according to tide tables or graphs), referred to as Mean Lower Low Water (MLLW, more information available at: http://tidesandcurrents.noaa.gov/datum_options.html).

Q: How do you record the width of the site if the back of the shoreline is not parallel to the water (e.g., a U-shaped site)?
A: If the shoreline site is irregularly shaped, you will need to measure the width in a few different places in order to get an accurate estimate of total shoreline area. Please sketch the shape of the site in the data sheet notes section. Break the shoreline into a series of rectangles and measure the length and width of each. This does not need to be done at every survey.

Q: What should I do if I cannot determine the debris material type?
A: If you don't know whether an item is rubber, plastic, metal, etc., record it under "other", provide a description, and take photos.

Q: I found a piece of natural driftwood. Should I record this on the survey sheet?
A: No. Natural woody debris does not fall under the official definition of marine debris. Only processed or treated lumber should be recorded.

Q: I found an item that is coated in one material type, and composed of another. How do I record it?
A: Items should be recorded according to the primary material type on the surface of the item.

Q: I found multiple pieces of a larger piece of debris. Should I record it as one item or multiple items?
A: Record the item in the condition you found it. If the item was broken when you found it, record each piece separately. If it broke while you were examining it, record the debris as one item only.

Q: There is debris beyond the first barrier or change in substrate at the back of the shoreline. Can I record those items?
A: Items located beyond the first barrier can be noted and described in the notes section of the data sheet (or on a separate data sheet), but this data should be compiled separately from the shoreline debris data.

Q: What should I do if I find debris fouled with what might be invasive species?
A: If you suspect that you may have found debris with invasive species, please take clear photos of the item, attached organism, and any identifying marks on the object. Remove the item from the water or shoreline and place on dry land well above the high tide line. You may want to contact local taxonomic experts listed at http://www.anstaskforce.gov/Tsunami.html. In your report note the current location of the item.

Q: What should I do if I find a piece of hazardous debris?
A: If you encounter hazardous items such as oil or chemical drums, contact your local authorities (a 911 call), state environmental health agency, and the National Response Center 1-800-424-8802. Provide as much information as possible so the authorities can determine how to respond.

Q: What should I do if I find a derelict vessel or other large object that may become a hazard to navigation?
A: Contact your local authorities (a 911 call), state environmental health agency, and the U.S. Coast Guard Pacific Area Command at 510-437-3701. Provide as much information as possible so the authorities can determine how to respond.

Q: What should I do if I find an item that may be a valuable or significant memento?
A: If an item has unique identifiers and may be traceable to an individual or group, please take photos and report the item to DisasterDebris@noaa.gov (note that the item was found during a monitoring survey). Use your best judgment to determine what may or may not be valuable.

Q: I am completing standing-stock surveys. Why do I need to take GPS coordinates of all four transects at every survey?
A: Taking GPS coordinates of each transect helps NOAA to track the location of transects and to ensure that the survey site location is not changing over time (due to moving landmarks or shifting

beach dynamics). Additionally, it helps to ensure that site start/end points are located correctly and that equipment is functioning properly.

Q: I am completing standing-stock surveys, and at multiple surveys I have been encountering the same item. Should I tally this item at each survey (assuming it is in one of the random transects)?
A: Yes! This is part of the reason that standing-stock surveys are informative. They provide information on the density of debris on the shoreline and how it changes over time. Debris that remains on the shoreline for long periods of time is part of the "standing-stock." The persistence of the item can be noted in the notes section of the data sheet.

Data Entry and Submission

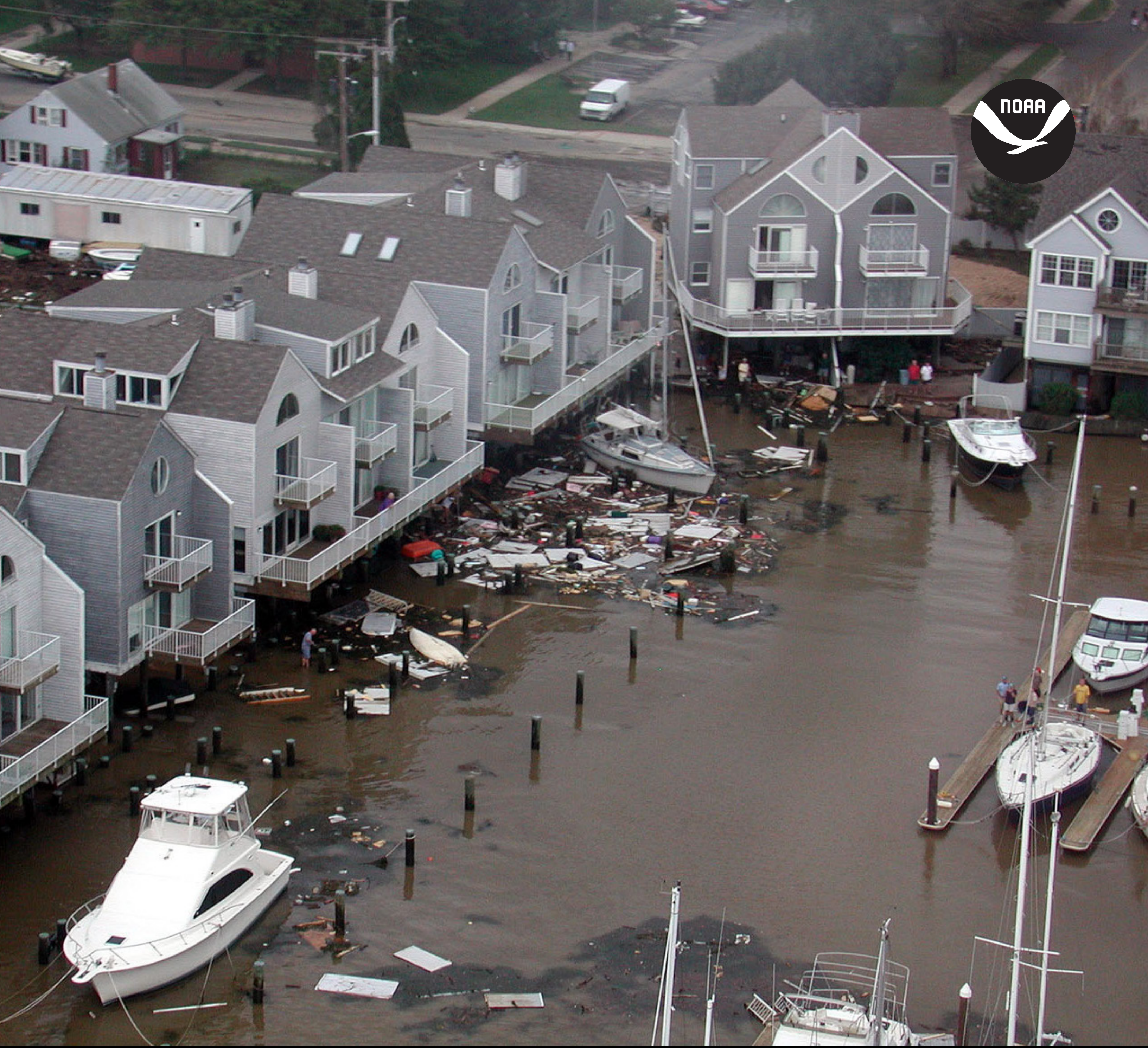
Q: How do I get access to the NOAA MD-MAP database?
A: Send an email to MD.monitoring@noaa.gov for questions about the database or to request a login.

Q: How often should I upload data to the NOAA MD-MAP database?
A: Please enter data into MD-MAP as soon as possible after each survey to ensure that data is entered accurately.

Penny Pritzker
United States Secretary of Commerce

Dr. Kathryn D. Sullivan
Acting Under Secretary of Commerce for Oceans and Atmosphere

Dr. Holly A. Bamford
Assistant Administrator, National Ocean Service



Maryland Marine Debris Emergency Response Guide: Comprehensive Guidance Document

NOAA Marine Debris Program
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
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Photo: Crystal Payton, Federal Emergency Management Agency

Table of Contents

List of Acronyms

ACP	Area Contingency Plan
ADV	Abandoned or derelict vessel
BMP	Best Management Practice
C&D	Construction and Demolition Debris
CBRA	Coastal Barrier Resources Act
CBRS	John H. Chafee Coastal Barrier Resources System
CERCLA	Comprehensive Environmental Response Compensation Liability Act
ECP	Emergency Conservation Program (of FSA)
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ERMA	Environmental Response Management Application
ESA	Endangered Species Act
ESF	Emergency Support Function
ESFO	Ecological Services Field Office (of USFWS)
EWP	Emergency Watershed Protection Program (of NRCS)
FEMA	Federal Emergency Management Agency
FOSC	Federal On-Scene Coordinator
FSA	Farm Service Agency
GIS	Geographic Information Systems
HOA	Home Owners Association
LIDAR	Light Detection and Ranging
MDE	Maryland Department of the Environment
MDNR	Maryland Department of Natural Resources
MDOT	Maryland Department of Transportation
MDP	Maryland Department of Planning
MEMA	Maryland Emergency Management Agency
MHT	Maryland Historical Trust (of MDP)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (of NOAA)
NPS	National Park Service
NRC	National Response Center
NRCS	Natural Resources Conservation Service
NRP	Natural Resource Police (of MDNR)
NRT	Navigation Response Team (of NOAA)
NWR	National Wildlife Refuge (of USFWS)
ORR	Office of Response and Restoration (of NOAA)
RCRA	Resource Conservation and Recovery Act
RP	Responsible Party
SCF	State Coordinating Function
SHPO	State Historic Preservation Office
SSC	Scientific Support Coordinator (of NOAA)
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service

Definitions

Abandoned or sunken vessel – Any vessel that: (1) Is left illegally or has remained without permission for more than 30 days on public property, including public marinas, docks, or boatyards; (2) Has remained at the following locations for more than 90 days without the consent of the owner or person in control of the property: (i) A private marina or property operated by a private marina; or (ii) A private boatyard or property operated by a private boatyard; (3) Has remained at the following locations for more than 30 days without the consent of the owner or person in control of the property: (i) A private dock; or (ii) At or near waters' edge on private property; (4) Has remained on private property other than the private property described in items (2) and (3) of this subsection for more than 180 days without the consent of the owner or person in control of the property; or (5) (i) Has been found adrift or unattended in or upon the waters of the State, and is found in a condition of disrepair as to constitute a hazard or obstruction to the use of the waters of the State or presents a potential health or environmental hazard; and (ii) Is not: 1. Historic property as defined in § 5A-301 of the State Finance and Procurement Article; or 2. Submerged archaeological historic property as defined in § 5A-333 of the State Finance and Procurement Article (Md. Code Ann. § 8-721(a)).

Acute waterway debris incident – An incident that results in the release of large amounts of waterway debris. This may include natural incidents such as severe storms or anthropogenic incidents such as maritime disasters.

Area Contingency Plan (ACP) – Reference document prepared by an Area Committee for the use of all agencies engaged in responding to environmental emergencies in a defined geographic area. The purpose of the ACP is to define the roles, responsibilities, resources, and procedures necessary to address oil and hazardous substance incidents. For Maryland, the *Upper Chesapeake Bay Estuary Area Contingency Plan* is prepared by the Area Committee and maintained by U.S. Coast Guard District 5, Sector Maryland-National Capital Region (U.S. Coast Guard [USCG], 2012).

Chemical, biological, radiological, and nuclear-contaminated debris – Debris contaminated by chemical, biological, radiological, or nuclear materials (Federal Emergency Management Agency [FEMA], 2018).

Coastal zone (ACP coastal zone) – U.S. Coast Guard area of responsibility for response under the National Contingency Plan, with geographic boundaries defined in the *Upper Chesapeake Bay Estuary Area Contingency Plan* (USCG, 2012).

Coastal zone (under Maryland Coastal Zone Management Program) – The Maryland coastal zone extends from three miles out in the Atlantic Ocean to the inland boundaries of the following 16 counties and Baltimore City that border the Atlantic Ocean, Chesapeake Bay, and the Potomac River up to the District of Columbia: Anne Arundel, Baltimore, Calvert, Carolina, Cecil, Charles, Dorchester, Harford, Kent, Prince George's, Queen Anne's, St. Mary's, Somerset, Talbot, Wicomico, and Worcester (Maryland Department of Natural Resources, n.d.).

Construction and demolition debris (C&D) – Components of buildings and structures, such as lumber and wood, gypsum wallboard, glass, metal, roofing material, tile, carpeting and other floor coverings, window coverings, pipe, concrete, asphalt, equipment, furnishings, and fixtures (FEMA, 2018).

Electronic waste (e-waste) – Electronics that contain hazardous materials, such as computer monitors, televisions, cell phones, and batteries. These products may contain minerals and chemicals that require specific disposal methods (FEMA, 2018).

Eligible applicant – Entities who may receive public assistance reimbursement funding from the Federal Emergency Management Agency (FEMA) under the Stafford Act. Eligible applicants include state and local governments, federally recognized Indian tribal governments, and certain private non-profits that serve a public function and have the legal responsibility to remove the debris (FEMA, 2018).

Eligible debris – Debris that is a direct result of a presidential major disaster declaration, in the designated disaster area, and whose removal is in the public interest (i.e., eliminating the immediate threat of significant damage to improved public or private property or ensuring economic recovery of the affected community to the benefit of the community at large). Debris includes, but is not limited to, vegetative debris, construction and demolition debris, sand, mud, silt, gravel, rocks, boulders, and vehicle and vessel wreckage. Debris removal from waterways that is necessary to eliminate the immediate threat to life, public health and safety, or improved property is considered eligible (FEMA, 2018; 44 C.F.R. § 206.224).

Emergency (state definition) – The threat or occurrence of: (1) A hurricane, tornado, storm, flood, high water, wind-driven water, tidal wave, earthquake, landslide, mudslide, snowstorm, drought, fire, explosion, and any other disaster in any part of the State that requires State assistance to supplement local efforts in order to save lives and protect public health and safety; or (2) An enemy attack, act of terrorism, or public health catastrophe (Md. Code Ann. § 14-101(c)).

Emergency (FEMA definition) – Any occasion or instance for which, in the determination of the president, federal assistance is needed to supplement state and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen or avert the threat of a catastrophe in any part of the United States (42 U.S.C. § 5122(1)).

Emergency (USACE definition) – A situation which would result in an unacceptable hazard to life, a significant loss of property, or an immediate, unforeseen, and significant economic hardship if corrective action requiring a permit is not undertaken within a time period less than the normal time needed to process the application under standard procedures (33 C.F.R. § 325.2(e)(4)).

Emergency Support Function (ESF) – Mechanism for grouping functions most frequently used to provide federal support to states and federal-to-federal support, both for declared disasters and emergencies under the Stafford Act and for non-Stafford Act incidents. The state of Maryland utilizes the State Coordinating Function (SCF) approach, similar to the federal ESFs, and assigns corresponding state agencies to each SCF in the *Maryland Consequence Management Operations Plan* as prepared by Maryland Emergency Management Agency (Maryland Emergency Management Agency [MEMA], 2019). The Environmental Protection SCF and the Natural Resources SCF are the two most commonly applied SCFs during response to a waterway debris incident, whereas ESF-3, Public Works and Engineering, and ESF-10, Oil and Hazardous Materials Response, are the most commonly applied federal support functions.

Environmental Sensitivity Index Map – Maps produced by the National Oceanic and Atmospheric Administration (NOAA) that are a compilation of information about coastal shoreline sensitivity, biological resources, and human use resources. This information is used in planning to create cleanup strategies before an accident occurs so that authorities are prepared to act in the event of a spill (National Oceanic and Atmospheric Administration [NOAA], 2019a).

Federally maintained waterways and channels – A waterway that has been authorized by Congress and which U.S. Army Corps of Engineers operates and maintains for general (including commercial and recreational) navigation (FEMA, 2010).

Hazard to navigation – An obstruction, usually sunken, that presents sufficient danger to navigation so as to require expeditious, affirmative action such as marking, removal, or re-definition of a designated waterway to provide for navigational safety (33 C.F.R. § 64.06).

Hazardous substance – (A) Any substance designated pursuant to section 311(b)(2)(A) of the Federal Water Pollution Control Act, (B) any element, compound, mixture, solution, or substance designated pursuant to 42 U.S.C. § 9602, (C) any hazardous waste having the characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by Act of Congress), (D) any toxic pollutant listed under section 307(a) of the Federal Water Pollution Control Act, any hazardous air pollutant listed under section 112 of the Clean Air Act, and (F) any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to section 7 of the Toxic Substances Control Act. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph and the term does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas; 42 U.S.C. § 9601(14)).

Hazardous waste – Regulated under the Resource Conservation and Recovery Act (RCRA) and contains properties that make it potentially harmful to human health or the environment. A RCRA hazardous waste is a waste that appears on one of the four hazardous waste lists or exhibits at least one of the following four characteristics: ignitability, corrosivity, reactivity, or toxicity (FEMA, 2018).

Household hazardous waste/material – Hazardous products and materials that are used and disposed of by residential consumers, including some paints, stains, varnishes, solvents, pesticides, and other products containing volatile chemicals that catch fire, react, or explode under certain circumstances or that are corrosive or toxic (FEMA, 2018).

Improved property – Any structure, facility, or equipment that was built, constructed, or manufactured. Examples include buildings, levees, roads, and vehicles. Land used for agricultural purposes is not improved property, nor are vacant lots, forests, heavily wooded areas, and unused areas (44 C.F.R. § 206.221(d)).

Incident waterway debris – See definition for Waterway debris.

Infectious waste – Waste capable of causing infections in humans and can include animal waste, human blood and blood products, medical waste, pathological waste, and discarded sharps (needles, scalpels, or broken medical instruments; FEMA, 2018).

Inland zone (ACP inland zone) – U.S. Environmental Protection Agency area of responsibility for response under the National Contingency Plan, with geographic boundaries defined in the *Upper Chesapeake Bay Estuary Area Contingency Plan* (USCG, 2012).

Major disaster – Any natural catastrophe (including any hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, or drought), or, regardless of cause, any fire, flood, or explosion, in any part of the United States, which in the determination of the president causes damage of sufficient severity and magnitude to warrant major disaster assistance under this Act to supplement the efforts and available resources of states, local governments, and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby (42 U.S.C. § 5122(2)).

Marine debris – 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 Great Lakes (33 U.S.C. § 1956(3)).

National Oil and Hazardous Substances Pollution Contingency Plan (National Contingency Plan, NCP) – Federal Government's blueprint for responding to both oil spills and hazardous substance releases (U.S. Environmental Protection Agency, 2018).

Navigable waterways – Navigable waterways include both those waterways which are federally maintained and those waterways which are not federally maintained. U.S. Army Corps of Engineers defines navigable waters of the United States as those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the waterbody, and is not extinguished by later actions or events which impede or destroy navigable capacity (33 C.F.R. § 329.4; 33 C.F.R. § 2.36).

Obstruction – Anything that restricts, endangers, or interferes with navigation (33 C.F.R. § 64.06).

Oil – Oil of any kind or in any form, including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil (33 U.S.C. § 1321(a)(1)).

Pollutant or contaminant – Includes, but is not limited to, any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring; except that the term "pollutant or contaminant" shall not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of 42 U.S.C. § 9601(14) and shall not include natural gas, liquefied natural gas, or synthetic gas of pipeline quality (or mixtures of natural gas and such synthetic gas; 42 U.S.C. § 9601(33)).

Pollution – (1) "Pollution" means every contamination or other alteration of the physical, chemical, or biological properties, of any waters of the State. (2) "Pollution" includes change in temperature, taste, color, turbidity, or odor of the waters of the State or the discharge or deposit of any organic matter, harmful organism, or liquid, gaseous, solid, radioactive, or other substance into any waters of the State as will render the waters of the State harmful, detrimental, or injurious to public health, safety, or welfare, domestic, commercial, industrial, agricultural, recreational, other legitimate beneficial uses, or livestock, wild animals, birds, fish, or other aquatic life (Md. Code Ann. § 9-101(e)).

Putrescent debris – Debris that will decompose or rot, such as animal carcasses and other fleshy organic matter (FEMA, 2018).

Recoverable waterway debris – Generally any documented vessel, vehicle, recreational vehicle, or shipping container traceable to an owner (U.S. Army Corps of Engineers, 2010).

Severe marine debris event – An atypically large amount of marine debris caused by a natural disaster, including a tsunami, flood, landslide, or hurricane, or other source (33 U.S.C. § 1956(6)).

Soil, mud, and sand – Soil, mud, and sand deposited after floods, landslides, winds, and storm surges on improved public property and rights-of-way (FEMA, 2018).

Stafford Act – The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, provides the authorities and funding for federal support to state and local entities in responding to presidential major disaster and emergency declarations (U.S. Department of Homeland Security, 2013).

State Coordinating Functions (SCF) – State Coordinating Functions (SCF) feature a lead State Department/Agency/Office and one or more support State Departments/Agencies. The SCFs conduct state-level operations and support the needs of local jurisdictions and other State Departments/Agencies/Offices during consequence management activities (MEMA, 2019). The state of Maryland utilizes the State Coordinating Function (SCF) approach, similar to the federal ESFs, and assigns corresponding state agencies to each SCF in the *Maryland Consequence Management Operations Plan* as prepared by Maryland Emergency Management Agency (Maryland Emergency Management Agency [MEMA], 2019). The Environmental Protection SCF and the Natural Resources SCF are the two most commonly applied SCFs during response to a waterway debris incident, whereas ESF-3, Public Works and Engineering, and ESF-10, Oil and Hazardous Materials Response, are the most commonly applied federal support functions.

State wetlands – Any land under the navigable waters of the State below the mean high tide, affected by the regular rise and fall of the tide. Wetlands of this category which have been transferred by the State by valid grant, lease, patent or grant confirmed by Article 5 of the Maryland Declaration of Rights shall be considered "private wetland" to the extent of the interest transferred (Md. Code Ann. § 16-101(p)).

Vegetative debris – Whole trees, tree stumps, tree branches, tree trunks, and other leafy material. May be recyclable or have salvage value (FEMA, 2018).

Vehicles and vessels (FEMA definition) – Vehicles and vessels damaged, destroyed, displaced, or lost as a result of a disaster. These vehicles and vessels may eventually be abandoned because of the damage incurred or because the original owners have relocated. Vehicles and vessels may be classified as debris if they block public access and critical facilities (FEMA, 2018).

Vessel – Every description of watercraft, including an ice boat but not including a seaplane, that is used or capable of being used as a means of transportation on water or ice (Md. Code Ann. § 8-701(s)(1)).

Waters of the State – Waters of the State includes: (1) Both surface and underground waters within the boundaries of the State subject to its jurisdiction; (2) That portion of the Atlantic Ocean within the boundaries of the State; (3) The Chesapeake Bay and its tributaries; (4) All ponds, lakes, rivers, streams, public ditches, tax ditches, and public drainage systems within the State, other than those designed and used to collect, convey, or dispose of sanitary sewage; and (5) The floodplain of free-flowing waters determined by the Department of the Environment on the basis of the 100-year flood frequency (Md. Code Ann. § 8-101(g)).

Waterway debris (Incident waterway debris) – Any solid material, including but not limited to vegetative debris and debris exposed to oil, hazardous substances, pollutants or contaminants, that enters a waterway following an acute release incident and poses a threat to the natural or man-made environment. This may include shoreline debris and debris in some inland, non-tidal waterways.

White goods – Discarded household appliances such as refrigerators, freezers, air conditioners, heat pumps, ovens, ranges, washing machines, clothes dryers, and water heaters. May contain ozone-depleting refrigerants, mercury, or compressor oils that must be removed before disposal. May be recyclable or have salvage value (FEMA, 2018).

1. Introduction

1.1 Purpose

The purpose of this document is to improve preparedness for response and recovery operations following an acute waterway debris incident in coastal Maryland. The term acute waterway debris incident is used to describe an incident – either natural or anthropogenic – that results in the release of large amounts of waterway debris. This document outlines existing response structures at the local, state, and federal levels to facilitate a coordinated, well-managed, and immediate response to waterway debris incidents impacting the state of Maryland.

Individual organization roles and responsibilities are presented in text form as well as in a consolidated one-page flowchart that functions as a decision tree for waterway debris response. The document also includes an overview of permitting and compliance requirements that must be met before waterway debris removal work begins. This information is synthesized in a one-page reference handout.

Because all incidents are different, in reality some aspects of waterway debris response are subjective and not solely dependent on prevailing roles and authorities. This is especially true following a major, catastrophic, or unprecedented incident. This guide seeks to capture the most likely response structure and actions with the understanding that flexibility is an inherent component of an effective response.

The *Maryland Marine Debris Emergency Response Guide: Comprehensive Guidance Document* (*Guide*) serves as a complete reference for Maryland incident waterway debris response. The accompanying *Field Reference Guide* only includes the most pertinent information for quick reference in the field and during emergency response operations.

1.2 Scope of *Guide*

The *Guide* addresses potential acute waterway debris incidents affecting Maryland's coastal counties. Throughout this document, the term waterway debris (or incident waterway debris) is used in lieu of the term marine debris. In 33 U.S.C. § 1956(3), marine debris is 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 Great Lakes. Although vegetative debris is not included in the legal definition for marine debris, stakeholders have identified it as a common debris stream of concern following natural disasters. To account for both marine debris and vegetative debris in this document, the term waterway debris is used and includes any solid material, including but not limited to vegetative debris and debris exposed to or that has the potential to release oil, hazardous substances, pollutants or contaminants, that enters a waterway following an acute incident and poses a threat to the natural or man-made environment. This may include shoreline and wetland debris and debris in some inland, non-tidal waterways. This *Guide* specifically addresses waterway debris resulting from acute episodic incidents, such as disaster debris, and may not apply to chronic waterway debris issues.

1.3 *Guide* Maintenance

The *Maryland Marine Debris Emergency Response Guide* is a living document and is subject to change as additional information becomes available and updates are needed. The *Guide* will be maintained by the National Oceanic and Atmospheric Administration's (NOAA) Marine Debris Program in coordination with federal, state, and local stakeholders. Contact information will be verified annually, and the *Guide* will undergo a formal review every three years. The *Maryland Marine Debris Emergency Response Guide* and subsequent versions will be posted on NOAA's Marine Debris Program website at https://marinedebris.noaa.gov/ (National Oceanic and Atmospheric Administration [NOAA], 2019b).

2. Incident Waterway Debris in Maryland

2.1 Foreseeable Waterway Debris Incidents in Maryland

The state of Maryland offers a unique geography and demographic that makes it vulnerable to both natural and anthropogenic hazards that generate waterway debris. Maryland's coastal zone extends from three miles out in the Atlantic Ocean to the counties that border the Chesapeake Bay and the Potomac River. The coastal zone is comprised of 16 counties plus the city of Baltimore and is home to almost 70% of Maryland's residents (Maryland Department of Natural Resources, n.d.). Many of Maryland's coastal counties have borders along the Chesapeake Bay, the largest estuary in North America, which has the potential to carry large amounts of debris into the Atlantic Ocean.

The Maryland Emergency Management Agency (MEMA) conducted a risk analysis to identify the most probable and impactful hazardous events that could occur in Maryland. The method used for assessing identified hazards was based on several factors including historical occurrences, vulnerability of population, historical impacts, and local hazard mitigation plan hazard risk rankings. The most likely hazard events, meaning events that are likely to occur more than once every five years, were flood, coastal hazards, winter storms, wind, and thunderstorms (Maryland Emergency Management Agency [MEMA], 2016).

In the hazard risk analysis, coastal hazards included tropical storms, hurricanes, Nor'easters, sea level rise, and shoreline erosion. Due to Maryland's extensive shoreline and high coastal population, the majority of its residents are vulnerable to these coastal hazards. Figure 1 shows the coastal hazard ranking assessment for each of Maryland's coastal counties. Of the 16 coastal counties, 14 are considered to be at a high or medium-high risk for coastal hazards.

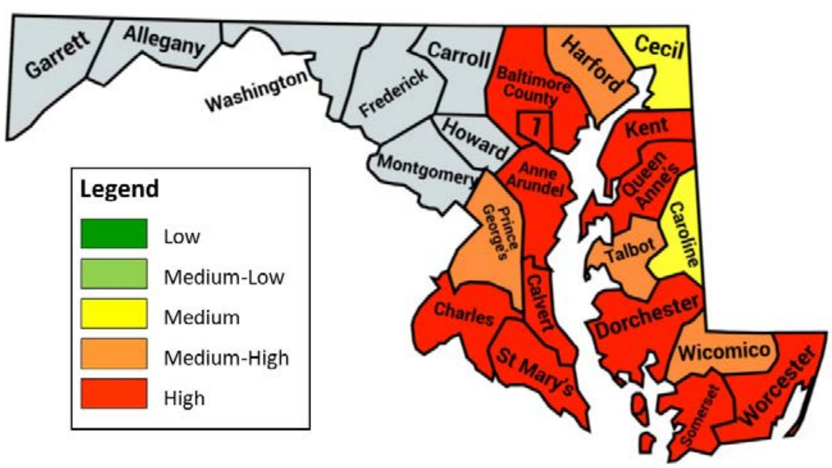


Figure 1. Maryland's coastal county risk assessment for coastal hazards. Coastal hazards include tropical storms, hurricanes, Nor'easters, sea level rise, and shoreline erosion. Data adapted from Maryland Emergency Management Agency (2016).

Flooding and coastal hazards were identified as the most frequent and widespread hazards to occur in Maryland (MEMA, 2016). Coastal hazards also have the potential to cause flooding as a secondary hazard, for example, flooding from a hurricane's storm surge. Flooding can produce significant amounts of waterway debris, potentially causing navigational hazards and water quality issues within the Chesapeake Bay and its tributaries. Since 2016, Maryland has suffered from three severe flooding events, resulting in three major disaster declarations and the opening of the Conowingo Dam along the Susquehanna River. When record-breaking rainfall forced officials to open the floodgates of the dam in July 2018 to prevent flooding, a large amount of debris was carried with it. Although difficult to quantify, researchers believe the amount and impact of debris was significant, especially since the Susquehanna River is the Chesapeake Bay's largest tributary and contributes about half of the bay's freshwater (about 19 million gallons per minute; Chesapeake Bay Program, 2019).

Regardless of the type of hazard to affect Maryland, debris removal projects have high costs in relation to other types of projects eligible for reimbursement through the Federal Emergency Management Agency (FEMA) following a presidentially declared disaster. Since 1962, Maryland has had 29 major disaster declarations, most of which have been the result of severe storms and flooding (Federal Emergency Management Agency [FEMA], n.d.). Maryland's vulnerability to such events highlights the importance of planning and preparedness for incident waterway debris.

2.2 Prominent Debris Types

Some agency authorities are dependent on both the location and type of debris. Therefore, response to debris in Maryland waterways may vary depending on the debris type to be removed. Primary debris types generated after a disaster as defined by FEMA (2018) include the following:

- Chemical, biological, radiological, and nuclear-contaminated
- Construction and demolition (C&D)
- Electronic waste (e-waste)
- Household hazardous waste/material
- Infectious waste
- Oil and hazardous substances
- Putrescent debris
- Soil, mud, and sand
- Vegetative debris
- Vehicles and vessels
- White goods

A description of each debris type is included in the Definitions section of this document. It is difficult to predict the exact mix of waterway debris that will be generated after a disaster since different types of hazard incidents generally result in different debris types. Table 1 includes an overview of typical debris streams for several natural hazards. Although Table 1 only covers natural hazards, man-made hazards such as an accident during waterway commerce are also concerns. Anthropogenic hazards are highly variable in both quantity and type of waterway debris released.

Natural Hazards	Typical Debris Streams								
	Vegetative	Construction and Demolition (C&D)	Oil and Hazardous Material	Household Hazardous Waste	White Goods	Soil, Mud, and Sand	Vessels and Vehicles	Putrescent or Infectious	Household/Personal Property
Hurricanes/Tropical Storms	X	X	X	X	X	X	X	X	X
Flooding	X	X	X	X	X	X	X	X	X
Tornadoes/Wind Storms	X	X	X	X	X		X	X	X
Earthquakes		X	X	X	X	X			X
Winter/Ice Storms	X			X					
Tsunamis	X	X	X	X	X	X	X	X	X

Table 2. Typical debris streams for different types of hazard incidents. Data adapted from Federal Emergency Management Agency (2007).

The type and quantity of waterway debris generated after a disaster is highly dependent on land use and existing infrastructure along Maryland waterways. For example, protected undeveloped areas along the eastern shore are likely to generate vegetative debris, while developed properties in Baltimore City are likely to generate C&D debris. A land cover map for Maryland is depicted in Figure 2 and illustrates the distribution of land use types in the state, including developed lands. Increased development in the floodplain will increase the likelihood of waterway debris following a natural hazard event.

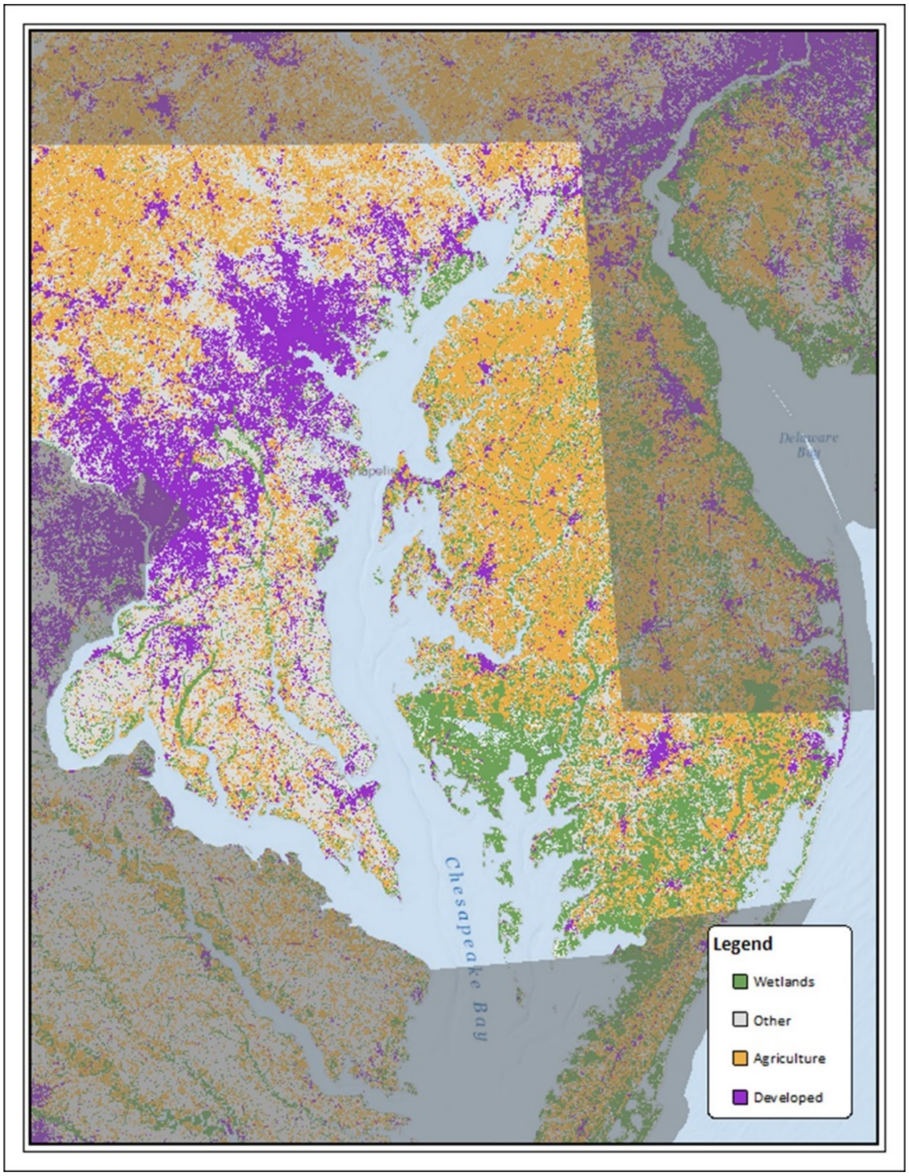


Figure 2. Land cover map for the coastal region of Maryland (National Oceanic and Atmospheric Administration, 2018b).

3. Maryland Incident Waterway Debris Response Flowchart

The "Maryland Incident Waterway Debris Response Flowchart" included in this section provides a visual one-page representation of organization roles and responsibilities. The flowchart functions as a decision tree for waterway debris response with color-coded endpoints. Yellow endpoints represent response to waterway debris that is exposed to or has the potential to release oil, hazardous substances, pollutants, or contaminants. Blue endpoints represent response to waterway debris that is not exposed to and does not have the potential to release oil, hazardous substances, pollutants, or contaminants. Endpoints within the green shaded area indicate that response may occur under Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) authorities and/or funding.

For detailed information regarding individual organization roles, responsibilities, and authorities, see Section 4.

Maryland Incident Waterway Debris Response Flowchart

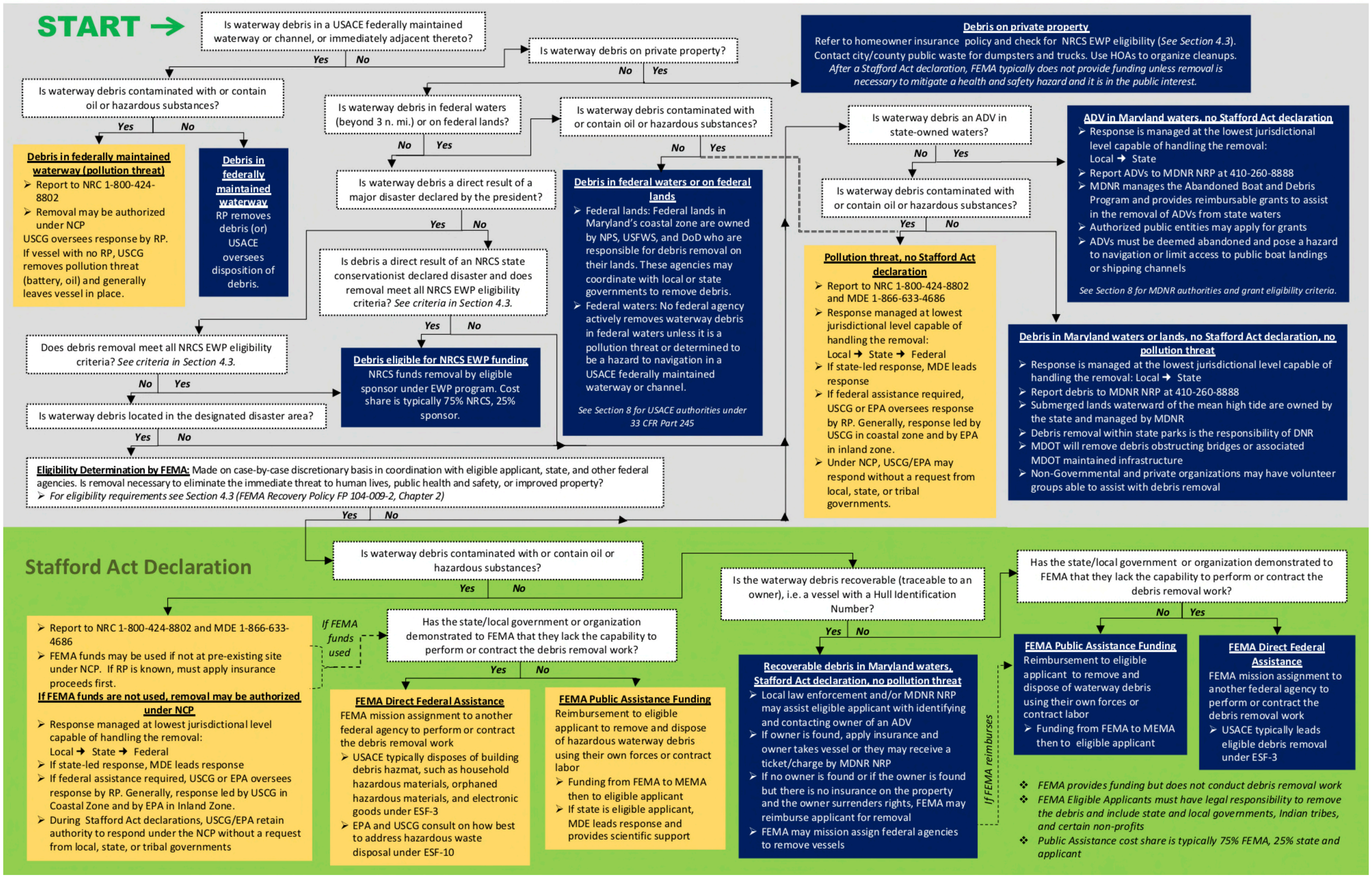
Waterway Debris/Incident Waterway Debris
Any solid material, including but not limited to vegetative debris and debris exposed to or that has the potential to release oil, hazardous substances, pollutants, or contaminants, that enters a waterway following an acute incident and poses a threat to the natural or man-made environment. This may include shoreline and wetland debris and debris in some inland, non-tidal waterways.

Acronyms

- ADV – Abandoned and Derelict Vessel
- DoD – U.S. Department of Defense
- EPA – U.S. Environmental Protection Agency
- ESF – Emergency Support Function
- EWP – Emergency Watershed Protection
- FEMA – Federal Emergency Management Agency
- HOA – Home Owner's Association
- MDE – Maryland Department of the Environment
- MDNR – MD Department of Natural Resources
- MDOT – Maryland Department of Transportation
- MEMA – Maryland Emergency Management Agency
- NCP – National Oil & Hazardous Substance Contingency Plan
- NPS – National Park Service
- NRC – National Response Center
- NRCS – Natural Resources Conservation Service
- NRP – Maryland Natural Resources Police
- RP – Responsible Party (Owner, Operator, Lessee)
- USACE – U.S. Army Corps of Engineers
- USCG – U.S. Coast Guard
- USFWS – U.S. Fish and Wildlife Service

Flowchart Key

- Response to waterway debris that is exposed to or has the potential to release oil, hazardous substances, pollutants, or contaminants
- Response to waterway debris that is not exposed to and does not have the potential to release oil, hazardous substances, pollutants, or contaminants
- Response occurring under Stafford Act authorities and/or funds



4. Roles and Responsibilities

In Maryland, response to an acute waterway debris incident is generally managed at the lowest jurisdictional level capable of handling the response and removal (MEMA, 2019). Initial response operations begin with local jurisdictions working with county or city emergency management agencies. Assistance from the state may be provided once local incident response resources are exhausted or resources are needed that the jurisdiction does not possess (MEMA, 2019). The federal government may supplement state and local response efforts when their resources have been exceeded or when unique capabilities are needed. Unlike the federal Emergency Support Function (ESF) concept, Maryland uses the State Coordinating Function (SCF) concept to apply state resources and assign state agency responsibilities. The Environmental Protection SCF and the Natural Resources SCF are the two most commonly applied SCFs during response to a waterway debris incident, whereas ESF-3, Public Works and Engineering, and ESF-10, Oil and Hazardous Materials Response, are the most commonly applied federal support functions.

Local, state, and federal agency roles and responsibilities as they relate to waterway debris response are outlined in the following sections followed by responsibilities of private landowners, volunteer organizations, and non-governmental organizations (NGOs). For a visual one-page representation of agency roles and responsibilities, see "Maryland Incident Waterway Debris Response Flowchart" in Section 3. For a map defining agency jurisdictional authorities, see Section 4.6. Additionally, response capabilities of each agency and corresponding contact information can be found in Appendices 8.3 and 8.4, respectively.

4.1 Local Agency Responsibilities

- May act as first responders to reports of waterway debris incidents that impact any of Maryland's 16 coastal counties or the city of Baltimore
- City and county emergency management agencies are the lead local agencies for emergency planning, preparedness, response, and recovery
- May declare a local state of emergency to enable jurisdiction to jurisdiction resource sharing outside of normal mutual aid (MEMA, 2019)
- Local law enforcement officers may lead the investigation to identify the owner of abandoned vessels
- May serve as project sponsor and/or receive debris removal funding from the Natural Resources Conservation Service (NRCS) Emergency Watershed Protection (EWP) Program if specific criteria are met. See Section 4.3 Natural Resources Conservation Service for EWP eligibility criteria.

Baltimore Region Disaster Debris Planning Task Force

- A network of local, regional, state, and federal debris stakeholders within the University of Maryland's Center for Health and Homeland Security Baltimore Urban Area Homeland Security Work Group
- Involved in planning, organizing, training, and exercising for all types of disaster debris within the Baltimore regional area
- Uses funds from the Baltimore Urban Area Homeland Security Work Group to support debris exercises

4.2 State Agency Responsibilities

Maryland Department of the Environment (MDE)

- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Conducts routine environmental monitoring for threats and hazards
- Provides subject matter expertise for environment-specific threats or hazards that may impact the state (MEMA, 2019)
- Determines the potential environmental impact of a threat and recommends measures to limit adverse impacts to the state (MEMA, 2019)
- Approves temporary debris staging sites

Land and Materials Administration

Oil Control Program

- Regulates all oil-related activities in the state
- When there is a release of oil into the environment, leads response and oversees the cleanup
- Maintains a 24-hour line for reporting oil spills in Maryland

Water and Science Administration

Wetlands and Waterways

- Implements the Wetlands and Waterways Program, which regulates the draining, dredging, and filling of tidal and nontidal wetlands and waterways
- Maintains the *Maryland State Wetland Conservation Plan,* which aims to increase the efficiency and effectiveness of wetlands regulation and management in Maryland
- Handles permit applications for piers, docks, marinas, channel dredging, and any other activities that use, encroach on, or disturb tidal wetlands owned by the state
- Serves as a clearinghouse and sends copies of permit applications to other state and federal agencies that might have jurisdiction or issues related to permits for a project. Maintains a joint permit application process with U.S. Army Corps of Engineers (USACE).
- For additional information on MDE permit and compliance requirements, see Section 5.

Sediment, Stormwater and Dam Safety

- Implements the Stormwater Management Program, which aims to reduce the adverse impacts of development on stormwater runoff
- Implements the Dam Safety Program, which ensures that all dams in Maryland are designed, constructed, operated, and maintained safely to prevent failures

Maryland Department of Natural Resources (MDNR)

- Serves as the lead agency for the Natural Resources SCF
- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Coordinates with and/or establishes relationships with natural resources sector partners
- Provides subject matter expertise for natural resources (MEMA, 2019)
- Identifies areas of the state likely to be impacted by threats or hazards, including key natural resource areas, and determine ways to limit impact (MEMA, 2019)
- Maintains the AccessDNR app, which includes boating and fishing regulation guides, maps of water access sites, and state park activities and locations

Chesapeake and Coastal Service

- Serves as the lead agency for implementing the Coastal Zone Management Act to ensure proper management of Maryland's coast and Chesapeake Bay watershed through local, regional, and state agency partnerships
- Houses and maintains geospatial products and services, such as Geographic Information System (GIS) data and interactive maps
    - The Coastal Atlas is an online mapping and planning tool that allows state and local decision-makers to explore data for coastal and ocean planning activities
- Administers the Chesapeake and Atlantic Coastal Bays Trust Fund, which funds projects targeting water quality, watershed restoration, and protection projects to reduce nonpoint source pollution
- Manages the Chesapeake Bay National Estuarine Research Reserve and associated Stewardship Program to protect the environment through conservation and restoration
- Manages state submerged lands waterward of the mean high tide line

Fishing and Boating Services

- Designate and mark navigation channels and natural resource conservation areas
- Conduct ice breaking operations to ensure year-round commerce
- Manage the Maryland Abandoned Boat and Debris Program
    - Consists of one vessel dedicated to removing hazards to navigation and abandoned vessels
    - Provides reimbursable grants and expertise to assist public agencies in the removal of abandoned boats and debris from state waters
    - Funded from the Maryland Waterway Improvement Fund, which is generated from the onetime 5% excise tax paid to the state when a boat is purchased and titled in Maryland

Natural Resources Police (NRP)

- May receive the first reports of waterway debris through the 24-hour Natural Resources Emergency or Assistance line. See Appendix 8.4 for contact information.
- Enforces state and federal commercial and recreational fishery laws and regulations
- Conducts search and rescue operations on all state waterways, responds to emergency calls, enforces boating safety laws, and investigates boating accidents
- May lead or assist investigation to identify an owner for an abandoned or derelict vessel
- May issue tickets or penalties for derelict vessels

Park Service

- Manages 72 state parks on 137,716 acres of land, including several areas that lie in part along the Chesapeake Bay
- Responsible for debris removal within the boundaries of state parks

Maryland Department of Planning (MDP)

Maryland Historical Trust (MHT)

- Serves as Maryland's State Historic Preservation Office (SHPO)
- Reviews proposed debris removal activities that involve a state or federal agency directly or through funding and/or issuance of permits or licenses for effects on historic properties in compliance with the Maryland Historical Trust Act and the National Historic Preservation Act
- For additional information on MHT compliance requirements, see Section 5.

- Maintains the Maryland Inventory of Historic Places
- Provides financial assistance through grants and tax credits for historic preservation activities and projects

- Serves as the lead agency for the Transportation SCF
- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Coordinates the removal of debris from all MDOT-maintained transportation facilities and infrastructure
- Conducts threat and hazard monitoring for potential impacts to transportation networks
- Disseminates threat and hazard awareness information to state watch centers

Port Administration (or Port of Baltimore)

- Operates the Port of Baltimore (Maryland Department of Transportation, n.d.)
- May request assistance from NOAA's Navigation Response Team (NRT) to survey ports and near-shore waterways to identify dangerous objects or changes in water depth following a disaster

- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Maintains a comprehensive statewide system of emergency management and coordinates with federal, state, county, and municipal governments, nonprofit organizations, and private agencies that have a role in emergency management
- Activates and staffs the State Emergency Operations Center (SEOC) when an emergency or disaster situation develops within the state
- Conducts comprehensive assessments of threats to the state to eliminate or reduce risk and vulnerability (MEMA, 2016)
- Maintains the *Maryland 2016 Hazard Mitigation Plan* and the *Maryland Consequence Management Operations Plan* (MEMA, 2016; MEMA, 2019)
- Following a Stafford Act declaration, serves as coordination point between FEMA and state and local eligible applicants
    - Serves as FEMA grantee and administers public assistance funding to eligible applicants
    - Assists state agencies and local governments in the preparation and submission of federal disaster assistance applications
- May pre-position emergency services resources to augment anticipated response efforts (MEMA, 2019)
- Provides subject matter expertise for governmental and non-governmental debris response operations
- Notifies NGO partners that an incident has the potential to occur and informs the community of ways assistance may be needed or requested (MEMA, 2019)
- Maintains a list of offers of assistance from NGO organizations and resources which may be available to assist in response operations (MEMA, 2019)

4.3 Federal Agency Responsibilities

Animal and Plant Health Inspection Service

- Veterinary Services program provides for removal and burial of diseased animal carcasses
- Manages Plant Protection and Quarantine program to reduce the risk of introduction and spread of invasive species through planning, surveillance, quick detection, and containment

Bureau of Safety and Environmental Enforcement

- Manages a Marine Trash and Debris Program to eliminate debris associated with oil and gas operations on the Outer Continental Shelf
- Regulates marine trash and debris for oil and gas operations and renewable energy development on the Outer Continental Shelf
- Enforces requirement that items be clearly marked to identify the owner and items lost overboard be recorded, reported, and retrieved if possible
- Requires annual training of offshore oil and gas workers to reduce marine debris

Farm Service Agency (FSA)

- Emergency Conservation Program (ECP) helps farmers repair damage to farmland caused by natural disasters, such as
  - Debris removal from farmland
  - Grading, shaping, or leveling damaged land
- Up to 75% of the cost to implement emergency conservation practices can be provided to farmers. Qualified limited resource producers may earn up to 90% cost-share.
- Locally-elected FSA County Committee is authorized to implement ECP and determine if land is eligible for ECP
- Farmers should inquire with their local FSA county office regarding ECP enrollment periods, which are established by FSA county committees.

Federal Emergency Management Agency (FEMA), Region III

- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Under the Stafford Act, provides reimbursement funding for eligible debris removal from navigable waterways (non-federally maintained) or wetlands during presidential major disaster declarations when another federal agency does not have authority to fund the activity
  - Provides funding to eligible applicants at a typical cost share of 75% FEMA, 25% state and eligible applicant
  - Issues mission assignments to other federal agencies for technical assistance, federal operations support, or to perform or contract debris removal when local and state capabilities are exceeded
- Makes eligibility determinations for debris removal on a case-by-case discretionary basis in coordination with the eligible applicant, state, and other federal agencies
  - Debris removal must be necessary to eliminate the immediate threat to life, public health and safety, or improved property (FEMA, 2018)
  - For navigable waterways, debris removal is limited to a max depth of 2 feet below the low tide draft of the largest vessel that utilized the waterway prior to the incident. Any debris below this zone is not eligible unless it is necessary in order to remove debris extending upward into an eligible zone (FEMA, 2018).
  - For non-navigable waterways, including natural waterways, debris removal is only eligible to the extent that it is necessary to eliminate an immediate threat including

the following: if the debris obstructs, or could obstruct, intake structures; if the debris could cause damage to structures; or if the debris is causing, or could cause, flooding to property during the occurrence of a 5-year flood (a flood that has a 20% chance of occurring in any given year; FEMA, 2018).

- Employs debris specialists that can be mobilized to assist eligible applicants with debris management
- May reimburse costs for use of side scan sonar that identifies eligible submerged debris and sunken vessels
  - The applicant is responsible for identifying debris deposited by the incident that poses an immediate threat. Random surveys to look for debris, including surveys performed using side scan sonar, are not eligible. However, if the applicant identifies an area of debris impacts and demonstrates the need for a survey to identify specific immediate threat, FEMA may provide Public Assistance funding for the survey in that location, including the use of side scan sonar.
- Provides geospatial support and hosts data, paper maps, and live data collection with interactive mapping through a shared group on ArcGIS Online
- FEMA must ensure compliance with federal laws, regulations, and executive orders prior to funding debris removal work. For additional information on permitting and compliance requirements, see Section 5.

National Oceanic and Atmospheric Administration (NOAA)

National Marine Fisheries Service (NOAA Fisheries)

Office of Habitat Conservation and Office of Protected Resources

- Reviews proposed debris removal activities that involve a federal agency (directly or through funding and/or issuance of a federal permit) for compliance with Magnuson-Stevens Fisheries Conservation and Management Act and Endangered Species Act (ESA)
- For additional information on NOAA Fisheries compliance requirements, see Section 5.

National Ocean Service

Office of Coast Survey

- Mobilizes NRT to survey ports and near-shore waterways for sunken debris, changes in water depth, and hazards to navigation following a disaster

Office of National Geodetic Survey

- Acquires and rapidly disseminates a variety of spatially-referenced remote-sensing datasets to support national emergency response. Imagery is obtained using high resolution digital cameras, film-based aerial camera systems, Light Detection and Ranging (LIDAR), and thermal and hyperspectral imagers.

Office of Response and Restoration, Emergency Response Division

- Serves as Scientific Support Coordinator (SSC) to coordinate application of NOAA assets and services during emergencies to help the Federal On-Scene Coordinator (FOSC) make timely operational decisions
- In the event of an oil spill, the SSC provides technical support, chemical hazard analyses, assessments of the sensitivity of biological and human-use resources, and recommends best actions moving forward

Office of Response and Restoration, Marine Debris Division

- Funds marine debris assessment and removal projects through grants or congressional supplemental funding
- Facilitates inter-agency coordination of planning and execution of responses to marine debris events
- Provides scientific support for debris response planning and operations, including baseline information, debris behavior, debris impact, debris survey and detection protocols, removal best management practices (BMPs), disposal guidance, and information management
- Develops external communications such as talking points appropriate for the public, informational graphics, intuitive interactive web content, and educational videos to ensure the public and partner agencies understand and act on sound science and information critical to response and recovery operations
- For events determined by the NOAA Administrator to be severe marine debris events, may develop interagency plans, assess composition volume and trajectory of associated marine debris, and estimate potential impacts to the economy, human health, and navigation safety

- Manages 18 national areas in the state of Maryland, including the Assateague Island National Seashore, which shares a border with Virginia
- May conduct incident waterway debris assessment and cleanup within their jurisdiction in coordination with county, state, and other federal partners
- Organizes volunteer cleanups on NPS lands when possible
- Provides BMPs to protect NPS lands and associated resources
- For a map of areas managed by NPS in Maryland, see Section 4.6.

- When funding is available, provides emergency financial and technical assistance through the Emergency Watershed Protection (EWP) Program for the following: to protect from additional flooding or soil erosion; to reduce threats to life and/or property from watershed impairment, including sediment and debris removal in floodplains and uplands; and to restore the hydraulic capacity to the natural environment to the maximum extent practical
    - Help communities address watershed impairments that pose imminent threats to lives and property as a result of natural disasters
    - Typical cost share is 75% NRCS and 25% project sponsor
    - Public and private landowners are eligible for assistance but must be represented by a project sponsor, including state government, legal subdivisions of the state, such as a city, county, water management district, drainage district, or any Native American tribe or tribal organization
    - EWP Program eligibility criteria include the following:
        - Waterway debris is a direct result of either a major disaster declared by the president or of an NRCS State Conservationist declared natural disaster
        - Waterway debris is a threat to life and/or property
        - Imminent threat was created by this event
        - Recovery measures are for runoff retardation or soil erosion prevention
        - Event caused a sudden impairment in the watershed
        - Economic, environmental, and social documentation are adequate to warrant removal action
        - Proposed removal action is technically viable and environmentally defensible

U.S. Army Corps of Engineers (USACE), Baltimore District

- Maintains pre-event contracts for activities within the Baltimore District area of responsibility and has the ability to access contract vehicles maintained by other USACE districts
- May request assistance from NOAA's NRT to survey ports and near-shore waterways
- Participates in the Baltimore Regional Disaster Debris Planning Task Force

Emergency Operations

- Serves as lead federal agency in support of FEMA under ESF-3 Public Works and Engineering
- Following a Stafford Act declaration, may lead eligible debris removal from navigable waterways (non-federally maintained) and wetlands if FEMA mission assigns another federal agency to perform or contract debris removal and surveying

Navigation

- Serves as lead federal agency for conducting surveys within the federally authorized channel for changes in water depth and hazards to navigation for commercial, recreational, and military use
- Responsible for operation, maintenance, and debris removal from federally maintained waterways and channels within Baltimore District. For a map of USACE federally authorized and maintained waterways and channels in Maryland, see Section 4.6.
- May use side-scan, multi, or single beam sonar to identify sunken debris
- May remove abandoned vessels or other debris from federally maintained navigable channels if an owner or responsible party (RP) cannot be identified and debris items are determined to be obstructions to navigation

Regulatory Program

- Baltimore District issues permits for debris removal within waterways and wetlands throughout the state. For additional information on USACE permitting and compliance requirements, see Section 5.

- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Removal of debris in waterways is only conducted by USCG when the debris has been contaminated with oil or a hazardous material
- Responds to oil discharges or threats of a discharge within navigable waterways. Responds to hazardous material releases or threats of release into the environment within the coastal zone as defined in the *Upper Chesapeake Bay Estuary Area Contingency Plan* (ACP; U.S. Coast Guard [USCG], 2012).
    - Removal actions generally limited to removing recoverable oil or hazardous materials from navigable waterways, its tributaries, or into the environment within the coastal zone. May also eliminate the substantial threat of a discharge of oil or HAZMAT into waterways or the environment within the coastal zone.
    - Under normal response operations involving vessels, the oil or HAZMAT will be removed and the vessel is left in place. Attempts are made to coordinate with the RP to refloat the vessel or remove it to prevent future oil or HAZMAT discharge. In extreme cases where the vessel remaining in the water presents "an imminent and substantial endangerment to public health and welfare, and the environment," USCG may begin a process to permanently remove the vessel (40 CFR § 300.130).

- Serves as lead federal agency (FOSC) under ESF-10 Oil and Hazardous Materials in the ACP coastal zone
    - Directs response in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)
    - Coordinates with state, tribal, and territorial governments and oversees response by a RP
    - Unlike response under a Stafford Act declaration, USCG may respond without a request from local, state, or tribal governments under the NCP. During Stafford Act declarations, USCG retains the authority to take action under the NCP.
    - Maintains a year-round, 24-hour telephone watch through the National Response Center (NRC) for reporting of oil and hazardous material releases. For contact information, see Appendix 8.4.
- Establishes a safety zone around hazards to navigation and broadcasts maritime safety warnings including the Broadcast Notice to Mariners and the Local Notice to Mariners to warn of debris obstructing watercourse or creating hazards to navigation within federally maintained waterways. USCG also notifies USACE of any hazards to navigation within federally maintained waterways.
- Following a Stafford Act declaration, may lead eligible debris removal from navigable waterways (non-federally maintained) and wetlands if FEMA mission assigns another federal agency to perform or contract debris removal and surveying
- May request assistance from NOAA's NRT to survey ports and near-shore waterways
- The Captain of the Port sets conditions used to alert the maritime community and affects changes in port operations necessary to prepare for tropical cyclone activity. This may include restricting or closing all port traffic.
- For a map of USCG sector boundaries and the ACP coastal-inland zone boundary in Maryland, see Section 4.6.

U.S. Environmental Protection Agency (EPA), Region III

- Participates in the Baltimore Regional Disaster Debris Planning Task Force
- Responds to oil and hazardous substance releases or threats of release in waterways within the inland zone as defined in the *Upper Chesapeake Bay Estuary ACP* (USCG, 2012). For a map of the ACP coastal-inland zone boundary in Maryland, see Section 4.6.
- Serves as lead federal agency (FOSC) under ESF-10 Oil and Hazardous Materials in the ACP inland zone and in incidents affecting both inland and coastal zones
    - Directs response in accordance with the NCP
    - Coordinates with state, tribal, and territorial governments and oversees response by RP
    - Unlike response under a Stafford Act declaration, EPA may respond without a request from local, state, or tribal governments under the NCP. During Stafford Act declarations, EPA retains the authority to take action under the NCP.
- Following a Stafford Act declaration, may lead removal of contaminated waterway debris under a FEMA mission assignment to perform or contract the work, as pursuant to a Memorandum of Understanding between FEMA, EPA, USCG, and USACE

U.S. Fish and Wildlife Service (USFWS)

Ecological Services Program

- Reviews proposed debris removal activities that involve a federal agency (directly or through funding and/or issuance of a federal permit) for compliance with ESA and Coastal Barrier Resources Act (CBRA)

- For additional information on USFWS compliance requirements, see Section 5.

National Wildlife Refuges (NWR)

- Manages five NWRs in Maryland, all of which are within Maryland's coastal zone
    - NWRs include: Blackwater NWR, Eastern Neck NWR, Martin NWR, Patuxent NWR, and Susquehanna NWR
- Coordinates and manages waterway debris assessment and cleanup in NWRs
- May coordinate with federal, state, and local partners to remove incident waterway debris within their jurisdiction
- Provides BMPs to protect listed threatened or endangered land and freshwater species, certain marine species, and their critical habitat
- For a map of NWRs in Maryland, see Section 4.6.

U.S. Navy

Supervisor of Salvage and Diving

- Manages and provides technical assistance for salvage, deep search and recovery, towing, and oil spill response operations
- Accesses and coordinates the U.S. Navy's hydrographic survey assets and capabilities
- Maintains an array of remotely operated vehicles, oil spill response, and salvage equipment
- Exercises and manages regional standing emergency salvage contracts to quickly draw upon the required resources of the commercial salvage industry (U.S. National Response Team, 2014)

4.4 Private Landowners

- May report acute waterway debris incidents to local emergency management agency or MEMA to begin a coordinated response. See Appendix 8.4 for MEMA 24r Watch Center contact information.
- May complete right-of-entry agreements with entities conducting private property debris removal or using private property as an access point
- After a Stafford Act declaration, debris removal from private property or privately-owned waterways and banks is generally the responsibility of the property owner and not eligible for FEMA funding unless its removal is necessary to mitigate a health and safety threat and is in the public interest (FEMA, 2018)
- May contact city or county public waste for dumpsters and trucks. May also contact Home Owners Association (HOA) to organize cleanups.
- May be eligible for debris removal funding from NRCS EWP Program if represented by a project sponsor and specific criteria are met. See Section 4.3 Natural Resource Conservation Service for EWP eligibility criteria.

4.5 Volunteer and Non-Governmental Organizations

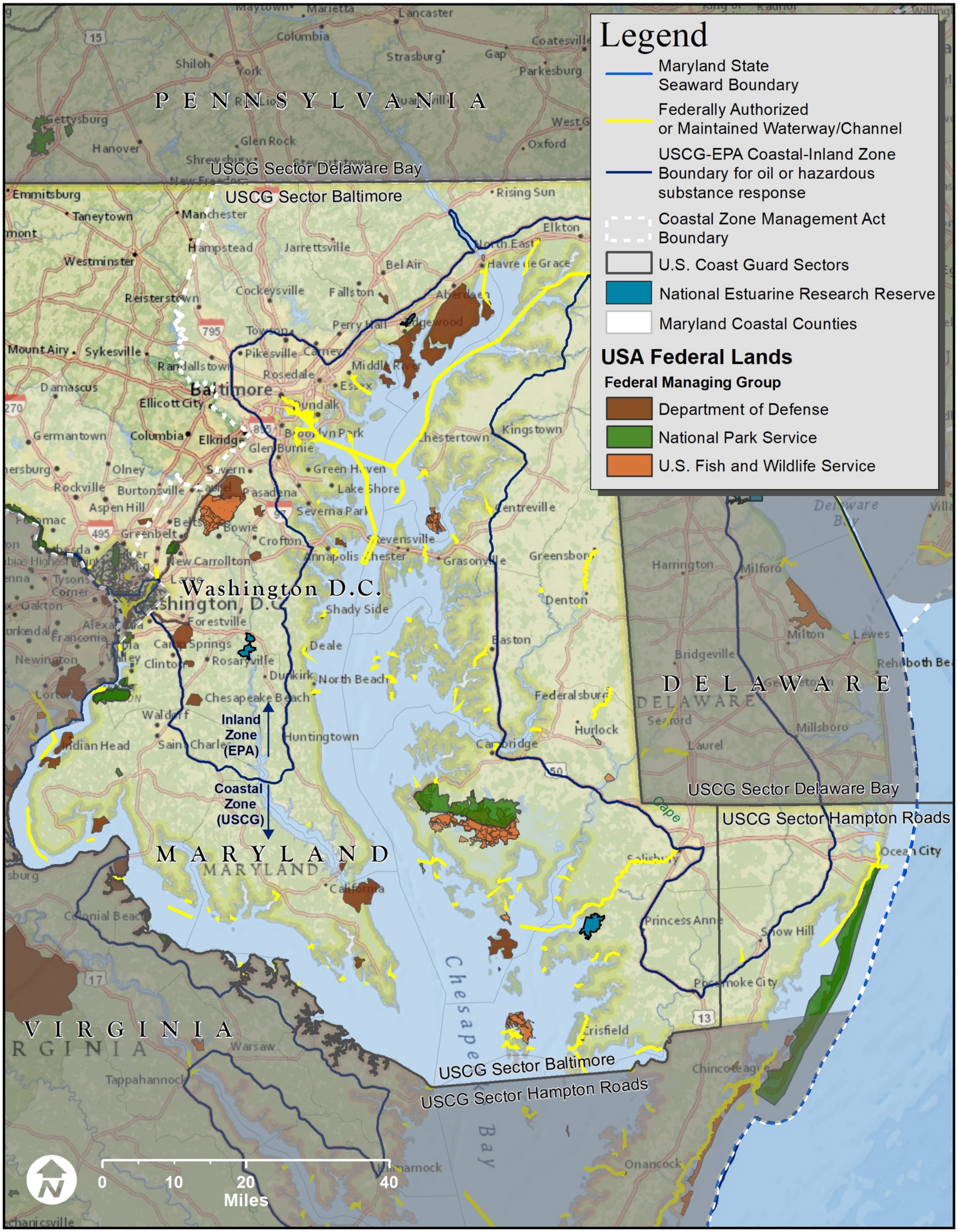
- Certain private nonprofit organizations that serve a public function and have the legal responsibility to remove the debris may serve as an eligible applicant and receive public assistance reimbursement funding from FEMA to perform or contract waterway debris removal following a Stafford Act declaration (FEMA, 2018)
- Non-governmental organizations may provide debris removal assistance or logistical support through funded projects and programs

4.6 Agency Jurisdiction Map

The "Maryland Incident Waterway Debris Response Map" on the following page displays relevant agency jurisdiction boundaries in Maryland's 16 coastal counties and the city of Baltimore. After an acute waterway debris incident, the agency (or agencies) responsible for removing debris will vary depending on where the debris is located. This map includes information that stakeholders identified as important in determining jurisdiction within the state.

For detailed information regarding local, state, and federal agency roles and responsibilities, see Sections 4.1, 4.2, and 4.3, respectively. For a visual one-page representation of agency roles and responsibilities, see Section 3.

Maryland Incident Waterway Debris Response Map



5. Permitting and Compliance Requirements in Maryland

Before waterway debris removal work can begin, organizations responsible for removal must meet certain permitting and compliance requirements. While the organization or individual conducting the debris removal work is responsible for obtaining necessary permits—such as a U.S. Army Corps of Engineers (USACE) permit—it is the responsibility of the lead federal agency to ensure compliance with the National Environmental Policy Act (NEPA) and to consult with tribal and resource agencies including the Maryland Department of the Environment (MDE), Maryland Historical Trust (MHT), U.S. Fish and Wildlife Service (USFWS), and National Oceanic and Atmospheric Administration (NOAA).

During response under a Stafford Act declaration, the Federal Emergency Management Agency (FEMA) provides funding to applicants for debris removal and is therefore considered the lead federal agency responsible for tribal and resource agency coordination. Federal emergency support function (ESF) 11 Agriculture and Natural Resources may be activated for Stafford Act incidents requiring a coordinated federal response to protect natural and cultural resources and historic properties (FEMA, 2008). If waterway debris removal is conducted without federal funding and there are no federal agencies involved in removal activities, USACE is considered the lead federal agency as the permitting agency (if a permit is required).

A description of individual agency requirements and authorities is outlined below and is summarized in the "Permitting and Compliance for Waterway Debris Removal in Maryland" handout in Section 5.3. Organization contact information can be found in Appendix 8.4, and select agency authorities are presented in Appendix 8.1.

5.1 State Agency Requirements

Maryland Department of the Environment (MDE)
Water and Science Administration

Wetlands and Waterways

- Issues tidal wetlands permits for debris removal activities on state-owned wetlands (including state-owned submerged lands) that negatively impact the environment
- A tidal wetlands permit may be required if the proposed debris removal project involves excavating, dredging, the discharge of fill or dredge material, or involves structures or work impacting wetlands
    - MDE and USACE have a joint permit application process. Applications are submitted to MDE and federal and state review will occur concurrently.

Maryland Department Natural Resources (MDNR)
Chesapeake and Coastal Service

- The federal consistency section reviews federal actions (including funding assistance applications) for consistency with federally-approved laws and policies of the Chesapeake and Coastal Service Program

Maryland Department of Planning (MDP)
Maryland Historical Trust (MHT)

- Administers duties of the State Historic Preservation Office (SHPO) and assists state and federal agencies in compliance with the Maryland Historical Trust Act of 1985 and National

Historic Preservation Act, which require state and federal agencies to consider potential effects on historic properties as defined in state and federal law

  - If a waterway debris removal project in Maryland involves a state or federal agency directly or through funding and/or issuance of permits or licenses, it is the responsibility of the lead state and/or federal agency to consult with MHT

5.2 Federal Agency Requirements

Federal Emergency Management Agency (FEMA)

- Serves as lead federal agency responsible for tribal and resource agency coordination when providing funding to applicants for debris removal under a Stafford Act declaration
  - Ensures applicant's debris removal operations avoid impacts to floodplains, wetlands, federally listed threatened and endangered species and their critical habitats, and historic properties (including maritime or underwater archaeological resources if waterways are impacted)
  - Requires applicant to stage debris at a safe distance from property boundaries, surface water, wetlands, structures, wells, and septic tanks with leach fields
  - May require site remediation at staging sites and other impacted areas upon completion of debris removal and disposal

National Environmental Policy Act (NEPA)

- NEPA requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions
- If a waterway debris removal project involves a federal agency (directly or through funding and/or issuance of a federal permit), it is the responsibility of the lead federal agency to ensure NEPA compliance. If multiple federal agencies play a major role in the debris removal, then there may be a joint lead agency that shares the lead agency's responsibility for management of the NEPA process (Council on Environmental Quality, 2007).
  - FEMA is provided with statutory exclusions under Section 316 of the Stafford Act, which exempts debris removal from the NEPA review process
  - Therefore, the NEPA review process is not required when FEMA is providing funding for waterway debris removal under a Stafford Act declaration. However, compliance with all other federal, state, and local environmental laws and regulations is still required, even when a project is statutorily excluded from NEPA review.
- For waterway debris removal operations, the impact of removal must be evaluated to minimize environmental and ecological damage to the maximum practical extent. In some cases, debris removal may be more environmentally damaging than leaving the debris in place.

National Oceanic and Atmospheric Administration (NOAA)

National Marine Fisheries Service (NOAA Fisheries)

- If a waterway debris removal project in Maryland involves a federal agency (directly or through funding and/or issuance of a federal permit), it is the responsibility of the lead federal agency to coordinate with NOAA Greater Atlantic Regional Fisheries Office prior to beginning debris removal work to ensure compliance with the Endangered Species Act (ESA) and Magnuson-Stevens Fisheries Conservation and Management Act
  - ESA directs all federal agencies to ensure the actions they take, including those they fund or authorize, do not jeopardize the continued existence of any listed

endangered or threatened species or result in the destruction or adverse modification of designated critical habitat unless an exemption has been granted. Generally, NOAA Fisheries manages marine and anadromous species while USFWS manages land and freshwater species and certain marine species such as manatee. If a federal agency determines their activities or actions will affect listed species or designated critical habitat—even if the effects are expected to be beneficial—they must consult with NOAA Fisheries or USFWS. See NOAA Greater Atlantic Regional Fisheries Office's endangered species web page for an up to date Maryland ESA-listed marine species list (NOAA, n.d.-c).
    - Magnuson-Stevens Fisheries Conservation and Management Act directs all federal agencies to ensure the actions they take, including those they fund or authorize, do not adversely affect essential fish habitat (EFH). If a federal agency determines their activities or actions may adversely affect EFH, they must consult with NOAA Fisheries. See NOAA's online essential fish habitat mapper to view maps for EFH (NOAA, 2018a).
- Consultation during emergencies can be expedited so federal agencies can complete their critical missions in a timely manner while still providing protections to listed species and EFH
    - During emergency waterway debris removal operations, NOAA Greater Atlantic Regional Fisheries Office utilizes the same process for initiating contact for both ESA and EFH consultations. Steps to complete the emergency response consultation process are outlined on the NOAA Fisheries website NOAA (n.d.-a).
- Additional information on ESA and EFH consultation during non-emergencies can be found on the NOAA Fisheries Section 7 website (NOAA, 2017 and EFH Assessment website (NOAA, n.d.-b), respectively

U.S. Army Corps of Engineers (USACE), Baltimore District

- USACE permit may be required for debris removal within waterways and wetlands if the activity involves dredging, the discharge of dredged or fill material, or involves structures or work impacting the navigability of a waterway. One or more permits may be needed depending on the scope of work to be conducted.
    - Applications are submitted to MDE, and both MDE and USACE review concurrently.
- Permits that may be required include:
    - **Nationwide Permit 3: Maintenance.** Authorizes repair, rehabilitation or replacement structures or fills destroyed or damaged by storms, floods, fires or other discrete events. This permit may be issued for removal or maintenance of culverts, sediments, or debris accumulated around outfalls, bridges, etc.
    - **Nationwide Permit 22: Removal of Vessels**. Authorizes temporary structures or minor discharges of dredged or fill material required for the removal of wrecked, abandoned, or disabled vessels, or the removal of man-made obstructions to navigation
    - **Nationwide Permit 33: Temporary Construction, Access, and Dewatering**. Issued for temporary structures, work, and discharges necessary for construction activities or access fills
    - **Nationwide Permit 37: Emergency Watershed Protection and Rehabilitation.** Issued for work conducted under the NRCS EWP Program
    - **Nationwide Permit 38: Cleanup of Hazardous and Toxic Waste**. Issued for the containment, stabilization, or removal of hazardous or toxic waste materials that are performed, ordered, or sponsored by a government agency with legal or regulatory authority, other than activities undertaken entirely on a Superfund site

- **Nationwide Permit 45: Repair of Uplands Damaged by Discrete Events.** Issued for activities associated with the restoration of upland areas damaged by storms, flood, or other discrete events

- In emergency situations, permitting procedures may be expedited and resource agency coordination may occur "after the fact" as opposed to before a permit is issued. This may result in additional work by the applicant once the emergency and immediate threat has been mitigated.
- Navigation Section reviews permit applications when activities intersect with federally maintained waterways and channels, including levee systems

U.S. Fish and Wildlife Service (USFWS)

Ecological Services Program

- If a waterway debris removal project in Maryland involves a federal agency (directly or through funding and/or issuance of a federal permit), it is the responsibility of the lead federal agency to coordinate with USFWS Chesapeake Bay Field Office prior to beginning debris removal work to ensure compliance with ESA and the Coastal Barrier Resources Act (CBRA)
    - ESA directs all federal agencies to ensure the actions they take, including those they fund or authorize, do not jeopardize the continued existence of any listed endangered or threatened species or result in the destruction or adverse modification of designated critical habitat unless an exemption has been granted. Generally, USFWS manages land and freshwater species and certain marine species such as manatee, while NOAA Fisheries manages marine and anadromous species. If a federal agency determines their activities or actions may affect listed species or designated critical habitat—even if the effects are expected to be beneficial— they must consult with USFWS or NOAA Fisheries. See USFWS's Information for Planning and Consultation website for an up to date list of Maryland's threatened and endangered land and freshwater species (U.S. Fish and Wildlife Service [USFWS], n.d.).
    - CBRA restricts federal expenditures and financial assistance that encourage development of coastal barriers so that damage to property, fish, wildlife, and other natural resources associated with the coastal barrier is minimized. The John H. Chafee Coastal Barrier Resources System (CBRS) is a collection of specific units of land and associated aquatic habitats that serve as barriers protecting the Atlantic, Gulf, and Great Lakes coasts. After a Stafford Act declaration, costs for debris removal and emergency protective measures in designated CBRS units may be eligible for reimbursement under FEMA's public assistance program provided the actions eliminate an immediate threat to lives, public health and safety, or protect improved property. A map of CBRS units in Maryland can be downloaded from USFWS's website (USFWS, 2015).
- For projects that do not involve federal permits or funding, USFWS consultation is not required, but is recommended. Harassing or harming ("taking") an endangered or threatened species or significantly modifying their habitat is still prohibited under ESA regardless of federal nexus involvement.
- Reviews may be expedited in emergencies, and USFWS staff may embed in response teams
- Each debris removal project is reviewed individually unless USFWS prepares a programmatic consultation. Under a programmatic consultation, all parties agree on certain conservation measures that must be implemented. If a waterway debris removal project arises that does not fit the programmatic measures, then it must be reviewed individually.

- USFWS may provide BMPs that provide necessary protections while allowing projects to go forward
- If the proposed waterway debris removal project will not impact listed threatened or endangered species, or if the federal consulting agency agrees to implement USFWS's recommendations, the consultation process is completed at the "informal" stage. However, if debris removal operations will adversely affect a listed species or critical habitat, the federal consulting agency must initiate a "formal" consultation, a process which typically ends with the issuance of a biological opinion by USFWS (or NOAA Fisheries, if the ESA-listed species affected is under NOAA Fisheries' purview).

5.3 Permitting and Compliance for Waterway Debris Removal in Maryland One-Pager

The "Permitting and Compliance for Waterway Debris Removal in Maryland" handout on the following page synthesizes permitting and compliance requirements that must be met before waterway debris removal operations begin. The top portion of the one-pager outlines the process to follow to stay in compliance, while the bottom portion highlights specific state and federal agency requirements with general contact information.

For detailed information regarding individual state and federal requirements, see Sections 5.1 and 5.2, respectively.

Permitting and Compliance for Waterway Debris Removal in Maryland

- In Maryland's coastal zone, a Maryland Department of the Environment (MDE) tidal wetlands permit and/or a U.S. Army Corps of Engineers (USACE) permit may be required if debris removal involves excavating, dredging, the discharge of fill or dredge material, or involves structures or work impacting navigable waterways or wetlands.
- MDE and USACE have a joint permit application process. Applications are submitted to MDE and federal and state review occur concurrently.
- The **lead federal agency** is responsible for compliance with National Environmental Policy Act (NEPA), federal coastal consistency, and consulting with tribal and resource agencies including Maryland Historical Trust (MHT), U.S. Fish and Wildlife Service (USFWS), and National Oceanic and Atmospheric Administration (NOAA) Fisheries as required.

Compliance Process when Permit is Required

Federally Funded Removal
(for example, FEMA funding under Stafford Act declaration)

No Federal Funding
(for example, state, local, or privately funded removal)

Federal Agency Coordination
Coordinate with federal funding agency regarding environmental compliance requirements before applying for MDE and/or USACE permit

- Lead federal agency is responsible for NEPA compliance, federal consistency with Maryland's Coastal Zone Management Program, and consultations with MHT, USFWS, and NOAA as required.
- FEMA is the lead federal agency under Stafford Act declaration.
- Debris removal under Stafford Act declaration may trigger emergency permitting processes.

Permit Application
Complete and submit joint permit application to MDE who distributes the application to USACE, and each agency issues separate permits

If USACE permit is required, USACE is the lead federal agency and will ensure NEPA compliance, federal consistency with Maryland's Coastal Zone Management Program, and consults with MHT, USFWS, and NOAA as required.

Permit Issued
Review all permit conditions including MD and resource agency requirements

Debris Removal Begins
All permit conditions and MDE and resource agency requirements must be followed during debris removal activities

About NEPA
The National Environmental Policy Act (NEPA) requires federal agencies to follow a specific planning process to ensure environmental consequences of a federally funded action are considered.

Agency Requirements and Legislation Details

U.S. Army Corps of Engineers (USACE)
Baltimore District Regulatory Program
410-962-3670

- Permit(s) that may be required for debris removal work within waterways and wetlands:
  - **NWP-3 Maintenance** for removal/maintenance of culverts, sediments or debris accumulated around outfalls, bridges, etc. in wetland areas
  - **NWP-22 Removal of Vessels** for removal of wrecked, abandoned, or disabled vessels or other man-made obstructions to navigation
  - **NWP-33 Temporary Construction, Access, and Dewatering** for temporary structures, work, and discharges necessary for construction activities or access fills
  - **NWP-37 Emergency Watershed Protection & Rehabilitation** for work done under NRCS's Emergency Watershed Protection program
  - **NWP-38 Cleanup Hazardous/Toxic Waste** for containment, stabilization, or removal of hazardous or toxic waste not under CERCLA/NCP
  - **NWP-45 Repair of Uplands Damaged by Discrete Events** for activities associated with the restoration of upland areas damaged by storms, floods, or other discrete events.

National Oceanic and Atmospheric Administration (NOAA)
NOAA Fisheries
ESA: 978-281-9328
EFH: 410-573-4559

- Consultation required if waterway debris response involves federal permits and/or funding (USACE permit, FEMA funding, etc.) to comply with:
  - Endangered Species Act (ESA) to ensure actions do not adversely affect listed threatened or endangered species or critical habitat for marine species
  - Magnuson-Stevens Fisheries Conservation and Management Act to ensure actions do not adversely affect Essential Fish Habitat (EFH)

MD Department of the Environment (MDE)
Wetlands and Waterways Program
410 537-3837

- Issues tidal wetlands permits for projects that may negatively impact any of these resources
- A tidal wetland permit may be required for debris removal projects that involve excavating, dredging, the discharge of fill or dredge material, or involves structures or work impacting wetlands.
- MDE and USACE have a joint permit application process. Permit applications are submitted through MDE and federal and state review occur concurrently.

MD Historical Trust (MHT)
Office of Preservation Services
410-697-9545

- Serves as the State Historic Preservation Office (SHPO) and assists state and federal agencies in compliance with the Maryland Historical Trust Act and the National Historic Preservation Act
- Consultation with MHT is required if waterway debris response involves a state or federal agency directly or through funding and/or issuance of permits or licenses (MDE or USACE permits, MEMA or FEMA funding, etc.) and has potential to affect historic properties

U.S. Fish and Wildlife Service (USFWS)
Chesapeake Bay Field Office
410-573-4599

- Consultation with Ecological Services Field Office required if waterway debris response involves federal permits and/or funding (USACE permit, FEMA funding, etc.) to comply with:
  - Endangered Species Act (ESA) to ensure actions do not adversely affect listed threatened or endangered species or critical habitat for land and freshwater species and certain marine species such as manatee
  - Coastal Barrier Resources Act (CBRA) to ensure actions do not encourage development on coastal barriers along the Atlantic coast

6. Maryland Waterway Debris Response Challenges

Waterway debris response challenges identified by stakeholders are outlined below, along with associated recommendations. These identified challenges will serve as future points of discussion and action for the Maryland waterway debris response community. Potential opportunities for addressing response needs include table-top activities to exercise this *Guide*, response exercises that incorporate debris scenarios, and coordination meetings associated with this document's formal review.

6.1 Response Challenges and Recommended Actions in Maryland

The following gaps in response and associated recommendations are compiled based on stakeholder input to improve preparedness for response and recovery operations following an acute waterway debris incident in Maryland. Recommended actions include logistics, policy, communication, and technology and resources actions to address gaps in response and meet pre- and post-event data needs.

6.1.1 Response Logistics

- **Challenge:** When severe storms cause dam failure, debris is transported across multiple jurisdictions.
  - **Actions:**
    - Work to remove build-up of debris annually or on a regular basis
    - Coordinate across jurisdictions to plan for dam failures

- **Challenge**: Many landfills will not accept large vessels.
  - **Actions**:
    - Identify requirements for specific disposal locations prior to an event, including the type of debris accepted at each location
    - Pre-plan to break down materials prior to disposal

- **Challenge**: It is difficult to determine end-state success (i.e. how to know when work is done and if it was successful), especially when debris is compounded across several events.
  - **Action**: Encourage pre-storm and post-storm assessments and monitoring by local and state agencies

- **Challenge**: There is no one standard way to deal with a waterway debris incident.
  - **Actions**:
    - Link *Guide* content to existing debris management documents
    - Encourage the implementation of periodic waterway debris-centric exercises in coordination with state and federal agencies, counties, and municipalities
    - Encourage entities hosting local planning meetings or conferences to invite relevant waterway debris response agencies and organizations

- **Challenge**: Responding to and removing debris in ecologically sensitive areas may be harmful to local species or habitat
  - **Action**: Coordinate with local agencies and NGOs to educate about debris removal and prevention in sensitive areas

- **Challenge:** Derelict commercial fishing gear routinely washes up along ocean and bay shorelines.
    - **Actions:**
        - Encourage development of state programs for marking derelict fishing gear
        - Pre-plan with local governments and municipalities to document and report derelict fishing gear that washes up in their jurisdiction

6.1.2 Policy

- **Challenge**: There is a lack of understanding at a local level of the differences between waterway ownership and jurisdiction versus responsibility for removal of debris in certain areas.
    - **Actions**:
        - Encourage MEMA to promote the use of the Environmental Response Management Application (ERMA), which is an online mapping tool that integrates static and real-time data to assist environmental responders and decision makers
        - Collaborate with NOAA about the possibility of adding agency authorities and geographic jurisdictions as a bookmark in ERMA
        - Encourage entities hosting local planning meetings or conferences to invite relevant waterway debris response agencies and organizations
        - For a jurisdictional map of federal and state response agencies, see Section 4.6.

- **Challenge**: It is difficult for responders to distinguish between disaster debris and historic debris, such as remains of shipwrecks.
    - **Actions**:
        - Develop trainings and guidance on historic sites and offer to volunteers and responders
        - Encourage Maryland Historical Trust to collaborate with other agencies to provide information regarding historical sites and compliance

- **Challenge**: There are challenges with jurisdictional limitations among agencies.
    - **Actions:**
        - Establish memorandums of understanding and agreements between agencies
        - Include citations for legal references in documents or materials used for incident waterway debris planning and response to highlight applicable authorities

- **Challenge**: Local debris management plans do not always include information specific to waterway debris response.
    - **Action**: Encourage and incentivize counties and municipalities to develop debris management plans that include waterway debris response information

- **Challenge**: There are limitations to federally funded debris removal projects.
    - **Action**: Make information about eligibility, removal criteria, and other limitations publicly available

        - For information about FEMA Public Assistance eligibility, see Section 4.3, FEMA Roles and Responsibilities.
        - For information about NRCS EWP Program criteria, see Section 4.3, NRCS Roles and Responsibilities.

- **Challenge**: There is no established procedure or mechanism for reporting a waterway debris incident outside of major disasters.
    - **Actions**: Establish a procedure for reporting of waterway debris and a mechanism for disseminating this information to local authorities and the public in coastal Maryland

6.1.3 Communication/Education

- **Challenge**: There is a need for increased availability and expanded scope of exercises and trainings.
    - **Actions**:
        - Expand audience list for exercises to include agencies who are not typically involved
        - Encourage the state to host a table top exercise focused on incident marine debris
        - Coordinate exercises in calendar format, possibly through MEMA

- **Challenge**: There is a lack of public understanding that the RP for abandoned vessels is the vessel owner.
    - **Action**:
        - Create a marine debris pamphlet that includes information about the responsibilities of vessel ownership to distribute to boat owners or marinas and display information through social media.

6.1.4 Resources

- **Challenge**: After an acute waterway debris incident that does not result in a presidential disaster declaration, there are limited funding sources for debris removal in state waters.
    - **Actions**:
        - Establish partnerships with private organizations and NGOs to assist with fundraising and contracting for debris removal in emergency situations
        - Develop a list of potential funding sources in the state of Maryland
        - Review requirements and eligibility for Public Assistance funding through MEMA during locally declared emergencies

- **Challenge**: Equipment in need of repair and/or low availability of equipment may delay post-disaster dredging projects.
    - **Actions**:
        - Encourage agencies and contractors to establish a routine for pre-storm maintenance of equipment
        - See Capabilities matrix in Appendix 8.3 for a list of debris response equipment capabilities by agency

6.2 Additional Resources

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8. Appendices

8.1 Select Agency Authorities

8.1.1 Local Government Authorities

- Environmental Issues, Md. Code Ann § 13-701 et seq.
- Intergovernmental agreements for disposal of garbage, Md. Code Ann § 5-104
- Local emergency plans, Md. Code Ann § 14-110
- Local state of emergency, Md. Code Ann § 14-111
- Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C § 5121 et seq.
- Waterways and Activities on Shores of Waterways, Md. Code Ann § 13-801 et seq.

8.1.2 State Agency Authorities

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.
- Federal Water Pollution Control Act (commonly known as Clean Water Act) as amended by the Oil Pollution Act of 1990, 33 U.S.C. § 1251 et seq.
  - Oil Pollution Liability and Compensation, 33 U.S.C. § 2701 et seq.
- Oil Contaminated Site Environmental Cleanup Fund, Md. Code Ann § 4-701
- Stormwater Management, Md. Code Ann § 4-201 et seq.
- Watershed Sediment and Waste Control, Md. Code Ann § 4-301 et seq.
- Water Pollution Control and Abatement, Md. Code Ann § 4-401 et seq.

- Abandoned, Lost, or Seized Personal Property, Md. Code Ann § 1-2A-01
- Conservation and Management of State Waters, Md. Code Ann § 8-201 et seq.
- Maryland Environmental Policy Act, Md. Code Ann § 1-301 et seq.
- Natural Resources Police Force, Md. Code Ann § 1-201 et seq.
- Organization, Powers, and Duties of Department, Md. Code Ann § -101 et seq.
- State Chesapeake Bay and Endangered Species Fund, Md. Code Ann § 1-701 et seq.

Maryland Historical Trust (MHT)

- Maryland Historical Trust Act of 1985, Md. Code Ann § 5A-325-326
- National Historic Preservation Act, 54 U.S.C. 300101 et seq.

- Maryland Port Commission and Maryland Port Administration, Md. Code Ann § 6-201 et seq.
- Organization and General Authority of the Department, Md. Code Ann § 2-101 et seq.
- Port of Baltimore, Md. Code Ann § 6-401 et seq.

- Coastal Zone Management Act of 1972, 16 U.S.C § 1451 et seq.
- Director of MEMA, Md. Code Ann § 14-104

- Emergency Management Advisory Council, Md. Code Ann § 14-105
- Emergency Management Assistance Compact, Md. Code Ann § 14-701-702
- Maryland Emergency Management Agency established, Md. Code Ann § 14-103
- Maryland Emergency Management Assistance Compact, Md. Code Ann § 14-803
- Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C § 5121 et seq.
- State of emergency – Declaration by Governor, Md. Code Ann § 14-107

8.1.3 Federal Agency Authorities

Animal, Plant and Health Inspection Service

- Animal Health Protection Act, 7 U.S.C § 8301 et seq.
- Plant Protection Act, 7 U.S.C § 7701 et seq.

Federal Emergency Management Agency (FEMA), Region III

- Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C § 5121 et seq.
  - Debris Removal, 42 U.S.C. § 5173
  - Essential Assistance, 42 U.S.C. § 5170b
  - Federal Emergency Assistance, 42 U.S.C. § 5192

National Oceanic and Atmospheric Administration (NOAA)

- Coastal Zone Management Act of 1972, 16 U.S.C § 1451 et seq.
- Endangered Species Act, 16 U.S.C. § 1531 et seq.
- Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. § 1801 et seq.
- Marine Debris Research, Prevention, and Reduction Act, 33 U.S.C. § 1951 et seq.
- Marine Mammal Protection Act of 1972, 16 U.S.C § 1361 et seq.
- Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act), 33 U.S.C. § 1401 et seq.
- National Marine Sanctuaries Act, 16 U.S.C § 1431 et seq.
- National Marine Sanctuary Program Regulations, 15 C.F.R. § 922

Natural Resources Conservation Service (NRCS)

- Emergency Watershed Protection Program, 7 C.F.R. § 624

U.S. Army Corps of Engineers (USACE), Baltimore District

- Authority for snagging and clearing for flood control (Section 208), 33 C.F.R. § 263.24
- Federal Water Pollution Control Act (commonly known as Clean Water Act) as amended by the Oil Pollution Act of 1990, 33 U.S.C. § 1251 et seq.
  - Permits for dredged or fill material (Section 404), 33 U.S.C. § 1344
- Flood Control and Coastal Emergency Act, 33 U.S.C. § 701n (Public Law 84-99)
- Permits for Structures or Work in or Affecting Navigable Waters of the United States, 33 C.F.R. § 322
- Removal of snags and debris, and straightening, clearing, and protecting channels in navigable waters, 33 U.S.C. § 603a
- Removal of Wrecks and Other Obstructions, 33 C.F.R. § 245
- Rivers and Harbors Appropriation Act of 1899 and 1945, 33 U.S.C. § 401 et seq.
  - Obstruction of navigable waters generally; wharves; piers, etc.; excavations and filling in (Section 10), 33 U.S.C. § 403

- Taking possession of, use of, or injury to harbor or river improvements, 33 U.S.C. § 408
  - Obstruction of navigable waters by vessels; floating timber; marking and removal of sunken vessels, 33 U.S.C. § 409
  - Removal by Secretary of the Army of sunken water craft generally; liability of owner, lessee, or operator, 33 U.S.C. § 414
  - Summary removal of water craft obstructing navigation; liability of owner, lessee, or operator, 33 U.S.C. § 415
  - Collection and removal of drift and debris from publicly maintained commercial boat harbors and adjacent land and water areas (Water Resources Development Act, Section 202), 33 U.S.C § 426m
- Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C § 5121 et seq.

U.S. Coast Guard (USCG), Sector Maryland-National Capital Region

- Abandoned Barge Act of 1992, 46 U.S.C. § 4701-4705
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.
- Federal Water Pollution Control Act (commonly known as Clean Water Act) as amended by the Oil Pollution Act of 1990, 33 U.S.C. § 1251 et seq.
  - Oil Pollution Liability and Compensation, 33 U.S.C. § 2701 et seq.
- Marking of structures, sunken vessels and other obstructions, 33 C.F.R. § 64
- National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. § 300
- Ports and Waterways Safety Act, 33 U.S.C. §1221 et seq.
- Saving life and property, 14 C.F.R. § 88

U.S. Environmental Protection Agency (EPA), Region III

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. § 9601 et seq.
- Federal Water Pollution Control Act (commonly known as Clean Water Act) as amended by the Oil Pollution Act of 1990, 33 U.S.C. § 1251 et seq.
- National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. § 300

U.S. Fish and Wildlife Service (USFWS)

- Coastal Barrier Resources Act, 16 U.S.C. § 3501 et seq.
- Endangered Species Act, 16 U.S.C. § 1531 et seq.
- Fish and Wildlife Coordination Act, 16 U.S.C. § 661 et seq.
- Marine Mammal Protection Act of 1972, 16 U.S.C § 1361 et seq.
- Migratory Bird Treaty Act, 16 U.S.C § 703 et seq.
- National Wildlife Refuge System Administration Act of 1966, 16 U.S.C. § 668dd et seq.
- National Wildlife Refuge System Improvement Act of 1997

8.2 Maryland Legislation Applicable to Waterway Debris Response

- Abandoned, Lost, or Seized Personal Property, Md. Code Ann § 1-2A-01
- Conservation and Management of State Waters, Md. Code Ann § 8-201 et seq.
- Management and development of Chesapeake Bay and other tidal waters; authority to acquire and maintain vessels and equipment; additional powers, Md. Code Ann § 8-202
- Maryland Environmental Policy Act, Md. Code Ann § 1-301 et seq.
- Maryland Historical Trust Act of 1985, Md. Code Ann § 5A-325-326
- Removal and disposal of abandoned or sunken vessels, Md. Code Ann § 8-721
- Stormwater Management, Md. Code Ann § 4-201 et seq.
- Throwing certain waste on certain waters of the State, Md. Code Ann § 8-726.1
- Throwing or dumping refuse on waters of State, Md. Code Ann § 8-726
- Watershed Sediment and Waste Control, Md. Code Ann § 4-301 et seq.
- Water Pollution Control and Abatement, Md. Code Ann § 4-401 et seq.

8.3 Agency Response Capabilities

	Yes - In-house Capability / Contract - Contracted capability	FEMA Region III[1]	NOAA[2]	USFWS ESFO	MEMA	MDNR	MHT	Annapolis Emergency Management	Annapolis Harbormaster	Baltimore County Solid Waste
Technology	Aerial photography and video	Yes / Cont.	Yes			Yes				
Technology	Automatic ID system for vessels									
Technology	Geographic Information Systems (GIS)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Technology	Multi-beam sonar	Contract	Yes							
Technology	Remote sensing	Contract	Yes				Yes			
Technology	Side-scan sonar	Contract	Yes			Yes	Yes			
Technology	Single-beam sonar	Contract	Yes			Yes				
Manpower	Compliance and permitting expertise	Yes	Yes	Yes		Yes	Yes	Yes		Yes
Manpower	Dive support	Contract	Yes[3]			Yes	Yes[5]			
Manpower	Environmental expertise (location of sensitive areas and endangered species present, etc.)	Yes / Cont.	Yes	Yes		Yes				
Manpower	GIS staff/technician	Yes / Cont.	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Manpower	Historical/cultural expertise	Yes / Cont.					Yes	Yes	Yes	
Manpower	Local Captains/navigation expertise to support operations	Contract				Yes				
Manpower	Private boat owners/operators (vessels of opportunity)									
Manpower	Public Affairs trained staff	Yes / Cont.	Yes		Yes	Yes		Yes	Yes	
Manpower	Technical expertise for removal operations (techniques, best management practices, etc.)	Yes / Cont.	Yes			Yes			Yes	
Manpower	Volunteer manpower (vetted for technical skills)	Yes / Cont.								
Manpower	Volunteer coordination	Yes						Yes		
Equipment	Aircraft- civil air patrol	Yes / Cont.	Yes							
Equipment	Airlift capabilities	Yes / Cont.								
Equipment	All-terrain vehicles or other vehicles for difficult terrain	Contract				Yes				
Equipment	Barge/Self-loading barge	Contract				Yes				
Equipment	Boom	Contract						Yes	Yes	
Equipment	Communications equipment (two-way radios etc.)	Contract	Yes		Yes	Yes	Yes	Yes	Yes	

Yes - In-house Capability

Contract - Contracted capability

		FEMA Region III[1]	NOAA[2]	USFWS ESFO	MEMA	MDNR	MHT	Annapolis Emergency Management	Annapolis Harbormaster	Baltimore County Solid Waste
Equipment (Cont.)	Crane/knuckleboom crane	Contract				Yes		Yes	Yes	
	Debris handling equipment (burners, grinders, etc.)	Yes / Cont.								Yes
	Excavator	Contract				Yes				Yes
	Remotely Operated Vehicle	Contract	Yes							
	Unmanned Aerial Vehicle	Contract	Yes					Yes		
	Vessels-shallow draft	Yes / Cont.	Yes			Yes	Yes[6]	Yes	Yes	
	Vessels-deep draft	Yes / Cont.	Yes			Yes		Yes	Yes	
	Other specialized equipment that cannot be readily procured immediately following a debris incident	Contract								
Logistics	Contract authority and oversight capabilities	Yes / Cont.	Yes			Yes		Yes		
	Docks for wet storage of vessels	Contract				Yes		Yes	Yes	
	Facility suitable for establishing an Emergency Operations Center	Yes / Cont.			Yes	Yes		Yes		
	Funding for waterway debris removal	Yes	Yes[4]		Yes	Yes		Yes	Yes	
	Legal representation/expertise	Yes	Yes			Yes		Yes		
	List of available locations for staging/off-loading areas					Yes		Yes	Yes	
	Pre-approved waterway debris removal contractors	Contract				Yes		Yes	Yes	
	Pre-designated landfill/disposal sites (to include vegetative and animal carcasses)	Contract				Yes		Yes	Yes	
	Pre-event contracts and staged agreements in place	Contract								
	Staging/Off-Loading: Land with water access to stage, offload debris (has not been evaluated for suitability or officially pre-designated)	Contract				Yes		Yes	Yes	
	Staging/Off-Loading: Pre-designated staging, off-loading and special handling areas (already evaluated for suitability)	Contract				Yes		Yes	Yes	
	Staging area for dry storage of vessels	Yes / Cont.				Yes		Yes	Yes	
	Other logistical support including fuel, housing, food, etc.	Yes / Cont.						Yes	Yes	

Note: Capabilities which could be used during waterway debris response in Maryland were either identified through research or were self-reported by an organization. Organizations were asked to indicate whether capabilities were in-house or were contracted through a third party. Footnotes refer to additional information provided for a particular capability.

[1]FEMA Capabilities reported 'Contract' may be contracted out or mission assigned to another federal agency. For example, USACE may be mission assigned to coordinate and/or identify local areas to use for operations.

[2]NOAA Some capabilities require contract support for staffing.

[3]NOAA Dive capabilities do not include sites with oil or hazardous pollutants.

[4]NOAA Funding through grant program and possible Congressional supplemental funding.

[5]MHT Dive capabilities do not include sites with oil or hazardous pollutants, are limited to inspection of potential historic properties, and may require contract support.

[6]MHT Limited to one 30-foot Maycraft survey boat and one 17-foot Carolina Skiff.

8.4 Agency Response Contacts

Local Agencies/Organizations

Agency	Division	Topic	Point of Contact	Phone	Email
City of Annapolis	Harbormasters Office	Vessel Capabilities	Tyler Northfield	410-263-7973	-
	Historic Preservation Commission	Historic/Cultural Expertise	Sherri Pippen	410-260-2200	-
	Information Technology/GIS	Geographic Information Systems	Shawn Wampler	410-263-7945	-
	Office of Emergency Management	Emergency Management	Patrick Donlan, Emergency Planner	410-216-9176	pbdonlan@annapolis.gov
	Public Information Office	Public Affairs	Susan O'Brien	410-263-1183	-
	Public Works	-	Marcia Patrick	410-263-949	-
		-	Phil Scrivener, Refuse Supervisor	433-336-5801	pscrivener@annapolis.gov
Anne Arundel County	Office of Emergency Management	Emergency Management	Chrissy Cornwell, Deputy Director	410-222-0605	emcorn00@aacounty.org
			J. Kevin Aftung, Director	410-222-0603	emaftu00@aacounty.org
Baltimore County	Division of Public Works	Public Works Capabilities	Michael Beichler	410-887-2794	mbeichler@baltimorecountymd.gov
Baltimore Metropolitan Council	-	Baltimore Regional Disaster Debris Planning Task Force	Eileen Singleton, Principal Transportation Engineer	410-732-0500x1033	esingleton@baltimoremetro.org

State Agencies

Agency	Division	Topic	Point of Contact	Phone	Email
Maryland Department of the Environment (MDE)	Land and Materials	Oil Control Program	24hr Oil Spill Reporting Line	1-866-633-4686	-
	Office of Emergency Preparedness	Emergency Management	Geoffrey Donahue, Director	410-365-8809	geoffrey.donahue@maryland.gov
	Solid Waste Operations	Solid Waste Program	Edward M. Dexter, P.G., Administrator	410-537-3315	ed.dexter@maryland.gov
		Solid Waste Operations	Martha Hynson, Chief, Solid Waste Operations	-	martha.hynson@maryland.gov
		Compliance	Brian Coblentz, Chief, Compliance Division	-	brian.coblentz@maryland.gov
	Water and Science	Tidal Wetland Permitting	Main Line	410-537-3837	-

State Agencies Continued

Agency	Division	Topic	Point of Contact	Phone	Email
Maryland Department of Natural Resources (MDNR)	Fisheries and Boating Service	Abandoned Boat and Debris Program	John Gallagher	410-463-6522	john.gallagher1@maryland.gov
			Matt Negley	410-463-6521	matt.negley@maryland.gov
	Parks Service	State Parks	Nita Settina, Superintendent	-	nita.settina@maryland.gov
	Chesapeake and Coastal Service	Coastal Zone Management coastal polices and federal consistency, marine debris technical expertise, GIS capabilities, aerial photography and video capabilities	Matt Fleming, Director	410-260-8719	matthew.fleming@maryland.gov
	Environmental Review	Policy and permitting guidance	Tony Redman	410-260-8336	tony.redman@maryland.gov
	Natural Resource Police	Reporting of debris	Natural Resources Emergency Line	800-628-9944 or 410-260-8888	-
Maryland Department of Planning (MDP)	Maryland Historical Trust (MHT)/SHPO	State Underwater Archeologist	Susan Langley	410-353-8777(c) 410-697-9564(o)	susan.langley@maryland.gov
		Administrator, Review and Compliance	Beth Cole	410-697-9541	beth.cole@maryland.gov
		Preservation Services	Main Line	410-697-9545	-
Maryland Department of Transportation (MDOT)	Office of Homeland Security, Emergency Management, and Rail Safety	Emergency Management	Mark Harris	410-865-1128	mharris@mdot.state.md.us
	Maryland Port Administration	Safety, Environment, and Risk Management	Bill Richardson, General Manager	410-633-1145	wrichardson@marylandports.com
Maryland Emergency Management Agency (MEMA)	Consequence Management	Maryland Joint Operation Center	24hr Watch Center	410-517-3600	mjoc.mema@maryalnd.gov
		Emergency Operations	Marcia Deppen	410-517-3638	marica.deppen@maryland.gov
	Mission Support	Communications Equipment Capabilities	Brian Wood	410-517-3648	brian.wood@maryland.gov
		Public Assistance Funding	Sara Bender	410-517-3620	sara.bender1@maryland.gov
		State Emergency Operations Center	Jeremy Scheinker	410-517-3641	jeremy.scheinker@maryland.gov
	Disaster Risk Reduction	State Disaster Recovery Coordinator	Dave Robbins	410-517-3650	dave.robbins@maryland.gov

Federal Agencies

Agency	Division	Topic	Point of Contact	Phone	Email
Bureau of Safety and Environmental Enforcement	Marine Trash and Debris Program	Planning and coordination	James Sinclair, Marine Ecologist	504-736-2789	james.sinclair@bsee.gov
Federal Emergency Management Agency (FEMA)	Region III	Recovery Division	Edward Budnick, Debris SME	267-319-6334	edward.budnick@fema.dhs.gov
			Matthew Werner, Senior Emergency Management Specialist	202-600-1768	matthew.werner@fema.dhs.gov
		Requests for assistance for capabilities	Region III Watch Center	215-931-5757	FEMA-R03-RRCC-WATCH@fema.dhs.gov
National Oceanic and Atmospheric Administration (NOAA)	National Marine Fisheries Service or NOAA Fisheries	EFH consultation	David O'Brien, Marine Habitat Resource Specialist	804-684-7828	david.l.o'brien@noaa.gov
			General Contact	410-573-4559	-
		ESA consultation	General Contact	978-281-9328	nmfs.gar.esa.section7@noaa.gov
			William Barnhill, Fishery Biologist	978-282-8460	william.barnhill@noaa.gov
			Brian Hopper, Fishery Biologist	410-573-4592	brian.d.hopper@noaa.gov
	National Ocean Service (NOS) Office of Response and Restoration (ORR) Emergency Response Division	Emergency Response	Ed Levine, Scientific Support Coordinator (SSC) Supervisor, East and Gulf Coasts	240-533-0387	ed.levine@noaa.gov
			Frank Csulak, USCG District 5 SSC	732-872-3005	frank.csulak@noaa.gov
			John Tarpley, Regional Operations Branch Chief	206-526-6338	john.tarpley@noaa.gov
	NOS, ORR, Marine Debris Division	Response capabilities and coordination	Jason Rolfe, Mid-Atlantic Regional Coordinator, Marine Debris Program	240-533-0442 (o) 301-461-3236 (c)	jason.rolfe@noaa.gov
	NOS, Office of Coast Survey	Navigation and preparation response	Steve Soherr, Regional Navigation Manager, Chesapeake & Delaware Bay	240-533-0080	steve.soherr@noaa.gov
National Park Service	Assateague Island National Seashore	-	Deborah Darden, Superintendent	410-629-6080	deborah_darden@nps.gov
		Park Rangers	Walt West, Chief Ranger	410-641-1443	-
		Resource Management	Bill Huslander, Chief	410-629-6061	bill_hulslander@nps.gov
	Fort McHenry National Monument and Historic Shrine	-	Tina Cappetta, Superintendent	410-962-4290x101	tina_cappetta@nps.gov
	Northeast Region	Natural Resources	Carmen Chapin, Chief	215-597-7700	carmen_chapin@nps.gov

Federal Agencies Continued

Agency	Division	Topic	Point of Contact	Phone	Email
Natural Resources Conservation Service (NRCS)	-	Emergency Watershed Protection (EWP) Program information	Allan Stahl, State Conservationist	443-482-2912	allan.stahl.md.usda.gov
U.S. Army Corps of Engineers (USACE) Baltimore District	-	Debris Removal	Jeff Peacock, Chief, Debris Unit	443-844-9290	jeffrey.d.peacock@usace.army.mil
		Emergency Management Response capabilities	24hr Emergency Operations Center	410-962-2013	cenab-eoc@usace.army.mil
			Dorie Murphy, Chief, Emergency Management	410-962-4224	dorie.murphy@usace.army.mil
		Navigation	Kevin Brennan, Chief, Navigation	410-9626113	kevin.m.brennan@usace.army.mil
		Regulatory Program	Main Line	410-962-3670	-
U.S. Coast Guard (USCG) District 5	Sector Maryland-National Capital Region	Maryland Command Center	Main Line	410-576-2525	-
		Potential to release oil or hazardous material	National Response Center (NRC)	1-800-424-8802	-
		Port Recovery/Security	Fred Dolbow, Port Recovery/Security Specialist	410-487-5616	frederick.h.dolbow@uscg.mil
U.S. Environmental Protection Agency (EPA)	Region III	Marine Protection, Research, and Sanctuaries Act	Kristin Regan	215-814-2711	regan.kristin@epa.gov
		Environmental Protection	Bill Steuteville	215-814-3264	steuteville.william@epa.gov
			Daniel T. Gallo, Environmental Protection Specialist	215-814-2091	gallo.dan@epa.gov
		NEPA	Barb Rudnick	215-814-3322	rudnick.barbara@epa.gov
		Potential to release oil or hazardous substance	National Response Center (NRC)	800-424-8802	-
U.S. Fish and Wildlife Service (USFWS)	Ecological Services	Chesapeake Bay Field Office	Trevor Clark	410-573-4527	trevor_clark@fws.gov

Wilbur L. Ross, Jr.
United States Secretary of Commerce

Dr. Neil Jacobs
Assistant Secretary of Commerce for Environmental Observation and Prediction,
performing the duties of Under Secretary of Commerce for Oceans and Atmosphere

Nicole R. LeBoeuf
Acting Assistant Administrator for Ocean Services
and Coastal Zone Management

U.S. Fish & Wildlife Service

ESA Basics

40 Years of Conserving Endangered Species

When Congress passed the Endangered Species Act (ESA) in 1973, it recognized that our rich natural heritage is of "esthetic, ecological, educational, recreational, and scientific value to our Nation and its people." It further expressed concern that many of our nation's native plants and animals were in danger of becoming extinct.

The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. The Interior Department's U.S. Fish and Wildlife Service (FWS) and the Commerce Department's National Marine Fisheries Service (NMFS) administer the ESA. The FWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromous fish such as salmon.

Under the ESA, species may be listed as either endangered or threatened. "Endangered" means a species is in danger of extinction throughout all or a significant portion of its range. "Threatened" means a species is likely to become endangered within the foreseeable future. All species of plants and animals, except pest insects, are eligible for listing as endangered or threatened. For the purposes of the ESA, Congress defined species to include subspecies, varieties, and, for vertebrates, distinct population segments.

As of January 2013, the FWS has listed 2,054 species worldwide as endangered or threatened, of which 1,436 occur in the United States.

How are Species Listed?

Section 4 of the ESA requires species to be listed as endangered or threatened solely on the basis of their biological status and threats to their existence. When evaluating a species for listing, the FWS considers five factors: 1) damage to, or destruction of, a species' habitat; 2) overutilization of the species for commercial, recreational, scientific, or educational purposes; 3) disease or

USFWS

Bart Gamett/USFWS

At home in streams and lakes in Washington, Oregon, Idaho, Montana, and Nevada, the threatened bull trout needs clean, cold water with deep pools, logs for hiding, connected habitat across the landscape and, for spawning and rearing, clean streambed gravel.

predation; 4) inadequacy of existing protection; and 5) other natural or manmade factors that affect the continued existence of the species. When one or more of these factors imperils the survival of a species, the FWS takes action to protect it. The Fish and Wildlife Service is required to base its listing decisions on the best scientific information available.

Candidates for Listing

The FWS also maintains a list of "candidate" species. These are species for which the FWS has enough information to warrant proposing them for listing but is precluded from doing so by higher listing priorities. While listing actions of higher priority go forward, the FWS works with States, Tribes, private landowners, private partners, and other Federal agencies to carry out conservation actions for these species to prevent further decline and possibly eliminate the need for listing.

Protection

The ESA protects endangered and threatened species and their habitats by prohibiting the "take" of listed animals and the interstate or international trade in listed plants and animals, including their parts and products, except under Federal permit. Such permits generally are available for conservation and scientific purposes.

What is "Take"?

The ESA makes it unlawful for a person to take a listed animal without a permit. Take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Through regulations, the term "harm" is defined as "an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." Listed plants are not protected from take, although it is illegal to collect or maliciously harm them on Federal land. Protection from commercial trade and the effects of Federal actions do apply for plants. In addtion, States may have their own laws restricting activity involving listed species.

Recovery

The law's ultimate goal is to "recover" species so they no longer need protection under the ESA. Recovery plans describe the steps needed to restore a species to ecological health. FWS biologists write and implement these plans with the assistance of species experts; other Federal, State, and local agencies; Tribes; nongovernmental organizations; academia; and other stakeholders.

Federal Agency Cooperation

Section 7 of the ESA requires Federal agencies to use their legal authorities to promote the conservation purposes of the ESA and to consult with the FWS and NMFS, as appropriate, to ensure that effects of actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species. During consultation the "action" agency receives a "biological opinion" or concurrence letter addressing the proposed action. In the relatively few cases in which the FWS or NMFS makes a jeopardy determination, the agency offers "reasonable and prudent alternatives" about how the proposed action could be modified to avoid jeopardy. It is extremely rare that a project ends up being withdrawn or terminated because of jeopardy to a listed species.

The ESA also requires the designation of "critical habitat" for listed species when "prudent and determinable." Critical habitat includes geographic areas that contain the physical or biological features that are essential to the conservation of the species and that may need special management or protection. Critical habitat designations affect only Federal agency actions or federally funded or permitted activities. Federal agencies are required to avoid "destruction" or "adverse modification" of designated critical habitat.

Critical habitat may include areas that are not occupied by the species at the time of listing but are essential to its conservation. An area can be excluded from critical habitat designation if an economic analysis determines that the benefits of excluding it outweigh the benefits of including it, unless failure to designate the area as critical habitat may lead to extinction of the listed species.

The ESA provides a process for exempting development projects from the restrictions if a Cabinet-level "Endangered Species Committee" decides the benefits of the project clearly outweigh the benefits of conserving a species. Since its creation in 1978, the Committee has only been convened three times to make this decision.

Working with States

Partnerships with States are critical to our efforts to conserve listed species. Section 6 of the ESA encourages States to develop and maintain conservation programs for threatened and endangered species. Federal funding is available to promote State participation. Some State laws and regulations are more restrictive than the ESA in granting exceptions or permits.

Working with Landowners

Two-thirds of federally listed species have at least some habitat on private land, and some species have most of their remaining habitat on private land. The FWS has developed an array of tools and incentives to protect the interests of private landowners while encouraging management activities that benefit listed and other at-risk species.

Habitat Conservation Plans

Section 10 of the ESA may be used by landowners including private citizens, corporations, Tribes, States, and counties who want to develop property inhabited by listed species. Landowners may receive a permit to take such species incidental to otherwise legal activities, provided they have developed an approved habitat conservation plan (HCP). HCPs include an assessment of the likely impacts on the species from the proposed action, the steps that the permit holder will take to avoid, minimize, and mitigate the impacts, and the funding available to carry out the steps.

HCPs may benefit not only landowners but also species by securing and managing important habitat and by addressing economic development with a focus on species conservation.

Safe Harbor Agreements

Safe Harbor Agreements (SHAs) provide regulatory assurance for non-Federal landowners who voluntarily aid in the recovery of listed species by improving or maintaining wildlife habitat. Under SHAs, landowners manage the enrolled property and may return it to originally agreed-upon "baseline" conditions for the species and its habitat at the end of the agreement, even if this means incidentally taking the species.

Candidate Conservation Agreements

It is easier to conserve species before they need to be listed as endangered or threatened than to try to recover them when they are in danger of extinction or likely to become so. Candidate Conservation agreements (CCAs) are voluntary agreements between landowners—including Federal land management Agencies— and one or more other parties to reduce or remove threats to candidate or other at-risk species. Parties to the CCA work with the FWS to design conservation measures and monitor the effectiveness of plan implementation.

Candidate Conservation Agreements with Assurances

Under Candidate Conservation Agreements with Assurances (CCAA), non-Federal landowners volunteer to work with the FWS on plans to conserve candidate and other at-risk species so that protection of the ESA is not needed. In return, landowners receive regulatory assurances that, if a species covered by the CCAA is listed, they will not be required to do anything beyond what is specified in the agreement, and they will receive an enhancement of survival permit, allowing incidental take in reference to the management activities identified in the agreement.

Conservation Banks

Conservation banks are lands that are permanently protected and managed as mitigation for the loss elsewhere of listed and other at-risk species and their habitat. Conservation banking is a free-market enterprise based on supply and demand of mitigation credits. Credits are supplied by landowners who enter into a Conservation Bank Agreement with the FWS agreeing to protect and manage their lands for one or more species. Others who need to mitigate for adverse impacts to those same species may purchase conservation bank credits to meet their mitigation requirements. Conservation banking benefits species by reducing the piecemeal approach to mitigation that often results in many small, isolated and unsustainable preserves that lose their habitat functions and values over time.

International Species

The ESA also implements U.S. participation in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a 175-nation agreement designed to prevent species from becoming endangered or extinct due to international trade. Except as allowed by permit, CITES prohibits importing or exporting species listed on its three appendices. A species may require a permit under the ESA, CITES, or both.

For More Information

For more information, contact the U.S. Fish and Wildlife Service at the address below, or visit *http://www.fws.gov/endangered/*.

U. S. Fish and Wildlife Service
Endangered Species Program
4401 N. Fairfax Drive, Room 420
Arlington, VA 22203
703-358-2171
http://www.fws.gov/endangered/

January 2013

NOAA FISHERIES

Marine Mammal Health and Stranding Response Program (MMHSRP)

Marine mammals are important indicator species of the ocean health. They are top level predators that eat many of the same fish that we do, and many species live in coastal areas utilized by people. When marine mammals show signs of illness, they may be signaling changes in the marine environment that might have significant implications for the overall health of our ocean ecosystems. Monitoring the health of marine mammals provides information on the impacts of human activities and the effectiveness of management actions (*i.e.*, fishery, vessel, noise, pollution), which is important for conservation and understanding the health of our oceans in a time of significant changes.

Establishment of the MMHSRP

The Marine Mammal Health and Stranding Response Program (MMHSRP) was established by Congress in 1992 under Title IV of the Marine Mammal Protection Act (MMPA) to:

1. Facilitate the collection and dissemination of reference data and assess health trends;
2. Correlate marine mammal health with available data on physical, chemical, biological and environmental parameters; and
3. Coordinate responses to unusual mortality events (UMEs).

Marine Mammal Stranding Network

Over 100 organizations partner with NOAA Fisheries to investigate marine mammal strandings. Stranding Network members are trained professionals and volunteers from nonprofit organizations, aquaria, universities, and federal, state or local governments. Each case provides information about the causes of strandings, baseline health information, and factors that may impact the health of marine mammal populations. Lessons learned from robust populations (*e.g.*, bottlenose dolphins) are helping identify threats, inform management actions and refine techniques to maximize success during emergencies with threatened or endangered species (*e.g.*, North Atlantic right whales, Hawaiian monk seals).

Number of Marine Mammal Strandings 2001-2015

Region	Cetaceans Live	Cetaceans Dead	Pinnipeds Live	Pinnipeds Dead	Total Strandings
GAR	2,439	4,374	4,453	7,674	18,942
SER	1,625	9,684	22	128	11,461
WCR	1,715	2,097	22,714	27,997	54,525
AKR	295	847	296	980	2,420
PIR	153	131	106	91	483
U.S. Totals	8,147	15,217	22,685	41,780	**87,831**

What is a marine mammal stranding?

A whale, dolphin, or porpoise (cetacean) stranding is when it is dead or alive on the beach, dead floating in U.S. waters, or in need of medical attention while free-swimming in U.S. waters. A seal or sea lion (pinniped) stranding is either when it is dead or in distress on the beach. Live stranded animals are usually in need of medical attention or cannot return to their natural habitat without assistance.

Why do marine mammals strand?

The reasons for strandings are often unknown but identified causes include:

- Trauma (ship strikes or bycatch)
- Ingestion of or entanglement in debris
- Weather or oceanographic events
- Starvation
- Pollution exposure
- Sound (human or natural)
- Harmful algal blooms and biotoxins
- Infectious diseases, including emerging or zoonotic diseases

Photos provided by: NOAA

Entanglement Response Program

Entanglements and fishery interactions continue to affect all cetaceans and pinnipeds in North America and are significant problems and causes of mortality or serious injury for endangered North Atlantic right whales and monk seals. The MMHSRP coordinates entanglement response programs for large whales, small cetaceans and pinnipeds. Since 1984, more than 95 large whales have been disentangled, and more than 100 small whales, dolphins, porpoises and pinnipeds are disentangled annually. Trained rescue personnel free marine mammals from fishing gear and new techniques are increasing the number of animals that can be helped. Through data from entanglement responses, the network has identified entanglement risk factors. NOAA is working with fishermen on gear modifications and other management actions to prevent future entanglements.

Unusual Mortality Event (UME) Investigations

UMEs are strandings that are unexpected and/or involve a significant die-off of any marine mammal population and demand an immediate response. The determination of whether a stranding qualifies as an UME is made by the Working Group on Marine Mammal Unusual Mortality Events and since 1991, the Working Group has helped NOAA Fisheries and the Stranding Network conduct investigations into 62 declared UMEs. A National Contingency Fund has been established to offset some costs incurred by the Stranding Network during investigations. Recent UMEs have included the cetaceans in the Northern Gulf of Mexico coincident with the Deepwater Horizon oil spill, California sea lions in California and large whales in Alaska

Marine Mammal Health Assessments

Working with partners from the Standing Network, academia, federal state and local agencies, and from across NOAA, the MMHSRP helps fund or conducts health assessment studies on wild marine mammal populations to develop baseline data, monitor trends and investigate the impacts of disease, natural toxins and pollution. The MMHSRP uses this information to determine health trends in marine mammals and marine ecosystems. Ongoing studies include health assessments of: bottlenose dolphins in the Atlantic Ocean and Gulf of Mexico, California sea lions, Northern fur seals, harbor seals and Northern elephant seals, and critically endangered species including North Atlantic right whales and Hawaiian monk seals. These ongoing health assessments provide valuable information on infectious diseases in marine mammals such as influenza and brucellosis and baseline health information for the Arctic.

Additional Resources

Marine Mammal Health and Stranding Response Program
http://www.nmfs.noaa.gov/pr/health/MMHSRP.html

National Marine Mammal Stranding Network
http://www.nmfs.noaa.gov/pr/health/networks.htm

UME Program
http://www.nmfs.noaa.gov/pr/health/mmume/events.html

Prescott Grant Program
http://www.nmfs.noaa.gov/pr/health/prescott/

National Report on Large Whale Entanglements

Confirmed in the United States in 2017

In 2017, 76 confirmed cases of large whale entanglements were documented along the coasts of the United States. Seventy of these U.S. entanglement cases involved live animals and six involved dead animals. All were independently confirmed by the Large Whale Entanglement Response Network. The number of confirmed cases for 2017 (n=76) does not include multiple reports of any individual entangled whale.

NOAA Fisheries tracks subsequent reports of a previously reported entangled whale to better understand the nature of the entanglement, associated injuries, and the animal's health status. The subsequent reports have been combined into a single record for the purposes of this summary to provide clarity on the number of entangled individuals. Fourteen additional cases were reported, but those entanglements could not be confirmed with the information received and the whales were not relocated by network members; thus, those reports were tracked but not included in the overall total. This summary report therefore represents a conservative estimate of the number of large whale entanglements confirmed in U.S. waters. Some of these entanglements may have originated in waters outside the United States given that large whales travel long distances between their feeding and breeding grounds, which can cross international boundaries and oceans. NOAA Fisheries tries to collect and identify entangling gear during each response in order to work with fishing communities to reduce future entanglements. However, definitive identification is not always possible.

Comparing Confirmed Entanglements in 2017 to Past Years

The number of confirmed entanglement cases nationwide in 2017 (n=76) is similar to the 10-year (2007-2016) average annual number of confirmed entanglements (n=69.5 $\pm$ 21.7). Although the number of overall entanglements in 2017 is within the 10-year average, the number of entanglements exhibits a decrease from the higher numbers seen in recent years in the Northeast, Mid-Atlantic, and West Coast regions (Figure 1). The five most frequently entangled large whale species in 2017 were humpback whales (*Megaptera novaeangliae*), gray whales (*Eschrichtius robustus*), minke whales (*Balaenoptera acutorostrata*), blue whales (*Balaenoptera musculus*), and North Atlantic right whales (*Eubalaena glacialis*). In three cases, although the entanglement was confirmed, the whale could not be identified to species, and therefore is considered "unidentified."

Entanglement responders from Georgia Department of Natural Resources work to remove gear from an entangled North Atlantic right whale on January 5, 2017. Photo taken under Permit No.18786-02.

Entanglement responders from Georgia Department of Natural Resources (above) work to remove gear from an entangled North Atlantic right whale on January 5, 2017. Photo taken under Permit No.18786-02.

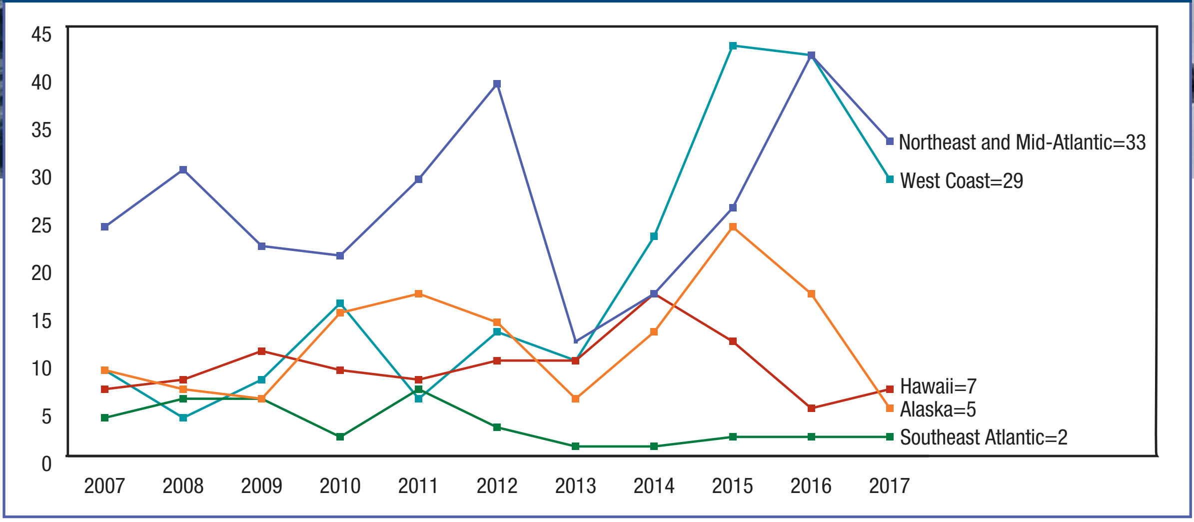


Figure 1: Confirmed large whale entanglements by region from 2007-2017

In 2017, most regions had a decrease or remained level in the number of entanglements when compared to recent years.

Humpback whale (Megaptera novaeangliae) (n=49 in 4 Regions): Humpback whale entanglements were only slightly elevated in 2017 compared to previous years (Table 1). Humpback whales are the most frequently reported entangled large whale species and represent 68.1 percent of all confirmed entanglements since 2007. NOAA Fisheries declared an Unusual Mortality Event (UME) for humpback whales due to elevated strandings along the U.S. East Coast, and three cases had evidence of entanglement or interactions with fishing gear.

Gray whale (Eschrichtius robustus) (n=11 in 1 Region): Gray whale entanglements in 2017 in U.S. waters were much higher than the 10-year average (Table 1). In the United States, gray whales only occur in the Pacific Ocean, and most gray whales migrate between their summer foraging grounds in Alaska and their winter breeding grounds in Mexico, passing by Washington, Oregon, and California on each trip. (However, a few gray whales have been reported in the Arctic and Gulf of Alaska in winter). The increase in entangled gray whales may suggest the animals overlapped with West Coast fishing efforts more than usual in 2017 during their annual migrations.

Minke whale (Balaenoptera acutorostrata) (n=7 in 1 Region): Minke whale entanglements were elevated in 2017 compared to previous years (Table 1). All confirmed minke whale entanglements occurred along the coast of New England, in the Gulf of Maine. All entanglements involved line and pot gear and four of the whales were reported after they had died.

Blue whale (Balaenoptera musculus) (n=3 in 1 Region): Blue whale entanglements have only recently been documented in U.S. waters, and three cases were reported in 2017 (Table 1).

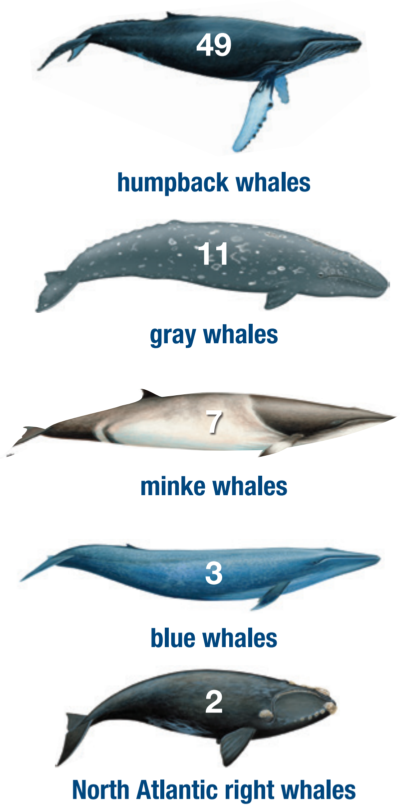
The first known blue whale entanglement in U.S. waters was confirmed in 2015, and 2017 represents the third year in a row that NOAA Fisheries has documented an entanglement case for this species. Despite their global distribution, blue whales are most commonly found in U.S. waters along the West Coast, and all confirmed entanglements of blue whales have been off the coast of California. While the overall number of 2017 confirmed entangled blue whales remains small (n=3), and represents fewer animals than for some other species (Table 1), it is important to continue tracking entanglement trends in this species. Confirmed cases from the past 3 years suggest that entanglements may now represent an emerging threat to this species.

North Atlantic right whale (Eubalaena glacialis) (n=2 in 2 Regions): North Atlantic right whale entanglements in U.S. waters were lower in 2017 than the 10-year average (Table 1). Although the U.S. confirmed entanglements were lower, the overall entanglement of this species remains high and of concern. Historically, North Atlantic right whales have migrated along the U.S. East Coast between their summer feeding grounds off the coasts of New England and Canada and their winter breeding grounds off the coasts of Georgia and northern Florida. NOAA Fisheries recently declared an Unusual Mortality Event (UME) for this species, based on a high number of dead whales discovered in Canadian and U.S. waters in 2017 and 2018. Five of the deaths in Canadian waters in 2017 were attributed to entanglements in fishing gear. In addition to two live entangled whales confirmed in U.S. waters, two North Atlantic right whales that stranded dead in U.S. waters are thought to have died due to entanglements. Given the endangered status of North Atlantic right whales—recent population estimates indicate only about 450 individuals remain—and declining trend of the species, any entanglement is a major threat to their recovery.

Table 1: The number of confirmed entanglements in 2017 and the 10-year average number of entanglements for each large whale species

Species	Confirmed Entanglements in 2017	10-Year Average (2007-2016)
Humpback Whale	**49**	47.6 ± 19.5
Gray Whale	**11**	6.3 ± 4.2
Minke Whale	**7**	5.0 ± 1.5
Blue Whale	**3**	0.4 ± 0.9
North Atlantic Right Whale	**2**	4.6 ± 2.6
Unidentified Whale	**2**	2.1 ± 1.8
Fin Whale	**1**	2.9 + 1.5
Sei Whale	**1**	0.3 + 0.5
Unidentified Whale	**0**	2.1 + 1.8
Sperm Whale	**0**	0.4 + 0.9

Five most frequently entangled large whale species in 2017:

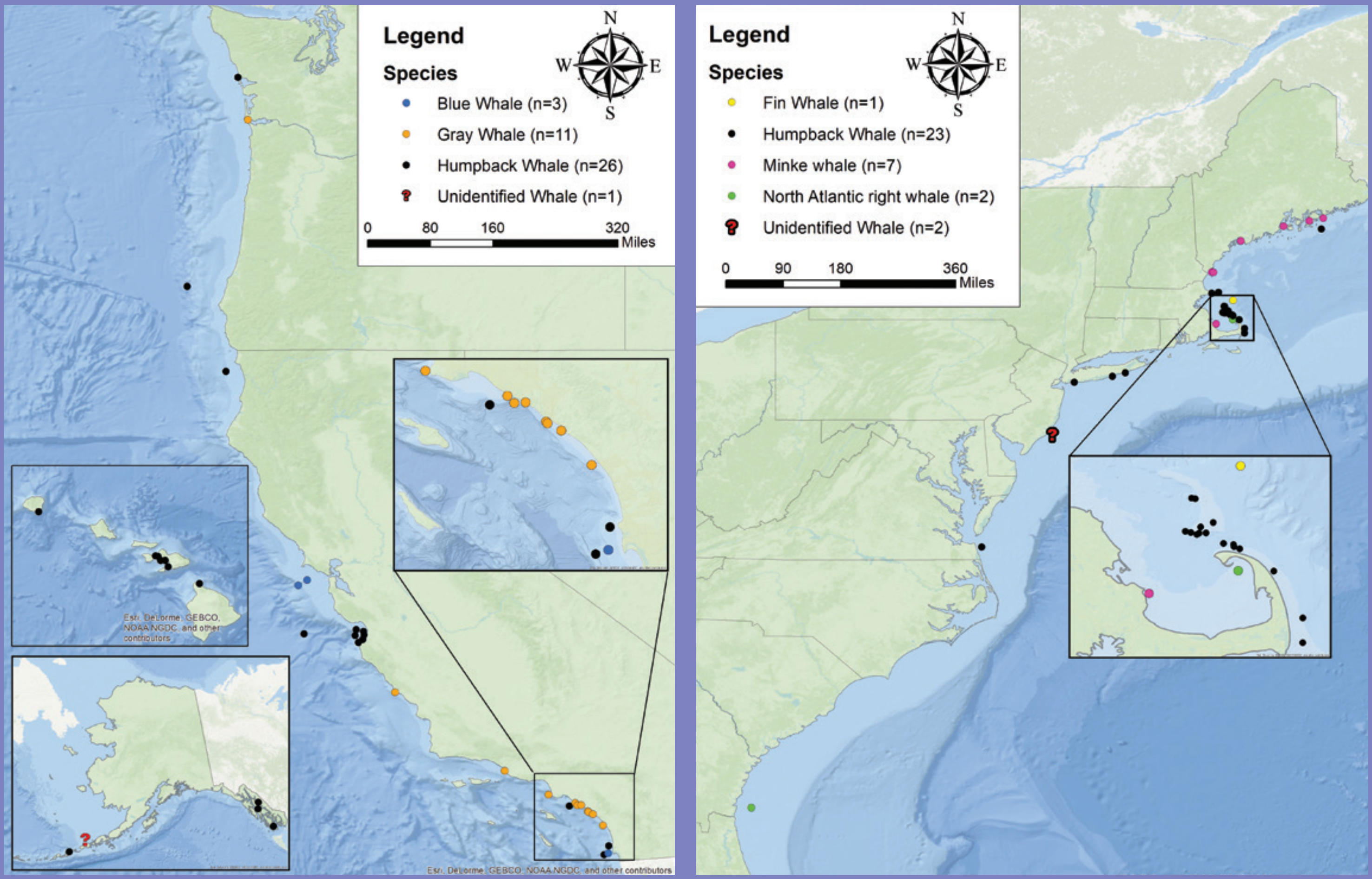


Location of Confirmed Entanglement Cases

In 2017, large whale entanglements were reported and confirmed in the waters of 13 states, along all U.S. coasts except within the Gulf of Mexico. More than half of all confirmed entanglements occurred in two states—32.9 percent in California waters (n=25) and 26.6 percent in Massachusetts waters (n=20). In California, a large number of entangled humpback whales were found in Monterey Bay (n=7) and most of the entangled gray whales were found in the lower half of the Southern California Bight (n=8). A high number of humpback whale entanglements were confirmed off the coast of the Main Hawaiian Islands (n=7), accounting for 14.3 percent of all humpback whale entanglements and 9.2 percent of all entanglements for all species combined. The entanglements off the coast of Massachusetts were concentrated along Cape Cod and Stellwagen Bank, and primarily involved humpback whales (n=16) (Figure 2).

An entangled humpback whale off of San Diego, CA. Documented large whale entanglements often involve the tail and flukes. Photo taken under Permit No. 18786. Credit: Keith Yip

Figure 2: The locations of all confirmed entanglement sightings in 2017.
Areas with significant numbers of whale entanglements include Massachusetts, California, and Hawaii.



Sources of Entanglements

Approximately 70 percent of confirmed cases in 2017 were entangled in fishing gear (line and buoys, traps, monofilament line, and nets). Another 24 percent of confirmed cases involved line that could not be attributed to a fishery (i.e., no clear evidence of traps, nets, or other gear associated with fishing). Although various marine industries introduce gear into the ocean (e.g., ropes, lines, nets, chains, and cables), one of the most common sources is commercial or recreational fishing. Therefore, it is likely some of the cases involving only line were incidental to fishing activities. Conversely, only 2 percent of entanglements were caused by non-fishery-related marine debris or were of unknown origin not related to fishing gear, further highlighting that fishing gear remains the largest entanglement threat to large whale species.

Rescue Operations to Disentangle Large Whales

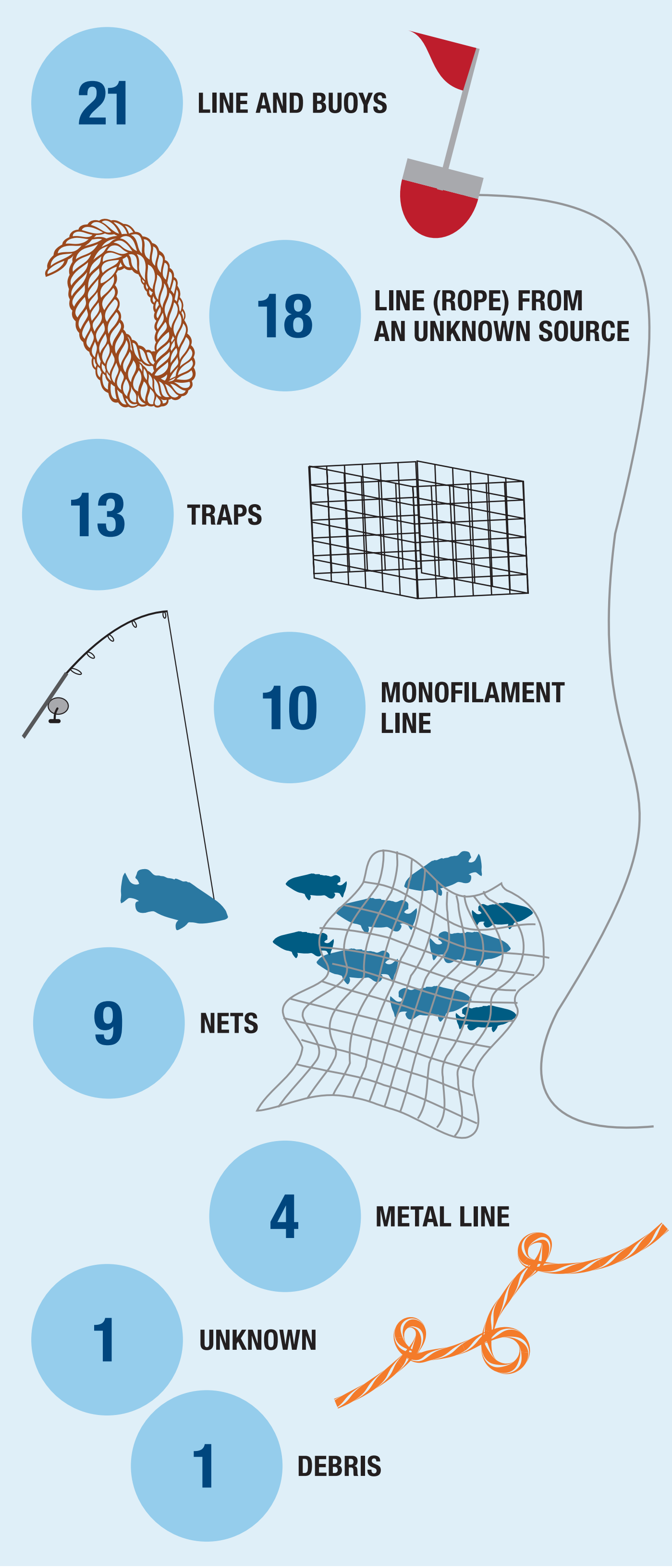
Of the 76 confirmed large whale entanglements in 2017, the Large Whale Entanglement Response Network was able to mount a response to 50 cases, and 25 animals (32.9%) were fully or partially disentangled (Table 2). Separately, one blue whale was disentangled by members of the public, and therefore did not require a network response.[1] While the network mobilized a response for an additional 24 live whales reported to the hotlines, those animals were not located by responders, and are presumed to still be entangled, have died, or have shed their gear.

1 Section 101(d) of the Marine Mammal Protection Act (MMPA) allows "Good Samaritans" to assist entangled marine mammals under special conditions. However, since the Endangered Species Act (ESA) does not have a comparable provision, the "Good Samaritan Exemption" does not apply to ESA-listed species of large whales. Thus, only professionally-trained responders authorized under MMPA/ESA Permit No. 18786-02 should attempt rescues of ESA-listed species. Due to human safety concerns, we further recommend that only professionally trained responders attempt whale disentanglements, even if legal under the MMPA.

Table 2: The outcomes of all confirmed 2017 entanglement cases.
Approximately half of network responses ended with the whale partially or fully disentangled.

Outcome	No Response	Response Initiated	Total
Full or Partially Disentangled	1	20	21
Self-Release	2	2	4
Presumed Alive/ Entangled	21	24	45
Dead	2	4	6
Total	26	50	76

Figure 3: The number and sources of confirmed entanglement cases in 2017.
The majority of entanglements were caused by fishing gear.



The National Large Whale Entanglement Response Network

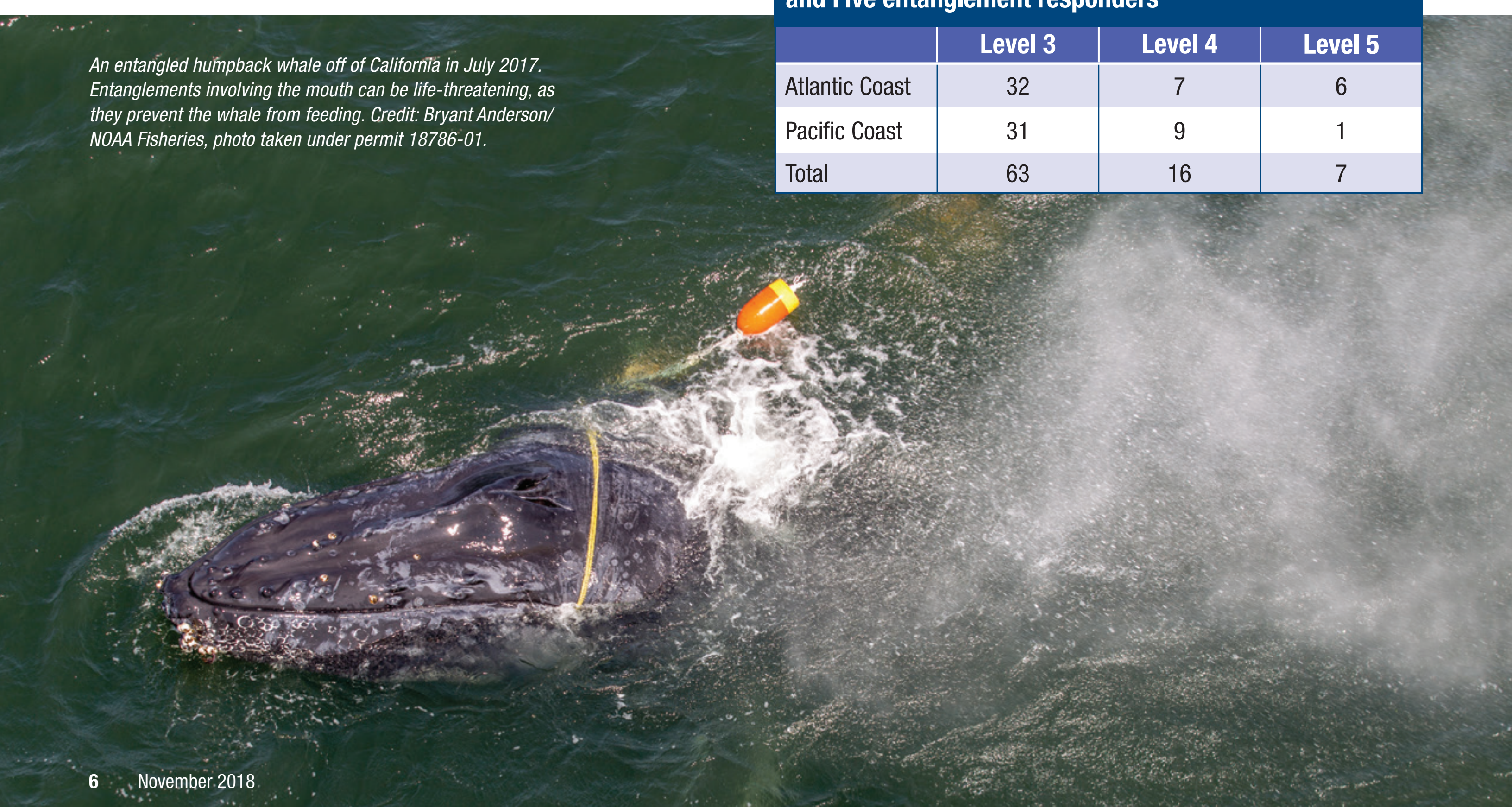
NOAA Fisheries coordinates the national Large Whale Entanglement Response Network, which is composed of four regional networks on the East Coast (from Maine to Texas) and West Coast (from Washington to California), and in Alaska and Hawaii. Network members represent a wide range of industry, non-profit, academic, and government organizations, and they are trained and authorized by NOAA Fisheries to conduct entanglement response activities. All large whale entanglement response operations on Endangered Species Act—listed species are conducted under the authority of the Marine Mammal Protection Act/Endangered Species Act Scientific Research and Enhancement Permit (No. 18786-02) issued to the Marine Mammal Health and Stranding Response Program, and the trained professional expert responders are listed as Co-Investigators under the permit. Responders are categorized into five levels, based on training and expertise:

- Level One and Two responders are trained to assess entangled large whales, and may be asked to assist in entanglement response activities by tracking and documenting the entanglement case from a distance.
- Level Three responders closely approach entangled whales for visual health assessments, and may attach tracking devices to the entangling gear so that the whale can be followed and quickly located.
- Level Four responders use tools to cut and remove the entangling gear. Level Four responders can perform these activities on all whale species except North Atlantic right whales, as this species is particularly dangerous to disentangle.
- Level Five responder duties are similar to Level Four, but may remove entangling gear from all species of whales, including North Atlantic right whales.

In general, Level One and Two responders are fishermen, boaters, and other members of the public who are trained to spot entangled whales and assess the situation. More than 100 individuals have completed the basic training to date. Responders at Level Three, Four, and Five are authorized under the MMPA/ESA permit to conduct entanglement response activities, including documenting the entanglement with photos and videos, attaching satellite tracking buoys, assessing the health of an entangled whale, and removing the entangling gear or debris. Nationwide, 86 people are authorized as Level Three, Four, and Five responders, and they are located across a wide geographic range (Figure 4).

Table 3: The total number of permitted Level Three, Four, and Five entanglement responders

	Level 3	Level 4	Level 5
Atlantic Coast	32	7	6
Pacific Coast	31	9	1
Total	63	16	7



An entangled humpback whale off of California in July 2017. Entanglements involving the mouth can be life-threatening, as they prevent the whale from feeding. Credit: Bryant Anderson/ NOAA Fisheries, photo taken under permit 18786-01.

Large whales are the largest animals on Earth, and disentangling them is inherently dangerous. NOAA supports the network by providing tools, training, and funding across the country to ensure that these activities are conducted in a manner that emphasizes human and animal safety. In 2017, NOAA conducted 47 training sessions, many of which were provided to current network members to help strengthen and increase their skills. Nine of these trainings were specifically provided to commercial fishermen and the public to help increase the capacity of the network by ensuring new Level One and Two responders are ready and available to assist as needed.

In 2017, the Large Whale Entanglement Response Network community suffered a great tragedy when a Canadian responder died during a rescue operation for an entangled North Atlantic right whale in the Gulf of St. Lawrence. The community is a close-knit group of international colleagues, and U.S. and Canadian responders train together and use the same protocols. NOAA temporarily suspended large whale entanglement response in the United States for several weeks while the circumstances surrounding the incident were investigated to determine whether additional precautions should be taken to prevent future accidents. NOAA Fisheries developed an online training course and required every U.S. entanglement responder to take it before operations resumed approximately 1 month after the tragedy. Twelve trainings were offered between July 18 and 27, and were made available to international colleagues. More than 90 people participated globally, including most of the U.S. Level Three and Four Responders, and all of the Level Five Responders.

Diagrams such as this one are often used by the Network to document cases and determine how best to remove entangling gear. Credit: Center for Coastal Studies

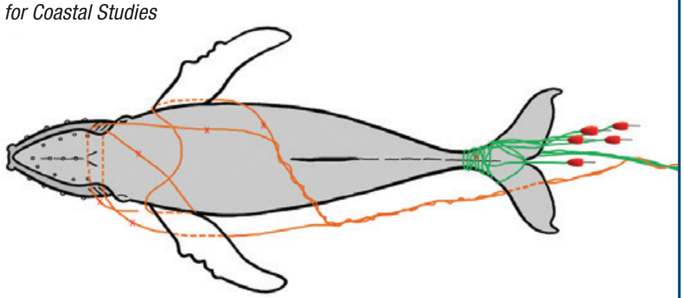
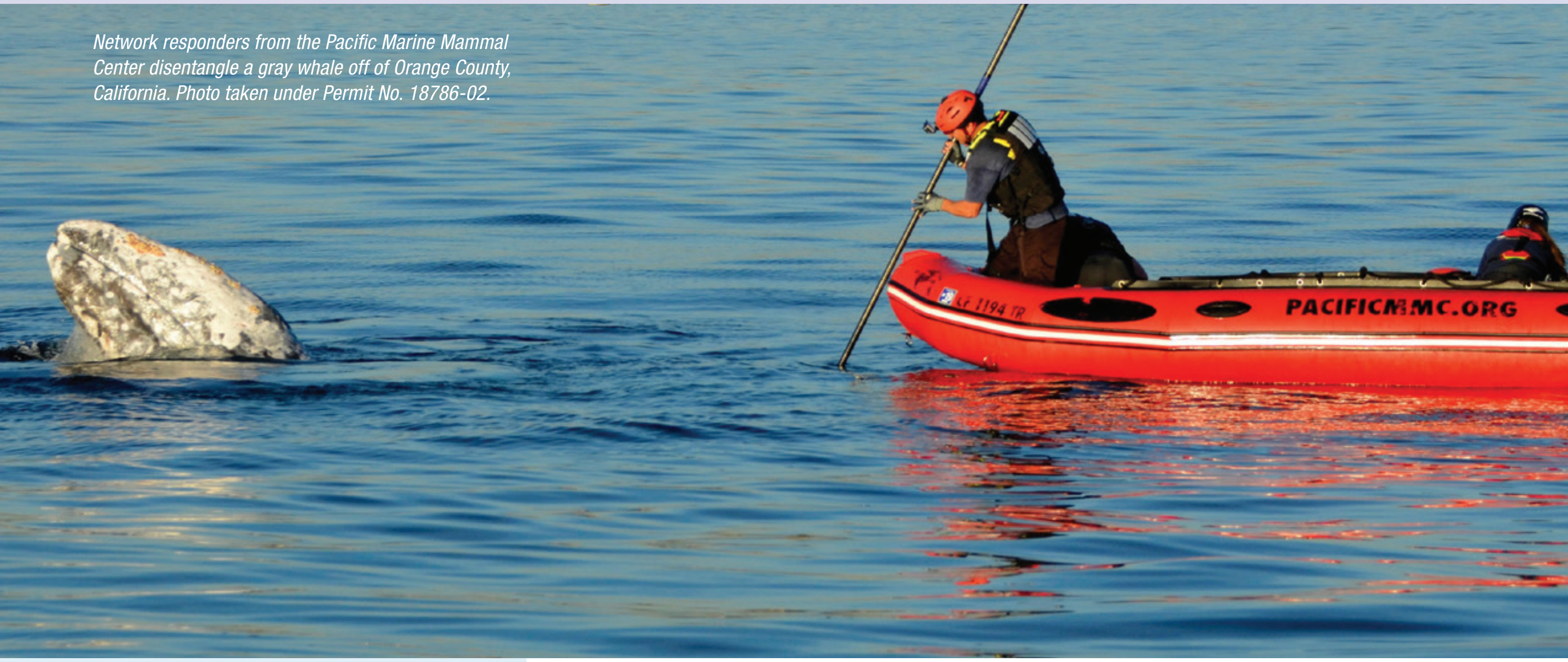


Figure 4: The locations of all Level Three, Four, and Five responders in the Large Whale Entanglement Response Network.

Note that multiple responders may be based at the same location, and often respond outside of their immediate area.



Network responders from the Pacific Marine Mammal Center disentangle a gray whale off of Orange County, California. Photo taken under Permit No. 18786-02.

When reporting an entangled whale, please include the following information:

1. **Location of the animal.**
2. **A detailed description of the entangling gear or debris.**
3. **Where the entanglement is located on the animal.**
4. **The direction and speed that the whale is moving, and if it is solitary or with other whales.**
5. **The behavior of the whale.**
6. **Species of the whale.**
7. **The approximate size and condition of the whale.**

What Members of the Public Can Do

The Large Whale Entanglement Response Network relies on reports of entangled whales from the public. If you encounter a whale that may be entangled, please contact your local network via the 24/7 regional hotline or contact the U.S. Coast Guard on VHF CH-16.

Regional Entanglement Hotlines	
Atlantic and Gulf Coasts	1-866-755-6622
California, Oregon, and Washington	1-877-SOS-WHALe (1-877-767-9425)
Alaska	1-877-925-7773
Hawaii	1-888-256-9840

Photos or videos of the whale (from a safe and legal distance of at least 100 yards) can also provide valuable information to entanglement responders. **Only trained and permitted responders should attempt to disentangle or closely approach an entangled large whale.** Whales are unpredictable and attempting to remove an entanglement is extremely dangerous to both you and the whale. Entanglement response should only be conducted by members of the Large Whale Entanglement Response Network who have been trained and authorized by NOAA Fisheries.

Marine Mammal Health and Stranding Response Program
Marine Mammal and Sea Turtle Conservation Division
Office of Protected Resources
www.fisheries.noaa.gov/marine-life-in-distress

frontiers in Marine Science

ORIGINAL RESEARCH
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Sea Turtle Bycatch Mitigation in U.S. Longline Fisheries

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Capture of sea turtles in longline fisheries has been implicated in population declines of loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) turtles. Since 2004, United States (U.S.) longline vessels targeting swordfish and tunas in the Pacific and regions in the Atlantic Ocean have operated under extensive fisheries regulations to reduce the capture and mortality of endangered and threatened sea turtles. We analyzed 20^{+} years of longline observer data from both ocean basins during periods before and after the regulations to assess the effectiveness of the regulations. Using generalized additive mixed models (GAMMs), we investigated relationships between the probability of expected turtle interactions and operational components such as fishing location, hook type, bait type, sea surface temperature, and use of light sticks. GAMMs identified a two to three-fold lower probability of expected capture of loggerhead and leatherback turtle bycatch in the Atlantic and Pacific when circle hooks are used (vs. J hook). Use of fish bait (vs. squid) was also found to significantly reduce the capture probability of loggerheads in both ocean basins, and for leatherbacks in the Atlantic only. Capture probabilities are lowest when using a combination of circle hook and fish bait. Influences of light sticks, hook depth, geographic location, and sea surface temperature are discussed specific to species and regions. Results confirmed that in two U.S.-managed longline fisheries, rates of sea turtle bycatch significantly declined after the regulations. In the Atlantic (all regions), rates declined by 40 and 61% for leatherback and loggerhead turtles, respectively, after the regulations. Within the NED area alone, where additional restrictions include a large circle hook (18/0) and limited use of squid bait, rates declined by 64 and 55% for leatherback and loggerhead turtles, respectively. Gains were even more pronounced for the Pacific shallow set fishery, where mean bycatch rates declined by 84 and 95%, for leatherback and loggerhead turtles, respectively, for the post-regulation period. Similar management approaches could be used within regional fisheries management organizations to reduce capture of sea turtles and to promote sustainable fisheries on a global scale.

Keywords: sea turtles, longline fishing, observer data, statistical models, bycatch reduction

INTRODUCTION

It is well-established that fisheries bycatch poses a significant threat to numerous sea turtle populations worldwide (Kaplan, 2005; Wallace et al., 2010, 2013). Pelagic longline fishing, a gear type present in all the world's oceans, is directly associated with high rates of bycatch and variable rates of mortality of sea turtles (Camiñas et al., 2006; Swimmer and Gilman, 2012). Sea turtle vulnerabilities to longline fishing gear are dependent on gear configuration as well as the species' geospatial, temporal, and vertical depth distributions (Wallace et al., 2013). Previous assessments of sea turtle bycatch in longline fisheries indicate significantly higher catch rates in fisheries setting gear at shallow depths (<60 m), typically targeting swordfish (*Xiphias gladius*), compared to most deep-set fishing targeting tuna (Lewison et al., 2004; Kaplan, 2005). Numerous investigations indicate a high percentage of turtles are released alive from shallow-set fishing gear (e.g., Swimmer et al., 2006, 2011, 2013; Piovano et al., 2009; Sales et al., 2010; Swimmer and Gilman, 2012), however a proportion of these turtles are assumed to subsequently die as a result of injuries, with likelihood of mortality a function of anatomical hooking location and degree of gear removal (see Ryder et al., 2006; Carruthers et al., 2009). Mitigating the effects of fisheries bycatch is a conservation priority worldwide, yet both research and managements actions are hindered by statistical challenges when analyzing rare and episodic events, as in common many examples of fisheries bycatch. Despite this, the magnitude of fisheries effort worldwide results in a cumulative negative effect on threatened populations, such as sea turtles, and therefore these challenges must be addressed for effective management.

Commercial longline fishing operations in United States (U.S.) Exclusive Economic Zone are regulated by the National Marine Fisheries Service, which aims to address the conservation needs of highly migratory populations of threatened and endangered marine species such as sea turtles while simultaneously managing domestic fisheries. U.S. fisheries must be in compliance with the Endangered Species Act (ESA) [as amended, 16 U.S.C. 1539(a) (2)] that requires federal agencies to ensure that any action they authorize (such as commercial fisheries), fund or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. The ESA, in addition to other statutes such as the Magnuson-Stevens Fisheries Conservation and Management Act and the Marine Mammal Protection Act, provide the regulatory regime for U.S. Federal fisheries.

In U.S. waters, pelagic longline fishing (PLL) involves the setting of a mainline to which baited hooks are attached by gangions (or branchlines), occurs in the Atlantic Ocean, Gulf of Mexico and Pacific Ocean. The fisheries in the Atlantic, Caribbean and Gulf of Mexico (herein "Atlantic data") are managed according to 11 distinct statistical areas (**Figure 1**). The sea turtle species most commonly captured as bycatch in both ocean basins are leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles (Witzel, 1999; Lewison et al., 2004; Gilman et al., 2007; Zollett, 2009), both of which are listed on the ESA as either endangered or threatened.

Starting in 2000, the Northeast Distant (NED) statistical area (8.9 million km^2) of the U.S. Atlantic PLL fishery, a highly productive area that includes the Grand Banks, was partially closed and then fully closed in 2001 in response to legal action aimed to reduce bycatch of endangered sea turtles (July 6, 2004, 69 *FR* 40734; U.S Dept. of Commerce, 2001; NMFS, 2004b). The NED portion of the Atlantic is primarily a swordfish-targeted fishery and was previously determined to have high rates of sea turtle bycatch (Witzel, 1999). Around the same time, in the U.S. North Pacific PLL fishery, the fishing grounds north of Hawaii (north of 28°N and between 150 and 168°W) were partially closed beginning in December 1999, and the entire longline swordfish fishery was closed in 2001 due to sea turtle bycatch. Beginning in April 2001, a spatial and seasonal closure off the U.S. North Pacific PLL fishing grounds south of 15°N during April-May was also implemented (NMFS, 2004a,b).

These temporary fisheries closures in both the Atlantic and Pacific Oceans lasted for ∼3 years. During this time, U.S. government-sponsored research was conducted in the NED that provided evidence that the use of a relatively large (18/0) circle hook in combination with ∼200–500 g Atlantic mackerel (*Scomber scombrus*) bait could significantly reduce bycatch rates of both loggerhead and leatherback sea turtles (Watson et al., 2005). Additionally, hook-and-bait combinations were also found to decrease the proportion of deeply ingested hooks in loggerhead turtles (Watson et al., 2005), thereby presumably increasing the rates of post-interaction survival. Based on these findings, both previously closed areas in the North Pacific and NED area of the Atlantic were re-opened with required use of circle hooks with minimum width dimensions equivalent to an 18/0 size hook (∼4.9 cm). In the Hawaii shallow-set-permitted fishery, bait type is limited to fish-only, whereas in the NED bait type allowances are made for use of squid bait in addition to fish bait. In both regions, additional regulations also included variations of limited entry and fishing effort, turtle bycatch limits, requirements for sea turtle education and outreach efforts, as well as increased on-board scientific observer coverage [NOAA, 50 *CFR* Part 660 (Pacific); NOAA 50 *CFR* Parts 223 and 635 (Atlantic)].

In this investigation, we used long-term fisheries observer data to assess the efficacy of regulatory measures on the probability of sea turtle bycatch in two U.S. pelagic longline fisheries. Specifically, we tested the null hypothesis that bycatch per unit effort (BPUE) was the same before and after regulations. Additionally, we used various statistical models to identify explanatory variables associated with the probability of sea turtle bycatch in both ocean basins, thereby providing further insight into the regulatory measures as well as new information on turtle species' vulnerabilities and responses to specific mitigation methods.

METHODS

Data Sources

Observer data for the analysis originated from the Pelagic Observer Program (POP) and the Longline Observer Data System for the Atlantic and North Pacific, respectively. POP data are maintained by the NMFS Southeast Fisheries Science

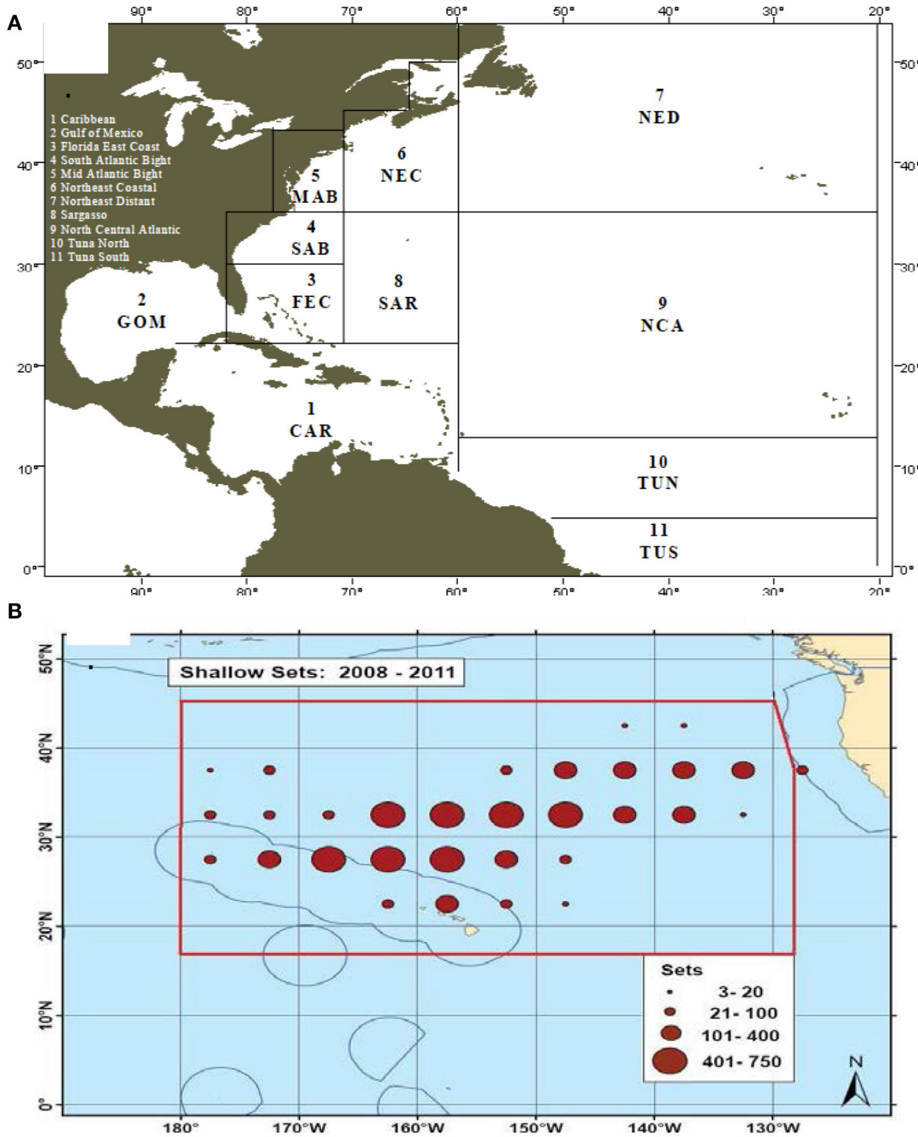

FIGURE 1 | United States **(A)**. Atlantic pelagic longline fisheries statistical reporting areas as recorded by NOAA NMFS Southeast Fisheries Science Center. CAR, Caribbean; GOM, Gulf of Mexico; FEC, Florida East Coast; MAB, Mid-Atlantic Bight; NCA, North Central Atlantic; NEC, Northeast Coastal; NED, Northeast Distant; SAB, South Atlantic Bight; SAR, Sargasso; TUN, Tuna North and TUS, Tuna South. **(B)** Location of shallow sets made by the Hawaii shallow-set longline fishery from 2008 to 2011 (source: NOAA Fisheries Pacific Islands Regional Office).

Center and have been previously described (Keene, 2016). For use in this study, POP data were limited to trips that targeted both swordfish and a mix of swordfish and tunas from 1992 to early 2015, which were analyzed jointly. These analyses omitted data from experimental operations when vessels used modified gear to test various outcomes (e.g., during the NED closure from 2001 to 2003). Pre-regulation data are defined as years 1992–2001, and post-regulation data start in mid 2004 after the fishery was re-opened. These data were combined and analyzed jointly. Observer coverage varied during this time, ranging between ∼3 and 5% of total fleet effort from 1992 to 2003 (Beerkircher et al., 2002) followed by a mandated minimum 8% coverage of the fleet beginning in 2004 (NMFS, 2004b).

The NMFS Pacific Islands Fisheries Regional Office maintains the Pacific observer data. Pacific data analysis was limited to the specified shallow-set (swordfish-target) sector of the fishery from 1994 to 2014. Pre-regulation data include data prior to February 2002, and the post-regulation period after May 2004. Between 1994 and 2000, observer coverage ranged from 3 to 10% (mean ∼5%) and increased to 20.5% in 2001. Observer coverage became mandatory (100% coverage) for all Hawaii-permitted pelagic longline vessels targeting swordfish since the fishery re-opened.

Data Caveats

General observer data characteristics and turtle bycatch specific to the different targeted sets from the Atlantic and Pacific Oceans are in **Table 1**. For both combined Atlantic and Pacific data, the number of observed sets analyzed is heavily skewed post-regulation vs. pre-regulation, which is a function of the mandated increased observer coverage when the fisheries were re-opened in 2004. For all data, nominal bycatch per unit effort (BPUE) was calculated as individual loggerhead and leatherback turtles caught for each unique set per 1,000 hooks. In certain situations, we collapsed categorical variables to achieve sufficient sample sizes and statistical rigor (see **Table 2**). Turtle size measurements are only available for loggerheads, as leatherback turtles were not boarded due to their size.

Analysis of sea surface temperature (SST) data obtained from both regions indicated a high degree of discrepancies when compared with satellite-derived data at a slightly broader scale and time span encompassing fishing location coordinates. This is largely due to the frequent collection of SST using unstandardized methods. Based on these findings, our statistical analyses included SST data derived from 5-day composites from AVHRR Pathfinder v4.1 (1985–2003). These SST data were continued by the AVHRR Global Area Coverage dataset (January 2003–April 2016) with a spatial resolution of $0.1^{\circ} \times 0.1^{\circ}$. Analyses included the weekly values when available, otherwise monthly data were used.

Analytical Methods

All analyses were conducted separately for the two regional data sets (Atlantic and Pacific) as well for each turtle species, leatherback, and loggerhead. On a few occasions, a subset of the Atlantic data, specifically the NED region, was analyzed separately given the enhanced regulatory requirements in this area (e.g., 18/0 circle hook). Turtle catch probability was uniquely referenced at the level of longline set, which refers to the individual mainline set (or haul) with baited hooks that remain soaking in the water for ∼8–12 h. Spatial statistics were used to generate spatio-temporal kernel density maps to visualize longline sets that captured one or more turtles. Finally, we used statistical models that incorporated a suite of variables that help explain and predict the probability of sea turtle bycatch on longline fishing vessels in the U.S. Atlantic and Pacific fleets.

TABLE 1 | General characteristics and sample sizes for observer data from the Pacific Hawaii-based shallow-set longline fishery, the Atlantic swordfish-set longline fishery, and Atlantic mixed-set longline fishery from ∼1992 to 2014.

General data characteristics	Pacific data (swordfish)	Atlantic data (swordfish)	Atlantic data (mixed-fishery)
Approximate time of initial set	Sunset	Sunset	Sunrise
Number of hooks between floats	Majority 4–5 (range: 3–21)	Majority 3–5 (range: 1–12)	Majority 4–5 (range: 2–10)
Mean number of light sticks per hook (all years)	0.57	0.92	0.38
Hook preferred pre-regulations	J 9	J 9	16/0
Hook regulations (type and minimum size)	Circle 18/0	Circle 16/0 or 18/0*	Circle 16/0
Bait preferred pre-regulations	Squid	Squid	Squid
Bait regulations	Fish only	Fish or squid**	Fish or squid
Sets with fish-only bait (all years)	13,713	890	262
Sets with squid-only bait (all years)	1,532	2,268	3,566
SEA TURTLES CAPTURED (ALL YEARS):			
Leatherback	105	415	429
Loggerhead	222	672	230

**In NED, hook must be 18/0.*
***In NED, squid bait is only allowable if using a non-offset hook.*

TABLE 2 | List of explanatory variables for Atlantic and Pacific observer data used in generalized additive mixed models.

Explanatory variable	Type	Description
Target species	Categorical	Atlantic data: mixed (swordfish and tuna) and swordfish. Hawaii: swordfish-target only.
Maximum hook depth	Continuous	Atlantic data: sum of lengths of floatline, branchline, dropline length. Does not account for mainline sag, sheer, or other factors. Hawaii: not consistently recorded.
Sea surface temperature (SST) °C	Continuous	Weekly SST were obtained from NOAA Pathfinder SST data by location (average of initial set and end of haul locations). When weekly was not available, monthly data were used.
Hook type	Categorical	Atlantic data: 9/0 J hook was predominant hook type pre-regulation, circle hooks (16/0 and 18/0) were used exclusively post-regulation. Pacific data: nearly 100% use of 9/0 J hooks pre-regulation and 100% use of circle hooks (18/0) post regulation.
Hook size	Categorical	Atlantic data: inclusive of circle hooks 16/0, 17/0, 18/0, 20/0, with sizes 16/0 and 18/0 represented in 66% of data. Very few 17/0 and 20/0. For analysis, data collapsed so that small circle hooks were sizes 16 and 17, large circle hooks were sizes 18 and 20. Small J hooks were sizes 7, 8, 9, and large J hooks were 10 &11. However, sample sizes in general were too small to make appropriate comparisons. Pacific data: nearly 100% use of size 9/0 J hooks prior to 2002 and 100% use of circle hooks size 18/0 after 2003.
Bait	Categorical	Atlantic data: Three categories-fish, mix of fish, and squid. Pacific data: Three categories—fish, squid, other (unknown). Mackerel is the most common fish species. Squid used nearly exclusively prior to regulations.
Soak duration	Continuous	From initial set time to end of set (haul).
Lightstick to hook ratio	Continuous	Ratio of total number of light sticks to number of hooks per set.
Number of hooks between floats	Continuous	Atlantic data: Mixed fishery range: 2–10 (majority 4 or 5 floats). Swordfish fishery range: 1–12 (nearly all between 3 and 5). Hawaii data: range: 3–21 (nearly all were 4 to 5).

Assessment of Regulations

In order to assess the efficacy of the conservation measures as a whole, we used non-parametric statistics (Mann-Whitney, due to lack of normality and homogeneity of the variances) to test the null hypothesis that sea turtle BPUE was similar before and after the regulations in mid 2004. Specifically, we compared BPUE for time periods before and after the regulations for leatherback and loggerhead turtles in the Atlantic and Pacific.

Identification of Spatio-Temporal Bycatch Patterns

Spatial kernel density maps were created for the locations of fishing effort and sets with turtle bycatch (>0) using the *"kde2d"* function in the *"MASS"* package in R (v.3.3.1).

Generalized Additive Mixed Models to Determine Probability of Turtle Bycatch

Longline observer data were analyzed to determine the probability of catching leatherback and loggerhead sea turtles using binomial GAMMs. We modeled the presence or absence of either sea turtle species within a single longline set. GAMMs are a non-linear regression technique in which the relationships between the dependent and the independent variables are modeled with non-parametric smooth functions and make allowances for complex relationships (Hastie and Tibshirani, 1990; Wood, 2006). A random intercept mixed models was used with individual vessel ID to account for repeated longline trips by individual vessels.

Species (leatherback, loggerhead) and region-specific (Atlantic, Pacific) full models were constructed that had the following generalized relationship (Equation 1). Specifically, given a dependent variable y and a set of x independent covariates, the relationship between them is established by:

$$y_{s,r} = \alpha + \alpha i + \sum_{j=1}^{m} g_i\left(x_{ij}\right) + \varepsilon_i \qquad (1)$$

The dependent term (y) in our models was binomial set data (0 = no turtle caught on a set; 1 = one or more turtles caught per set) and was modeled with a logit link function (Wood, 2006). α_i is the variance component around α associated with the vessel effect, g_i are one-dimensional cubic spline smoothing functions for each independent continuous covariates, x_{ij} were independent covariates that included distinct variable combinations dependent on region. Full species-specific models in both regions included independent covariates described in **Table 2** and **Table A1**. All models met the assumptions of constant variance and normal residuals.

Year as a variable was confounded with gear changes and thus omitted from the models. Maximum hook depth [sum of gangions (branchlines), droplines, and leaders] was only recorded by observers in the Atlantic and thus was not included in Pacific models. Additional predictor variables used in all full models included month, SST, bait type (categories: squid, fish, other), hook type (circle, J, other), light stick to hook ratio, soak duration of gear, and number of hooks between floats. Hook size, bait size, or hook offset were not analyzed due to limited sample sizes before and after regulations. A backward selection approach was used to identify the best model. We determined the best-fit models by minimizing the Akaike Information Criterion (AIC). Model selection **Appendix** and terms specific to turtle species and region are outlined in **Table 2**. All GAMM analyses were carried out using the "mgcv" package in R (v. 3.3.1).

RESULTS

Descriptive Summary of Atlantic Sea Turtle Bycatch Data

In total, Atlantic data in our analyses included 11,982 unique sets conducted on 1,762 trips from an approximately equal number of swordfish and mixed target trips. Throughout the 1992–2015 period, 844 leatherback and 902 loggerhead turtles were captured. Turtle bycatch per unit effort (BPUE; # individuals caught per 1,000 hooks, ±SD) rates in each of the statistical reporting areas within the Atlantic PLL fishery for all the years are reported (**Figure 2**), with clear distinction of the NED region, which had the highest turtle BPUE of any statistical reporting area within the Atlantic PLL fishery. BPUE tended to be higher for years prior to 2001. Bycatch rates are reported by year for all areas combined in **Figure 3**.

Ninety-four percent (94%) of all Atlantic sets showed zero leatherback turtles recorded. A single leatherback was caught on 611 sets, 2 or 3 were caught on 92 sets, and between 4 and 7 were caught on 6 sets. Ninety-five percent (95%) of sets showed zero loggerhead turtles recorded. A single loggerhead turtle was captured on 482 different sets, between 2 to 4 were caught on 87 sets, between 5 to 7 were caught on 12 sets, and between 9 to 12 were caught on 5 sets. Mean curved carapace length (CCL, cm) for loggerhead turtles brought on board was 73.3 cm (SD = 27.6).

Descriptive Summary of Pacific Sea Turtle Bycatch Data

Pacific observer records were from 15,472 sets from 460 unique trips during 1994–2014, which included observed capture of 105 leatherback and 222 loggerhead turtles (**Figure 4**). Ninety-nine percent (99%) of sets had zero leatherback turtles recorded. A single leatherback was caught on 103 sets and 2 were caught on 2 sets. Ninety-nine percent (99%) of sets had zero loggerhead turtles recorded. A single loggerhead was caught on 197 sets and 2 or 3 were caught on 25 sets. Mean CCL for all turtles brought on board was 62.8 cm (SD = 11.6), which is smaller than loggerheads measured in the Atlantic (CCL; mean = 73 cm, SD ± 27.8, **Figure 5**). Overall, the range of sizes for loggerhead turtles in the Atlantic was considerably broader than in the Pacific.

Frequency of Capture as a Function of Turtle Size and Sea Surface Temperature

In the Atlantic, the frequency of sets with bycatch in our study was highest within an approximate SST range between 22 to 26°C and 23 to 27°C for loggerheads and leatherbacks, respectively. In the Pacific, the peak range of SST with positive sea turtle

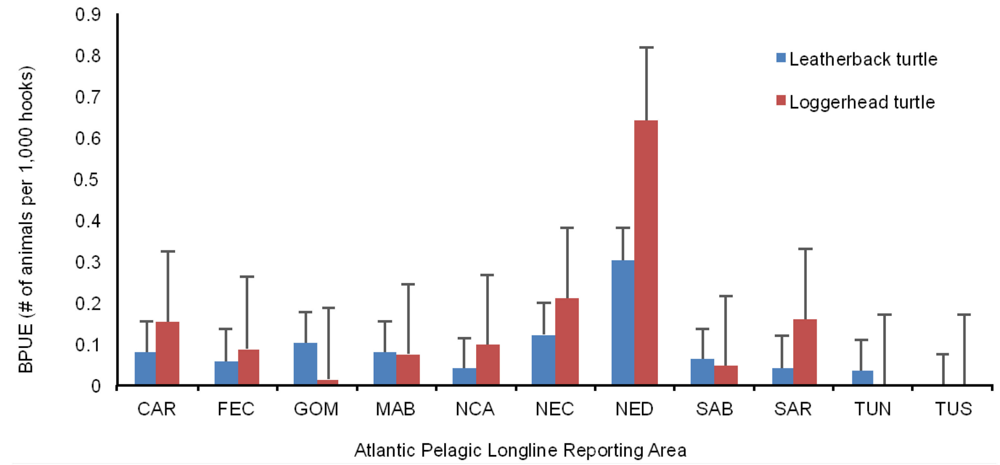

FIGURE 2 | Atlantic data. Mean turtle BPUE (# individuals caugh per 1,000 hooks ±SD) by statistical reporting area. CAR, Caribbean; GOM , Gulf of Mexico; FEC, Florida East Coast; MAB, Mid-Atlantic Bright; NCA , North Central Atlantic; NEC, Northeast Coastal; NED, Northeast Distant; SAB, South Atlantic Bight; SAR Sargasso; TUN, Tuna North and TUS, Tuna South.

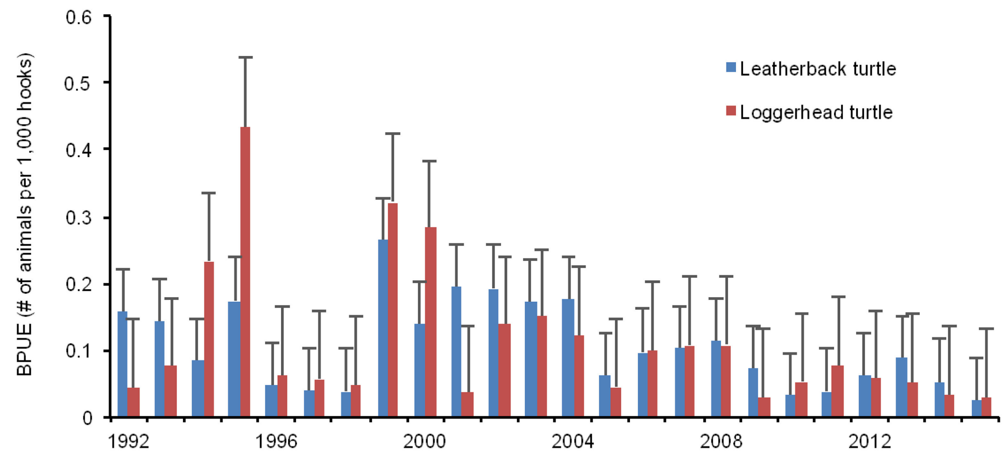

FIGURE 3 | Atlantic data Sea turtle bycatch per unit effort (BPUE, #individuals caught per 1,000 hooks, ±SD) by year.

captures occurred between 17 and 19°C for both loggerheads and leatherbacks (**Figure 5**).

Comparison of Bycatch before and after the Regulations

For Atlantic observer data inclusive of all reporting areas, bycatch rates of leatherback and loggerhead turtles were significantly lower during the post-regulation period, a reduction of 40 and 61%, respectively. Within the NED area alone, which had greater mitigation requirements than the rest of the Atlantic areas, turtle bycatch rates were further reduced during the post-regulation period, by 64 and 55% for leatherback and loggerhead turtles, respectively. For Pacific data, turtle bycatch rates were significantly lower during the post-regulation period, a reduction of 84 and 95% for leatherback and loggerhead turtles, respectively (**Table 3**).

Spatio-Temporal Sea Turtle Bycatch Patterns

Kernel density plots illustrate the distribution of observed longline sets with bycatch of at least one sea turtle by quarter for both the Atlantic and Pacific (**Figure 6**). Spatial and temporal patterns are fishery-dependent and largely driven by the distribution of fishing effort. In the Atlantic, longline sets that captured one or more turtles were most dense in southern latitudes during quarters 1 and 2 and shift northeast to the NED area in quarters 3 and 4. Sets with loggerhead turtle captures in the Gulf of Mexico (GOM) were most prevalent during quarter 2, whereas sets with leatherback turtles were most frequent in the GOM during quarters 1 and 2. Longline sets with leatherback turtles were most dense in the NED and coastal northern U.S. waters during quarters 3 and 4. Sets with loggerhead turtles in the Pacific observer data had less clear patterns, with the exception

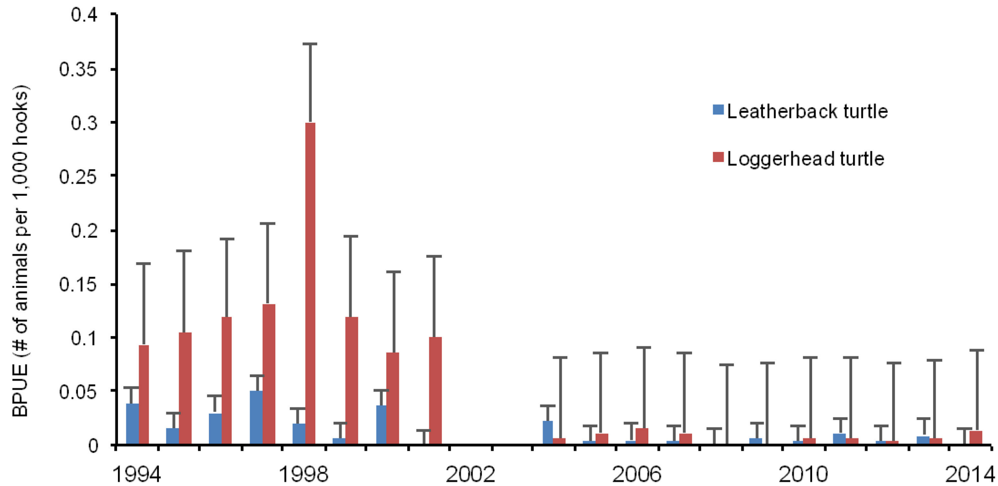

FIGURE 4 | Leatherback and loggerhead BPUE (# individuals caught per 1,000 hooks, ±SD) for Hawaii-permitted shallow set longline fishery by year.

of a high density of sets with loggerhead turtles in quarter 1 northeast of the main Hawaiian Islands. Similarly, sets with leatherback turtle interactions were most dense north of the main Hawaiian Islands during quarters 1 and 2, with density shifted further west during quarter 3.

Model Outputs and Relative Probabilities of Capture

The best-fit models with the final terms for each species and region are summarized in **Appendix**. Turtle bycatch probabilities as a function of significant terms in the model are shown in **Figure 7**. Model estimates of the individual variable effects on bycatch probability for all years of data collections are in **Table 4**. Both absolute and relative probabilities of bycatch for both leatherback and loggerhead turtles in the Atlantic and Pacific were determined using the rescaled GAMM model (**Table 5**). Since probabilities differed among the various statistical reporting areas of the Atlantic, we report on gear comparisons for the area of the NED given the enhanced regulatory requirements in this region and allowing for more valuable comparisons relative to sea turtle bycatch probability as a function of hooks and bait combinations. Bycatch probabilities are also reported for other statistical reporting areas in the rest of the Atlantic for circle hooks with fish bait (**Table 5**).

Probabilities of Turtle Capture

Loggerhead Bycatch in the Atlantic Ocean

The factors found to influence the capture of loggerhead turtles in the Atlantic are number of hooks between floats, ratio of light sticks to hooks, SST, bait type, hook type, and fishing area (**Figures 7A–G**; **Table 1A**). Probability of loggerhead bycatch is expected when the number of hooks between floats is 4 or 5, with light sticks attached at each hook, and when maximum estimated hook depth is ∼22 m or less. The GAMM identified an increased loggerhead catch probability with SST between ∼18 and 24°C. Plots of factors such as bait and hook type indicate loggerhead turtle bycatch probability is lowest when using only fish bait, and significantly increased when using squid bait. The use of J hooks results in significantly elevated bycatch probability as compared to circle hooks for the combined Atlantic statistical areas.

In regards to fishing location in the Atlantic, GAMMs identified the expected probability of catching a loggerhead is highest in the NED and NEC when using circle hooks and fish bait (**Table 5**). The expected probability of catching a loggerhead turtle on a set in the NED area using circle hooks and fish bait is 0.054 as compared to 0.111 if using circle hooks and squid bait, indicating a two-times (2.045) greater catch probability of a loggerhead using squid bait compared to fish bait. There is a reported 1.690 times greater catch probability of catching loggerhead turtles in the NED using J hooks with fish bait compared to using circle hooks with fish bait. In combination, there is a predicted 3.318 times greater catch probability of loggerhead turtles in the NED using the J hooks with squid bait as compared to circle hooks with fish bait (**Table 5**).

Leatherback Bycatch in the Atlantic

Based on the GAMM models, the expected probability of catching a leatherback turtle in the Atlantic Ocean is most influenced by month, number of hooks between floats, SST, bait type, hook type, and statistical reporting area (**Figures 7H–M**, **Table 5**). Bycatch probability is elevated during the months of October through December and within SST in the range of 18–24°C. Leatherback turtle bycatch probability is expected to be lowest when using only fish bait and circle hooks (measured separately) and significantly increases when using squid and J hooks (**Table 1A**). There is a significant elevated bycatch probability of leatherback turtles in the GOM, NEC, and NED regions of the Atlantic statistical reporting area. The probability of catching a leatherback turtle per set in the NED area of the Atlantic while using circle hooks and fish bait is 0.056 as compared to 0.089 if using circle hooks and squid bait, indicating

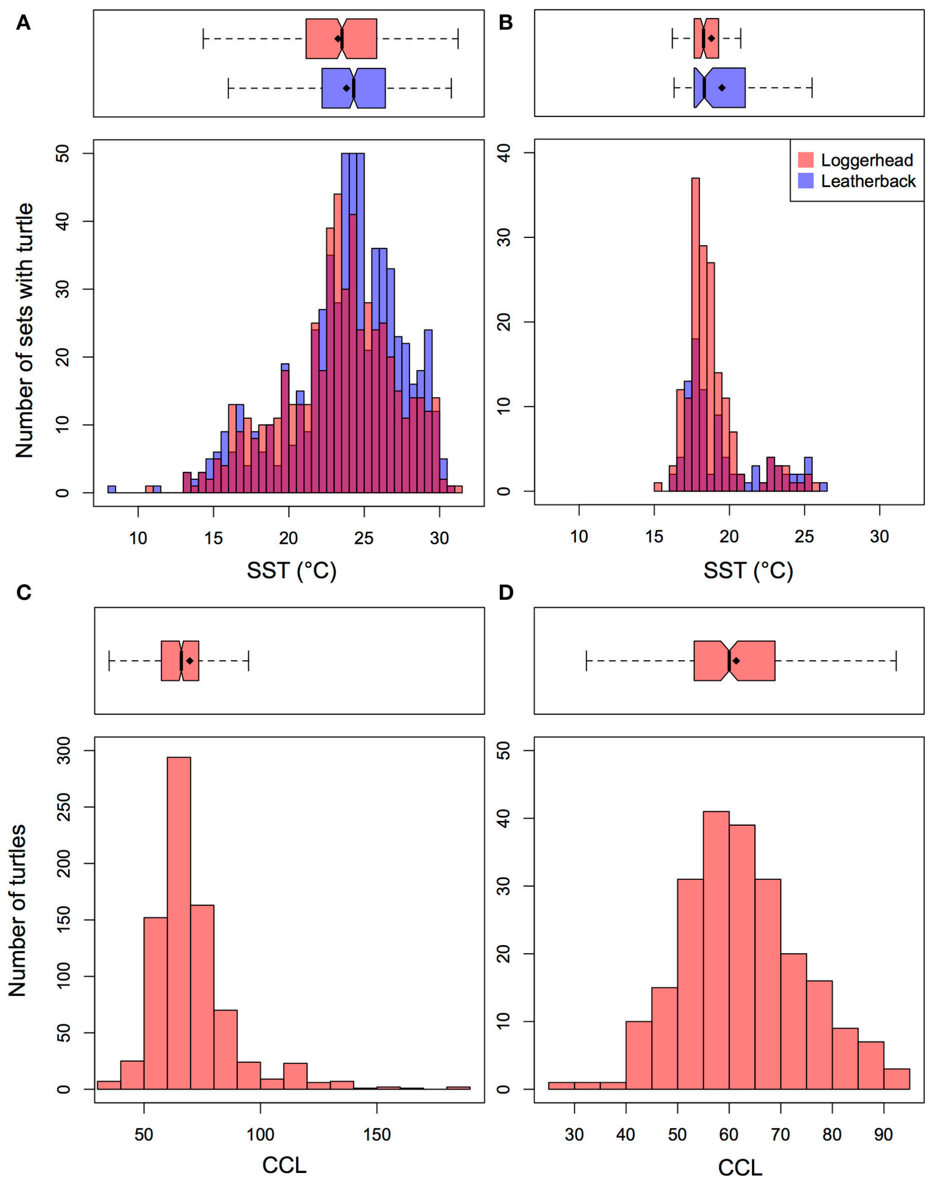

FIGURE 5 | Frequency of sets that caught loggerhead and leatherback turtles by set sea surface temperatures (SST) in the Atlantic **(A)** and Pacific **(B)**. Size frequency of loggerhead turtles captured in longline sets in the Atlantic **(C)** and Pacific **(D)**. Dots in paragraphs indicate mean and lines indicate median. Loggerhead turtle measurements in curved carapace length(CCL, cm).

a 1.589 times greater catch probability of leatherback turtles by using squid (vs. fish) bait. When bait is held constant, there is a 2.284 times greater catch probability of leatherback turtles in the NED using fish bait using J hooks as compared to using circle hooks. There is a 3.475 times greater catch probability of leatherback in the NED using the combination of J hooks with squid bait vs. circle hooks with fish bait (**Table 5**).

Loggerhead Bycatch in the Pacific (Hawaii Shallow Set Fishery)

The key variables influencing the probability of loggerhead bycatch in the Pacific include month, bait type, hook type and location (**Figures 8A–D**, **Table 4**). Loggerhead bycatch is expected to be highest during January and February and in two geographic locations (**Figure 8D**). Loggerhead turtle bycatch probability is lowest with use of fish bait (vs. squid or other) and circle hook (vs. J or other). GAMM results indicate the probability of loggerhead turtle catch in the Pacific is a predicted 2.890 times higher when using circle hooks with squid bait as compared to when using circle hooks with fish bait (0.018 vs. 0.006). There was a predicted 7.313 times greater catch probability of loggerheads using J hooks and fish bait as compared to circle hooks and fish bait. In combination, there is an expected 19.632 times greater catch probability when using the combination of J hooks with squid bait as compared to circle hooks with fish bait (**Table 5**).

Leatherback Bycatch in the Pacific (Hawaii Shallow Set Fishery)

Variables there were expected to influence the probability of leatherback turtle capture in the Pacific include month and hook type (**Figures 8E, F**, **Table 4**). GAMM results indicate a 3.72 times greater catch probability of leatherback turtles on J hooks vs. circle hooks (0.013 vs. 0.004; **Table 5**). Simultaneous gear changes due to regulatory measures limited additional comparisons.

TABLE 3 | Observer sampled nominal mean bycatch per unit effort (BPUE, per thousand hooks) before and after regulations by species by region.

Species	Pre-regulations BPUE (SD)	Post-regulations BPUE (SD)	% Change	Test statistic (Mann Whitney *U*)
ATLANTIC				
Loggerhead	0.17 (0.812)	0.07 (0.444)	−61	$P < 0.001$ (−6.565)
Leatherback	0.13 (0.569)	0.078 (0.378)	−40	$P = 0.002$ (−3.060)
NED				
Loggerhead	0.88 (1.905)	0.39 (1.569)	−55	$P < 0.001$ (−4.516)
Leatherback	0.44 (1.070)	0.16 (0.455)	−64	$P < 0.001$ (−3.866)
HAWAII				
Loggerhead	0.13 (0.468)	0.01 (0.088)	−95	$P < 0.001$ (−25.636)
Leatherback	0.03 (0.209)	0.01 (0.079)	−84	$P < 0.001$ (−8.120)

*NED identified in **Figure 1**.*

DISCUSSION

Value of Statistical Models for Bycatch Prediction

In this study, we used statistical models that allow for non-linear relationships (Hastie and Tibshirani, 1990; Guisan et al., 2002) and are thus highly suitable for modeling rare bycatch events, such as sea turtle bycatch in longline fisheries (McCracken, 2004; Coelho et al., 2013). Statistical models, such as GAMs and their extension the GAMMs, have been used extensively in marine fisheries research and management to forecast outcomes such as target species abundance, catch levels, etc. (Walsh and Kleiber, 2001). GAMs can also be used to identify species' associations with environmental variables, such as SST and depth, and therefore be valuable to predict the likelihood that a given species would inhabit or be captured in a particular environment (Forney et al., 2015). Using models to predict the probability of a relatively rare event, such as fisheries bycatch or ship strikes, is challenging due to a high proportion of zero captures resulting in a skewed distribution (Martin et al., 2015).

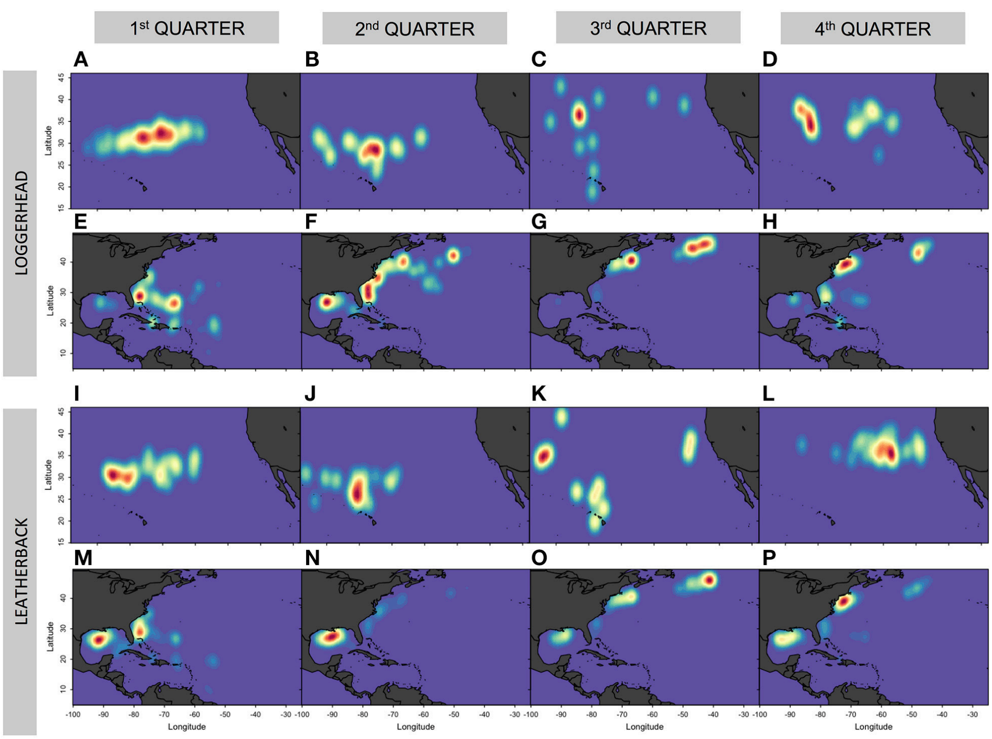

FIGURE 6 | Spatial kernel density plots of loggerhead (**top, upper figure**) and leatherback (**bottom, upper figure**) turtle captures by area and quarter from Atlantic observer data. Spatial kernel density plots of loggerhead (**top, lower figure**) and leatherback (**bottom, lower figure**) turtle captures by quarter from Hawaii observer data. Loggerhead turtle plots **(A–D)** are 1st through 4th quarter in Pacific and **(E–H)** are 1st through 4th quarter in the Atlantic. Leatherback turtle plots **(I–L)** are 1st through 4th quarter in in the Pacific and **(M–P)** are 1st through 4th quarter in the Atlantic.

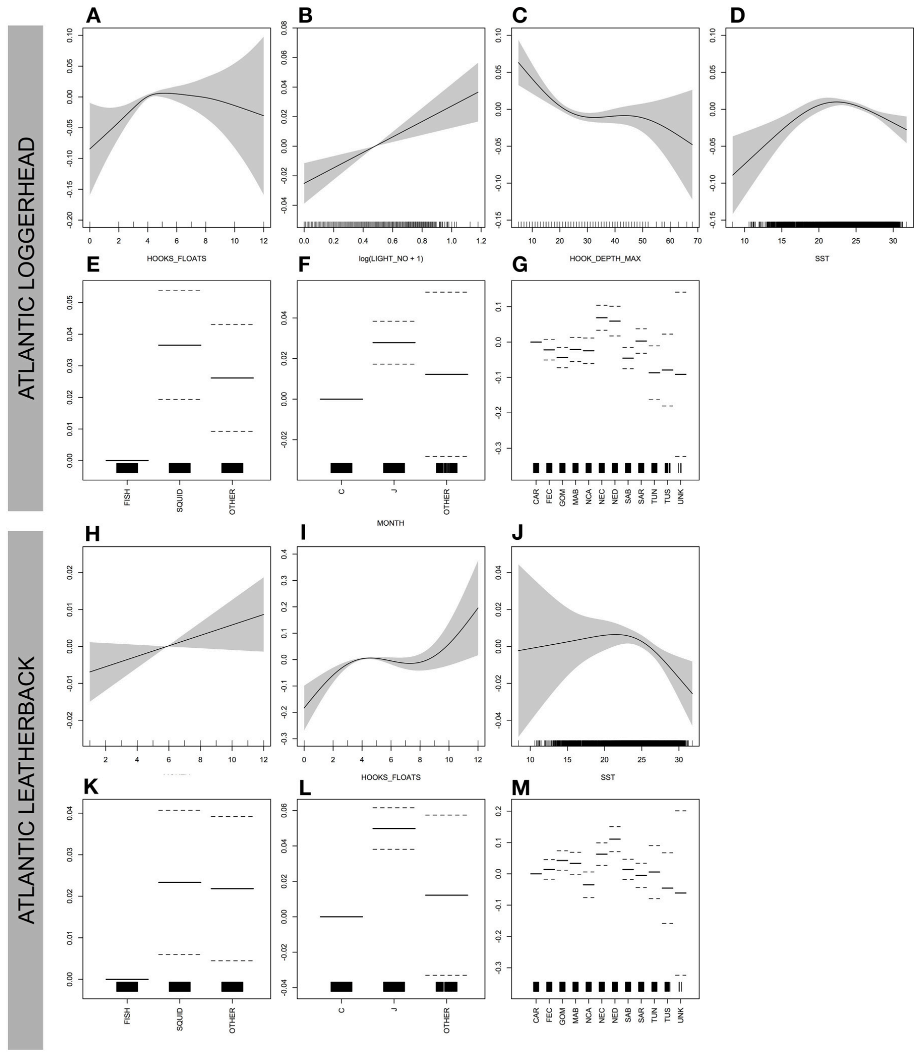

FIGURE 7 | Effect of gear characteristics and weekly averaged satellite derived sea surface temperature (wSST) on catch probability of loggerhead **(A–G)** and leatherbacks in the Atlantic Ocean **(H–M)**. The y-axis is in logit units and represents deviation from the logit mean. The smoothed probability of catch is scaled by its coefficient from the Generalized Additive Mixed Model (GAMM) model. The shaded area represents the upper and lower twice-standard-error curves. For factors (categorical variables), solid lines are the mean and the first factor is the reference group centered at zero, dashed lines represent upper and lower twice-standard errors. Positive (negative) values represent higher (lower) probability of catch from the mean capture probability. Vertical ticks on the x-axis indicate data distribution. For the Atlantic, the probability of loggerhead turtle capture is a function of **(A)** number of hooks between floats,**(B)** ratio of light sticks to hooks (log scale due to improve model fit), **(C)** maximum reported hook depth, **(D)** SST, **(E)** Bait type, **(F)** Hook Type, **(G)** Statistical Reporting, area. For the Atlantic, the probability of leatherback turtle capture is functional of **(H)** Month, **(I)** Number of hooks between floats, **(J)**, SST, **(K)** Bait Type, **(L)** Hook Type, **(M)** Statistical Reporting area.

In spite of the many challenges, recent modeling efforts have provided critical information with direct value to protected species management. Examples are numerous and across taxa, including seabirds (Majluf et al., 2002; Winter et al., 2011; Gilman et al., 2016a), marine mammals (Majluf et al., 2002; Orphanides, 2009; Redfern et al., 2013; Martin et al., 2015), sharks (Walsh and Kleiber, 2001; Minami et al., 2007), and sea turtles (Murray, 2009, 2011).

GAMMs in this study resulted in the highest explanatory power for the probability of bycatch of loggerhead turtles in the Pacific, with the least explanatory ability for leatherback bycatch in the Atlantic. In general, much of the expected bycatch probability for both turtle species was explained in time and space, which is largely a function of the fishery effort and the overlap between target species and sea turtle foraging habitats. Given the fishery-dependent nature of these data, there is no way to isolate the bycatch probability independent from the fishing effort, especially as it relates to space and time. However, these analysis incorporates additional characteristics of the operational components of the fishery including gear specifications such as hook and bait type and approximate hook depth that can provide insights on ways to decrease sea turtle bycatch probability within a specific region during normal fishing operations. As our primary goal was to understand the effects gear differences and spatio-temporal terms have on bycatch probability, we focused on these covariates in the models and their resultant statistical

TABLE 4 | GAMM selection parameters and outputs.

		Models (Species and region)			
		Loggerhead atlantic	**Leatherback atlantic**	**Loggerhead pacific**	**Leatherback pacific**
Parametric terms		**Estimate (sig.)**			
Intercept	**Category**	−3.6308 (***)	−4.47(***)	−5.39 (***)	−5.423 (***)
BAIT (reference: FISH)	SQUID	0.7773 (***)	0.508 (*)	1.074 (*)	(ns)
	OTHER	0.5277 (*)	0.522 (**)	1.01 (*)	(ns)
HOOK (reference: C-HOOK)	J-HOOK	0.5656 (***)	0.906 (***)	2.03 (***)	1.32 (***)
	OTHER	0.009	0.3088	1.21 (***)	0.8313
AREA (reference: CAR)	FEC	−0.5636 (*)	0.1348	–	–
	GOM	−1.6917 (***)	0.754 (*)	–	–
	MAB	−0.5037	0.692 (.)	–	–
	NCA	−0.3759	−0.952 (.)	–	–
	NEC	0.5045	1.045 (**)	–	–
	NED	0.6031	1.481 (***)	–	–
	SAB	−1.1756 (***)	0.1221	–	–
	SAR	−0.2415	−0.2018	–	–
	TUN	−13.5392	−0.0907	—	–
	TUS	−12.7777	−13.0401	–	–
	UNK	−13.7820	−12.1695	–	–
Smooth terms		**EDF (sig.)**			
LAT, LON		–	–	2.91 (***)	(ns)
MONTH		(ns)	1 (.)	1 (***)	1 (***)
SST		2.53 (***)	2.017 (*)	(ns)	(ns)
LIGHTSTICK TO HOOK RATIO		1 (***)	(ns)	(ns)	(ns)
HOOK DEPTH MAX		2.01 (**)	(ns)	–	–
HOOKS PER FLOAT		2.36 (.)	2.334 (*)	(ns)	(ns)
SOAK DURATION		(ns)	(ns)	(ns)	(ns)
Adj. R-sq		5.92%	1.97%	6.15%	0.81%

*Statistical significance (p-values): 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1; EDF, Estimated degrees of freedom.*

estimates and significance. Despite the potential importance to turtles' presence in a given location, habitat variables, such as fronts, eddies, and primary productivity, were not included in modeling efforts. We acknowledge, that inclusion of these variables might have improved model fit (adjusted R^2) by explaining the oceanographic context surrounding each longline set.

Interpretation of Findings

Spatial Distribution and SST

Using all Atlantic data, we modeled the probability of turtle bycatch as a function of location (statistical reporting areas) and identified an elevated bycatch risk in the NED and NEC for loggerhead turtles and in the NED for leatherbacks. This finding was expected as the NED is primarily a swordfish-targeting region where hooks are set shallow at night with a high light stick-to-hook ratio that results in a combination of variables associated with an increased probability of catching primarily loggerhead turtles according to our models.

Similar to previous studies, our results identified the influential role of SST regarding the probability of catching loggerhead and leatherback turtles in both the Atlantic and Pacific oceans. In general, there is a broader range of temperatures recorded in the Atlantic (∼10–30°C) vs. Pacific data (∼16–26°C), due to the fact that US fleets operate over a wider latitudinal range in the Atlantic than the Pacific. The frequency of sets with sea turtle bycatch in the Atlantic was highest within approximate SST ranges between 22°C to 26°C and 23°C to 27°C for loggerheads and leatherbacks, respectively. These ranges are nearly identical to those previously reported (Watson et al., 2005; Brazner and McMillan, 2008; Foster et al., 2012; Huang, 2015). The range of SST with positive sea turtle captures was more protracted in the Pacific, with the frequency of sets with sea turtle bycatch highest when SST ranged between ∼17 and 19°C for both loggerheads and leatherbacks. These ranges overlap entirely with the species' at-capture peak SST ranges previously reported in the North Pacific (Howell et al., 2008, 2015; Kobayashi et al., 2008; Abecassis et al., 2013).

TABLE 5 | Capture probabilities of leatherback and loggerhead sea turtles from GAMM models and associated absolute and relative increases in the Atlantic or Pacific Oceans by longline sets for combinations of hook type, bait, and area.

Ocean basin	Area (Atlantic only)	Turtle species	Hook type	Bait type	Capture interaction probability per set	Within hook type comparison (x increase in relative terms)	Between hook type comparison (x increase in relative terms)
Atlantic	FEC	Loggerhead	Circle	Fish	0.018		
Atlantic	FEC	Leatherback	Circle	Fish	0.015		
Atlantic	GOM	Loggerhead	Circle	Fish	0.006		
Atlantic	GOM	Leatherback	Circle	Fish	0.029		
Atlantic	MAB	Loggerhead	Circle	Fish	0.019		
Atlantic	MAB	Leatherback	Circle	Fish	0.026		
Atlantic	NCA	Loggerhead	Circle	Fish	0.021		
Atlantic	NCA	Leatherback	Circle	Fish	0.005		
Atlantic	NEC	Loggerhead	Circle	Fish	0.050		
Atlantic	NEC	Leatherback	Circle	Fish	0.037		
Atlantic	NED	Loggerhead	Circle	Fish	0.054	0.000	0.000
Atlantic	NED	Loggerhead	Circle	Squid	0.111	2.045	2.045
Atlantic	NED	Loggerhead	J	Fish	0.092	0.000	1.690
Atlantic	NED	Loggerhead	J	Squid	0.181	1.963	3.318
Atlantic	NED	Leatherback	Circle	Fish	0.056	0.000	0.000
Atlantic	NED	Leatherback	Circle	Squid	0.089	1.589	1.589
Atlantic	NED	Leatherback	J	Fish	0.128	0.000	2.284
Atlantic	NED	Leatherback	J	Squid	0.195	1.521	3.475
Atlantic	NED	Leatherback	Circle	Fish	0.010		
Atlantic	SAB	Loggerhead	Circle	Fish	0.009		
Atlantic	SAB	Leatherback	Circle	Fish	0.015		
Atlantic	SAR	Loggerhead	Circle	Fish	0.024		
Atlantic	SAR	Leatherback	Circle	Fish	0.011		
Atlantic	TUN	Loggerhead	Circle	Fish	0.000		
Atlantic	TUN	Leatherback	Circle	Fish	0.012		
Atlantic	TUS	Loggerhead	Circle	Fish	0.000		
Atlantic	TUS	Leatherback	Circle	Fish	0.000		
Pacific		Loggerhead	Circle	Fish	0.006	0.000	0.000
Pacific		Loggerhead	Circle	Squid	0.018	2.890	2.890
Pacific		Loggerhead	J	Fish	0.047	0.000	7.313
Pacific		Loggerhead	J	Squid	0.125	2.685	19.632
Pacific		Leatherback	Circle		0.004		0.000
Pacific		Leatherback	J		0.013		3.720

"Within hook type comparison" results represent the percent increase for squid or "other" category baits relative to fish bait within each hook type category (Circle, J, or Other). "Between hook type comparison" results represent the percent increase for sets using J hooks or "other" category hooks with squid or "other" category baits relative to capture probabilities on circle hooks used with fish bait only.

SST has been previously identified as a strong predictor of sea turtle movements (Kobayashi et al., 2008; Mansfield et al., 2009), and thus SST can serve a valuable role as a means to reduce sea turtle bycatch. For pelagic longline fisheries operating in the north Atlantic, Brazner and McMillan (2008) investigated the frequency of loggerhead turtle capture as a function of SST and suggested limiting fishing activity in SST $>20°C$ to minimize loggerhead bycatch. In the North Pacific, Howell et al. (2008, 2015) used extensive satellite tracking data to identify oceanographic features such as SST that could be used to predict the presence of loggerhead and leatherback turtles with the ultimate goal to develop a means to reduce sea turtle captures in longline fisheries. The result is an internet-based product, NOAA TurtleWatch (www.pifsc.noaa.gov/eod/turtlewatch.php), that serves to provide information on preferred sea turtle habitat, specifically SST, that can be used by managers and fishers to make dynamic decisions to reduce the incidental capture of loggerhead and leatherback turtles during longline fishing operations (Howell et al., 2008, 2015). This is particularly valuable in the shallow-set sector of the Hawaii fishery that operates under sea turtle bycatch limits, whereby the fishery is mandated to immediately cease fishing operations until the remainder of the calendar year once a certain number of turtle interactions by species occurs. Howell et al. (2015) proposed a dynamic management concept based upon a SST habitat boundary, whereby fishing effort should be avoided in the

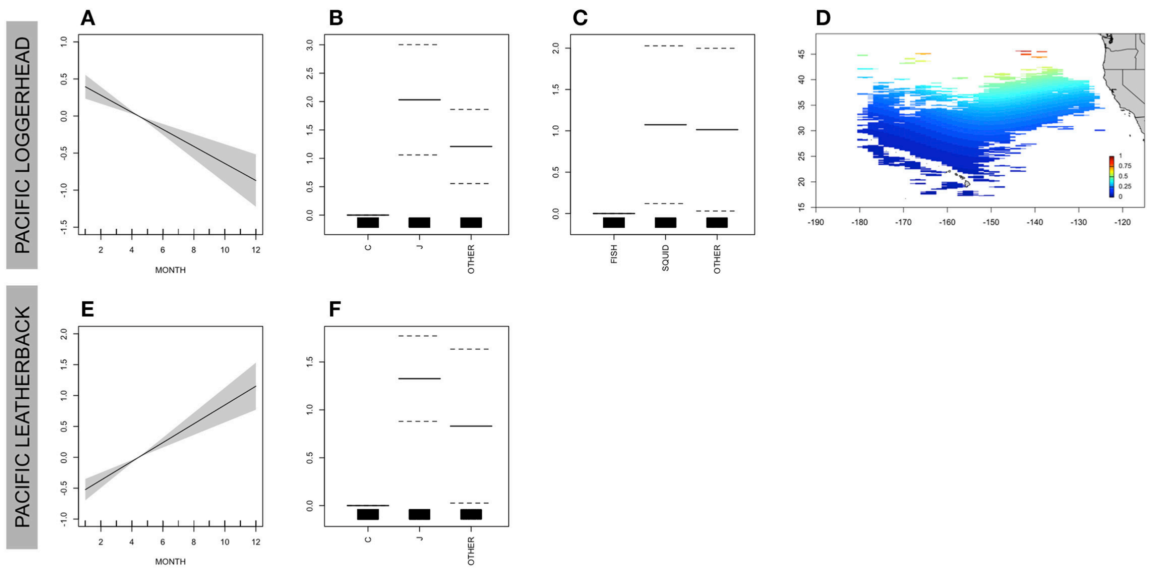

FIGURE 8 | Effect of gear characteristicsand location on the probability of catch of loggerheads **(A–D)** and leatherbacks **(E,F)** in the Pacific. The *y*-axis is in logit units and represents deviation from the logit mean. The smoothed probability of capture is scaled by its coefficient from the Generalized Additive Mixed Model (GAMM) model. The shaded area represents the upper and lower twice-standard-error curves. For factors, solid lines are the mean and the first factor is the reference group centered at zero, dashed lines represent upper and lower twice-standard errors. Positive (negative) values represent higher (lower) probability of catch from the mean capture probability. Vertical ticks on the x-axis indicate data distribution. For the Pacific, the probability of loggerhead turtle capture is a function of **(A)** Month, **(B)** Hook Type, **(C)** Bait Type, **(D)** Location (scaled between 0 and 1 catch probability). For the Pacific, the probability of leatherback turtle capture is a function of **(E)** Month, and **(F)** Hook Type.

SST range of 17.0–18.5°C to minimize interactions with both loggerheads and leatherbacks. In calculating the potential impact of this restriction on the Pacific observer data presented herein, the observed number of turtles captured would have been reduced by 94 (42%) loggerhead turtles and 46 (44%) leatherback turtles.

The Role of Bait in Bycatch

Our findings on the significance of bait type influencing the probability of capturing sea turtles are consistent with other experiments conducted in the Atlantic, whereby it was determined that the largest reduction in (primarily leatherback) turtle bycatch was achieved with use of fish bait, specifically mackerel (Watson et al., 2005; Santos et al., 2012). Based on results of numerous investigations, there is general consensus that replacing squid bait with fish bait will reduce sea turtle bycatch. However, regulations requiring use of fish bait to reduce sea turtle bycatch must be balanced against the potential target species catch loss, a concern that has been previously evaluated (Watson et al., 2005; Yokota et al., 2009; Curran and Bigelow, 2011; Coelho et al., 2012). Further, bait choice can also potentially increase bycatch of certain sharks or other vulnerable species (Foster et al., 2012; Santos et al., 2012; Gilman et al., 2016b). As with other bycatch reduction techniques, success in adopting these measures may be fishery dependent. Among the factors that need to be evaluated include the target species, bait, hook type, and intended hook depth, the species and life-stage of bycaught turtles, fishing area (which is co-related with SST) and season, and other bycatch species potentially affected. In the U.S. Atlantic longline fishery, NED fishers have the choice to use fish or squid bait, yet if they use squid it must be accompanied by a circle hook (18/0) with no offset. It is clear that mandated use of fish bait in all areas would lead to further reductions in sea turtle bycatch.

Ratio of Light-Sticks to Hooks

Unlike leatherback turtles that are primarily externally hooked in the armpit, shoulder or flipper, loggerhead turtles are primarily captured as a result of actively biting and/or swallowing a baited hook (Watson et al., 2005). Based on these observations, Watson et al. (2005) proposed the potential attraction to light sticks, or phototaxis, as an explanation of loggerhead turtle bycatch rates in longline gear. Despite the interest to investigate the role of lights in sea turtle bycatch, such analysis was not possible in the previous NED experiments given that this variable remained constant throughout the time-series. In this study, with data from both swordfish-target and mixed-target sets, variation existed in operational factors such as ratio of lightsticks deployed per hook, whereby lights are generally placed near each hook on swordfish-style sets and likely every other hook in a mixed target set. This overlap allowed for further exploration on the role of lightstick use on the probability of turtle capture. This study identified a positive linear relationship regarding loggerhead turtle bycatch probability and lightstick use. Based on earlier speculations of the role of lightsticks in attracting sea turtles to longline fishing gear, Wang et al. (2007) conducted behavioral experiments with captive loggerhead turtles using an orientation arena to conclude that lightsticks of varying wavelengths significantly attract turtles. These results from the GAMMs, in combination with the laboratory studies (Wang et al., 2007), provide evidence that loggerhead turtles are drawn to the vicinity of longline gear (baited hooks) with increased illumination. Additional bycatch reduction may be gained for loggerhead turtles by reducing or eliminating the use of lightsticks in longline gear.

Hook Type

In all models there was a significant lower probability of bycatch with circle hooks compared to J hooks. The finding of reduced probability of sea turtle bycatch on circle hooks is consistent with a number of different studies and has been thoroughly discussed (Watson et al., 2005; Yokota et al., 2009; Curran and Bigelow, 2011; Santos et al., 2012; Serafy et al., 2012).

Hook Depth

Estimates of theoretical hook depths can be inferred using information on gear characteristics, such as the length of the longline, number of hooks between floats and catenary geometry; however the actual hook depths may be shallower due to shoaling by environmental factors (Bigelow et al., 2006). In this study, two variables serve as a proxy for hook depth: maximum hook depth (sum of the lengths of the gangion, float line, and leader), and number of hooks between floats. The maximum hook depth was reported only in the Atlantic data and does not account for any shoaling, hence the actual hook depth is likely to differ. However, the term was significantly linked to the probability of capturing loggerhead turtles, which is greatly increased when the hook depth is within the top ∼25 m of the sea surface. Additionally, the GAMM indicated an increased probability of capturing a loggerhead when there were 3–5 hooks between floats (**Figure 7A**), indicating a relatively shallow-set longline. These data also indicate a reduced capture risk in sets with fewer than 3 hooks between floats, yet this is likely biased by the relatively few sets in this category (<3% of all sets). The result of an increased bycatch probability for leatherback turtles at greater depth than loggerheads has been previously reported (Watson et al., 2005; Gilman et al., 2006).

The captures of loggerhead turtles in shallow-set gear is consistent with previous studies in the same region (Watson et al., 2005; Brazner and McMillan, 2008; Foster et al., 2012) and can partially explain why rates of turtle bycatch in deep-set longline fishing are an order of magnitude lower than on shallow-set gear (Gilman et al., 2006; Beverly et al., 2009). Elimination of shallow hooks as a means to reduce sea turtle bycatch has been proposed (Polovina et al., 2003; Beverly and Robinson, 2004) and tested. Initial experiments in a deep-set fishery indicated that the method may not be cost-effective due to the reduced catches of economically important epi-pelagic species, such as wahoo (*Acanthocybium solandri*) and the decreased fishing efficiency (Beverly et al., 2009). However, there are ways to set additional weighted lines and to modify fishing vessel speed that can effectively reduce shallow hooks in a deep-set fishery (see Beverly and Robinson, 2004; Gilman et al., 2006). Additional experimentation with modified fishing gear techniques could aid in the identification of fishing methods that optimize the catch of target species while minimizing bycatch. In addition to the effects of other potential gear changes, such as expanded use of circle hooks, more information is required about potential impacts on other species, including other listed species (e.g., sharks, rays) as well as target species (e.g., tuna, swordfish, secondary retained species). The potential economic loss balanced against conservation gains of eliminating shallow hooks is fishery-specific and must be evaluated as such (Beverly et al., 2009; Watson and Bigelow, 2014).

Four Limitations to Analysis

Limitations to Observer Data

The value of observer data is greatly enhanced when efforts are taken to ensure that observations are drawn from a truly representative sample of the fishery at large, both in time and space. In the Atlantic, where observer coverage ranged from 3% to a maximum of 8% of the total fleet effort, the ability to accurately assess the probability of a rare event is limited. This is further hindered by the fact that the 11 statistical reporting areas within the Atlantic are highly heterogeneous, with geographic ranges from the relatively warm waters of the Gulf of Mexico to near frigid waters of the Georges Banks in the North Atlantic. For this and other reasons, annual estimates of both marine mammal and sea turtle bycatch in the U.S. Atlantic pelagic longline fleet are determined specific to each reporting area (Garrison and Stokes, 2014). Additionally, disproportionate sampling in time and space further limits the utility of these data. As a specific example, the potential "hotspot" observed for leatherback turtles captured in the Gulf of Mexico may simply be an artifact of the shift of fisheries observers placed on vessels in this area to ensure adequate coverage after regulations concerning bluefin tuna (*Thunnus thynnus*) quotas. In the near future, we aim to conduct additional analyses specific to individual regions in order to better interpret the bycatch "hotspot" maps given the biases of disproportionate sampling efforts.

Assumptions of Independence of Fishing Sets

Our analyses relies upon an assumption that sets are independent despite the concern that they may not be due to their temporal-spatial similarity to other sets within a single trip (see McCracken, 2004). However, numerous investigations, including Murray (2011) posed that factors affecting estimated bycatch rates were similar between set (haul) and trip and have thus justified its use as the sampling unit.

Changes in Sea Turtle Populations

Our analyses presume that population trends of the bycaught turtles are essentially stable. There are numerous reasons for this decision, including the lack of accurate information regarding the nesting beach origin of the bycaught turtles, which may vary by season of capture; the population trends of each of these nesting populations, as well as the lag time to account for the time between nesting and when they are caught. Therefore, given an inability to calculate population-specific annual trends during this 20+ year period with a high degree of certainty, each model assumes stable trends. A consequence of this limitation is a potential misinterpretation of findings whereby reduced BPUE of turtles post-regulations are erroneously attributed to the effectiveness of mitigation measures when in reality the change is due to a decline in population trends.

An alternative explanation of our findings is that turtle populations are declining, which is certainly the case for leatherback turtles in the Pacific (Tapilatu et al., 2013). The reduced leatherback bycatch rate in the Pacific may reflect population declines. In the Atlantic, however, it has been proposed that adult female (nesting) populations of loggerhead and leatherback turtles are increasing (Ehrhart et al., 2014; Stewart et al., 2016), in which case one might conclude that the fishing restrictions were even more effective than expected. A challenge for future studies will be to incorporate population assessments and life history parameters into ecological models to isolate potential effects of population changes with respect to fisheries effort and sea turtle bycatch rates.

Other Regulatory Changes

Pacific data have unique challenges given the simultaneous nature of regulatory requirements and gear changes in the Hawaii shallow-set fishery that confound data and limit some analysis. The 2004 regulations created an immediate change in use of both bait and hook type, making no allowances for an overlap of different combinations (such as circle hooks with squid bait), rendering it difficult to separate the explanatory effects of bait and hook type. Differences between hook and bait types could only be observed prior to the regulation, yet during this time circle hooks were never used. In this type of scenario, the degree of interrelatedness among hook type, bait type, and year is sufficiently high as to essentially be represented by a single variable. Similarly, location is confounded with SST and thus only location was selected for modeling purposes. Our modeling confirmed these correlations, as regulation, bait, and hook variables all performed similarly as predictors of sea turtle bycatch.

In the Atlantic, the U.S. has multiple regulatory regimes regarding the management of highly migratory fish stocks of tunas, swordfish, billfish, and sharks that may have also influenced fishing effort and observer coverage reported herein. Specifically, year-round closures in the De Soto Canyon of the Gulf of Mexico and the Florida East Coast, as well as seasonal closures in the Charleston Bump and in the Mid-Atlantic (Figure 4.4, NMFS, 2015). Additional regulations involving individual fishing quotas for bluefin tuna and the requirement of weak hooks in the Gulf of Mexico for bluefin tuna bycatch reduction have also been modified during the time period of this analysis (Jan 13, 2011, FR 76, 9). While not intended specifically to protect sea turtles in this region, these closures, as well as changes in gear regulations, may also have affected rates of sea turtle bycatch in Atlantic longline fisheries.

Ecosystem Level Impacts of Findings

This analysis focused on sea turtle bycatch before and after circle hook requirements in the United States. However, there are many other non-target species, such as seabirds, marine mammals, and sharks bycaught in pelagic longline fisheries. Several studies and symposiums have evaluated the effectiveness of circle hooks across and found that reductions are not necessarily achieved for all non-target bycatch species taxa (Kerstetter and Graves, 2006; Serafy et al., 2012; Huang, 2015). In some cases, circle hooks may increase bycatch of sharks (see Gilman et al., 2016b). There is a clear need for further investigation of cross-taxa bycatch solutions in pelagic longline fisheries. Additional research should include evaluating the use of multiple mitigation techniques to reduce the bycatch of several non-target species. For example, testing deep-setting "hook pods" with circle hooks to reduce both seabird and sea turtle bycatch may benefit both taxa. As managers strive to use an ecosystem based fisheries management approach, cross-taxa bycatch reduction studies will become increasingly important. Studies like this will serve as the building blocks for cross-taxa bycatch reduction strategies.

CONCLUSIONS

This study highlights the key variables influencing the probability of sea turtle capture in pelagic U.S. longline fisheries in the Atlantic and Pacific Oceans, as well as how these risks have changed after new regulations. The various analyses have confirmed that in two U.S.-managed longline fisheries, both nominal bycatch and probabilities of bycatch significantly declined, which we attribute to fisheries regulations that mandated changes to traditional longline fishing gear. For combined Atlantic observer data, mean bycatch rates declined by 40 and 61% for leatherback and loggerhead turtles, respectively, for the post-regulation period. Within the NED area alone, where additional restrictions include a relatively larger circle hook (18/0) plus limitations on use of squid bait, sea turtle bycatch rates declined by 64 and 55% for leatherback and loggerhead turtles, respectively, for the post-regulation period. These reductions represent large reductions in sea turtle bycatch despite earlier predictions of even greater conservation gains (Watson et al., 2005). Sea turtle population benefits were even more pronounced for the Hawaii shallow set fishery, where mean bycatch rates declined by 84 and 95% for leatherback and loggerhead turtles, respectively, for the post-regulation period. We consider the existence of numerous confounding factors, as discussed above, in this assessment of the efficacy of the regulation. However, the consistency in observations with results from relevant controlled and comparative experiments (Watson et al., 2005; Gilman et al., 2006) strongly support the inference that the mandated changes in hook and bait were the dominant factors in reducing loggerhead and leatherback bycatch in U.S. commercial longline fisheries during this 20^{+} year investigation period.

In addition to assessing the conservation value of regulatory measures, our work also highlights the value of maintaining a long term (∼22 year) data set of observed target and non-target species caught in U.S. longline fisheries. This information is critical for fisheries managers both in the development of regulatory measures, as well as monitoring and evaluation of their effectiveness. While this research largely relied on data from human observers, in the future, electronic monitoring of vessels when human observation is limited can further assist in assessment of sea turtle (and likely other non-target species) bycatch issues.

The use of statistical models, such as GAMMs, can assist managers in identifying explanatory variables that influence the probability of rare bycatch events, such as sea turtles in longline fishing gear. Information gleaned from these analyses can be applied to management measures that aim to reduce or minimize sea turtle bycatch in longline fisheries. In this analysis, we identified that extending a prohibition of squid bait, eliminating baited hooks at relatively shallow depths ($<\sim$30 m) and implementing temporary closures specific to SST boundaries could be used in addition to changes in hook requirements to further extend sea turtle protection measures.

Our analyses leads us to conclude that the regulations implemented significantly reduced sea turtle bycatch in U.S. longline fisheries and were effective in achieving management goals. Similar exercises evaluating additional fisheries management actions would be highly valuable, not only for sea turtles but also for additional protected species, such as relative new requirements aimed to minimize bycatch with false killer whales (*Pseudorca crassidens*). Regulatory actions taken by the U.S. can serve as a model for other countries that deploy and manage pelagic longline fishing fleets and organizations, such as regional fisheries management organizations (RFMOs) that manage pelagic longline fisheries. Other nations and RFMOs should evaluate these measures for adoption to significantly reduce sea turtle bycatch in pelagic longline fisheries across the globe.

AUTHOR CONTRIBUTIONS

YS, AG, and BS collectively identified the research questions and pursued refining the questions throughout a year plus writing process. YS and CB worked together on all the statistical analysis. YS did and nearly all of the writing and consulted individuals throughout the process regarding various contributions. KB was useful as a statistical consultant and also assisted with conceptual aspects of the paper as well. KK was instrumental regarding data collection and access to data. KS assisted with data management as well as quantitative aspects of the analysis. KS also assisted with graphing for tables and figures. DF provided expert opinion and commentary throughout the data acquisition, data analysis, and writing of the manuscript.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

TABLE A1 | GAMM best-fit model selection.

Model Terms (Parametric and Smoothed)	ADJ. R^2	AIC	Δ AIC
ATLANTIC LOGGERHEAD			
MONTH + SST + MAXIMUM HOOK DEPTH + SOAK DURATION + HOOKS BTW FLOATS + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	0.0603	3, 307.168	–
MONTH + SST + MAXIMUM HOOK DEPTH + HOOKS BTW FLOATS + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	0.0593	3, 304.347	−2.821
SST + MAXIMUM HOOK DEPTH + HOOKS BTW FLOATS + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	**0.0592**	**3,300.428**	−6.74
ATLANTIC LEATHERBACK			
MONTH + SST + MAXIMUM HOOK DEPTH + SOAK DURATION + HOOKS BTW FLOATS + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	0.0211	−955.7212	–
MONTH + SST + HOOKS BTW FLOATS + SOAK DURATION + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	0.0198	−1258.2395	−302.5183
MONTH + SST + HOOKS BTW FLOATS + LIGHTSTICK RATIO + AREA + BAIT TYPE + HOOK TYPE	0.0197	−1270.2896	−314.5684
MONTH + SST + HOOKS BTW FLOATS + AREA + BAIT TYPE + HOOK TYPE	**0.0197**	**−1,278.0982**	−322.377
PACIFIC LOGGERHEAD			
LAT,LON + MONTH + SST + SOAK DURATION + HOOKS BTW FLOATS + LIGHTSTICK RATIO + BAIT TYPE + HOOK TYPE	0.0712	1, 569.829	–
LAT,LON + MONTH + SST + SOAK DURATION + HOOKS BTW FLOATS + BAIT TYPE + HOOK TYPE	0.0712	1, 568.971	−0.858
LAT,LON + MONTH + SST + SOAK DURATION + BAIT TYPE + HOOK TYPE	0.0692	1, 567.155	−2.674
LAT,LON + MONTH + SST + BAIT TYPE + HOOK TYPE	0.0615	1, 550.83	−18.999
LAT,LON + MONTH + BAIT TYPE + HOOK TYPE	**0.0615**	**1,541.656**	**−28.173**
PACIFIC LEATHERBACK			
LAT,LON + MONTH + SST + SOAK DURATION + HOOKS BTW FLOATS + LIGHTSTICK RATIO + BAIT TYPE + HOOK TYPE	0.01	1, 052.135	–
MONTH + SST + SOAK DURATION + HOOKS BTW FLOATS + LIGHTSTICK RATIO + BAIT TYPE + HOOK TYPE	0.00888	1, 049.232	−2.90
MONTH + SST + SOAK DURATION + LIGHTSTICK RATIO + BAIT TYPE + HOOK TYPE	0.00855	1, 048.598	−3.54
MONTH + SST + SOAK DURATION + BAIT TYPE + HOOK TYPE	0.0087	1, 048.598	−3.54
MONTH + SST + BAIT TYPE + HOOK TYPE	0.00827	1, 044.384	−7.75
MONTH + SST + HOOK TYPE	0.0081	1, 040.879	−11.26
MONTH + HOOK TYPE	**0.0081**	**1,036.879**	**−15.26**

GAMMs model catch probability of loggerhead and leatherback turtles on USA pelagic longline fisheries in the Atlantic and Pacific Oceans as a function of gear characteristics, sea surface temperature, and spatio-temporal terms [month, area, latitude (LAT), and longitude (LON)]. Best-fit model indicated by bold text. AIC, Akaike information criteria; DF, Degrees of freedom; ΔAIC, Difference in AIC relative to full model.