FY2016 VIRGINIA COASTAL ZONE MANAGEMENT PROGRAM GRANT

Monitoring Marine Debris in Virginia's Coastal Zone

Project Report: April 2014 through June 2018

August 1, 2019

NOAA Grant #: NA16NOS4190171. Grant Year FY2016, Task # 81.

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This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through two grants: # NA13NOS4190135, Task #81 and # NA16NOS4190171, Task #81. Grant funds were provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Commerce, NOAA or any of its sub-agencies.

Suggested Citation:

Register, K., Trapani, C., Swingle, M. 2019. Monitoring Marine Debris in Virginia's Coastal Zone, Project Report: April 2014 through June 2018. NOAA CZM Grant NA16NOS4190171, Task 81. Virginia Aquarium & Marine Science Center Foundation Scientific Report 2019-03, Virginia Beach, VA, 80 pp.

Cover Photo by Christina Trapani. *Volunteers remove debris from the beach after a Chincoteague National Wildlife Refuge Accumulation Survey.*

All photos by Christina Trapani unless otherwise noted.

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- http://www.longwood.edu/cleanva/publications.html
- https://www.deq.virginia.gov/Programs/CoastalZoneManagement/CZMIssuesInitiatives/MarineDebris.aspx

ACKNOWLEDGEMENTS

The authors are grateful to the Virginia Coastal Zone Management (CZM) Program which provided funding from the NOAA Office for Coastal Management for this research.

We would like to acknowledge the volunteers who have dedicated many hours, often dealing with extreme temperatures, wind and insects, to complete 207 surveys, especially: Jennifer Jeffers, Glen Fields, Cathy Roberts, Kathy O'Hara, Erica Ryder, Sharon Ross, Craig Grube, Ben Hamm, Maureen Hamm, Hillary Foster and Peg Goodman. We would also like to thank staff at Back Bay National Wildlife Refuge, especially Lauren Mowbray, Chincoteague National Wildlife Refuge, especially Kevin Holcomb, Fisherman Island National Wildlife Refuge, especially Pamela Denmon, and City of Hampton and Hampton Clean City Commission, especially Cris Ausink, for their assistance in obtaining permits and permission to monitor the four survey sites. We also thank Longwood University students and Clean Virginia Waterways interns for assistance with data entry: Hilary Foster, Tim Davis, Emily DeMasi, Danielle Zipfel, and Alex Lee. Special thanks to W. Harrison Kish for his assistance with this final report.

We would also like to thank staff of the NOAA Marine Debris Program and Office of Response and Restoration for technical assistance, especially Jason Rolf, Mid-Atlantic Regional Coordinator, and Sherry Lippiatt, NOAA Marine Debris Program California Regional Coordinator.

Acronyms

CZM	Virginia Coastal Zone Management Program
DEQ	Virginia Department of Environmental Quality
VAQ	Virginia Aquarium & Marine Science Center
CVW	Clean Virginia Waterways
MDMAP	NOAA's Marine Debris Monitoring and Assessment Project
NOAA	National Oceanic and Atmospheric Administration
NWR	National Wildlife Refuge

About the Virginia Aquarium & Marine Science Center

The mission of the Virginia Aquarium is to inspire conservation of the marine environment through education, research and sustainable practices. The Aquarium is operated by the City of Virginia Beach in collaboration with the Virginia Aquarium Foundation (VAQF). The organization is committed to being a conservation leader through actions for a common purpose and shared commitment, not only to conserve wild animals and habitats, but to build and operate a facility that contributes to the well-being of every member of the community. The Aquarium is confronting today's environmental challenges through actions in order to model an institutional pathway to a healthy, biodiverse and sustainable future.

About Clean Virginia Waterways of Longwood University

Clean Virginia Waterways (CVW) mission is to enhance the health of Virginia's water resources through pollution prevention, education, and stewardship activities involving Virginians from the classroom to the boardroom. Founded in 1995, CVW is a program of Longwood University in Farmville, Virginia and is affiliated with the Ocean Conservancy. CVW has organized the International Coastal Cleanup in Virginia since 1995 and is recognized as a leader in researching litter and marine debris topics: sources, impacts and solutions. CVW focuses on prevention of land-based litter through education, collaboration, engaging the public in hands-on stewardship through cleanup events and social marketing research.

About the Virginia Coastal Zone Management Program

The Virginia Coastal Zone Management (CZM) Program is a network of Virginia state agencies and coastal localities that implement the state's coastal management laws and policies. The program operates under the federal Coastal Zone Management Act of 1972, as amended, with funding from the National Oceanic and Atmospheric Administration. The Virginia Department of Environmental Quality serves as the lead agency for the network. The Virginia CZM Program has provided leadership and funding to strategically address marine debris through prevention, interception, innovation, and removal for ecological, social and economic benefits.

About Christina Trapani

Christina Trapani worked with stranded sea turtles and marine mammals for more than a decade at the Virginia Aquarium & Marine Science Center. Her experience in working on Virginia's remote beaches and with sea turtles led her towards an interest in marine debris. In 2008, she started a retail business offering alternatives to single-use plastics (Eco Maniac Company). In 2013, she started Christina Trapani Consulting, and has worked with organizations on environmental research and education projects focused on marine debris in Virginia.

Co-authors, from left to right, Katie Register, Mark Swingle, and Christina Trapani at Chincoteague NWR after initial site selection.

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Debris on the beach at Chincoteague NWR.

Monitoring Marine Debris in Virginia's Coastal Zone

EXECUTIVE SUMMARY

Human-made debris in the world's rivers, coastal waters and oceans is a fast-growing threat that is increasingly recognized as requiring urgent action. Marine debris has been shown to impact marine animals from the smallest zooplankton to the largest species – including whales. It also has negative impacts on critical habitat. In addition to ecosystem threats, larger marine debris items can impede navigation and this form of pollution has economic and societal costs.

How can communities, government agencies, non-profit organizations, and interested citizens best understand the extent of marine debris (also known as plastic pollution) in order to craft effective policies and campaigns to prevent this form of water pollution? Careful and regular monitoring and analysis of data about the human-made debris on beaches allows researchers to: identify hotspots of debris accumulation; understand the products and material types that are most frequently found on beaches; reveal temporal and spatial trends; and understand the scope of the marine debris problem.

For a little more than four years (April 2014 through June 2018), a project team led by the Virginia Aquarium & Marine Science Center and its partners conducted monthly monitoring of marine debris on four coastal beaches in Virginia. The monitoring team conducted 54 surveys on Back Bay National Wildlife Refuge in Virginia Beach; 51 surveys on Chincoteague National Wildlife Refuge in Accomack County; 50 surveys on Fisherman Island National Wildlife Refuge in Northampton County, and 52 surveys on Grandview Nature Preserve in Hampton.

Over the four years of monitoring, a total of 15,276 pieces of debris were documented, of which the vast majority (83.0%) were made of plastic. Ocean Conservancy estimates that 84% of all items collected during the International Coastal Cleanup are made up of plastic (Mallos, 2016), and this project's data indicate a nearly identical percentage. Fisherman Island NWR accounted for 55.5% of the total debris items – more than the other three sites combined. Volunteers contributed more than 2,135 hours during the project. They played an essential role in allowing surveys to be completed in manageable periods of time, especially considering that surveys were designed to be conducted during low tide.

The results of this monitoring effort will assist communities as they craft campaigns and policies to reduce the amount of litter and trash that ends up becoming marine debris in rivers, coastal waters, and on beaches. The information can also help managers develop strategies to effectively remove debris, especially for high-deposition beaches that are home to endangered and threatened species. This report provides a summary of the development and implementation of the project's monitoring program, as well as a detailed look at the data, including debris composition by material and product type.

Support for this marine debris monitoring project was provided by the NOAA Office for Coastal Management through two grants from the Virginia Coastal Zone Management Program to the Virginia Aquarium & Marine Science Center Foundation (Grants #NA13NOS4190135, Task #81 and # NA16NOS4190171, Task #81). The project coordination partners included the Virginia Aquarium & Marine Science Center, Clean Virginia Waterways of Longwood University, and Christina Trapani Consulting.

Debris on the beach at Fisherman Island NWR.

INTRODUCTION

Growing concern about the impacts of debris in ocean and coastal waters, along with increasing emphasis on stormwater management as it relates to litter and debris, have led to a new urgency to understand and address the sources of marine debris in Virginia. According to the National Oceanic and Atmospheric Administration (NOAA), marine debris has become one of the most widespread pollution problems in the world's oceans and waterways.

To strategically address this problem, the Virginia Coastal Zone Management (CZM) Program undertook a participatory and collaborative planning process starting in 2012. One of the initial steps was to organize the first Virginia Marine Debris Summit (February 27-28, 2013, in Virginia Beach) during which participants discussed the many gaps in knowledge about marine debris, including the need for high-value data about the quantity and types of debris found on Virginia's beaches. While extensive data exists about the types of litter and trash found on Virginia's beaches and in coastal waters, these data are mostly of the "snapshot" variety and needed to be supplemented with data collected using more rigorous protocols. The Virginia Marine Debris Reduction Plan, developed in 2014 under Virginia CZM Program leadership, calls for more research in order to better understand the sources, impacts, and solutions to marine debris (Register & McKay, 2014). This research project grew out of the priorities found in the Virginia Marine Debris Reduction Plan.

Systematic monitoring of marine debris is necessary in order to understand sources, locations, amounts, movement, impacts, and rates. Long-term monitoring also supports evaluation of the effectiveness of educational outreach, pollution prevention strategies, and policies that are put in place to reduce this form of pollution. For example, government agencies and non-profit environmental groups worked together to monitor debris in the streams and rivers of Washington D.C. before and after a policy was enacted to decrease the use of single-use plastic bags. The Alice Ferguson Foundation observed an 87.5% decrease in plastic bags during volunteer river cleanups between 2007 and 2016. Further, studies showed that D.C. residents were using 60% fewer single-use plastic bags (OpinionWorks, 2013). Monitoring data will also facilitate regional and site-specific comparisons over time and will provide insights into priority targets for prevention and clean-up activities. This grant project used the Marine Debris Shoreline Survey protocols developed by the NOAA Marine Debris Program (Opfer, Arthur & Lippiatt, 2012; Lippiatt, Opfer & Arthur, 2013).

All members of the project team have a history of engagement in marine debris reduction efforts in Virginia including: balloon debris monitoring programs; data collection through the International Coastal Cleanup and other organized clean-up programs; cigarette litter prevention campaigns; and creation of social marketing campaigns to reduce litter and marine debris. The Virginia Aquarium, Clean Virginia Waterways, Christina Trapani Consulting, the Virginia CZM Program, and other stakeholders will use this information to further inform policies and social marketing campaigns that focus on preventing litter and marine debris.

Project Objectives

The objectives of this project were to initiate a marine debris monitoring program that included:

- recruitment and training of volunteer monitors to work with a contract survey coordinator
- collection of data from April 2014 through June 2018 (including four hurricane seasons, summer/fall 2014-17);
- analysis of data to provide insights about the marine debris problem in coastal Virginia
- development of a plan to continue monitoring after the initial grant period

Project coordinators planned to develop and strengthen partnerships with other pollution-prevention non-profits, ocean advocacy organizations, the U.S. Fish and Wildlife Service, and others. Project monitoring data will serve as a baseline against which Virginia can evaluate the effectiveness of the Virginia Marine Debris Reduction Plan, as well as policies and social marketing campaigns that focus on decreasing the sources of litter and marine debris.

All monitoring data would be entered into NOAA's database. The project team planned to: analyze all data to determine the most frequently recorded items per site, as well as overall; present monitoring data relative to factors such as deposition rate, composition, and seasonality; and examine items of special interest, including fishing-related debris, smoking-related debris, and balloon-related litter.

A major objective of the project team was to collect data through several hurricane seasons since there are few natural events that can create such large changes to beach profiles and subsequent marine debris deposition and accumulation. A final objective was to use resources efficiently to maximize the project survey period.

Volunteers conduct an Accumulation Survey at Grandview Nature Preserve.

METHODOLOGY

Getting Started

During the first few months of the initial grant in 2014, the Virginia Aquarium hired a marine debris research contractor, Christina Trapani, to join the project team and begin the process of selecting the monitoring sites, and to manage all volunteer recruitment/training and monthly surveys. Trapani led all of the monthly monitoring surveys except for one in 2018 that was led by Mark Swingle of the Virginia Aquarium.

Project supplies were purchased, including: digital camera, GPS unit, clipboards, work gloves, grabbers, water and food coolers, Rite-in-Rain paper, wooden site markers, and bamboo tomato stakes. Clean Virginia Waterways provided a measuring wheel and Virginia Aquarium provided a hanging scale. Surfrider Foundation donated 20 reusable grain bags sourced from a local brewery to be used as the project's debris collection bags. The survey coordinator created a volunteer application and began recruiting volunteers. Contacts were made with the VAQ Stranding Response Team, Surfrider Foundation, Lynnhaven River Now, Tidewater and Eastern Shore Chapters of the Virginia Master Naturalists, Eastern Shore Waste Watchers, Back Bay Restoration Foundation, and Back Bay NWR. A volunteer training was held at Back Bay NWR on April 13, 2014 and all volunteers practiced survey methods using the NOAA protocol.

Monitoring Sites

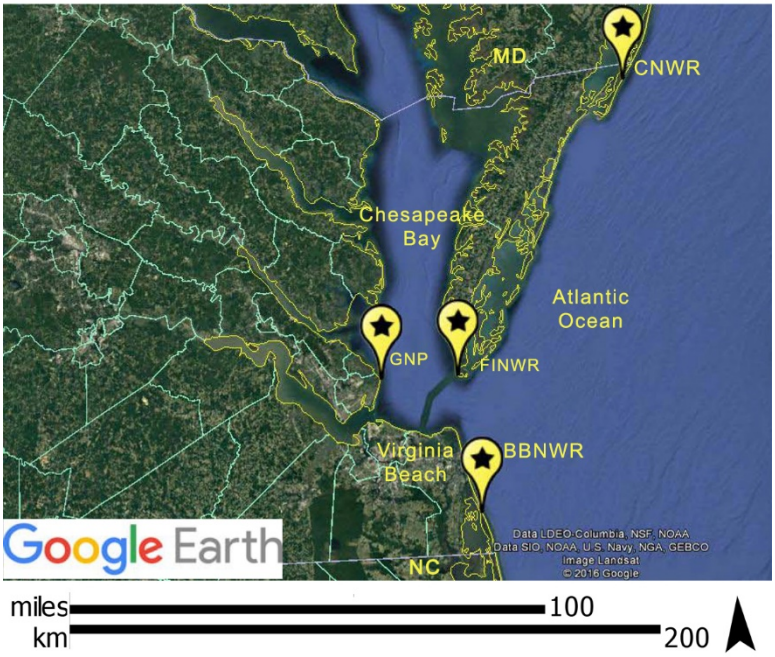


Figure 1. A map of the four monitoring sites included in this study: Chincoteague National Wildlife Refuge (CNWR), Grandview Nature Preserve (GNP), Fisherman Island National Wildlife Refuge (FINWR), and Back Bay National Wildlife Refuge (BBNWR).

The project team selected one site within the Chesapeake Bay (Grandview Nature Preserve in Hampton), one site located at the entrance to the Chesapeake Bay (Fisherman Island National Wildlife Refuge in Northampton County), and two sites on the Atlantic Ocean (Chincoteague National Wildlife Refuge in Accomack County, and Back Bay National Wildlife Refuge in Virginia Beach) (Figure 1).

Site selection was partly informed by the project team's knowledge of marine debris deposition derived from two decades of data collected as part of the International Coastal Cleanup in Virginia. The sites were also selected based upon their relative isolation from the public and public accessibility.

Each beach monitoring site included adjacent 100-meter areas, an Accumulation Survey area and a Standing-Stock Survey area, as described in NOAA's *Marine Debris Shoreline Survey* protocol.

Two of the selected sites (Chincoteague NWR and Back Bay NWR) were in the general locations of a previous marine debris monitoring research project, the *National Marine Debris Monitoring Program* (NMDMP), that was conducted by Ocean Conservancy and funded by EPA between September 2001 and September 2006 (Sheavly, 2010). It was hoped this would give the project team an opportunity to compare debris composition in these areas over time.

Chincoteague NWR Site

On March 28, 2014, Swingle (VAQ), Katie Register (CVW) and Trapani travelled to Chincoteague NWR and met with their biology staff regarding site selection. Shore bird and sea turtle nesting were considered and a northern site that was less likely to have nests was selected. The Chincoteague NWR site is located seven miles (11.3 km) north of the Visitor's Center and could only be accessed by foot from the beach or via a restricted service road that runs through the Refuge. During shore bird nesting season, beach walkers may not venture above the high tide line. During the entire 51 months of monitoring, only 2-3 beach walkers were encountered by survey teams. The beach was cleaned annually during the International Coastal Cleanup, but volunteers were directed not to clean in or around the monitoring site. Changes in the beach observed over time included the occasional formation of a steep slope from dune to low tide line. The wooden stakes that were placed to mark the monitoring site slowly disappeared over time as sand built up near the back of the barrier beach (Figure 2).

Figure 2. The monitoring site at Chincoteague NWR looking towards the south. Vegetative dunes can be seen on the right side. Inset: Map of the Chincoteague NWR monitoring site in relation to the Visitors Center, closest population center, and the Virginia/Maryland state line.

Fisherman Island NWR Site

Figure 3. FINWR biologist, Pam Denmon (left) and Katie Register (right) discuss site location at Fisherman Island NWR.

Register and Trapani, with the assistance of refuge staff, completed site selection on Fisherman Island NWR on March 27, 2014 (Figure 3). They chose a site that was least likely to be used by shore birds for nesting (Figure 4). Fisherman Island NWR is closed to the public except for guided tours in October through March and occasional beach cleanup efforts. Refuge staff were aware of the monitoring site and instructed birders and cleanup volunteers not to remove trash from the area. Fisherman Island is a barrier island in the mouth of Chesapeake Bay and is susceptible to erosion, extreme tides and a changing beach face to a greater extent than any of the other monitoring sites. Large wood structures, pieces of piers or pilings, occasionally appeared on the site and were too large to be removed. The island was used as a military installation during World Wars I and II and these structures are likely from this era. The Chesapeake Bay Bridge-Tunnel is located just south of the site.

Figure 4. Fisherman Island NWR site looking towards the south. The Chesapeake Bay Bridge-Tunnel can be seen in the background. Inset: map of the Fisherman Island NWR monitoring site.

Back Bay NWR Site

Trapani and volunteer, Kathy O'Hara selected a site at Back Bay NWR about ¼ mile (400 m) from the beach access (Figure 5). The Back Bay NWR site was located on the "North Mile", an area of the refuge closed to the public. Though the public was not permitted in this area, the location was less than a mile (1.6 km) south of Sandbridge, a resort area of Virginia Beach that is very heavily occupied during the summer months. While the beach face did not seem to change over time, it was observed that the length of the sites decreased in size by almost four meters in the four years of the project. This may have been due to a measuring wheel malfunction or the "hilly" nature of the beach during the initial site measurement.

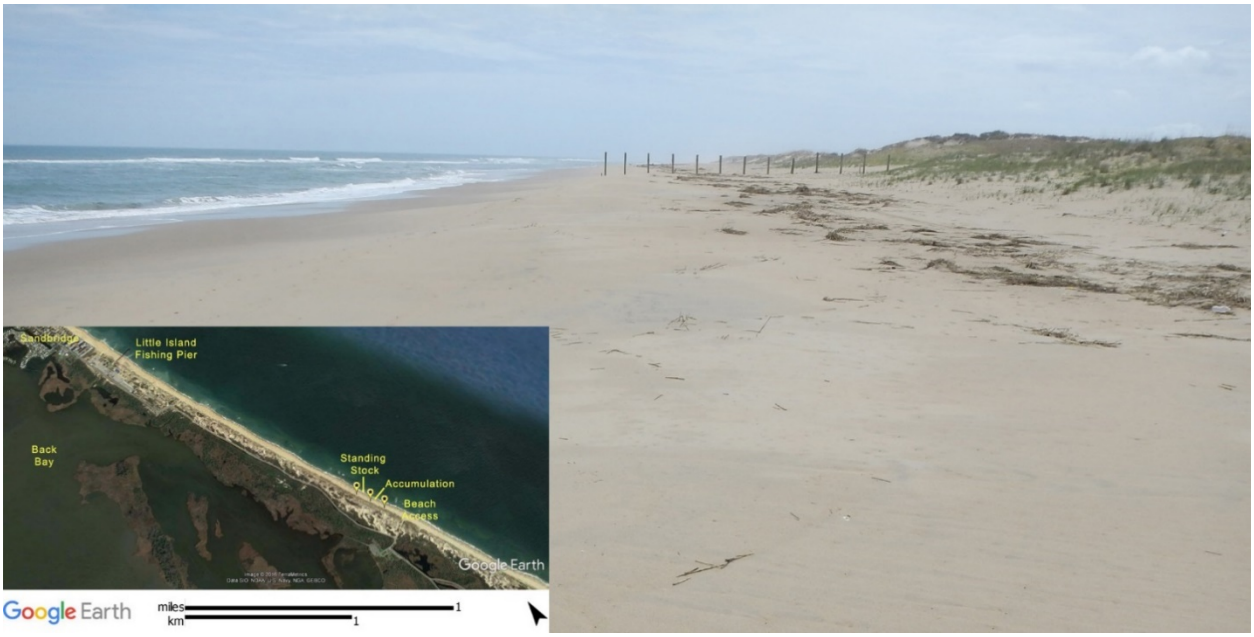


Figure 5. Back Bay NWR site looking towards the south. The gate marking the south side of the North Mile can be seen in the background. Inset: map of the Back Bay NWR site in relation to Sandbridge, the neighboring resort section of Virginia Beach.

Grandview Nature Preserve Site

Initially, Naval Amphibious Base Little Creek was considered as a potential site but was not approved for use due to military concerns over access. Grandview Nature Preserve, managed by the City of Hampton, was then selected as the fourth monitoring site (Figure 6). Park officials were aware of the project, but no permits were required. Swingle and Trapani selected a site at about ½ mile (800 m) from the beach access, with the assistance of volunteer Kathy O'Hara who was familiar with the Preserve. Grandview Nature Preserve is located between the city of Hampton, particularly the Grandview neighborhood, and the Back River. While the beach at the Preserve is accessible to the public, it is approximately one mile (1.6 km) from the nearest parking area and is not frequented by an excessive number of people. This was the only monitoring site adjacent to a nearby river that drained into the bay. During the first several months of monitoring, survey teams observed a significant number of old bricks believed to be left from the collapse of the Grandview Lighthouse during Hurricane Flossy in 1956 (Figure 7). These bricks were not counted during surveys. A large wood pole was observed in the

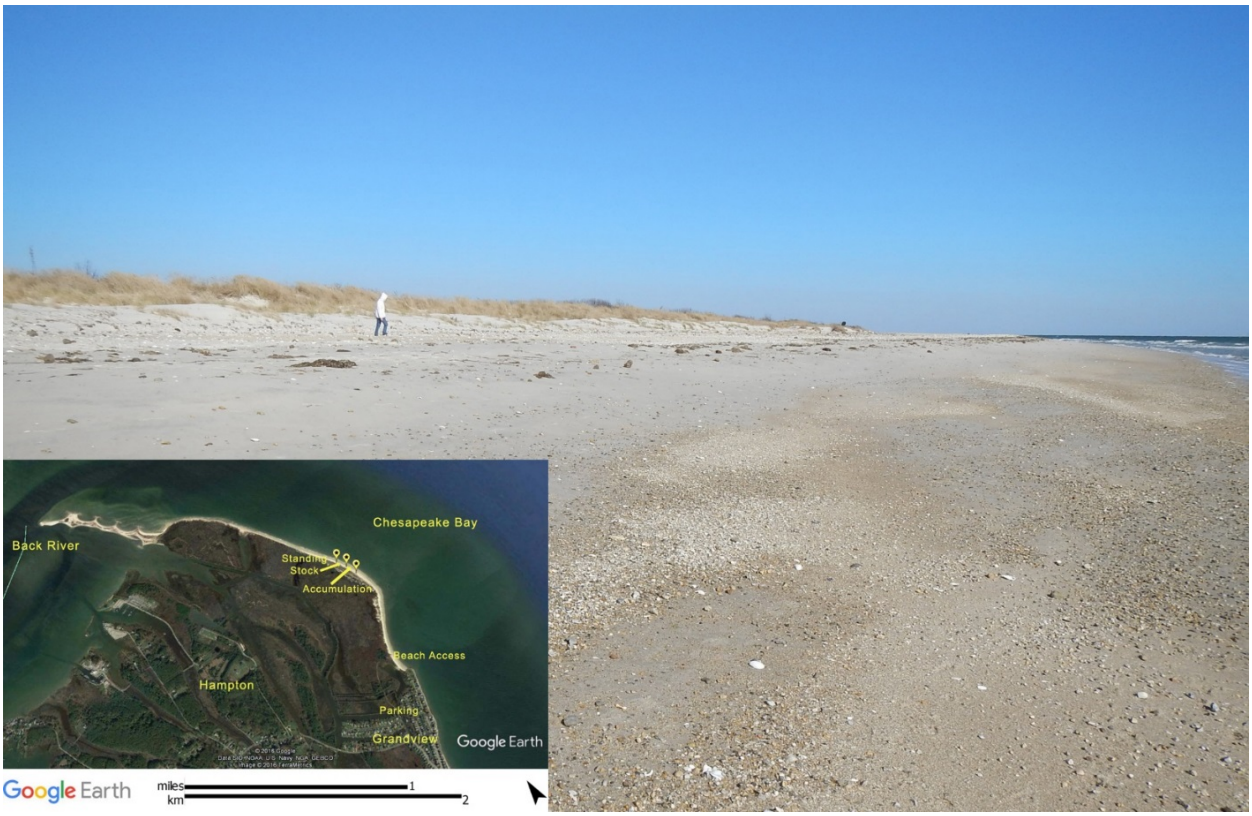


Figure 6. Grandview Nature Preserve site looking towards the north. Vegetation marking the back barrier can be seen on the left side. Inset: Map of the Grandview Nature Preserve site in relation to the closest population centers and the Back River.

Accumulation Survey area starting in early 2016 and remained in the area throughout the duration of the project surveys. The pole eventually became overgrown with dune grasses and was considered behind the barrier. A large fishing net was also observed in the Accumulation Survey area for many months but eventually became completely buried in sand.

Figure 7. Several old bricks observed at Grandview Nature Preserve in June 2014.

Permits

Research permits were secured and renewed each year for the three National Wildlife Refuge monitoring sites. These permits stipulated that if a shore bird or sea turtle should nest in a site, the site would not be accessible until the nest had fully incubated and hatched and/or fledged. With this potential restriction in mind, monitoring sites were chosen in areas that were least likely to have nesting shore birds. Back Bay NWR and Chincoteague NWR have occasional loggerhead sea turtle nests that can occur anywhere on their ocean-facing beaches, though this situation did not occur in the monitoring sites during the study period.

Site Characterizations

NOAA's *Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment* (Lippiatt *et al.,* 2013) requires that site-specific features be recorded annually for each site (Table 1). Site Characterization Sheets were completed annually in March/April for all four sites from 2014 through 2018.

Table 1. Physical and geographical features of each monitoring site (summarized below) are included on Site Characterization Sheets that were updated each year per the NOAA MDMAP protocol.

Monitoring Site	**Average Width (m)** (back of beach to water)	**Tidal Distance (m)** (from low- to high-tide line)++	**Back of shoreline** (substrate change or first barrier)	**Aspect** (direction when viewing the water)	**Nearest population center distance (km)** +++	**Nearest river input (km)** +++
CNWR	47.2m	36.4m	vegetated dunes	East SE	16.0km	NA
FINWR	48.0m	31.0m	vegetated dunes	West	8.0km	NA
BBNWR	43.3m	25.1m	vegetated dunes	East	1.6km	NA
GNP	42.3m	18.5m	vegetation	East SE	1.0km	2.5km

+ Data from Tides On-line (https://tidesandcurrents.noaa.gov/tide_predictions.html)
++ Average from the 5 Site Characterization Sheets from 2014-2018.
+++ Distances measured using Google Earth.

Survey Period

Under the original grant, *Monitoring of Marine Debris in Virginia's Coastal Zone*, nine months of surveys were to be conducted starting in April 2014. Efficient use of resources throughout the project allowed for the original timeline to be extended to 30 months, ending in September 2016. The extended project survey period included three Atlantic hurricane seasons. Although no hurricanes made landfall in Virginia during the project, there were several tropical storms and nor'easter storms. The second grant, *Monitoring and Assessment of Marine Debris in Virginia's Coastal Zone,* allowed monitoring surveys to continue until June 2018, for a total of 51 months.

Volunteers

Figure 8: Four volunteers practice surveying a Standing-Stock transect during the initial volunteer training at Back Bay NWR.

Volunteer recruitment for this project involved numerous groups, including the Virginia Aquarium Stranding Response Team, Surfrider Foundation, Lynnhaven River NOW, Tidewater and Eastern Shore Chapters of the Virginia Master Naturalists, Back Bay NWR and Chincoteague NWR. Interested volunteers were provided with a digital copy of the NOAA protocols and a link to the online monitoring toolbox. A volunteer training was held at Back Bay NWR in April 2014 (Figure 8). Volunteers who joined the project after the initial orientation were trained during their initial survey efforts.

Volunteers contributed more than 2,135 hours during the four plus years of this project. They played an essential role in allowing surveys to be completed in manageable periods of time, especially considering that surveys were designed to be conducted during low tide. A core group of about 10 volunteers became very efficient in assisting the survey coordinator with the completion of surveys in a timely and accurate manner.

Scheduling

Throughout the project survey period, surveys at each monitoring site were scheduled every 28 days (plus or minus 3 days) based on local times for low tide. At the beginning of each month, a survey schedule was generated and sent to volunteers. On average, two volunteers assisted the survey coordinator during each site visit. The survey coordinator often picked-up volunteers at designated locations to facilitate car-pool transportation. This was especially important for the Fisherman Island NWR and Chincoteague NWR sites due to the significant tolls and travel distance associated with these monitoring sites when departing from Virginia Beach.

Figure 9. A snow-covered beach on Fisherman Island NWR in March 2015. A survey was conducted though conditions were challenging.

Weather was often a challenge for scheduling, and it was not uncommon for surveys to be rescheduled due to storms, strong winds, extreme cold and/or rain (Figure 9). During the project survey period, only four surveys were cancelled due to weather. The February 2015 survey at Grandview Nature Preserve was cancelled due to excessive snow and ice cover on the beach throughout the survey window. The Fisherman Island NWR survey in October 2016 was

cancelled due to Tropical Storm Matthew. The January 2017 Fisherman Island NWR survey was cancelled due to snow cover on the beach. The Chincoteague NWR survey in April 2017 was cancelled due to several days of strong winds and storms resulting in excessively high tides. Another survey at Grandview Nature Preserve had to be rescheduled due to the discovery of unexploded ordinance on the beach.

Survey Protocols

This project used the Marine Debris Shoreline Survey protocols and data sheets developed by the NOAA Marine Debris Program (Opfer *et al*., 2013). NOAA Marine Debris Program's Marine Debris Monitoring and Assessment Project (MDMAP) includes protocols, data sheets and data analysis assistance so groups across the nation can use a standardized system to collect rigorous data about marine debris deposition. This standardized protocol and open-access database allows for data sharing among scientists and policy makers as they work together to address the sources of this type of water pollution.

According to "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*," a technical memo by the NOAA Marine Debris Program, there are four main objectives for a monitoring program:

- 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 (Lippiatt *et al*., 2013).

The program's protocol has two types of beach surveys: Standing-Stock Surveys are used to determine debris density (number of items per square meter); and Accumulation Surveys are used to determine debris flux (number of items per unit area per time). In both types of surveys, all debris items greater than or equal to 1 inch (2.5cm) within a survey area were recorded. Each survey area is 328 ft (100 meters) in length and varies in width based upon the beach profile.

Standing-Stock 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/m2 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)." (Lippiatt *et al.,* 2013)

Figure 10. Volunteers measure transects for a Standing-Stock Survey at Back Bay NWR. A measuring tape was used to measure out the 5-meter sections and tomato stakes were used to mark the edges.

For the Standing-Stock Surveys, the 100-meter area is divided into 20 five meter transects. Four transects are then selected using a random number table. Using a tape measure and the measurement chart provided in the Shoreline Field Guide, the selected transects are then staked out (using tomato stakes) from the low tide line to the back of the shoreline to mark each complete transect (Figure 10). GPS coordinates and photos are taken at each end of a transect, and then the transect length is recorded. Generally, two volunteers and a data recorder walk a transect from low tide line to back of shoreline (or vice versa). Volunteers survey specific areas and call out what kind of debris they observe. In the Standing-Stock Surveys, debris is recorded but left in place. The time from start of survey to completion is also recorded. Each Standing-Stock Survey required four transects and four data sheets to be completed and entered into the NOAA database (http://mdmap.orr.noaa.gov/).

The four randomly selected transects represent only one fifth of the total 100-meter Standing-Stock Survey area. As a result, the total debris counts for Standing-Stock Surveys were much less than in the Accumulation Surveys.

Accumulation Survey

"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/m2/time), as opposed to the concentration or Standing-Stock of debris...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." (Lippiatt *et al.,* 2013)

Each Accumulation Survey area was 100 meters (328 feet) in length and the entire area was surveyed. For this survey method, the survey coordinator and volunteers walked transects parallel to the shoreline. Depending on the amount of debris being observed, both the

volunteers and survey coordinator searched for debris (always looking right), recorded what they found, and collected the debris for removal from the beach (Figure 11). If the survey site appeared to be heavily littered, the survey coordinator would function only as the data recorder while the volunteers removed debris. GPS coordinates were recorded at the four corners of the Accumulation Survey area, and a width (low tide to back of the shoreline) was recorded at each end. Debris observed behind the back of the shoreline (i.e., in the dunes) was also recorded in a separate section of the survey notes.

Figure 11. Volunteers sift through wrack and trees looking for debris on Fisherman Island during an Accumulation Survey.

In both survey types, photographs were taken of unusual items and large items were photographed and documented with a measuring tape for more accurate recording (initially, large item measurements were estimated).

Data Sheets

NOAA Shoreline Debris Survey Data Sheets were filled out during each monitoring site survey (Figure 12), one for the Accumulation Survey and one for each Standing-Stock Survey transect. This included season, date, time, weather, recent precipitation, and the number of people engaged in the survey. Debris on the data sheet is classified into the following categories: plastic, metal, glass, rubber, processed lumber (no natural wood), cloth/fabric and other/unclassifiable (Table 2). All debris items equal to or great than 1 inch (2.5 cm) within the survey area were recorded. Following the NOAA protocol, at least 50% of an item had to be present in order to be recorded as an identifiable item. When less than 50% of the item was present, the item was tallied as a single fragment. Data sheets included a "notes" area for other observations. Blank data sheets can be downloaded from this site: https://marinedebris.noaa.gov/research/monitoring-toolbox

Figure 12. A volunteer (left) reads off the transect coordinates from a Standing-Stock Survey at Chincoteague NWR while partner, Mark Swingle (right), records the coordinates onto the data sheet.

In March 2016, NOAA introduced a revised data sheet referred to as "v2". This revised data sheet had the following changes:

- The original data sheet was used for both Standing-Stock and Accumulation Surveys. The revised version has a different data sheet for each type of survey.
- A section to record debris behind the survey area's back barrier was added.
- Balloons, once recorded only under the plastic section, are broken down into plastic (foil/mylar or plastic balloons) and rubber (latex balloons).

Table 2. NOAA MDMAP Data Sheet uses six major debris categories and sub-categories to categorize debris. In addition, there is an option for materials that don't fit into the other categories (Summary table from Bimrose et al., 2018).

Category	Sub-categories
Plastic	Hard foam and film fragments, bags, foil balloons, beverage bottles, bottle/container caps, buoys and floats, cigar tips, cigarette lighter, cigarettes, cups, fishing lures/line, food wrapper, other jugs or containers, oyster farm debris*, personal care products, rope/net pieces, utensils, shotgun wads*, six-pack rings, straws, other (e.g., toy, pen)
Wood	Cardboard cartons, lumber/building material, paper and cardboard, paper bags, other (e.g., cork, toothpick)
Glass	Beverage bottles, jars, glass fragments, other (e.g., picture frame)
Cloth/Fabric	Clothing and shoes, fabric pieces, gloves, rope/nylon, towels/rags, other (e.g., seat belt, curtains)
Metal	Aerosol cans, aluminum/tin cans, metal fragments, other (e.g., bottle caps)
Rubber	Flip flops, gloves, latex balloons, rubber fragments, other (e.g., rubber bands)
Unclassified	Wax, leather, items of unknown material type

Data Entry

Virginia Aquarium and Clean Virginia Waterways project staff coordinated all data collection and data entry processes. Data sheets were scanned and sent to Clean Virginia Waterways of Longwood University by Trapani. Staff of CVW printed and reviewed all data sheets for completeness, then entered all data into the NOAA online database (https://mdmap.orr.noaa.gov/login). Original copies of all survey data sheets are stored at the Virginia Aquarium, printed copies are stored at Clean Virginia Waterways and digital scans of all datasheets are stored in the Longwood University cloud server (https://longwood.app.box.com/).

FINDINGS & DISCUSSION

A total of 207 Accumulation Surveys and 207 Standing-Stock Surveys were completed during the project period from April 2014 through June 2018 – one of each survey type per survey day at each of the four sites: Back Bay NWR (n=54); Chincoteague NWR (n=51); Fisherman Island NWR (n=50); Grandview Nature Preserve (n=52) (See Appendix I for a list of completed surveys and their dates).

For this section, survey data were analyzed to provide insights into the sources, composition, abundance and movement of marine debris.

Data presentations are organized into the following categories:

- Total Debris: Comparing the Sites
- Debris by Material Type: Aggregate of All Four Sites
- Debris by Material Type: Comparing the Sites
- Composition of Top 20 Debris Items by Site
- Land-based vs. Water-based Sources of Debris
- Plastic Debris Items: Comparing the Sites
- Accumulation Surveys
    - Total debris items by type
    - Total debris by site
    - Total debris by material type
    - Plastic debris grouped by user category
- Standing-Stock Surveys
    - Total debris items by type
    - Total debris by site
    - Total debris by material type
    - Plastic debris grouped by user category
- Yearly Debris Totals
- Debris Deposition: Seasonality, Storms and Population
- Debris of Special Interest
    - Smoking-related litter
    - Plastic straws
    - Balloons and attached ribbons
    - Clam aquaculture netting
    - Bottle caps
    - Cardboard and paper
    - Shotgun shells and wads
    - Large items
    - Spray foam and burned/melted plastic
    - Other results
    - Debris composition over time: 2001–2006 and 2014–2018

Total Debris: Comparing the Sites

This data presentation summarizes and compares the totals of all debris items for each of the four monitoring sites. In the field, survey teams recognized a trend that clearly emerged when looking at the data: Fisherman Island NWR had a disproportionate share of marine debris on its beaches relative to the other survey sites. As seen in Figure 13 and Table 3, the majority (55.5%) of all debris items recorded during surveys was found on Fisherman Island NWR – more than the other three sites combined. Back Bay NWR followed at 17.6%, then Grandview Nature Preserve at 14.5%, and Chincoteague NWR at 13.4%.

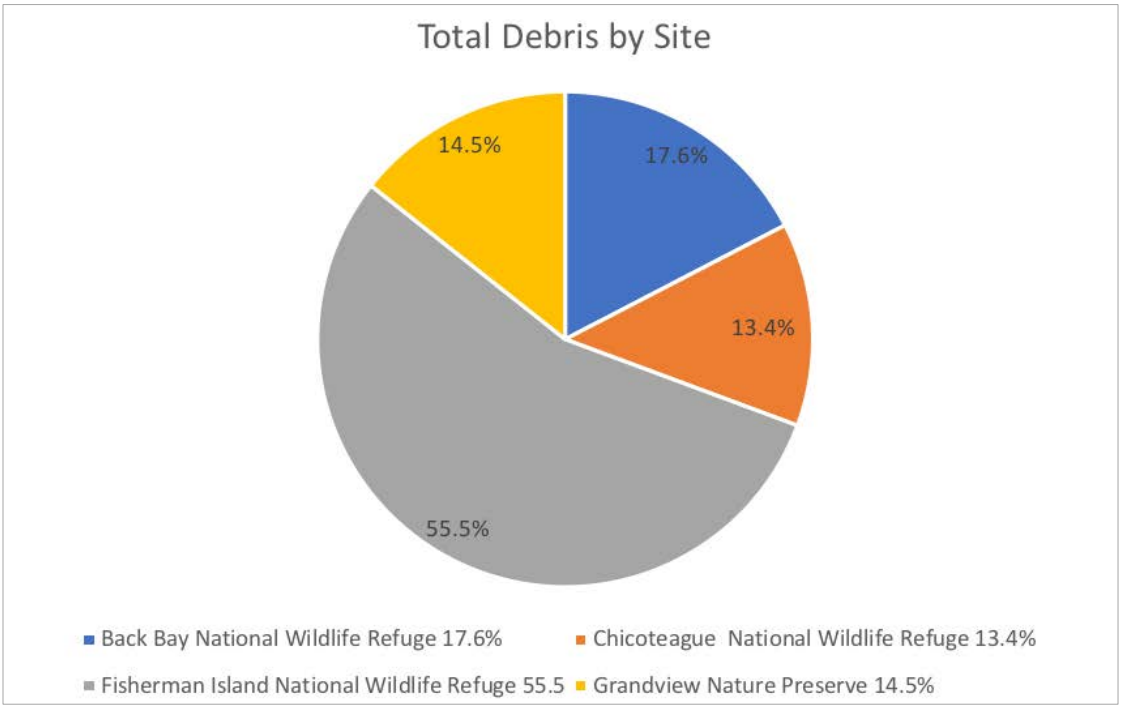


Figure 13. Percentages of aggregate total of debris items attributed to the four beach monitoring sites during the project survey period (April 2014–June 2018).

Table 3. Total debris items in Accumulation Surveys, Standing-Stock Surveys, and aggregate for each of the four beach monitoring sites during the project survey period (April 2014–June 2018).

Monitoring Site	Accumulation debris totals	Standing-Stock debris totals	Total per Site
Chincoteague NWR	1,484	538	2,022
Fisherman Island NWR	6,744	1,632	8,376
Back Bay NWR	2,013	634	2,647
Grandview Nature Preserve	1,662	522	2,184
Totals	11,903	3,326	15,229

The finding that the majority of debris items were recorded on just one of the four monitoring sites underscores the impact of site location and local conditions on the rates of marine debris deposition and accumulation. Fisherman Island NWR is located at the mouth of Chesapeake Bay and the monitoring site is on the west side of the island. This means that the prevailing surface outflow in the northern portion of the bay mouth is generally directed at the beach monitoring site. The Chesapeake Bay has an extremely large watershed, potentially contributing to the marine debris at the bay mouth. On a more local level, the lower bay area is one of the most popular destinations in the country for recreational and commercial fishing and boating, and its shorelines host some of the most densely populated areas of the state. These factors, along with the complex circulation patterns around the bay mouth, create a beach location that is potentially impacted by marine debris from a variety of sources. The monitoring site at Grandview Nature Preserve is also located in the lower bay, however its beach is oriented in a different direction than at Fisherman Island NWR. Grandview Nature Preserve is not located in the bay mouth and is therefore less likely to have prevailing surface water flow directed at the beach. Back Bay NWR, and Chincoteague NWR monitoring sites are ocean-facing beaches and significantly more remote from the Chesapeake Bay or other estuaries with large population centers and outflow from large watersheds. These factors may help to explain the relative distribution of total debris items when comparing the four monitoring sites.

Lighter and less dense plastic items dominated the debris counts on ocean-facing beaches and Fisherman Island NWR, while denser materials such as lumber and metals were more prevalent on Grandview Nature Preserve. Since Fisherman Island NWR and the ocean-facing sites received a larger proportion of plastic, this may indicate that plastic debris is indicative of debris that is deposited on the beaches by waves (sometime referred to as "ocean sourced").

Debris by Material Type: Aggregate of All Four Sites

During this study, 83% of all debris recorded was plastic (Figure 14).

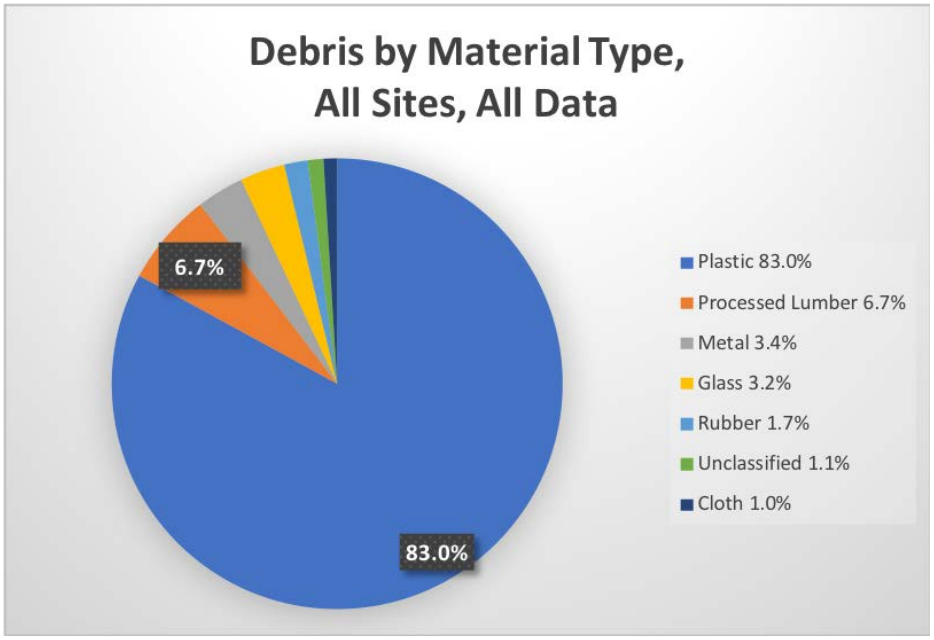


Figure 14. Percentages of aggregate total of debris items by material type attributed to the four beach monitoring sites during the project survey period (April 2014–June 2018).

Plastic debris accounted for more than 85% of all debris on three sites: Fisherman Island NWR (88.2%), Chincoteague NWR (86.3%), and Back Bay NWR (85.1%) (Figure 15). In contrast, Grandview Nature Preserve's debris consisted of 55.1% plastic. Metal and glass pieces, non-nylon rope pieces, as well as processed lumber and cardboard were recorded more frequently

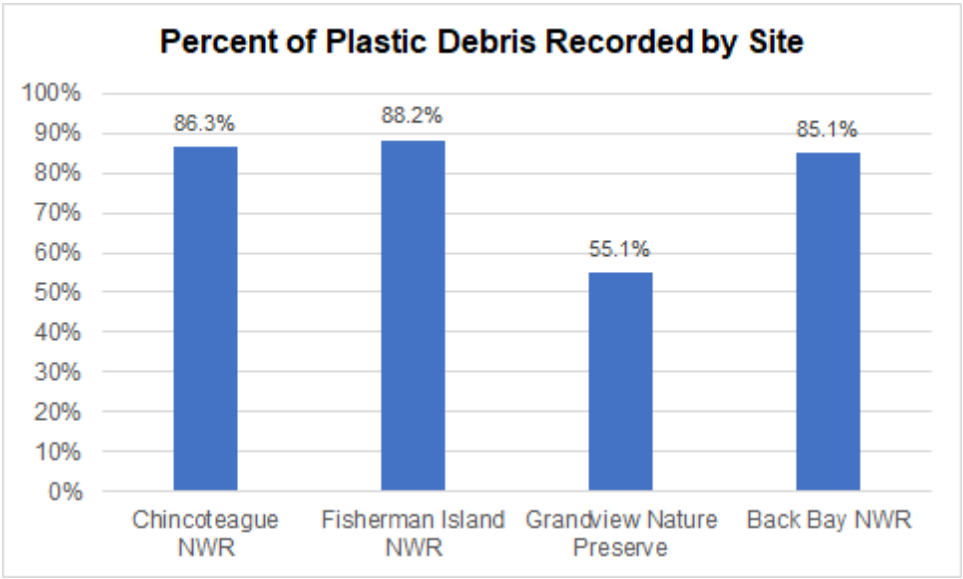


Figure 15. More than 85% of debris on three of the four sites was made of plastic. The exception was Grandview Nature Preserve which had 55.1% of its debris made of plastic.

at the Grandview Nature Preserve location more than any other location. These data suggest that plastic from the ocean is a driver of debris accumulation on ocean-facing beaches.

A total of 11,903 pieces of debris were documented during the Accumulation Surveys, and 3,373 pieces of debris were documented during the Standing-Stock Surveys, for a total of 15,276 items (Table 4). Processed lumber products (including lumber, cardboard, paper and building materials) comprised 6.7% of debris items, followed by metal at 3.4%, glass at 3.2%, rubber at 1.7%, and cloth at 1.0%. Debris that could not be classified under one of these material types accounted for another 1.1% of the items.

Table 4. Total debris items and percentages by material type in Accumulation Surveys, Standing-Stock Surveys, and aggregate for all four beach monitoring sites during the project survey period (April 2014–June 2018).

Material	Accumulation Totals (entire site)	Standing-Stock Totals (20% of the entire site)	Grand total	Percent of Total
Plastic	9,865	2,769	12,634	83.0%
Processed Lumber	809	206	1,015	6.7%
Metal	388	127	515	3.4%
Glass	375	114	489	3.2%
Rubber	197	60	257	1.7%
Unclassified	161	10	171	1.1%
Cloth	108	40	148	1.0%
TOTALS	**11,903**	**3,326**	**15,229**	

Discussion: The finding that 83.0% of all debris recorded on the four Virginia coastal beaches was made of plastic is nearly identical to the Ocean Conservancy's estimate that 84% of all items collected during the International Coastal Cleanup are made up of plastic (Mallos, 2016). It is interesting to note that the processed lumber debris was mostly comprised of processed lumber boards and waxed paper fish boxes or pieces of these boxes.

Debris by Material Type: Comparing the Sites

During this study, 83% of all debris recorded was plastic. However, as mentioned above, debris from Back Bay NWR, Chincoteague NWR, and Fisherman Island NWR consisted of more than 85% plastic while Grandview Nature Preserve's debris only consisted of 55% plastic (Figure 16). Metal and glass pieces, non-nylon rope pieces, as well as processed lumber were recorded more frequently at the Grandview Nature Preserve site when compared to the other monitoring sites. The elevated percentage of rubber material at Chincoteague NWR can be attributed to latex balloons and fragments.

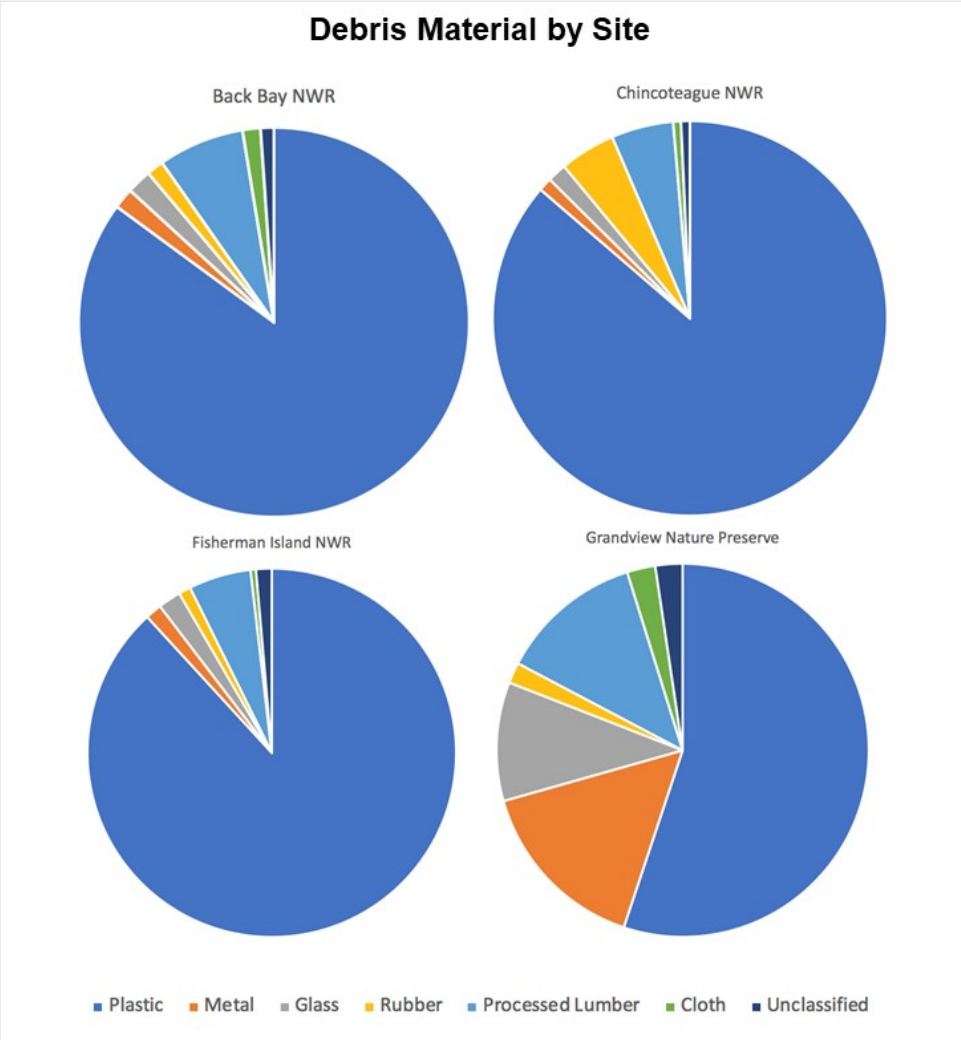


Figure 16. Pie charts representing the percent of debris types for each monitoring site.

Composition of Top 20 Debris Items by Site

The most frequently found debris items for the four monitoring sites are listed in rank order in Table 5. Consumer-related products, including food- and beverage-related items, dominate each list.

Table 5. The most frequently found debris items for the four monitoring sites are listed in rank order.

Back Bay NWR Top 20 Debris Items

Rank	Item	Number of Items Recorded
1	**Bottle/Container Caps**	255
2	**Food Wrappers**	180
3	**Lumber/Building Material**	130
4	**Cigarettes**	100
5	**Balloons, Mylar + Latex**	99
6	**Plastic Beverage Bottles**	89
7	**Plastic Rope/Net**	56
8	**Plastic Bags**	54
9	**Straws**	46
10	**Other Jugs/Containers**	37
11	Paper and Cardboard	35
12	**Cigar Tips**	34
13	**Fishing Lures & Line**	31
14	**Cups, plastic**	20
15	Personal Care Products	15
16	**Aluminum/Tin Cans**	13
17	**Disposable Cigarette Lighters**	11
18	Buoys & Floats	7
19	Glass Beverage Bottles	7
20	Plastic Utensils and Clothing/shoes (TIE)	6

Chincoteague NWR Top 20 Debris Items

Rank	Item	Number of Items Recorded
1	**Balloons Mylar + Latex**	220
2	**Bottle/Container Caps**	186
3	**Plastic Rope/Net**	86
4	**Plastic Beverage Bottles**	86
5	**Straws**	70
6	**Lumber/Building Material**	68
7	**Food Wrappers**	65
8	**Plastic Bags**	49
9	**Other Jugs/Containers**	31
10	**Cups, plastic**	28
11	**Fishing Lures & Line**	19
12	**Cigar Tips**	17
13	**Cigarettes**	15
14	Personal Care Products	11
15	Tires	10
16	**Disposable Cigarette Lighters**	7
17	**Aluminum/Tin Cans**	6
18	Paper and Cardboard	6
19	Clothing & Shoes	4
20	Floats/Buoys, glass beverage bottle, paper bags, rope/net non-nylon (TIE)	2

Bold= items that are on all four "top 20" lists

Green = consumer-related products

Yellow = smoking-related products

Blue = fishing-related products

Orange = balloons

Fisherman Island NWR Top 20 Debris Items

Rank	Item	Number of Items Recorded
1	**Bottle/Container Caps**	405
2	**Plastic Rope/Net**	384
3	**Balloons Mylar + Latex**	283
4	**Plastic Beverage Bottles**	280
5	**Food Wrappers**	257
6	**Lumber/Building Material**	256
7	**Cigarettes**	210
8	**Cups, plastic**	139
9	**Other Jugs/Containers**	119
10	Paper and Cardboard	97
11	**Plastic Bags**	96
12	**Fishing Lures & Line**	66
13	**Straws**	65
14	**Aluminum/Tin Cans**	63
15	Buoys & Floats	60
16	**Cigar Tips**	44
17	Glass Beverage Bottles	35
18	**Disposable Cigarette Lighters**	29
19	Personal Care Products	25
20	Rope/Net Pieces (non-nylon)	23

Grandview Nature Preserve Top 20 Debris Items

Rank	Item	Number of Items Recorded
1	**Lumber/Building Material**	135
2	**Aluminum/Tin Cans**	118
3	Paper and Cardboard	94
4	**Bottle/Container Caps**	88
5	**Cigarettes**	87
6	**Plastic Beverage Bottles**	81
7	**Balloons Mylar + Latex**	58
8	**Food Wrappers**	56
9	**Plastic Bags**	47
10	**Plastic Rope/Net**	47
11	Rope/Net Pieces (non-nylon)	36
12	**Fishing Lures & Line**	31
13	**Other Jugs/Containers**	19
14	**Straws**	18
15	**Cigar Tips**	11
16	**Cups, plastic**	11
17	Cardboard Cartons	8
18	Clothing & Shoes	7
19	**Disposable Cigarette Lighters**	6
20	Rubber Gloves	5

Bold= items that are on all four "top 20" lists

Green = consumer-related products

Yellow = smoking-related products

Blue = fishing-related products

Orange = balloons

The majority of the most frequently found items on the four monitoring sites were food- and beverage-related, including bottle/container caps, food wrappers, plastic beverage bottles, cups, aluminum/tin cans, and straws. All three smoking-related items (cigarettes, cigar tips and disposable lighters) made the top 20 list for all four sites. Balloons were the #1 most frequently recorded debris type on Chincoteague NWR, #3 on Fisherman Island, #5 on Back Bay NWR, and #7 on Grandview Nature Preserve. Smoking-related litter, bottle caps, balloons, and other debris items are discussed in more detail later in this report.

Plastic balloons (also known as "foil" or "Mylar") and latex balloons were aggregated in the above tables. For the first several years of this research, the NOAA data sheet had just one category for balloons in the plastic category. In the MDMAP revised data sheet, starting in March 2016, balloons were listed under both plastic and rubber, allowing for future documentation and analysis of different types of balloons.

Bottle/container caps were the most frequent debris item on Back Bay NWR and Fisherman Island NWR. They were in second place on Chincoteague NWR and came in #4 on Grandview Nature Preserve. When added to the plastic beverage bottles category, which also finished in the top ten at all four project survey sites, it is clear that single-use plastic beverage containers are one of the most significant components of marine debris in Virginia. When added to glass beverage bottles and aluminum/tin cans, which also are components of the top twenty for every monitoring site, it is clear that beverage containers as a group are one of the most significant contributors to marine debris in Virginia.

Figure 17. Several aluminum bottles and cans can be seen in the detritus at Grandview Nature Preserve.

It is interesting that aluminum/tin cans ranked #2 at Grandview Nature Preserve, though were not in the top ten at any of the other sites. Twenty-five (21%) of the 118 cans on Grandview Nature Preserve were recorded during one Accumulation Survey in December 2014 (Figure 17). Throughout the survey period, the survey teams observed that many of the cans were old and had likely floated in so may have been fishing/boating related. Grandview Nature Preserve was also unique in that lumber/building materials as well as paper/cardboard ranked higher than the other sites. There were also higher percentages of metal and glass debris at Grandview Nature Preserve as compared to other sites. This might be due to the location of Grandview Nature Preserve, as it is closer to a population center than the other monitoring sites (see Table 1), or the fact that Grandview Nature Preserve is located wholly within the Chesapeake Bay, while the other three monitoring sites were either ocean facing (Back Bay NWR and Chincoteague NWR) or at the mouth of the Chesapeake Bay (Fisherman Island NWR).

Comparing "Top 20" to Data from the International Coastal Cleanup in Virginia

Since 1995, thousands of volunteers have participated in the International Coastal Cleanup in Virginia, during which they removed debris items while also filling out data sheets on the types and quantities of debris they found. In Table 6, the 20 most frequently found debris items from a 20-year period (1995-2014) are shown. The items listed on Ocean Conservancy's ICC data

sheets are not exactly the same as the items on the NOAA MDMAP data sheet. Because of these differences in the data sheets, direct comparisons are not possible. Still, many similarities in the data sets can be seen.

Table 6. The 20 most frequently found debris items recorded by volunteers in the International Coastal Cleanup in Virginia from a 20-year period (1995-2014). Item groups in bold indicate that they are also listed in the 20 most frequently found debris items during the current project survey period (April 2014–June 2018).

Rank	Items
1	**Cigarettes/Cigarette Filters**
2	**Beverage Bottles (Plastic) 2 liters or less**
3	**Food Wrappers/Containers**
4	**Bags**
5	**Beverage Cans**
6	Beverage Bottles (Glass)
7	**Cups, Plates, Forks, Knives, Spoons**
8	**Caps, Lids**
9	**Straws, Stirrers**
10	**Building Materials**
11	Tires
12	**Balloons**
13	Clothing, Shoes
14	Tobacco Packaging/Wrappers
15	Toys
16	**Fishing Line**
17	**Rope**
18	**Cigar Tips**
19	Bait Containers/Packaging
20	**Cigarette Lighters**

Comparing the ICC data with data from this project's four monitoring sites, it is easy to see the similarities: cigarette debris, plastic bottles, food wrappers, bags, cans, cups, caps, straws, balloons, fishing line, rope and building materials are all in the top twenty items in each data set. The ICC cleanups occur on inland rivers as well as coastal beaches, therefore it is likely that fewer water-based sources of debris are found in the aggregate data from ICC cleanup events.

Land-based vs. Water-based Sources of Debris

In most discussions of marine debris, the sources are divided into those that likely come from land-based activities vs. water-based sources (also referred to as ocean-based). According to the NMDMP study, 60% to 80% of marine debris originates from land-based sources (Sheavly, 2010).

The circumstances and behaviors that produce land-based sources include poor solid waste management practices: littering in urban areas and on road sides; inadequately covered trucks; overflowing trash receptacles; fireworks; helium-filled balloon releases; items left by beach visitors; smoking-related littering; and poor waste management on industrial facilities or in landfills. Examples of land-based sources are: cigarettes; cigarette lighters; cigar tips; food wrappers; plastic beverage bottles; other jugs/containers; bottle/container caps; 6-pack rings; bags; cups; plastic utensils; straws; balloons; and personal care products. Littered items are transported to the marine environment primarily via wind and stormwater runoff into rivers, streams, and bays.

Water-based sources include trash that enters the water from: commercial fishing boats; shoreline and coastal fishing; aquaculture; cruise ships; cargo ships; recreational boats; military fleets; research vessels; and offshore installations such as wind farm and oil and gas platforms. Examples include: fishing nets; crab and fish pots; buoys and floats; fishing line and lures; aquaculture netting; plastic rope; and boat supplies, etc. Some water-based debris of concern in Virginia are crab pots and clam netting that is used to protect young clams from predation in coastal aquaculture operations.

Figure 18. Aluminum cans and a plastic bottle among beach detritus of horseshoe crab molts and red beard sponges at Grandview Nature Preserve. It is difficult to determine if debris originated from land- or water-based sources.

Some items could potentially be from either source – for example, a plastic bottle could make its way to a beach after being littered on land or could have been tossed into the water by a boater. Debris from all types of materials can derive from land-based or water-based sources (Figure 18).

For the following analysis, debris counts from land-based versus water-based sources were compared for each monitoring site (Figure 19 and Table 7). Note that there are assumptions on what signifies land-based vs. water-based debris

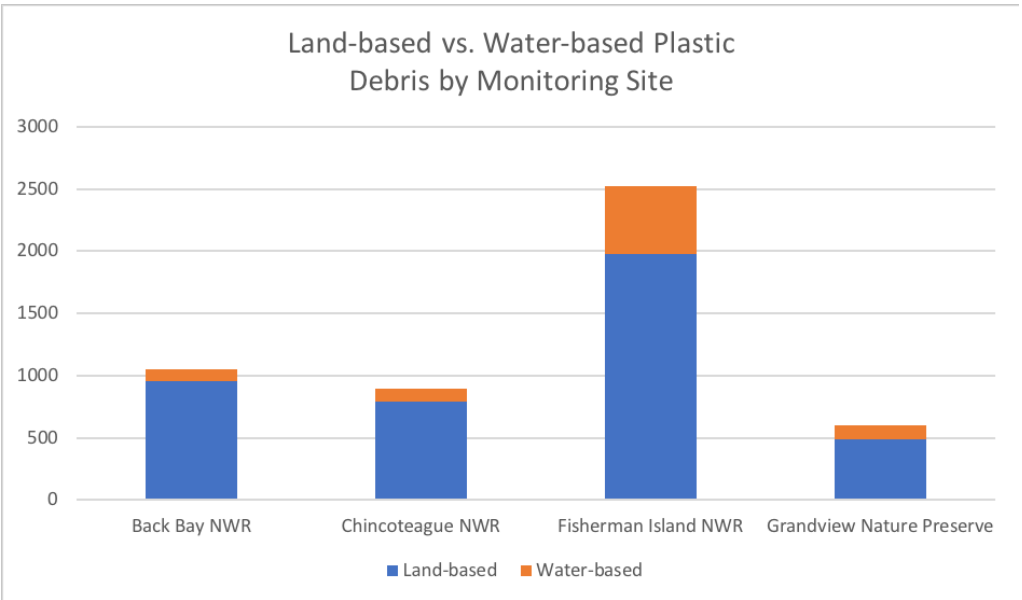


Figure 19. Total plastic debris counts for land-based vs. water-based debris for all monitoring sites. Note that there are assumptions on what signifies land-based vs water-based debris.

Table 7. Total debris items from land-based vs. water-based sources at four beach monitoring sites during the project survey period (April 2014–June 2018).

Monitoring Site	**Land-based Debris** (number of items)	**Water-based Debris** (number of items)	**Total per Site**	**Percent of total that was water-based**
Chincoteague NWR	789	109	898	12.1
Fisherman Island NWR	1,976	545	2,521	21.6
Back Bay NWR	952	97	1,049	9.2
Grandview Nature Preserve	488	115	603	19.1
Totals	4,205	866	5,071	

Survey teams recorded considerably more land-based vs. water-based debris at all four monitoring sites. The site with the most water-based debris was Fisherman Island NWR, where 21.6% of the total debris count was from water-based sources. Water-based debris represented 9.2% of the total count at Back Bay NWR, 12.1% at Chincoteague NWR and 19.1% at Grandview Nature Preserve. Grandview Nature Preserve is located in close proximity to a river/inlet as well as a marina. In addition, both Grandview Nature Preserve and Fisherman Island NWR are located in the lower Chesapeake Bay, an area of very active recreational and commercial fishing and boating activity. These factors may explain the higher percentages of water-based debris at these two sites.

Data for water-based debris are based on data entered on the data sheets during monitoring from 2014–2018, and include plastic ropes and nets; buoys and floats; fishing lures and line; non-nylon rope and net pieces. In addition, monitors noted crab baskets, crab traps, and clam

netting (plastic nets that cover clam aquaculture beds in coastal waters)—items not on the NOAA data sheet.

Plastic Debris Items: Comparing the Sites

As seen in Figure 20, the debris items made of plastic were dominated by bottle/container lids, "other plastic items," and food wrappers. Cigarette butts accounted for 12% of the debris at Grandview Nature Preserve, but only 2% at Chincoteague NWR. This is likely due to the proximity of each site to population centers and thus the ability of people to be on the beach smoking at Grandview Nature Preserve vs. Chincoteague NWR. Grandview Nature Preserve was the only site with a nearby river inlet (Back River), so it is possible that some of the cigarette litter originated in stormwater runoff. Note that the filters on cigarette butts are made from cellulose acetate, thus are included in this data set of plastic debris items.

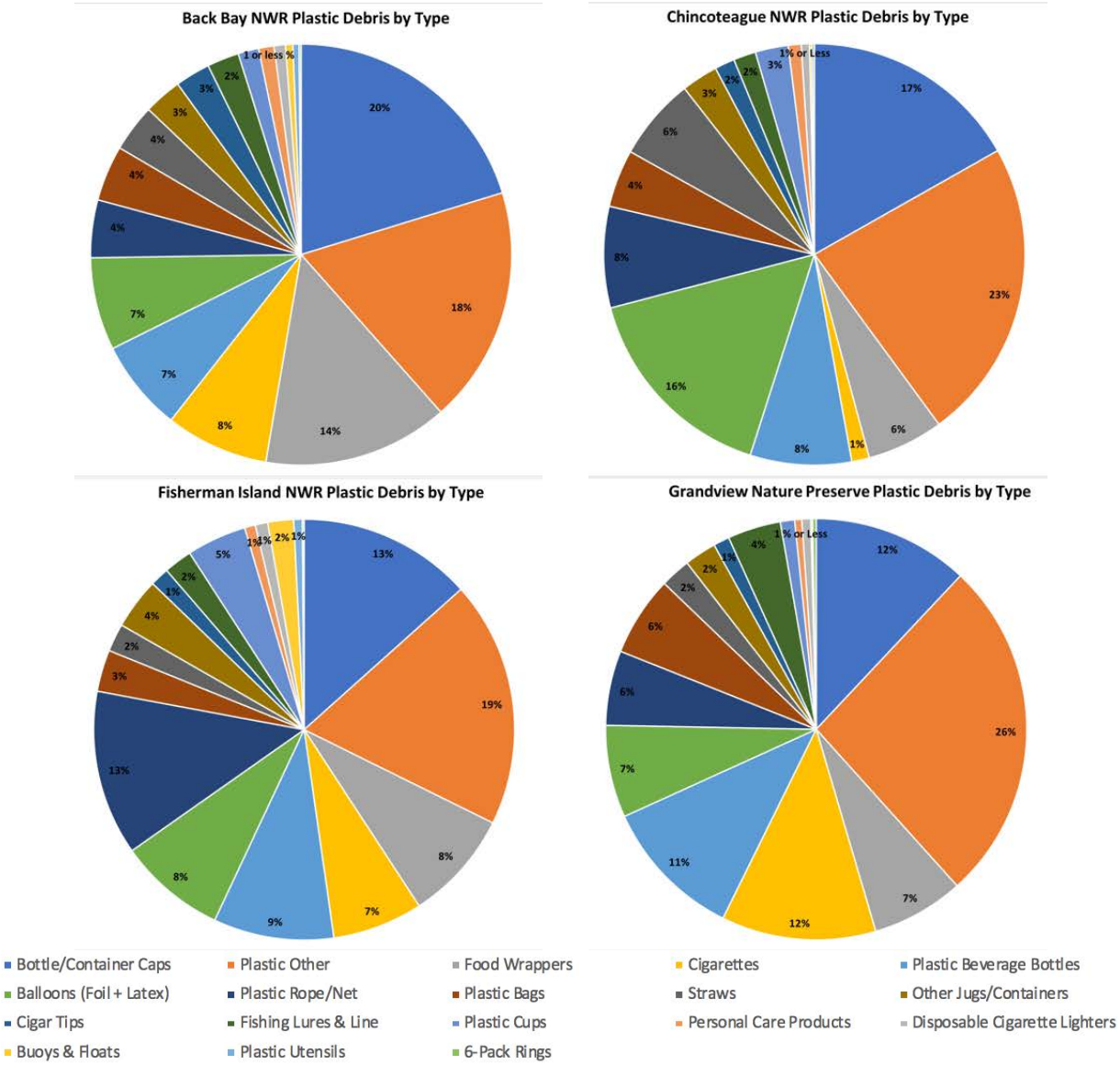


Figure 20. Percentages of total plastic debris items by type at four beach monitoring sites during the project survey period (April 2014–June 2018).

Accumulation Surveys

Total Debris Items by Type

The previous presentations of data in this report were based on aggregating all data from each monitoring site for both the Accumulation Surveys and the Standing-Stock Surveys. The following sections will look at the data from the Accumulation Surveys separately from the Standing-Stock Surveys.

As seen in Table 8, a total of 11,903 debris items were recorded during the Accumulation Surveys. Fisherman Island NWR accounted for the majority of the debris items (n=6,744). For each of the four monitoring sites, debris made of plastic greatly exceeded the other types of materials. All debris items were recorded and removed from the Accumulation Survey areas during each monthly survey.

Table 8. Total debris items by type from Accumulation Surveys at four beach monitoring sites during the project survey period (April 2014–June 2018).

	Plastic	Metal	Glass	Rubber	Processed Lumber	Cloth	Unclassified	Totals
Chincoteague NWR	1,276	15	27	73	72	10	11	1,484
Fisherman Island NWR	5,957	91	138	67	364	27	100	6,744
Back Bay NWR	1,719	32	31	29	158	23	21	2,013
Grand View Nature Preserve	913	250	179	28	215	48	29	1,662
Totals	9,865	388	375	197	809	108	161	11,903

On the following pages, figures show presentations of data collected in the Accumulation Surveys, including:

- Total debris by site
- Total debris by material type
- Plastic debris grouped by user category

The data presented in these figures shows the total number of debris items collected within the 100-meter survey area per survey day for the four beach monitoring sites during the project survey period (April 2014 through June 2018).

All charts were prepared using templates found in the NOAA Marine Debris Program's Marine Debris Monitoring and Assessment Project Toolbox. (https://marinedebris.noaa.gov/research/monitoring-toolbox)

Total Debris by Site

The following four charts (Figures 21–24) show the total debris counts for the **Accumulation Surveys** per monitoring site per survey day during the project survey period (April 2014 through June 2018).

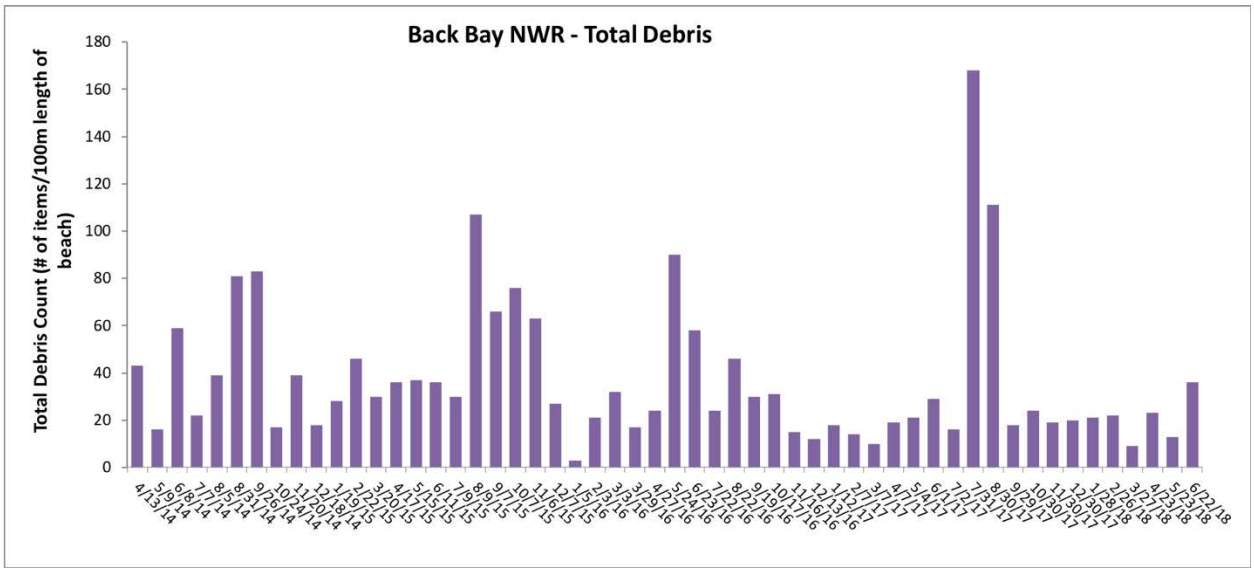


Figure 21: Total debris counts per 100m length of beach per monthly Accumulation Survey on Back Bay National Wildlife Refuge.

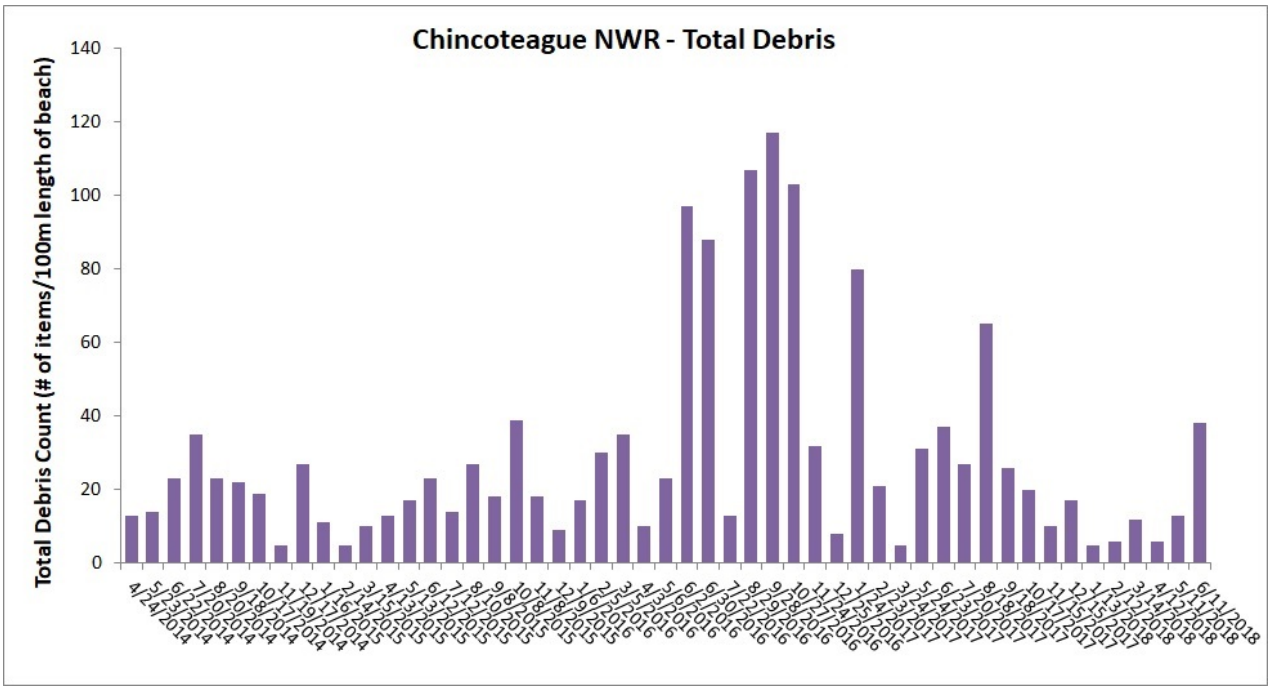


Figure 22: Total debris counts per 100m length of beach per monthly Accumulation Survey on Chincoteague National Wildlife Refuge.

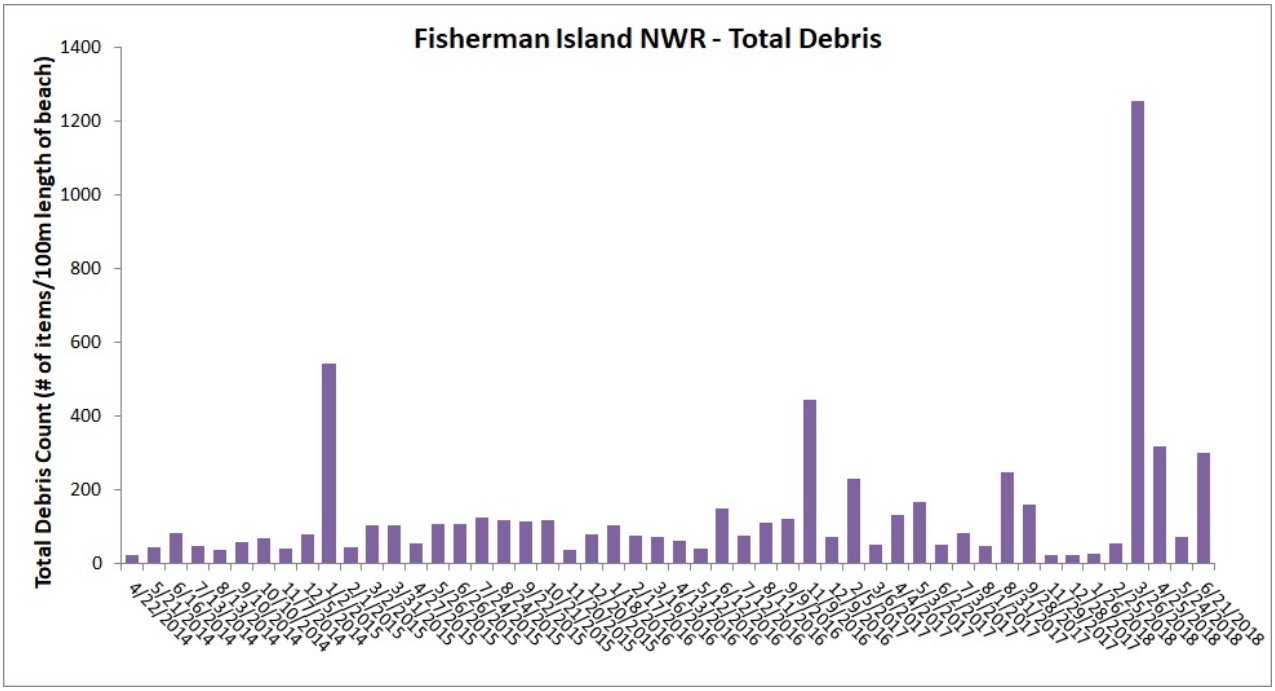


Figure 23: Total debris counts per 100m length of beach per monthly Accumulation Survey on Fisherman Island National Wildlife Refuge. Note: during the Accumulation Survey in March 2018, 1071 pieces of foamed plastic were recorded.

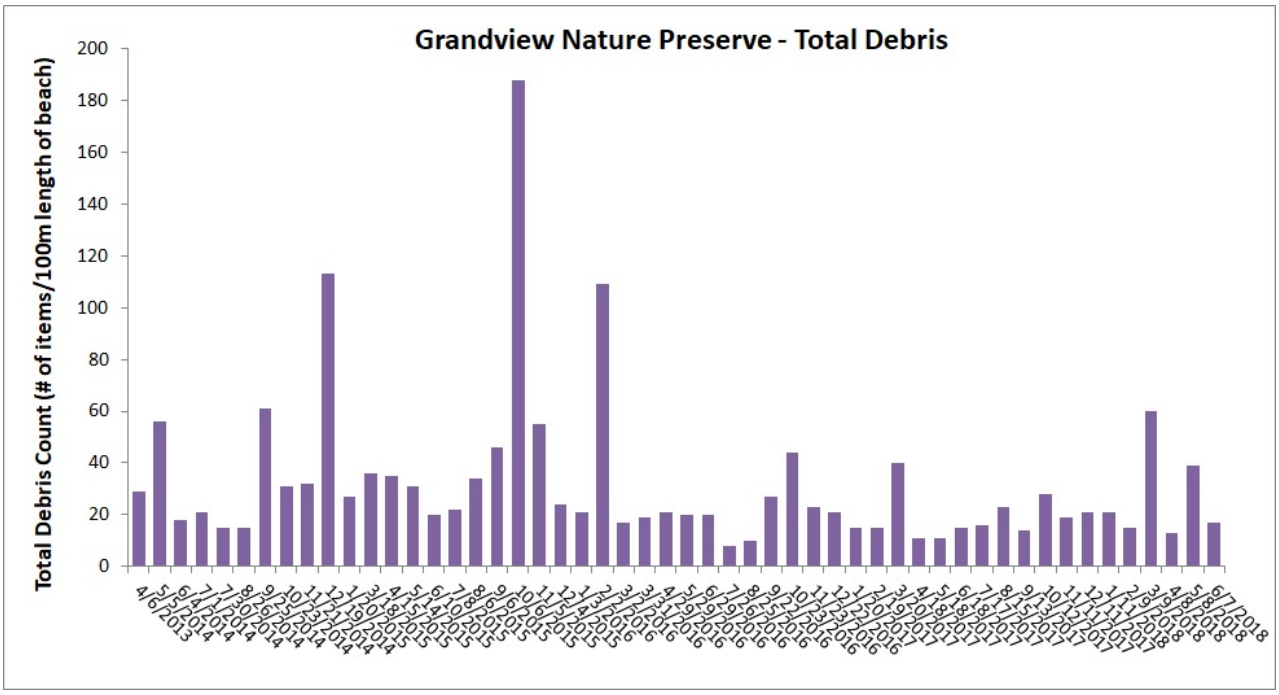


Figure 24: Total debris counts per 100m length of beach per monthly Accumulation Survey on Grandview Nature Preserve.

Observation: The survey team noted that on particularly windy days, the amount of debris recorded seemed lower than usual. This may be due to winds blowing debris back into the water or covering up debris with sand. When looking at the peaks in debris counts compared to recent weather events, some of the elevated counts may be attributed to storms, however, others cannot. Several factors may be able to explain this: wave action, wind direction, and speed as well as tidal fluctuations.

Total Debris by Material Type

The following figures display the breakdown of debris items according to material type per monitoring site per survey day during the project survey period (April 2014 through June 2018) based on data collected in the **Accumulation Surveys** (Figures 25-28). Note that the relative abundances of different material types varied from month to month, but that the predominant material type found on each monitoring site was plastic. Debris counts do not take into account the width of the beach surveyed.

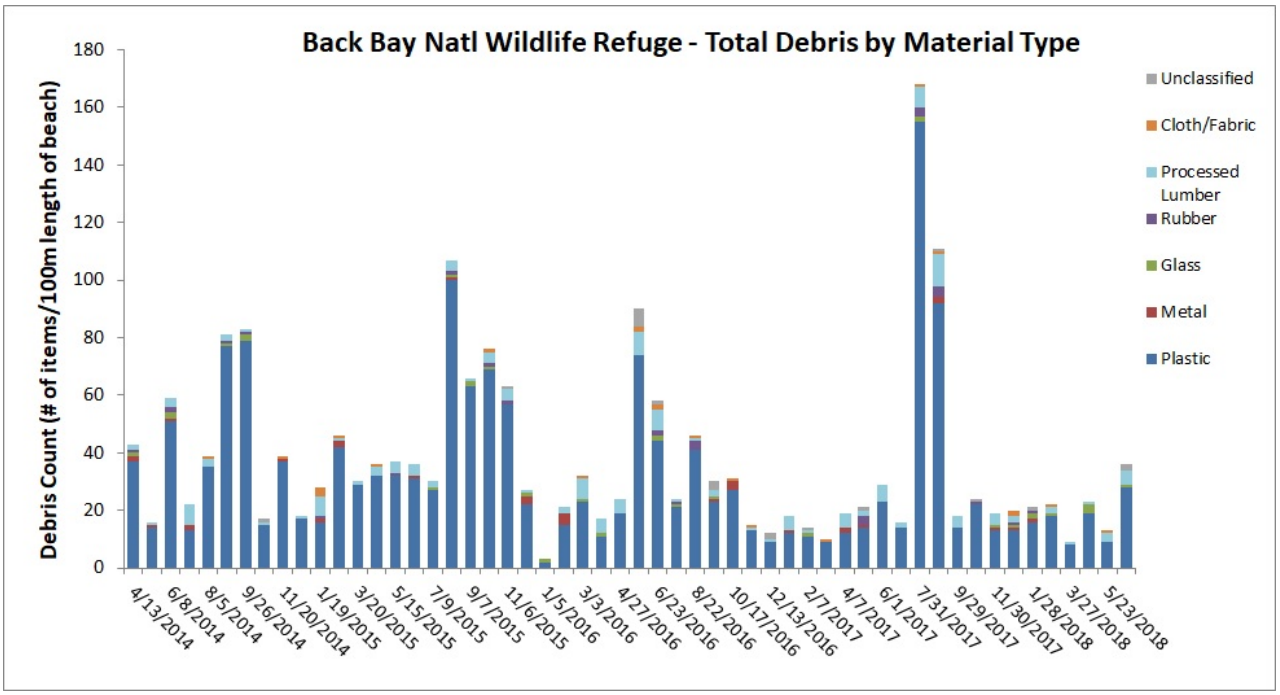


Figure 25: Total debris counts per 100m length of beach by material type per monthly Accumulation Survey on Back Bay National Wildlife Refuge.

Bar Graph showing total debris by Material over time on Back Bay NWR

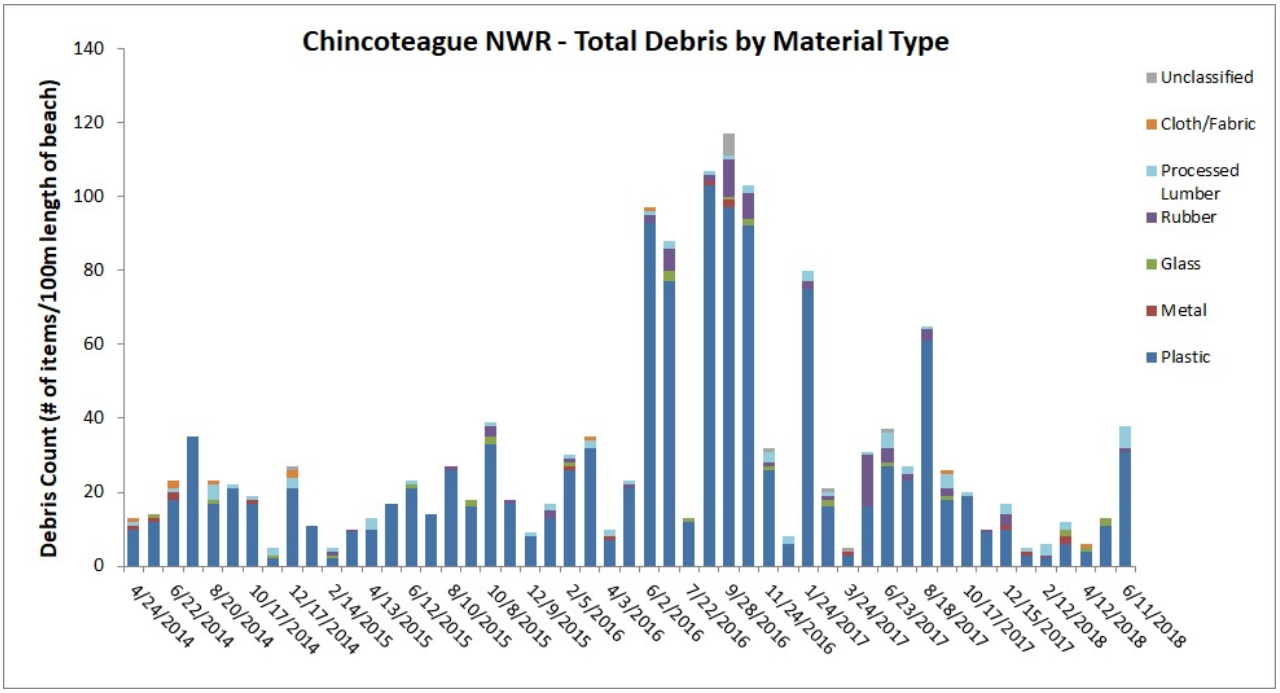


Figure 26: Total debris counts per 100m length of beach by material type per monthly Accumulation Survey on Chincoteague National Wildlife Refuge.

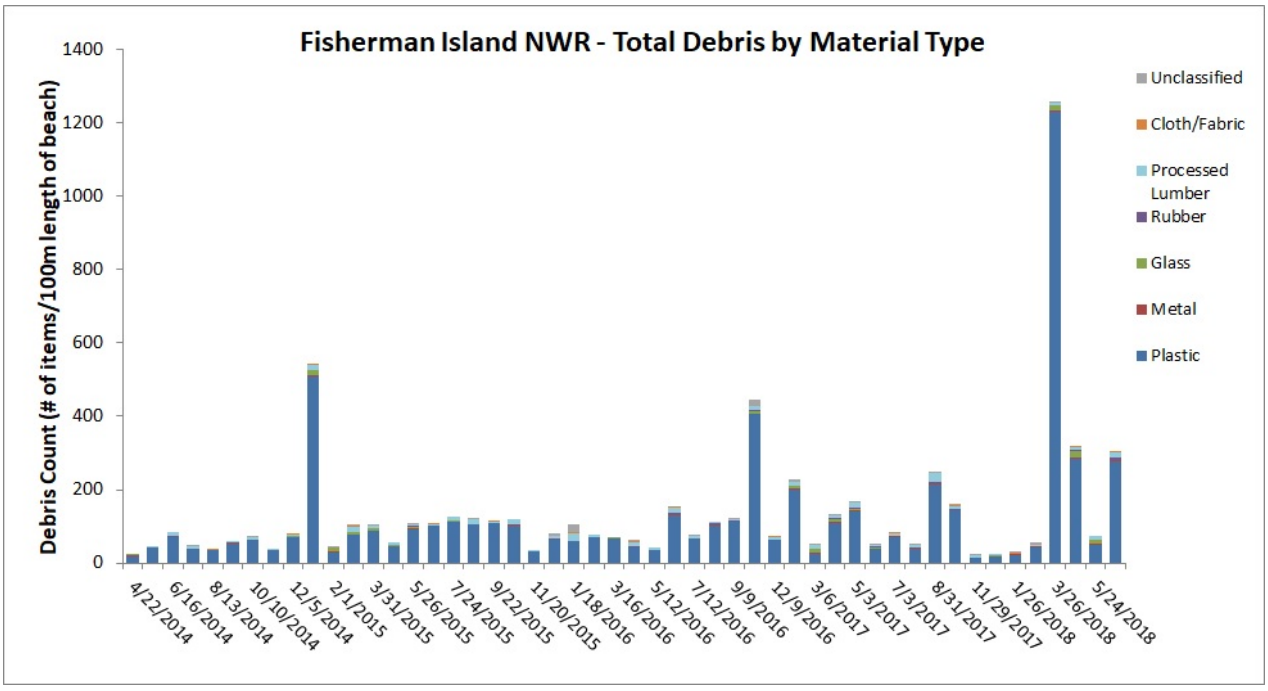


Figure 27. Total debris counts per 100m length of beach by material type per monthly Accumulation Survey on Fisherman Island National Wildlife Refuge.

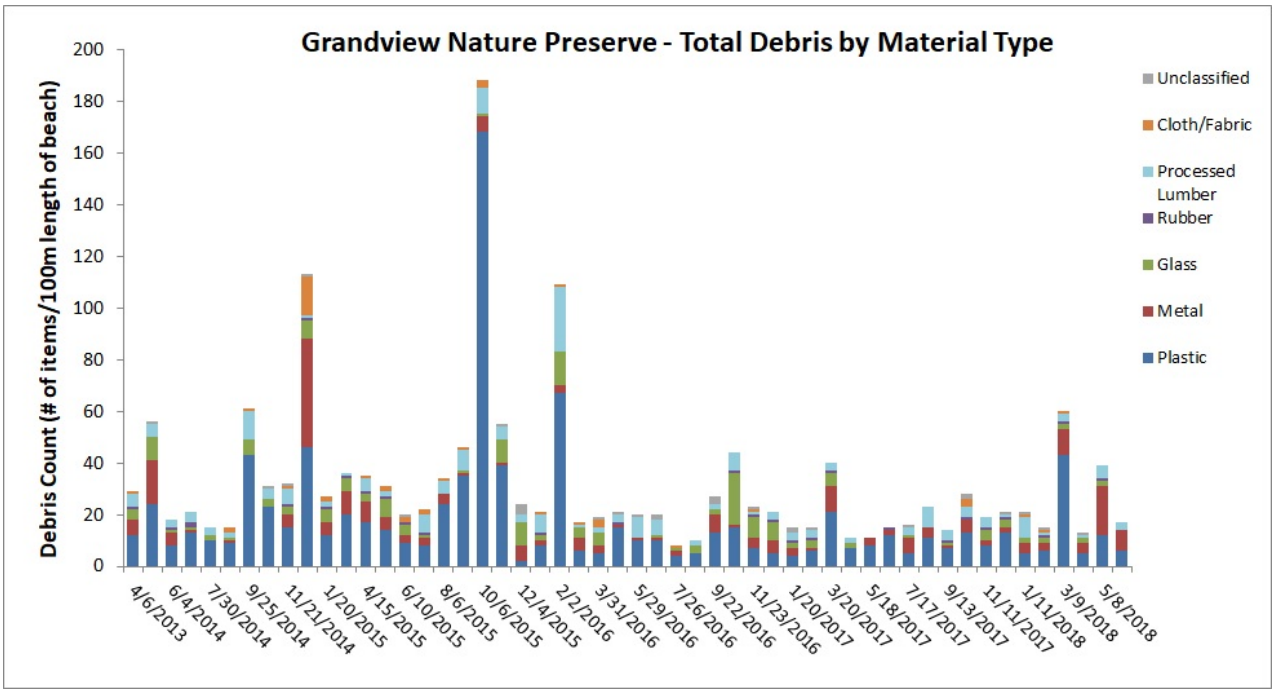


Figure 28. Total debris counts per 100m length of beach by material type per monthly Accumulation Survey on Grandview Nature Preserve.

Plastic Debris Grouped by User Category

Figures 29 to 32 present the plastic debris counts per 100-meter Accumulation Survey area per survey day for the four monitoring sites. The items are grouped based on user categories: consumer products, smoking products >2.5 cm, and fishing-related products. Consumer products include: food wrappers; plastic beverage bottles; other jugs/containers; bottle/container caps; 6-pack rings; bags; cups; plastic utensils; straws; balloons; and personal care products. Smoking Products >2.5 cm include: cigar tips; cigarettes; and disposable cigarette lighters. Fishing-related products include: plastic rope/net; buoys & floats; and fishing lures & line. Note that the filters on cigarette butts are made from cellulose acetate, thus are included in this data set of plastic items.

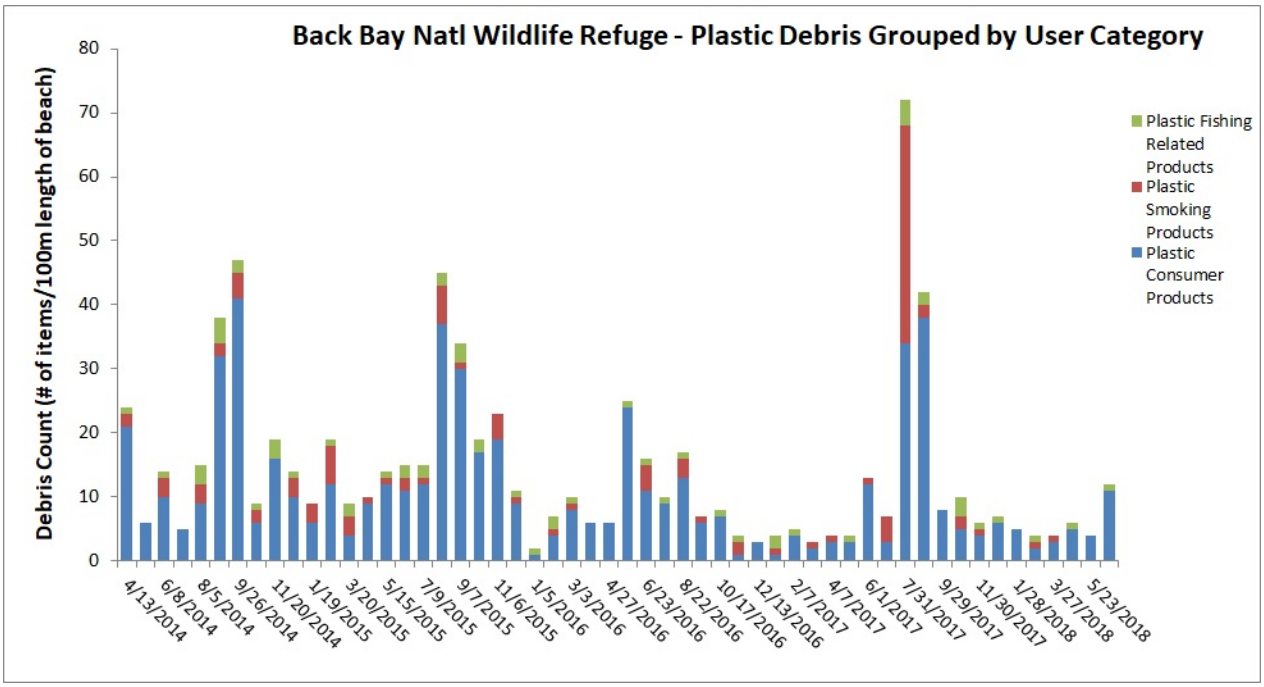


Figure 29. Plastic debris counts by user category per 100m length of beach per monthly Accumulation Survey on Back Bay National Wildlife Refuge.

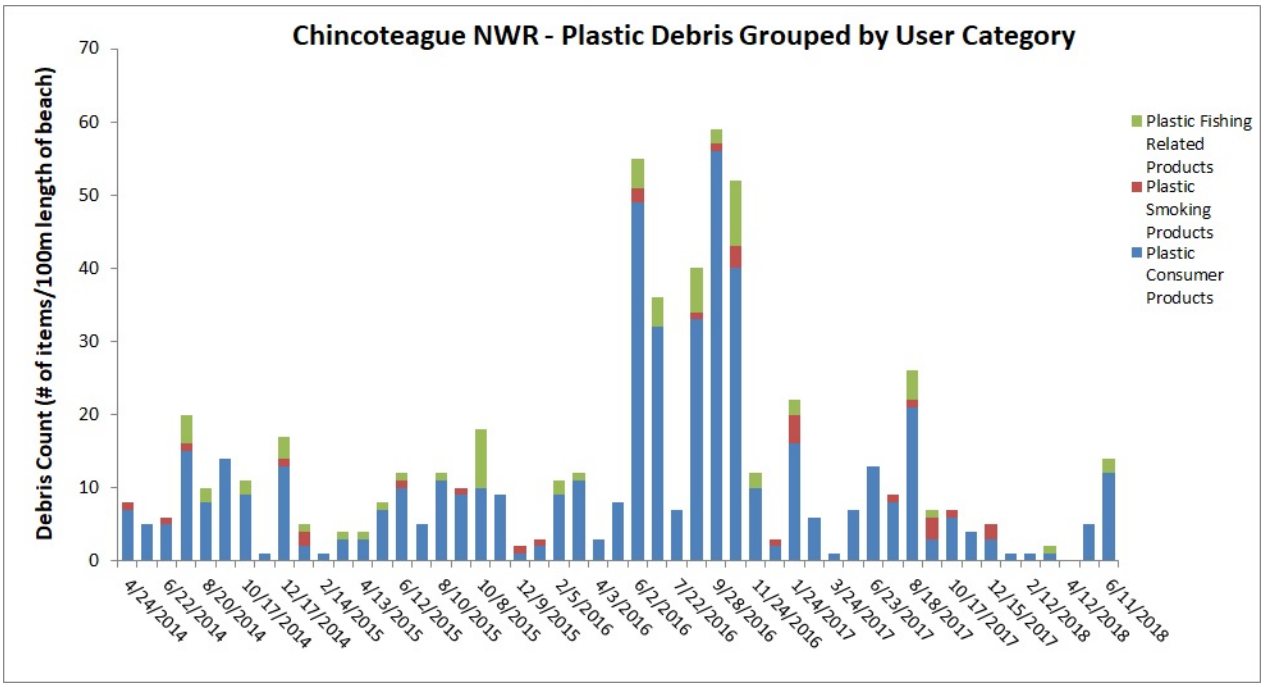


Figure 30. Plastic debris counts by user category per 100m length of beach per monthly Accumulation Survey on Chincoteague National Wildlife Refuge.

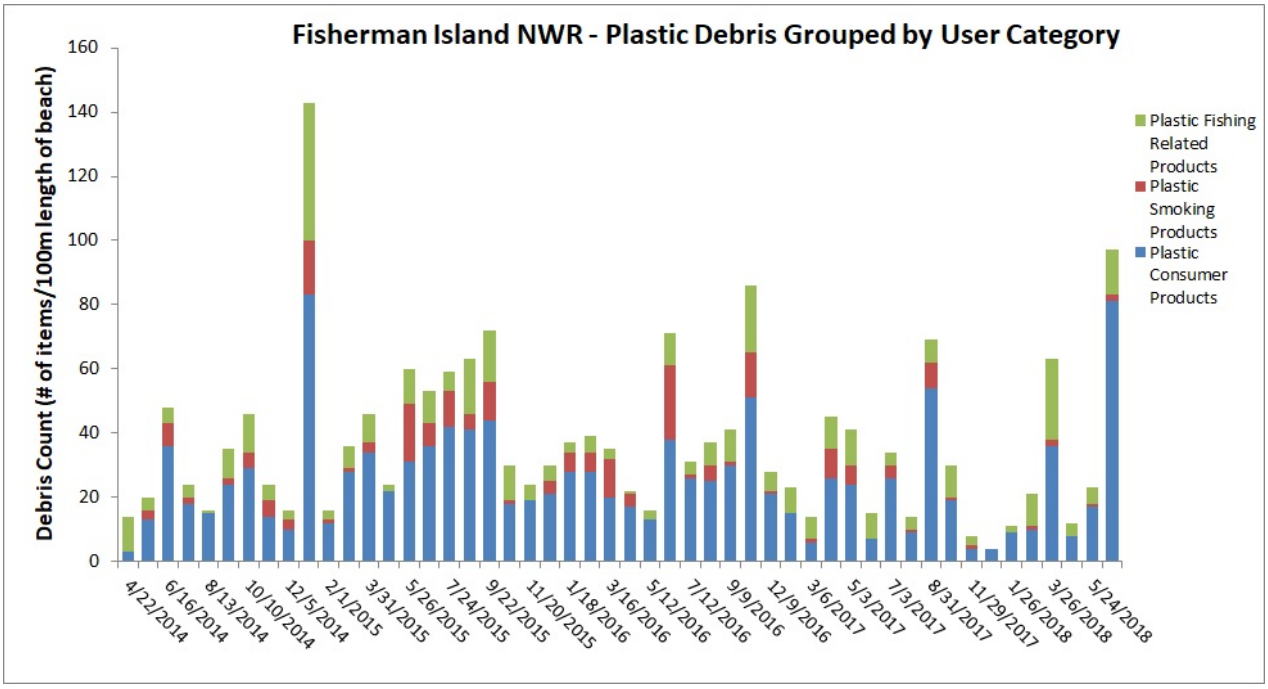


Figure 31. Plastic debris counts by user category per 100m length of beach per monthly Accumulation Survey on Fisherman Island National Wildlife Refuge.

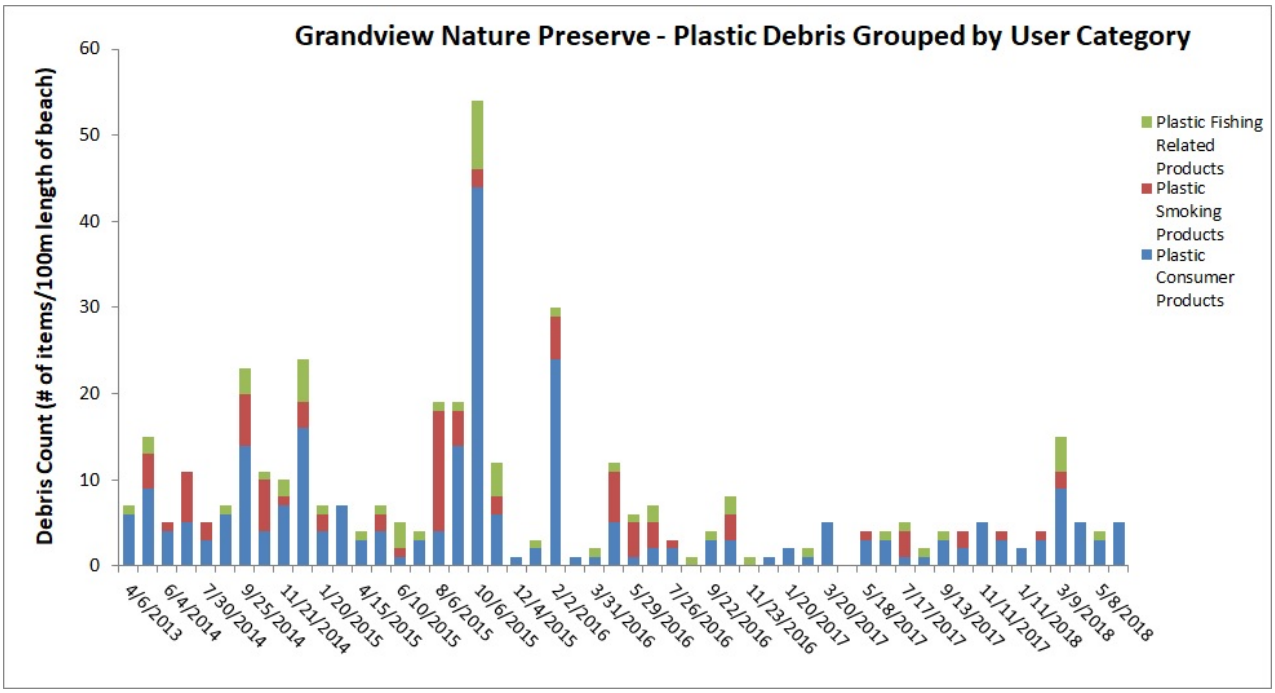


Figure 32: Plastic debris counts by user category per 100m length of beach per monthly Accumulation Survey on Grandview Nature Preserve.

Volunteers search for debris during an Accumulation Survey at Back Bay NWR.

Standing-Stock Surveys

Total Debris Items by Type

This section presents data from the Standing-Stock Surveys. Standing-Stock Surveys are used to determine debris density (number of items per square meter). All debris items greater than or equal to 1 inch (2.5cm) within a survey area were recorded, but not removed from the survey area.

As seen in Table 9, a total of 3,326 debris items were recorded during the Standing-Stock Surveys. Fisherman Island NWR accounted for the majority of the debris items (n=1,632). For each of the four monitoring sites, debris made of plastic greatly exceeded the other types of materials.

Table 9. Total debris items by type from Standing-Stock Surveys at four beach monitoring sites during the project survey period (April 2014–June 2018).

	Plastic	Metal	Glass	Rubber	Processed Lumber	Cloth	Unclassified	Totals
Chincoteague NWR	475	6	6	20	27	2	2	538
Fisherman Island NWR	1,450	28	31	22	86	12	3	1,632
Back Bay NWR	536	13	25	8	35	16	1	634
Grandview Nature Preserve	308	80	52	10	58	10	4	522
Totals	2,769	127	114	60	206	40	10	3,326

On the following pages, figures show presentations of data collected in the Standing-Stock Surveys, including:

- Total debris by sites
- Total debris by material type
- Plastic debris grouped by user category

The data presented in these figures shows the total number of debris items collected within the randomly selected 5 meter transects (4 each per survey) per survey day for the four beach monitoring sites during the project survey period (April 2014 through June 2018). Debris items recorded during the Standing-Stock Surveys were not removed from the survey areas per the NOAA protocol.

All charts were prepared using templates found in the NOAA Marine Debris Program's Marine Debris Monitoring and Assessment Project Toolbox. (https://marinedebris.noaa.gov/research/monitoring-toolbox)

Total Debris by Site

The following four charts (Figures 33–36) show the total debris counts for the Standing-Stock Surveys per monitoring site per survey day during the project survey period (April 2014 through June 2018).

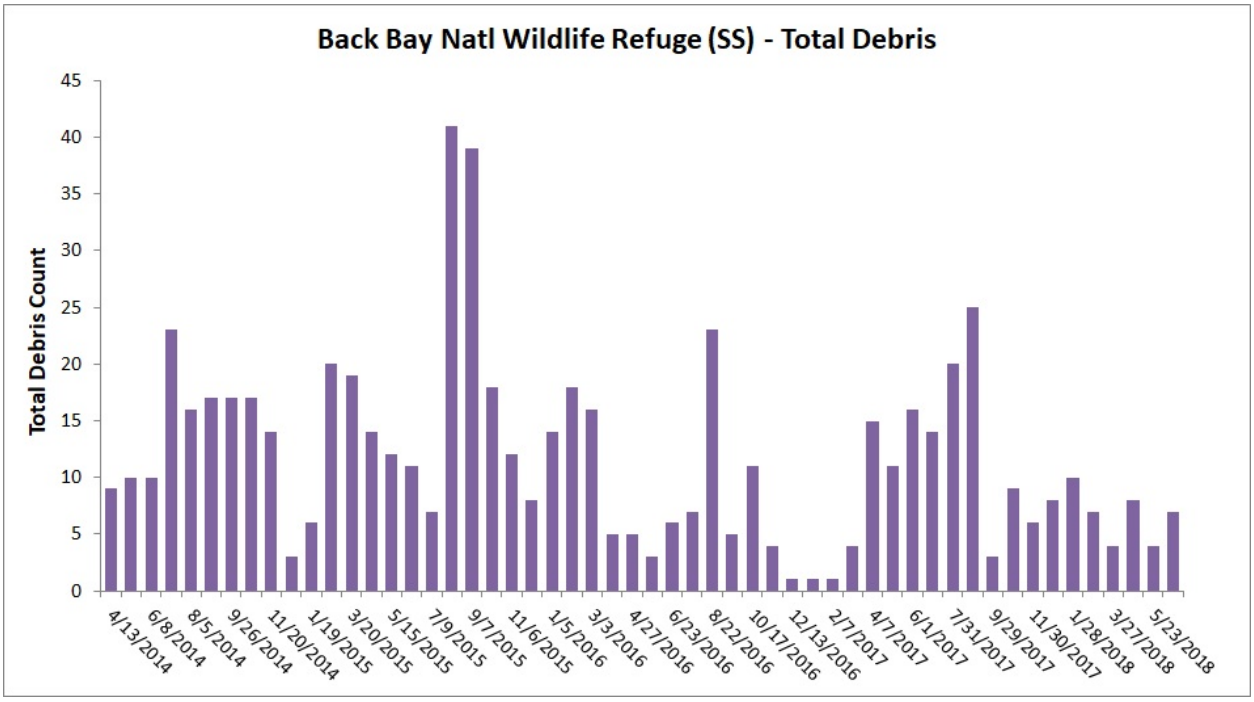


Figure 33. Total debris counts per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge.

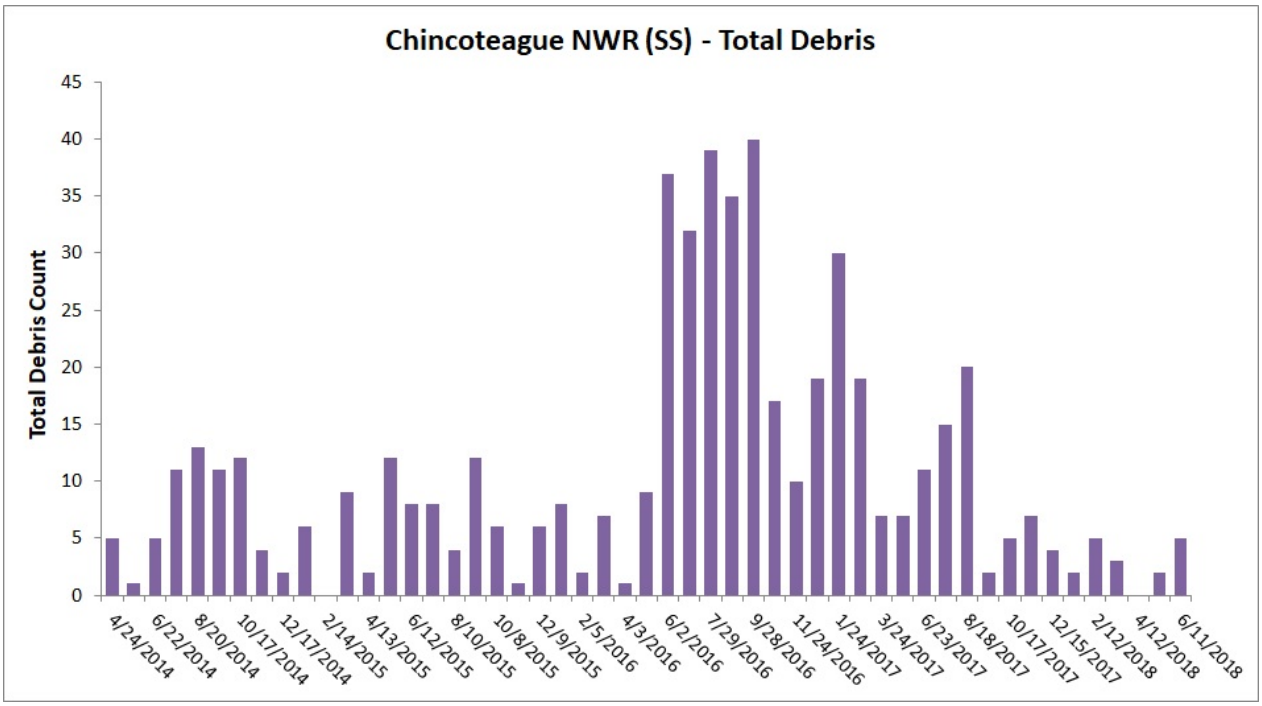


Figure 34. Total debris counts per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge.

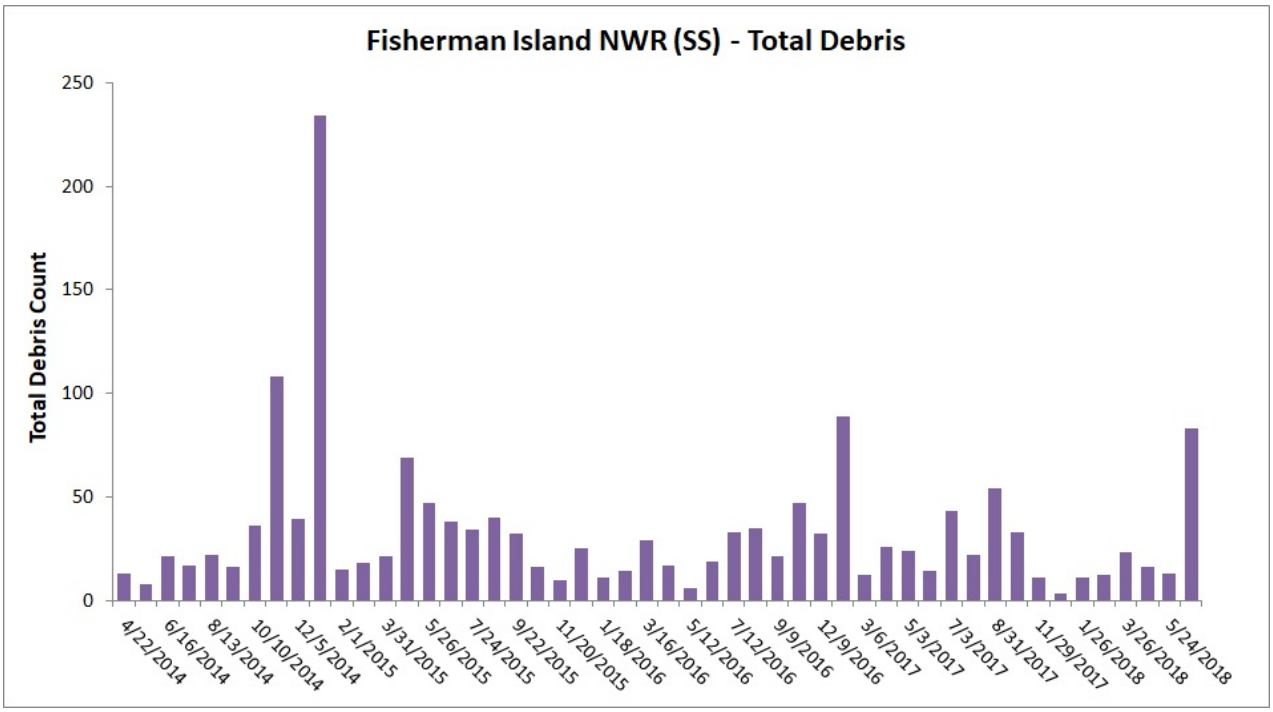


Figure 35. Total debris counts per monthly Standing-Stock Survey on Fisherman Island National Wildlife Refuge. Note: there was no peak for the March 2018 survey as seen during the Accumulation Survey for the same date.

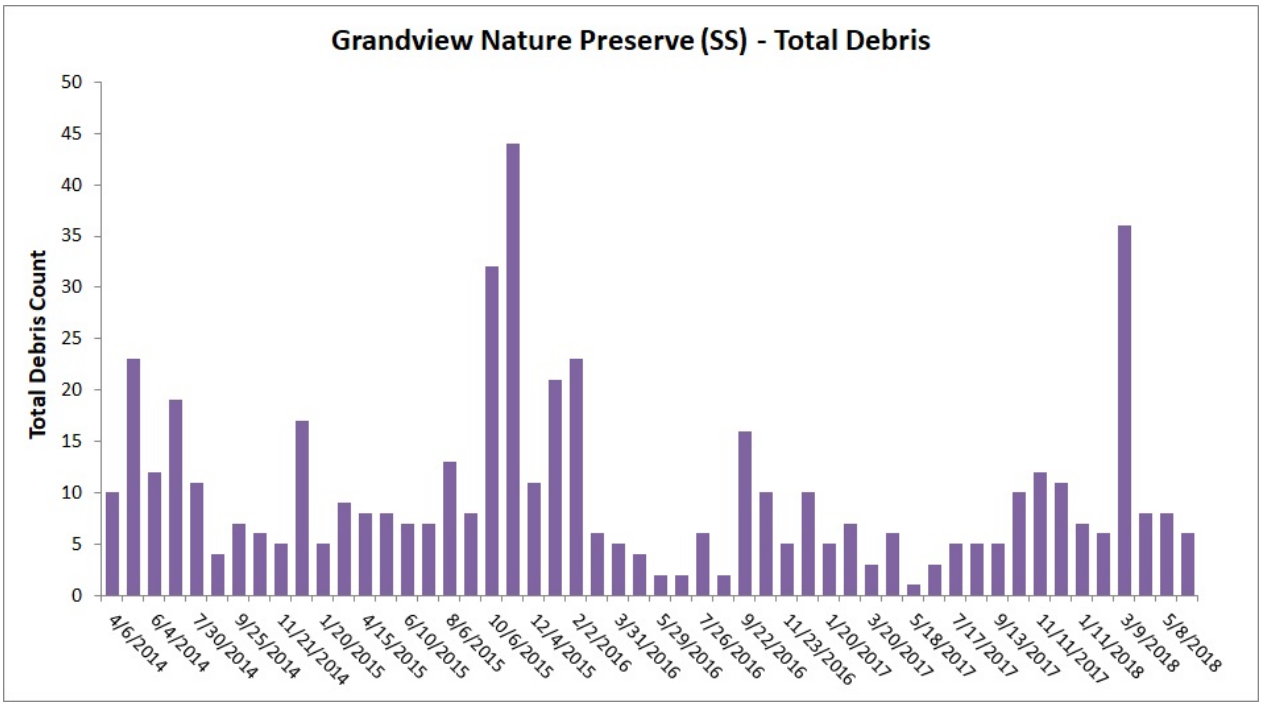


Figure 36. Total debris counts per monthly Standing-Stock Survey on Grandview Nature Preserve.

Total Debris by Material Type

The following figures display the breakdown of debris items according to material type per monitoring site per Standing Stock-Survey during the project survey period (April 2014 through June 2018) (Figures 37-40). Note that the relative abundances of different material types varied from month to month, but that the predominant material type found on each monitoring site was plastic. Debris counts do not take into account the width of the beach surveyed.

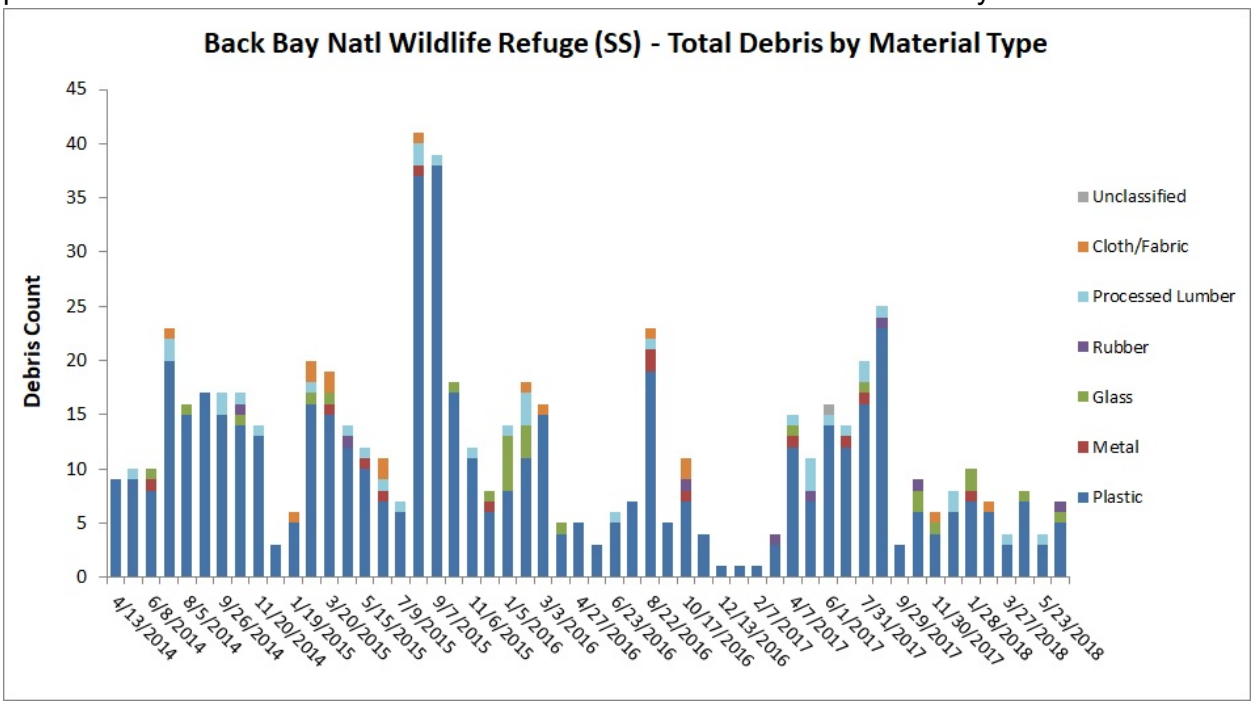


Figure 37. Total debris counts by material type per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge.

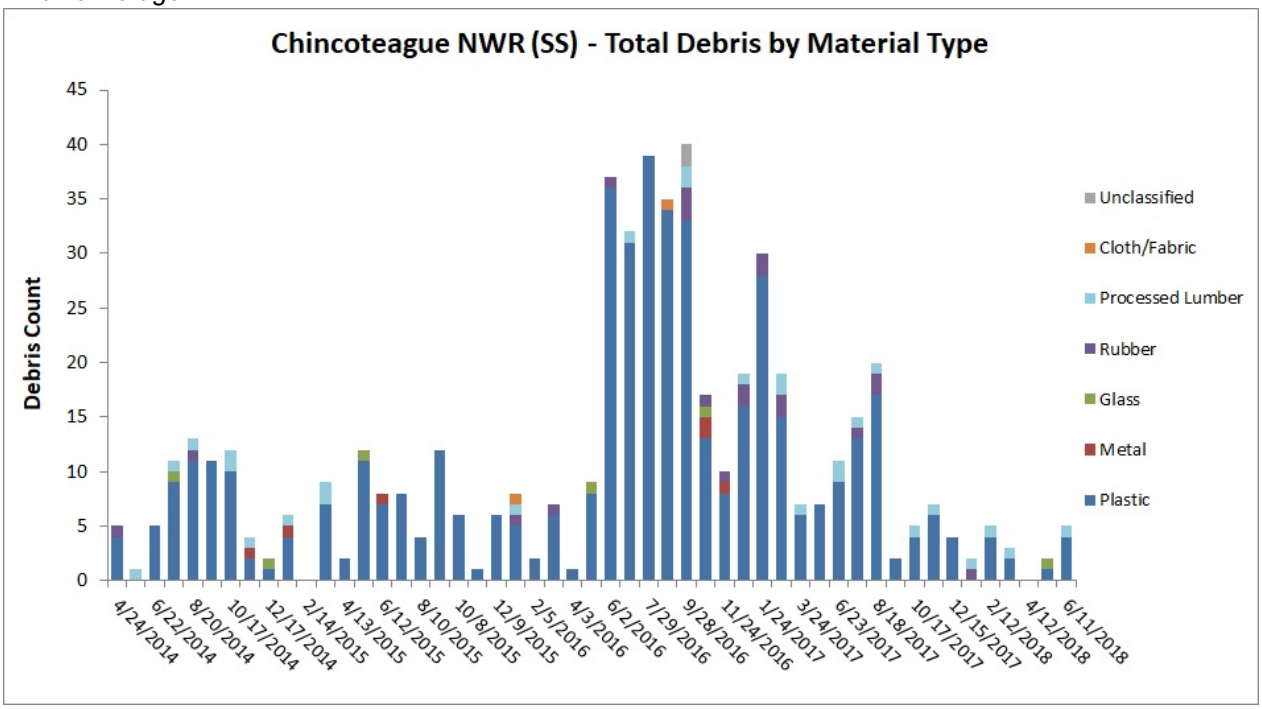


Figure 38. Total debris counts by material type per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge.

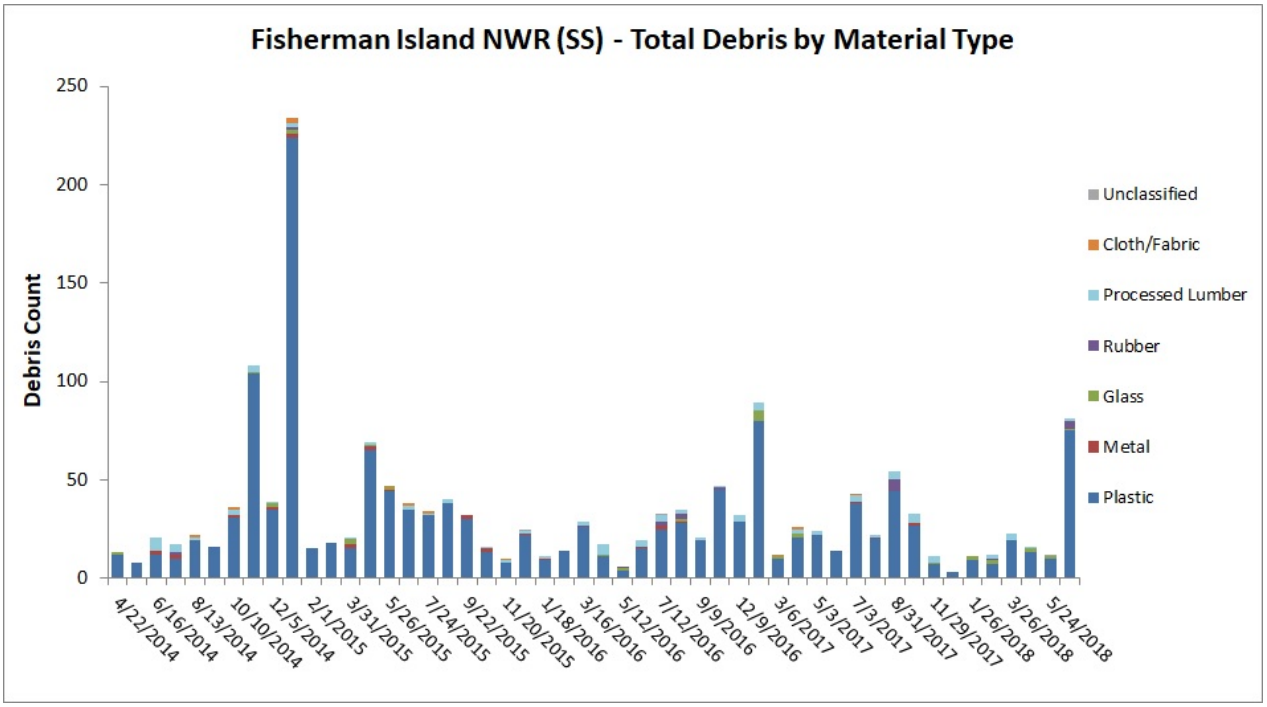


Figure 39. Total debris counts by material type per monthly Standing-Stock Survey on Fisherman Island National Wildlife Refuge.

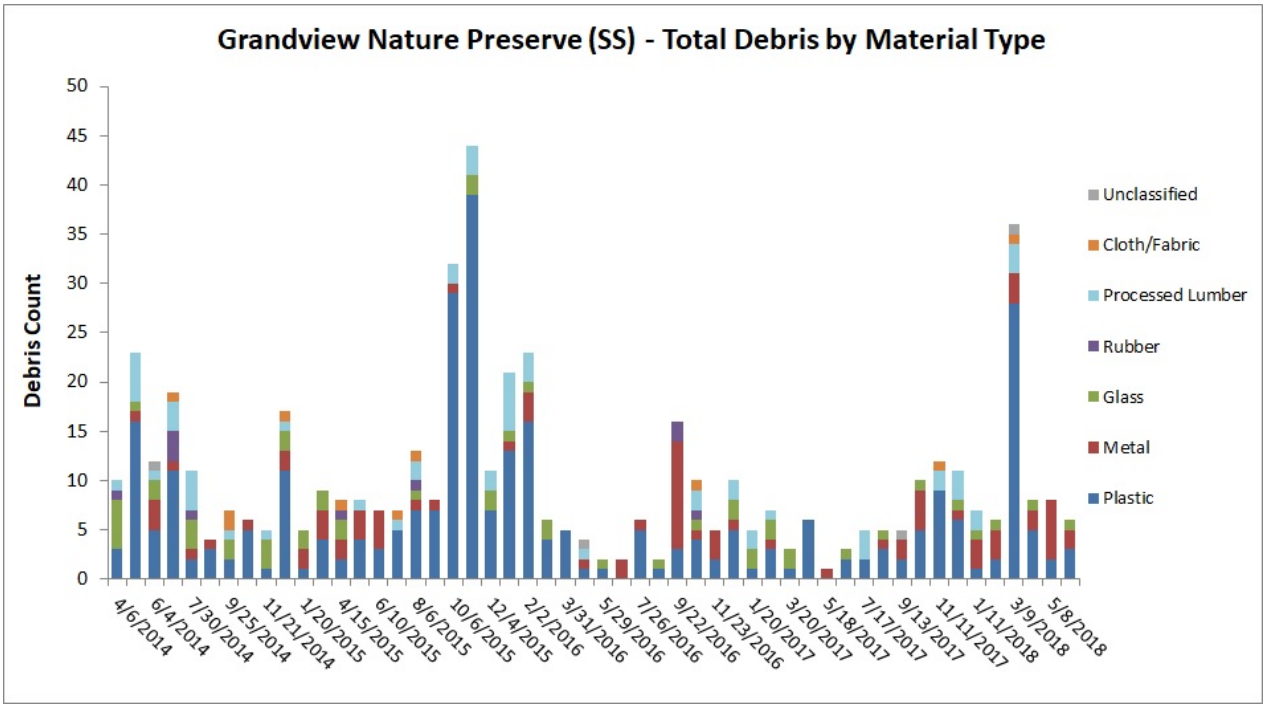


Figure 40. Total debris counts by material type per monthly Standing-Stock Survey on Grandview Nature Preserve.

Plastic Debris Grouped by User Category

Figures 41 to 44 focus on just the plastic debris counts recorded during the Standing-Stock Surveys. The items are charted based on user categories: consumer products, smoking products >2.5 cm, and fishing-related products. Consumer Products include: food wrappers, plastic beverage bottles, other jugs/containers, bottle/container caps, 6-pack rings, bags, cups, plastic utensils, straws, balloons, and personal care products. Smoking Products >2.5 cm include: cigar tips, cigarettes, and disposable cigarette lighters. Fishing-Related Products include: plastic rope/net, buoys & floats, and fishing lures & line. Note that the filters on cigarette butts are made from cellulose acetate, thus are included in this data set.

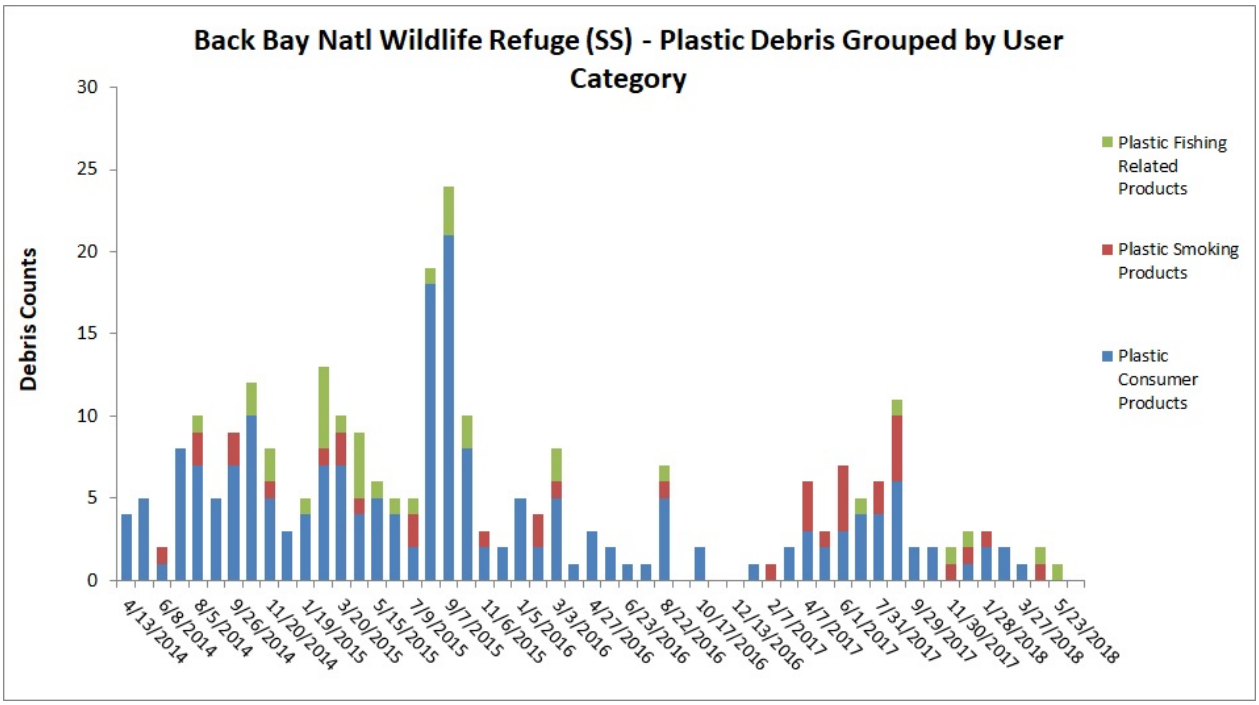


Figure 41. Plastic debris counts by user category per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge.

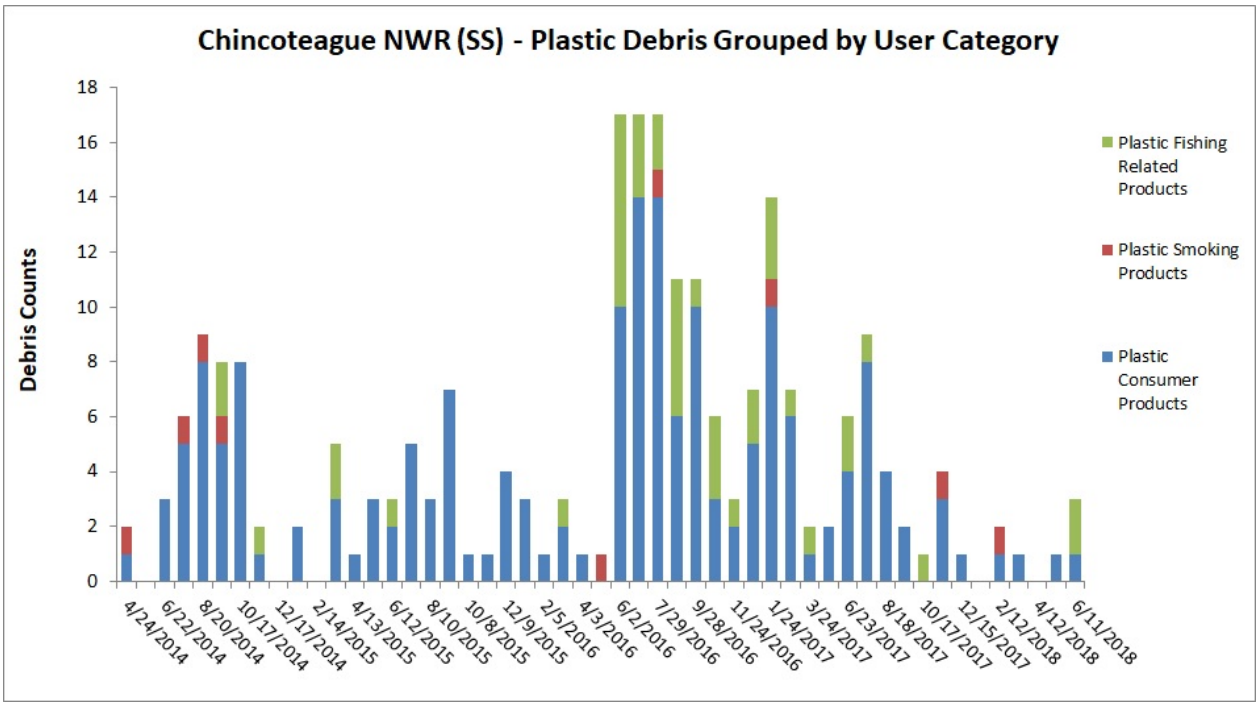


Figure 42. Plastic debris counts by user category per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge.

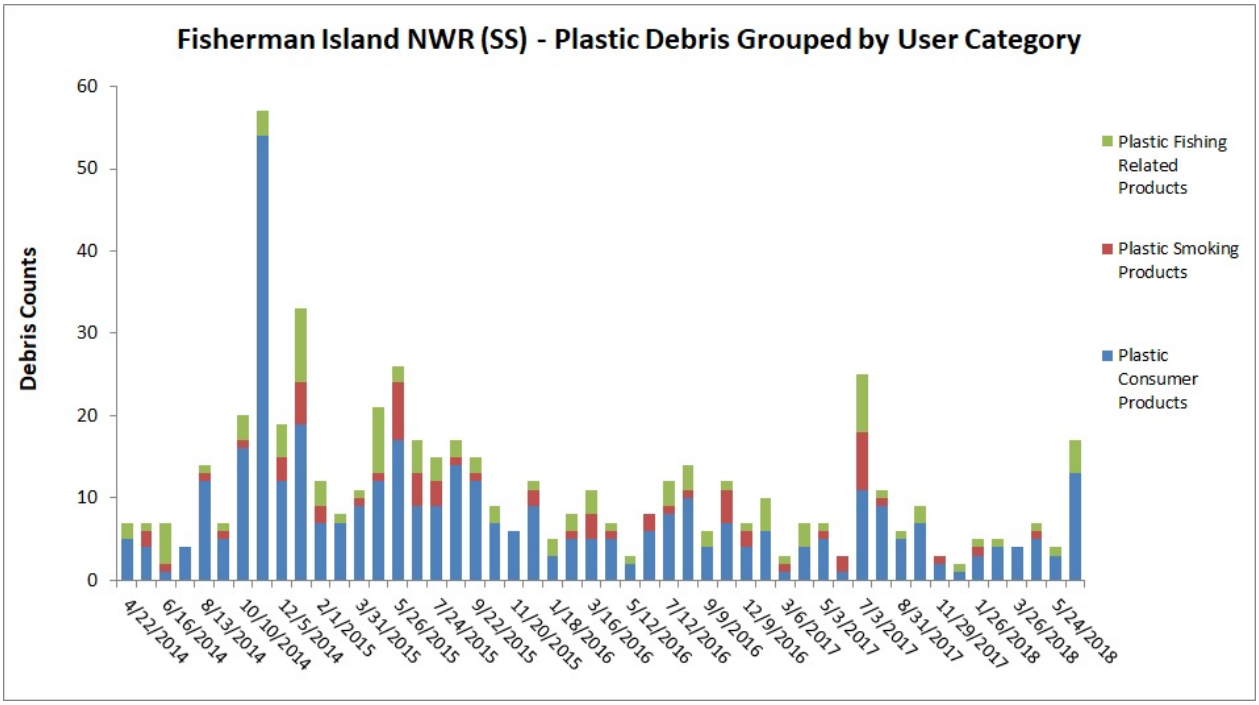


Figure 43. Plastic debris counts by user category per monthly Standing-Stock Survey on Fisherman Island National Wildlife Refuge.

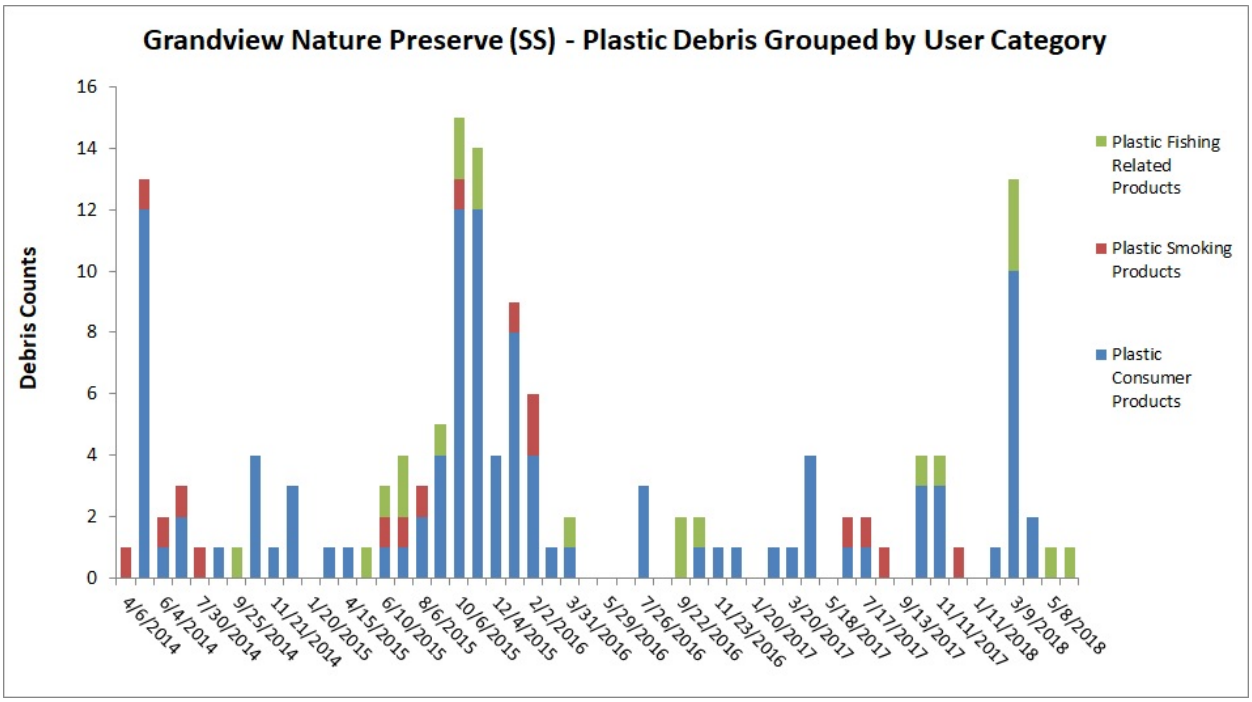


Figure 44. Plastic debris counts by user category per monthly Standing-Stock Survey on Grandview Nature Preserve.

One of the goals of Standing-Stock Surveys is to determine debris density (number of items per square meter). See Appendix III for figures that illustrate how the debris density (loads) changed for each monitoring site between Standing-Stock Surveys.

Volunteers search for debris during a Standing-Stock Survey at Back Bay NWR.

Yearly Debris Totals

Table 10 and Figure 45 display yearly totals for each site. Because monitoring started in April 2014, the "years" shown below cover 12-month periods starting in April. Note: The last three months of data (April–June 2018) are not included in these charts.

Table 10. Debris totals recorded per site for 12-month periods (April through March) from 2014 to 2018.

Monitoring Site	**Year 1** (4/2014–3/2015)	**Year 2** (4/2015–3/2016)	**Year 3** (4/2016–3/2017)	**Year 4** (4/2017–3/2018)
Back Bay NWR	702	761	443	645
Chincoteague NWR	286	336	999	337
Fisherman Island NWR	1,870	1,495	1,684	2,282 *
Grandview Nature Preserve	582	814	336	361
Totals	**3,440**	**3,406**	**3,462**	**3,625**

**In year 4, the Fisherman Island NWR March 2018 survey reported 1,071 pieces of foamed plastic.*

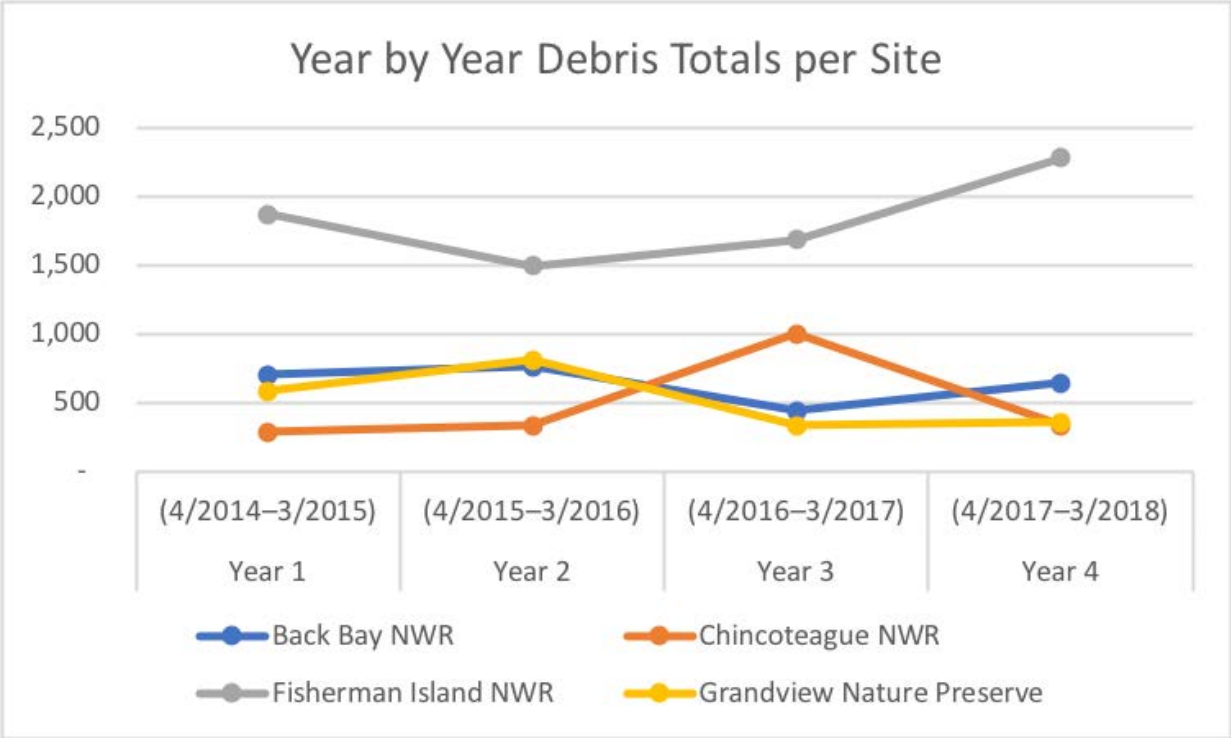


Figure 45. Line graph representing year by year debris totals per site for all four monitoring sites.

While debris totals varied slightly year to year, there were no statistically significant differences. It is interesting that Back Bay NWR and Grandview Nature Preserve saw a decrease in the debris count when comparing Year 2 to Year 3. In the same period, debris on Fisherman Island NWR slightly increased while the count for Chincoteague NWR tripled. If the 1,071 pieces of foamed plastic were removed from the annual total for Fisherman Island NWR in Year 4, then that year would have had the lowest count of debris for that monitoring site.

Debris of Special Interest

Smoking-related Debris

Figure 46. Balloon and smoking related litter, from left to right: a balloon stem used to fill balloons, a cigarette filter, a cigar tip, and a cigarette filter with paper still attached. The cigarette filters, made of cellulose acetate, are barely recognizable as the fibers start to separate.

Cigarette butts (n=412), cigar tips (n=112), and disposable lighters (n=52) accounted for 3.7% of the total debris items recorded between April 2014 and June 2018 (Figure 46). Fisherman Island NWR, which has the most restricted access of all the study sites, had the largest number of smoking-related debris items with 283, or 50.1% of all smoking-related debris recorded (Table 11). However, Back Bay NWR had the highest percentage of occurrence of all cigarette-related litter, by monitoring site at 5%.

Table 11. Total smoking-related debris items recorded between April 2014 and June 2018 on the four Virginia coastal beach monitoring sites.

Monitoring Site	Cigarette Butts	Cigar tips	Disposable lighters	Total per Site
Back Bay NWR	100	34	11	145
Chincoteague NWR	15	17	7	39
Fisherman Island NWR	210	44	29	283
Grandview Nature Preserve	87	17	5	98
Totals	412	112	52	565

In addition, 16 chewing tobacco containers were recorded in the notes section of the data sheets: Fisherman Island NWR (n=9), Back Bay NWR (n=3), Grandview Nature Preserve (n=3), and Chincoteague NWR (n=1).

According to data collected by volunteers in the International Coastal Cleanup, cigarette butts are the #1 most commonly found type of debris in Virginia, in the U.S., and in the world. Worldwide, cigarette butts account for 11.6% of all debris. In the U.S., cigarette butts account for 14.4% of all debris, and in Virginia they account for 14.7% (Ocean Conservancy, 2018). The International Coastal Cleanup data are based on cleanups that take place inland as well as on coastal beaches -- maybe accounting for the presence of more smoking-related litter than found on the four beaches that were monitored as part of this project.

Plastic Straws

Since 1988 when Ocean Conservancy started tracking the "Dirty Dozen" or the "Top Ten Items" from the International Coastal Cleanup data, plastic straws have been part of those lists (Sarah Kollar, personal communication, 2019). Likewise, plastic straws were among the most frequently found items on the Virginia beaches during this project.

In 2015, marine biologists posted a video of an olive ridley turtle with a plastic straw lodged in its nares (nose). The video went viral and as a result, awareness for the issue of single-use plastic straws as marine debris increased, restaurants around the country began switching to paper straws and/or straws on request, and cities and towns began banning single-use plastic straws. It will be interesting to see if the number of single-use plastic straws found during cleanups decrease over the next few years.

Bottle Caps

A total of 934 plastic bottle/container caps were recorded during the study period (Table 12). They were the #1 most frequently found identifiable debris item on three of the four monitoring sites. On Grandview Nature Preserve they came in 4th place after lumber/building material, aluminum/tin cans, and paper/cardboard. The largest number of bottle/container caps were found on Fisherman Island NWR (n=405).

Table 12. Plastic caps from bottles and containers were recorded 934 times.

Monitoring Site	Standing-Stock Surveys	Accumulation Surveys	Totals
Back Bay NWR	53	202	**255**
Chincoteague NWR	49	137	**186**
Fisherman Island NWR	72	333	**405**
Grandview Nature Preserve	20	68	**88**
Totals	**194**	**740**	**934**

Balloons and Attached Ribbons

A total of 660 balloons were recorded during the project surveys, representing 4.3% of debris items. The balloon debris, however, was not uniformly distributed. As seen in Table 13, Fisherman Island NWR accounted for 42.9% (n=283) of the total balloon debris, while Grandview Nature Preserve (located almost due west across the Chesapeake Bay) registered the fewest number of balloons at 58 (or 8.8% of all balloons). It should be noted that the earlier (2012) version of the NOAA Shoreline Survey Data Sheet included balloons only under the "plastic" section of the sheet. NOAA's revised data sheet now lists balloons under both plastic (for "Mylar" or foil balloons, Figure 47) and rubber (latex balloons).

Table 13. Number of balloons found at each survey site during the project.

Monitoring Site	Balloon Litter Totals per Site
Back Bay NWR	99
Chincoteague NWR	220
Fisherman Island NWR	283
Grandview Nature Preserve	58
Totals	**660**

It is also worth noting that the NOAA protocol requires that items that are less than 50% of their original form be recorded as fragments. Because many balloons found during this project were less than 50% of their original form, these numbers would be higher if they had been recorded as balloons rather than fragments. The protocol also required that balloons with plastic ribbon be recorded as ribbon, if the volume of ribbon was larger than the volume of the balloon. This may have also affected the total balloon count.

Figure 47. A volunteer removes a foil balloon from the wrack on Fisherman Island NWR.

Balloons were the #1 most frequently recorded debris type on Chincoteague NWR, #3 on Fisherman Island NWR, #5 on Back Bay NWR, and #7 on Grandview Nature Preserve.

While the 660 balloons were found on Virginia's beaches, it is impossible to determine where the helium-filled balloons started their journeys since balloons can travel hundreds of miles before bursting or deflating (Witmer, Register & McKay. 2017).

Previous research confirms that balloons accumulate on coastal beaches where they are often the most common type of trash. According to *Balloon Litter on Virginia's Remote Beaches* (Trapani, O'Hara & Register, 2018), presence of balloons and balloon-related pieces of litter (e.g., plastic ribbons) varied between the coastal beaches they surveyed (Cedar Island, Hog Island, Smith Island, Fisherman Island NWR and False Cape State Park) from 25 items per mile on Cedar Island, to more than 272 items per mile on Fisherman Island NWR. During their 5-year study, 11,441 balloon-related litter items were recorded during 46 surveys. The majority of the

balloon litter (60%) was found between the high tide line and the dune vegetation – critical habitat for nesting birds, sea turtles, and diamondback terrapins (Trapani *et al.,* 2018).

Clam Aquaculture Netting

Virginia is the top producer of aquaculture clams in the U.S. with Virginia's Eastern Shore being the top producing location of aquaculture clams in Virginia (VIMS, 2018). Young clams are protected from predators such as sting rays and skates by being covered with netting. Clam netting debris was most prevalent on Fisherman Island NWR. The netting pieces were often large (up to 20 feet in length) and occasionally partially buried (Figure 49). If the entire net could not be removed, exposed pieces were cut and removed during the surveys.

Figure 49. A large piece of clam netting found partially buried on the beach during an Accumulation Survey at Fisherman Island NWR in June 2017.

Cardboard and Paper

Figure 50. A waxed cardboard fish box on the beach at Grandview Nature Preserve, found during an Accumulation Survey in August 2017.

Much of the cardboard/paper recorded was from waxed cardboard fish boxes (Figure 50). These boxes and pieces of boxes were most prevalent on Fisherman Island NWR and Grandview Nature Preserve. Due to the protocol to record items that were less than 50% of the original item to be recorded as fragments, many of the pieces of boxes were recorded as cardboard fragments and not identified as pieces of these fish boxes.

Shotgun Shells and Wads

In the notes section of the data sheets, researchers recorded all shotgun shells and shotgun wads at the request of researchers from the Virginia Institute of Marine Science. A total of 77 shotgun shells and 162 shotgun wads were recorded during the project study period (Figure 51 and Table 14).

Figure 51: Shotgun wads and shells found during an Accumulation Survey at Fisherman Island NWR in November 2016.

Table 14. Shotgun shells and shotgun wads recorded in the notes section of the data sheet.

Monitoring Site	Shotgun shells	Shotgun wads	Totals
Back Bay NWR	6	15	**21**
Chincoteague NWR	5	4	**9**
Fisherman Island NWR	42	89	**131**
Grandview Nature Preserve	24	54	**78**
Totals	**77**	**162**	**239**

Large Items

Items measuring more than 12 inches (2.5 cm) were recorded in the large debris section of the data sheet. Much of this debris included treated lumber, fishing nets, rope, and balloons, especially foil balloons and any balloons with attached ribbon. In some cases, especially on Fisherman Island NWR, debris was too large to remove (Figure 52) and was therefore recorded during each survey as long as the item remained in the survey area, including in the Accumulation Survey sites.

Figure 52: Volunteers pick up trash next to a large piece of lumber during an Accumulation Survey on Fisherman Island NWR in May 2017.

Spray Foam and Burned/Melted Plastic

In the last year of this project, the project team observed an increase in pieces of spray foam (often used for insulation or repairs) and what appeared to be "rocks" of burned/melted plastic on Fisherman Island NWR (Figure 53). While there is no definitive explanation for this, it is interesting to note that starting in early 2015, the Coast Guard anchorages located near Thimble Shoals Channel, an area near the Bay-side of Virginia Beach, stopped welcoming commercial vessels. This resulted in ship traffic anchoring in the Chesapeake Bay between Cape Charles and Fisherman Island NWR. Some of the ships are container vessels, but most

Figure 53. A piece of burned plastic (left) and a piece of spray foam (right) collected from Fisherman Island NWR.

transport coal. The ships were close enough to be seen from the Fisherman Island NWR monitoring site. While the project team learned that Navy ships compress their plastic waste into disks for easier storage and disposal (https://www.public.navy.mil/usff/environmental/Pages/CityAtSea.aspx), this project team is unaware of any processes that cargo ships may be using and if these burned/melted plastic "rocks" or the increase in presence of spray foam are at all related to the cargo ship anchorage location.

Other Results

The project team discussed the nature of balloon-related litter with the NOAA Marine Debris Program. NOAA staff were interested in providing clear guidance on how to record balloon litter on the MDMAP forms. With input from this project team, a new item – "Balloons-Latex" – was added to the NOAA data collection form under the Rubber category in 2016. The revised form also clarified the Plastic Balloons category with a new designation – "Balloons-Mylar". In addition, in January 2015, project team member Katie Register (CVW) attended and contributed to a NOAA Marine Debris Program meeting which was focused on marine debris data collected by citizens.

Debris Composition Over Time: 2001–2016 and 2014–2018 Data

Two of the project monitoring sites (Back Bay NWR and Chincoteague NWR) were selected because they were in similar locations to sites from the *National Marine Debris Monitoring Program* (NMDMP) research that was conducted by Ocean Conservancy in 2001 through 2006 (Sheavly, 2010). During NMDMP, the monitoring site on Chincoteague NWR was located much closer to the public beach than the current project site. The NMDMP monitoring site on Back Bay NWR was located south of the beach access road which is an area open to the public (Figure 54). The NMDMP survey areas were 500 meters in length and used entirely for accumulation surveys where debris was removed during monitoring.

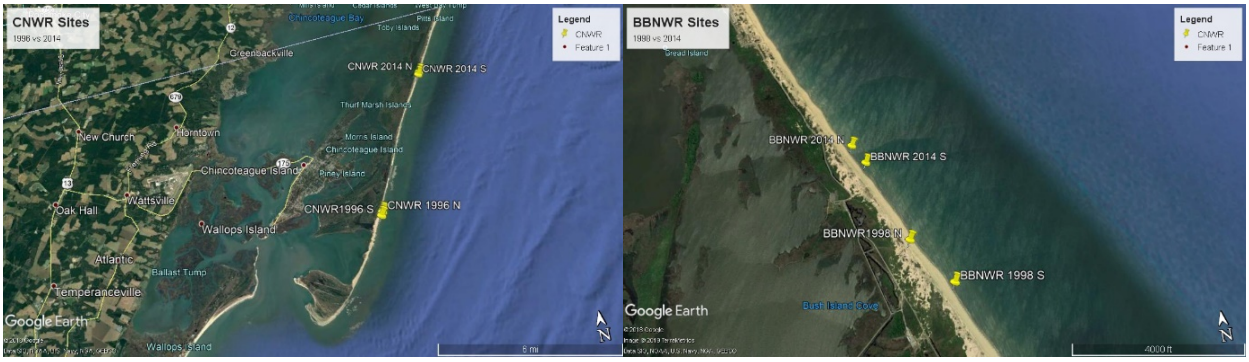


Figure 54. Maps of the Chincoteague NWR sites (left) and Back Bay NWR sites (right). The markers show that the sites surveyed during the NMDMP project were located further south in both cases and more easily accessible to the public than the sites used in this project.

NMDMP's goal was to *"…standardize marine debris data collection in the United States using a scientifically valid protocol to determine marine debris status and trends."* The purpose of the study was to *"…answer the following questions:*

Is the amount of debris on coastlines changing over a five-year period?
What are the major sources of the debris?"

Trained teams of volunteers collected marine debris data every 28 ± 3 days on selected beaches throughout the U.S. The standardized data sheet used in the NMDMP research included 31 debris indicator items that were grouped according to sources of debris: land-based, ocean-based, and general source. They were not categorized based on material type (e.g., plastic, metal, glass, etc.)

Ocean-based Source Indicator Items in the NMDMP study were: gloves, plastic sheets (≥ 1 meter), light bulbs/tubes, oil/gas containers (>1 quart), pipe-thread protectors, nets (≥ 5 meshes), traps/pots, fishing line, light sticks, rope (≥ 1 meter), salt bags, fish baskets, cruise line logo items, floats/buoys.

Land-based Source Indicator Items in the NMDMP study were: syringes, condoms, metal beverage cans, motor oil containers (1-quart), balloons, six-pack rings, straws, tampon applicators, cotton swabs.

General Source Indicator Items in the NMDMP study were: plastic bags (<1 meter), plastic bags (≥ 1 meter), strapping bands (open), strapping bands (closed), plastic beverage bottles, plastic food wrappers.

Because of differences in the items listed in the NMDMP data sheet and the MDMAP data sheet, and because there were differences in the monitoring sites and protocols, it was not possible to directly compare the data sets. For example, the NMDMP surveys in 2001-2006 examined survey areas that were 500 meters (0.3 miles) in length, while the NOAA MDMAP protocols require survey areas of 100 meters (328 feet) in length. Despite the differences, looking at the top ten most frequently found items for both sites from both study periods indicates some trends. Tables 15 and 16 present the top ten debris items recorded for Back Bay NWR and Chincoteague NWR during the two study periods.

Several items were among the top ten most frequently found debris items in both the 2001-2006 and 2014-2018 studies: plastic bags, balloons, plastic beverage bottles, rope and straws. Further, the NMDMP study found that land-based items were the most abundant, comprising an average of 63% of debris collected in Region 2 (that is the region that included the Back Bay NWR and Chincoteague NWR sites). For this same region, general source items comprised 30.2% with only 6.9% of debris from ocean-based items. Unfortunately, specific debris data from the NMDMP study for the individual sites could not be located, thus the need to look at the regional averages.

Table 15. Top ten marine debris data collected on Back Bay NWR as part of National Marine Debris Monitoring Program (NMDMP) 2001-2006 as compared to the top ten items found in the current project survey period 2014-2018. Debris items in bold appear on the top ten list for both survey periods.

Back Bay NWR 2001–2006

Rank	Debris Item
1	**Plastic Bags, Small**
2	**Balloons**
3	**Beverage Bottles, Plastic**
4	**Straws**
5	**Rope**
6	Beverage cans, metal
7	Plastic Bags, Large
8	Food Bottles
9	Open Straps
10	Floats & Buoys

Back Bay NWR 2014–2018

Rank	Debris Item
1	Bottle/Container Caps
2	Food Wrappers
3	Lumber/Building Material
4	Cigarettes
5	**Balloons, Mylar + Latex**
6	**Plastic Beverage Bottles**
7	**Plastic Rope/Net**
8	**Plastic Bags**
9	**Straws**
10	Other Jugs/Containers

Table 16. Top ten marine debris data collected on Chincoteague NWR as part of National Marine Debris Monitoring Program (NMDMP) 2001-2016 as compared to the top ten items found in the current project survey period 2014-2018. Debris items in bold appear on the top ten list for both survey periods.

Chincoteague NWR 2001–2006

Rank	Debris Item
1	**Beverage Bottles, Plastic**
2	**Balloons**
3	**Plastic Bags, small**
4	Bottles, misc
5	**Rope**
6	**Straws**
7	Beverage cans, metal
8	Plastic Sheets
9	Food Bottles
10	Light Sticks

Chincoteague NWR 2014–2018

Rank	Debris Item
1	**Balloons Mylar + Latex**
2	Bottle/Container Caps
3	**Plastic Rope/Net**
4	**Plastic Beverage Bottles**
5	**Straws**
6	Lumber/Building Material
7	Food Wrappers
8	**Plastic Bags**
9	Other Jugs/Containers
10	Cups, plastic

This difficultly in directly comparing marine debris from various studies over time enforces the calls by many organizations within the U.S. and internationally for standardized monitoring protocols and data collection.

Conclusion

Four years of monitoring marine debris on Virginia coastal beaches provides valuable insights on the regional and local scope of the problem, as well as sources of debris. These data can help government agencies, non-profit groups, beach managers, coastal planners and communities as they inform policies, regulations, beach management, cleanup strategies to expedite removal of debris, and social marketing outreach campaigns that focus on changing the behaviors that lead to marine debris. One example of how data can drive change: in 2017 staff from the Virginia CZM Program and CVW met with leaders in the clam aquaculture industry to discuss voluntary measures that would lead to fewer derelict clam nets on Virginia's beaches.

This project expanded knowledge about the marine debris problem on Virginia's coastal beaches and established a baseline of data. Project partners developed expertise in using the NOAA protocols and managing all aspects of an on-going monthly monitoring program. Monthly monitoring stopped in June 2018 as the second grant was wrapping up.

As seen in other studies and data collected by volunteers during the International Coastal Cleanup, the marine debris recorded during this project was primarily composed of plastic items and single-use disposables (Mallos, 2016). One significant trend that emerges from this and other studies is that a very significant portion of total marine debris is composed of plastic, glass, and aluminum beverage containers. When plastic bottle caps are added, these may collectively be the most significant sources of marine debris recorded in Virginia. Within this group, plastic bottles and caps are by far the major contributors. What makes this category of debris so perplexing is that there are very robust recycling streams for these items. Beverage containers, whether plastic, glass, or aluminum, have historically been high-value items in the recycling stream and thus there is significant land-based infrastructure for collection (recycling containers can be readily accessible at home or when traveling). Because the containers have recycling value, there has also been extensive development of public messaging and promotion of recycling by the businesses that produce and recycle these products. Despite these conditions, improper disposal continues to be a very real and significant problem. The reality of the marine debris problem associated with beverage containers is therefore a result of several major factors – relatively poor participation of the public in recycling and the overwhelming prevalence of single-use plastic bottles. Continued education and social marketing campaigns to encourage improved recycling and waste disposal are of course important steps. However, the results of this and other marine debris studies clearly indicate that this will not be enough. Source reduction, as in this example with single-use plastic bottles, must be a major focus of future efforts if Virginia and the rest of the country want to achieve reductions in marine debris on coastal beaches.

Continued monitoring will help identify trends in debris deposition. Though this report does not examine in detail factors such as seasonality, weather (storms), or distance to population centers as potential drivers of marine debris, these questions could be worthy of future analysis.

For example, after analyzing a subset of our data for seasonality, authors of the report "Significance of Location on Marine Debris: 2011 Japanese Tsunami and the Chesapeake Bay" found no evidence of seasonal trends in debris deposition (Amestoy, Holliday & Schofield, 2019). In fact, each site had different peaks in debris counts. Further, the authors found, "When the composition over time data was compared to strong storm data from NOAA, there was no correlation between these storms and debris amount. Furthermore, population of the counties these sites exist in were analyzed to see if there was a correlation between population and debris amount. There was no correlation."

Future monitoring will also help measure the effectiveness of outreach campaigns, laws and policies that focus on reducing litter and marine debris. Perhaps most importantly, the data from long-term monitoring projects provides information that should incentivize further development of source reduction strategies, especially for the most ubiquitous materials such as those originating from single-use plastics.
Projects such as this also help raise awareness about the urgency of plastic pollution in our waterways and rivers through the use of volunteer citizen scientists and media coverage.

Project partners recommend that monitoring continue on the same sites after a few years so data from 2014–2018 can be compared with further data to determine trends in marine debris composition and accumulation. If future monitors are based in Virginia Beach, then Fisherman Island NWR, Back Bay NWR and Grandview Nature Preserve would be the logical sites to monitor. If future monitoring of Chincoteague NWR is desired, it is recommended that a local team of volunteers be trained. Using standard monitoring protocols will be critical in order to determine trends over time.

Our USFWS partners on the National Wildlife Refuges were instrumental in the success of this project. Their local knowledge of the area and wildlife allowed the project team to choose sites that were easily accessible, isolated as much as possible from public visitation, and unlikely to become temporarily inhabited by shorebird or sea turtle nests. They also assisted with the annual permitting process and provided access to areas otherwise closed to the public. During weather events, project team members could call NWR partners to provide information on the state of the beach at the survey sites. This was especially important for the Chincoteague NWR site that required a 2.5 hour drive from Virginia Beach.

The project team from the Virginia Aquarium & Marine Science Center and Clean Virginia Waterways of Longwood University were excited to be contributing to the NOAA Marine Debris Monitoring and Assessment Project and appreciated the ongoing support of NOAA and the Virginia CZM Program.

Challenges and Recommendations

General

Many challenges were experienced during the course of this project. The most significant challenges involved the classification of debris and the data collection process (discussed below). Other general challenges included:

Weather: Winter often brought frigid temperatures which became a potential concern regarding the safety of survey volunteers. Cold weather was also a factor affecting battery depletion and GPS functioning. High winds, while more of an inconvenience, probably caused sand burial of debris as the survey team observed less debris on days of winds in excess of 20 mph.

Insects: Biting flies and mosquitoes often created uncomfortable conditions for surveys, especially during the warmer months. Tick checks were also often in order, especially on Fisherman Island NWR. While wind can be an inconvenience at times, a good breeze in the summer provided some relief from biting insects.

Bird watchers & nature lovers removing debris: Volunteers often observed large piles of collected trash at the waste cans on Grandview Nature Preserve. It is unknown if the project survey sites were cleaned by well-meaning beach goers. The Grandview Nature Preserve site was chosen because of its distance from the beach access, hoping that most people would not remove trash from a more remote location. Grandview Nature Preserve biologists and staff at all of the NWR sites were instructed to let people know to avoid all survey site areas. However, the survey teams interacted with beach walkers on Grandview Nature Preserve that spoke about picking up trash on that beach.

Working around nesting seasons: The survey sites at the National Wildlife Refuges are particularly susceptible to potential restrictions due to sea turtle or shore bird nesting. Should a nesting event occur on any of the survey sites, it would require abandonment of the site during the nesting and/or hatching/fledging period. Project staff worked with refuge biologists to choose sites where this was least likely to occur. During the project period, there were no nests in any of the survey sites, though a loggerhead sea turtle nested approximately ¼ mile (400 meters) north of the Back Bay NWR Standing-Stock Survey site in the summer of 2016.

Site Markers: Wooden stakes were intentionally used to mark the survey sites in the event they were washed out to sea during storms. In the case of Fisherman Island NWR and Chincoteague NWR, all markers eventually disappeared and were replaced over time as a result of storms. GPS coordinates were used to re-establish site boundaries, especially at Fisherman Island NWR due to the constant erosion and shifting landscape of that beach. Chincoteague NWR markers were replaced about once each year using the GPS coordinates from the original site characterization. Grandview Nature Preserve site markers were consistently found removed or moved. Eventually, GPS coordinates were utilized to establish the survey site boundaries each month.

Site Characterizations. All survey sites were established to measure 100 meters (328 feet), however subsequent site measurements indicated some level of variability. There may be several factors influencing the variability:

- The measuring wheel used may slip in soft sand while taking measurements.
- The beaches themselves may change over time. Chincoteague NWR had several beach face slope changes over the project period and Back Bay NWR often develops a "hilly" surface.
- Initial measurements were made at the middle of the beach. The perspective of a straight line from the semi-permanent markers at the back of the shoreline (wooden stakes) may be slightly different each time, changing the location of the

start of the site. GPS is often used establish locations but also has a +/- error of up to 10 feet.

Data Collection

NOAA Protocols were followed for this project, however the data collection process vs. the protocols raised many questions. Several concerns were shared with Sherry Lippiatt from NOAA and the following challenges and subsequent recommendations are based on those conversations as well as experiences from 51 months of surveys.

Concern: NOAA defines marine debris as "...*any persistent solid material that is manufactured or processed...*" Coal found on Virginia's beaches: while organic, it is not naturally occurring on Virginia coastal beaches and has likely been processed. The survey team often encountered and subsequently recorded coal during monitoring surveys.

Recommendation: By this reasoning, any organic material that has clearly been processed should be recorded as marine debris. But under this understanding of "processed", organic items such as bamboo (or other wood) stakes used for markers, fruit and vegetables, and cut flowers would be included. This requires further discussion.

Concern: Balloon-related litter presents challenges in recording on the current NOAA data sheet. Balloon-related litter includes different types of balloons (foil/plastic, latex, weather balloons), and their many attachments (e.g., plastic ribbons, valves, messages/notes, etc.). For example, the protocol requires that if the volume of the latex balloon is less than the volume of plastic ribbon, the latex balloon itself is not counted in the balloon-litter count, only the plastic ribbon.

Recommendation: Basic balloon-related litter information should be recorded as described in the protocol. Research teams can decide what level of information they would like to collect regarding balloon-litter and may be inclined to modify the data sheet in order to answer specific questions.

Concern: Labels from plastic drink bottles were a commonly found item. Project staff were advised to record them as food wrappers. This is an item that probably needs further discussion as project staff believe that a bottle label is not actually a food wrapper, but a part (<50%) of another item.

Recommendation: During the latter part of this project, bottle labels were recorded in the "other" category as "bottle labels". Just like bottle caps, which have their own category, bottle labels are part of another item but are frequently found on their own.

Concern: Items such as tires and balloons have their own category on the datasheet but are more often than not, over 12 inches (.3 meters) and must be recorded as large items.

Recommendation: While the data is not lost if it is recorded descriptively in the large items section, it may also make sense to record tires, balloons, rope, etc. in their categories, but note those that are more than 12 inches (.3 meters). This allows items to be recorded within their category, making data analysis more efficient while maintaining large item documentation. This will also make data entry into the MD-MAP more accurate.

Concern: The survey team initially believed that items in the Standing-Stock Survey area should not be touched and recorded as is. Items such as a rope or balloon ribbon that may measure over 12" if unraveled, were measured as found on the beach. This led to further questions/concerns such as: if a foil balloon is found in the Standing-Stock Survey site folded or partially buried, showing less than 12 inches (.3 meters), it is recorded as a foil balloon. If the foil balloon is still partially inflated or flat on the beach, showing more than 12 inches (.3 meters), it will likely be recorded as a large item. Therefore, the same size items have the potential to be recorded in two ways if left *in situ*.
Recommendation: Unbury or move the item to reveal and measure its full size then return the item to its *in situ* position as accurately as possible.

Concern: When several items are found wrapped-up together, the prevalent item is the only item recorded. In one example, a nylon rope with 5 plastic ribbons with latex nubs was to be recorded under large items naming the prevalent nylon rope as the only item. Project staff are concerned that, in this example, the collection of data for 5 balloons should also be included in this observation.
Recommendation: We recommend that each identifiable item be recorded so as not to lose potentially important information.

Concern: Items found in the Accumulation Survey site that are too large to be removed are recorded at every survey.
Recommendation: Be sure to note that any items that can't be removed are recorded as a repeat so they are not entered into the dataset each time.

Concern: Following the NOAA protocol, at least 50% of an item had to be present in order to be recorded as an identifiable item. When less than 50% of the item was present, the item was tallied as a single fragment. When an item is clearly identifiable, especially a food wrapper or balloon, it is still only recorded as a fragment.
Recommendation: As with large items, perhaps record identifiable items under the appropriate category with notation that they are a fragment or less than 50%.

Concern: Monitoring surveys included one Accumulation Survey and four Standing-Stock Survey transects, resulting in five three-page sets of datasheets that had to be tallied, scanned, entered into a database, then stored.
Recommendation: Digitize the process so data can be entered into an app, on or off-line. This would not only streamline the data collection process, but it could also allow for quality control at the time of data collection, more options for data collection points (large items, fragments and micro-debris) and of course, less paper.

Beyond the written protocol
Throughout the course of the project period, different methods were tried and tested for completing the surveys both effectively and efficiently. Some examples include:

Green bamboo tomato stakes were utilized to mark transects: these markers are easily inserted into the sand, easily seen from a distance, inexpensive, and lightweight. One of the project volunteers sewed a bag to carry the stakes.

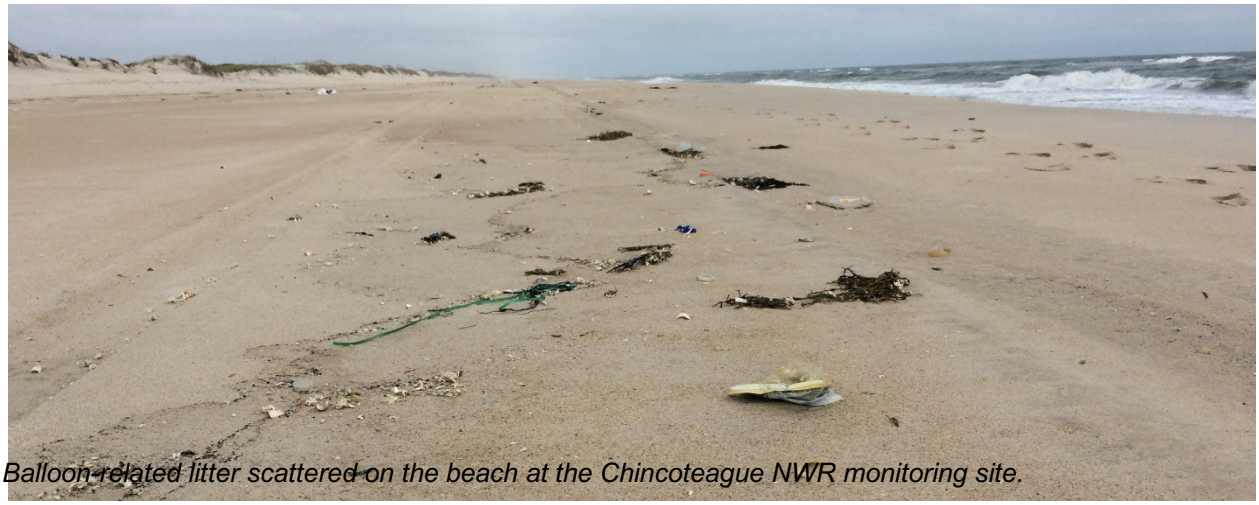
If enough volunteers are available, a 5-meter piece of string can be used to measure the width of the Standing-Stock Survey transects at each end, rather than using a measuring tape. However, this procedure requires two people so there may be times when using a measuring wheel is more convenient.

Reusable grain bags from a local brewery were used to collect debris during the Accumulation Surveys, rather than relying on single-use plastic trash bags. If disposal requires a trash bag, all debris can be condensed into the single-use bags.

A wagon was used for a few surveys (Figure 55) towards the end of the project. While it was convenient for carrying equipment and heavy bags of trash, it was not designed for soft sand conditions. A wagon or cart designed for the beach would prove very useful for these types of surveys.

When selecting sites for monitoring surveys, it is important to keep in mind available modes of transportation. A 4-wheel drive truck was required to access Fisherman Island NWR and had one not been available, this monitoring site may not have been as easily accessible.

Figure 55. A volunteer pulls a wagon with survey equipment towards the site at Grandview Nature Preserve. The green bamboo stakes and carry bag can be seen in the wagon.



Balloon-related litter scattered on the beach at the Chincoteague NWR monitoring site.

Literature Cited

Bimrose, K., Lindquist, K., Roletto, J. 2018. Marine Debris—Monitoring and Assessment Program at Greater Farallones National Marine Sanctuary: July 2012—June 2017. Marine Sanctuaries Conservation Series ONMS-1X-XX. US Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.

Lippiatt, S., Opfer, S., and Arthur, C. 2013. Marine Debris Monitoring and Assessment. NOAA Technical Memorandum NOS-OR&R-46. https://marinedebris.noaa.gov/mdmap-protocol-documents-and-field-datasheets

Ocean Conservancy. 2018. Building a Clean Swell: 2018 International Coastal Cleanup Report. Washington D.C. Available on: https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/annual-data-release/

Opfer, S., Arthur, C., and Lippiatt, S. 2012. NOAA marine debris shoreline survey field guide, National Oceanic and Atmospheric Administration Office of Response and Restoration Marine Debris Program, NOAA, Silver Spring, MD, USA; Available on: https://marinedebris.noaa.gov/mdmap-protocol-documents-and-field-datasheets

OpinionWorks. 2013. D.C. Resident and Business Bag Use Surveys. Prepared for the Alice Ferguson Foundation on behalf of the District Department of the Environment (DDOE). https://ggwash.org/view/38159/the-data-proves-the-dc-bag-fee-is-working

Mallos, N. 2016. Marine Debris and Wildlife: Impacts, Sources and Solutions. Written Testimony of Nicholas J. Mallos, Director, Trash Free Seas, Ocean Conservancy before the US Senate Environment and Public Works Committee.

Register, K. and McKay, L. 2014. Developing a Marine Debris Reduction Plan for Virginia. Virginia Coastal Zone Management Program (Virginia Department of Environmental Quality).

Register K., Trapani, C., and Swingle, M. 2016. Monitoring Marine Debris in Virginia's Coastal Zone Project Report. NOAA CZM Program Grant NA13NOS4190171, Task 81. Clean Virginia Waterways of Longwood University, Farmville, VA, 24 pp.

Sheavly, S. B. 2010. National Marine Debris Monitoring Program. Lessons learned. Ocean Conservancy, Washington, D.C. 26p.

VIMS. 2018. Virginia Shellfish Aquaculture—Situation and outlook Report. VIMS Marine Resource Report No. 2018-9. continues to lead in clam and oyster aquaculture. Available on: https://www.vims.edu/research/units/centerspartners/map/aquaculture/index.php

Witmer, V., Register, K. & McKay, L. 2017. Balloon Release Research in Virginia and Reducing Balloon Debris through Community-Based Social Marketing. Virginia Coastal Zone Management Program (Virginia Department of Environmental Quality).

Appendix I

Survey Locations and Dates

Site	Date
BBNWR	4/13/2014
BBNWR	5/9/2014
BBNWR	6/8/2014
BBNWR	7/7/2014
BBNWR	8/5/2014
BBNWR	8/31/2014
BBNWR	9/26/2014
BBNWR	10/24/2014
BBNWR	11/20/2014
BBNWR	12/18/2014
BBNWR	1/19/2015
BBNWR	2/22/2015
BBNWR	3/20/2015
BBNWR	4/17/2015
BBNWR	5/15/2015
BBNWR	6/11/2015
BBNWR	7/9/2015
BBNWR	8/9/2015
BBNWR	9/7/2015
BBNWR	10/7/2015
BBNWR	11/6/2015
BBNWR	12/7/2015
BBNWR	1/5/2016
BBNWR	2/3/2016
BBNWR	3/3/2016
BBNWR	3/29/2016
BBNWR	4/27/2016
BBNWR	5/24/2016
BBNWR	6/23/2016
BBNWR	7/22/2016
BBNWR	8/22/2016
BBNWR	9/19/2016
BBNWR	10/17/2016
BBNWR	11/16/2016
BBNWR	12/13/2016
BBNWR	1/10/2017
BBNWR	2/7/2017
BBNWR	3/7/2017
BBNWR	4/7/2017
BBNWR	5/4/2017
BBNWR	6/1/2017
BBNWR	7/2/2017
BBNWR	7/31/2017
BBNWR	8/30/2017
BBNWR	9/29/2017
BBNWR	10/30/2017
BBNWR	11/30/2017
BBNWR	12/30/2017
BBNWR	1/28/2018
BBNWR	2/26/2018
BBNWR	3/27/2018
BBNWR	4/23/2018
BBNWR	5/23/2018
BBNWR	6/22/2018

Site	Date
CNWR	4/24/2014
CNWR	5/23/2014
CNWR	6/22/2014
CNWR	7/20/2014
CNWR	8/20/2014
CNWR	9/18/2014
CNWR	10/17/2014
CNWR	11/19/2014
CNWR	12/17/2014
CNWR	1/16/2015
CNWR	2/14/2015
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CNWR	4/5/2016
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CNWR	6/30/2016
CNWR	7/29/2016
CNWR	8/29/2016
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CNWR	10/27/2016
CNWR	11/24/2016
CNWR	12/25/2016
CNWR	1/24/2017
CNWR	2/23/2017
CNWR	3/24/2017
CNWR	5/24/2017
CNWR	6/23/2017
CNWR	7/20/2017
CNWR	8/18/2017
CNWR	9/18/2017
CNWR	10/17/2017
CNWR	11/15/2017
CNWR	12/15/2017
CNWR	1/13/2018
CNWR	2/12/2018
CNWR	3/14/2018
CNWR	4/12/2018
CNWR	5/11/2018
CNWR	6/11/2018

Site	Date
FINWR	4/22/2014
FINWR	5/21/2014
FINWR	6/16/2014
FINWR	7/13/2014
FINWR	8/13/2014
FINWR	9/10/2014
FINWR	10/10/2014
FINWR	11/7/2014
FINWR	12/5/2014
FINWR	1/2/2015
FINWR	2/1/2015
FINWR	3/2/2015
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FINWR	4/4/2017
FINWR	5/3/2017
FINWR	6/2/2017
FINWR	7/3/2017
FINWR	8/1/2017
FINWR	8/31/2017
FINWR	9/28/2017
FINWR	11/29/2017
FINWR	12/28/2017
FINWR	1/26/2018
FINWR	2/25/2018
FINWR	3/26/2018
FINWR	4/25/2018
FINWR	5/24/2018
FINWR	6/21/2018

Site	Date
GNP	4/6/2014
GNP	5/5/2014
GNP	6/4/2014
GNP	7/1/2014
GNP	7/30/2014
GNP	8/26/2014
GNP	9/25/2014
GNP	10/23/2014
GNP	11/21/2014
GNP	12/19/2014
GNP	1/20/2015
GNP	3/18/2015
GNP	4/15/2015
GNP	5/14/2015
GNP	6/10/2015
GNP	7/10/2015
GNP	8/6/2015
GNP	9/6/2015
GNP	10/6/2015
GNP	11/5/2015
GNP	12/4/2015
GNP	1/3/2016
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GNP	3/2/2016
GNP	3/31/2016
GNP	4/29/2016
GNP	5/29/2016
GNP	6/29/2016
GNP	7/26/2016
GNP	8/25/2016
GNP	9/22/2016
GNP	10/23/2016
GNP	11/23/2016
GNP	12/22/2016
GNP	1/20/2017
GNP	2/19/2017
GNP	3/20/2017
GNP	4/18/2017
GNP	5/18/2017
GNP	6/18/2017
GNP	7/17/2017
GNP	8/15/2017
GNP	9/13/2017
GNP	10/12/2017
GNP	11/11/2017
GNP	12/11/2017
GNP	1/11/2018
GNP	2/9/2018
GNP	3/9/2018
GNP	4/8/2018
GNP	5/8/2018
GNP	6/7/2018

Appendix II

Total Debris (Flux) for Each Site Based on Accumulation Survey Data

Accumulation Surveys are used to determine debris flux (number of items per unit area per time). All debris items greater than or equal to 1 inch (2.5cm) within a survey area were recorded. Each survey area is 328 ft (100 meters) in length and varies in width based upon the beach profile.

The figures in this section illustrate **the flux (rate of change, or rate of deposition) of debris items at each monthly survey**. Flux is best used to understand **how much debris accumulates on the shoreline monitoring site between surveys.** More specifically, these values are the number of items collected per meter squared per day (number of items/m2/day). Note that there is no flux value for the first survey.

The following figures show flux in three different categories:

- Total debris (Accumulation Survey) by site -- Flux
- Total debris (Accumulation Survey) by material type -- Flux
- Plastic debris (Accumulation Survey) grouped by user category -- Flux

All charts were prepared using templates found in the NOAA Marine Debris Program's Marine Debris Monitoring and Assessment Project Toolbox.
(https://marinedebris.noaa.gov/research/monitoring-toolbox)

Total Debris (Accumulation Survey) by Site -- Flux

The following four figures (Figures 56 – 59) illustrate the flux or deposition rate of debris items at each monthly Accumulation Survey. The figures show how much debris accumulated on the shoreline monitoring site between surveys. Note that there is no flux value for the first survey.

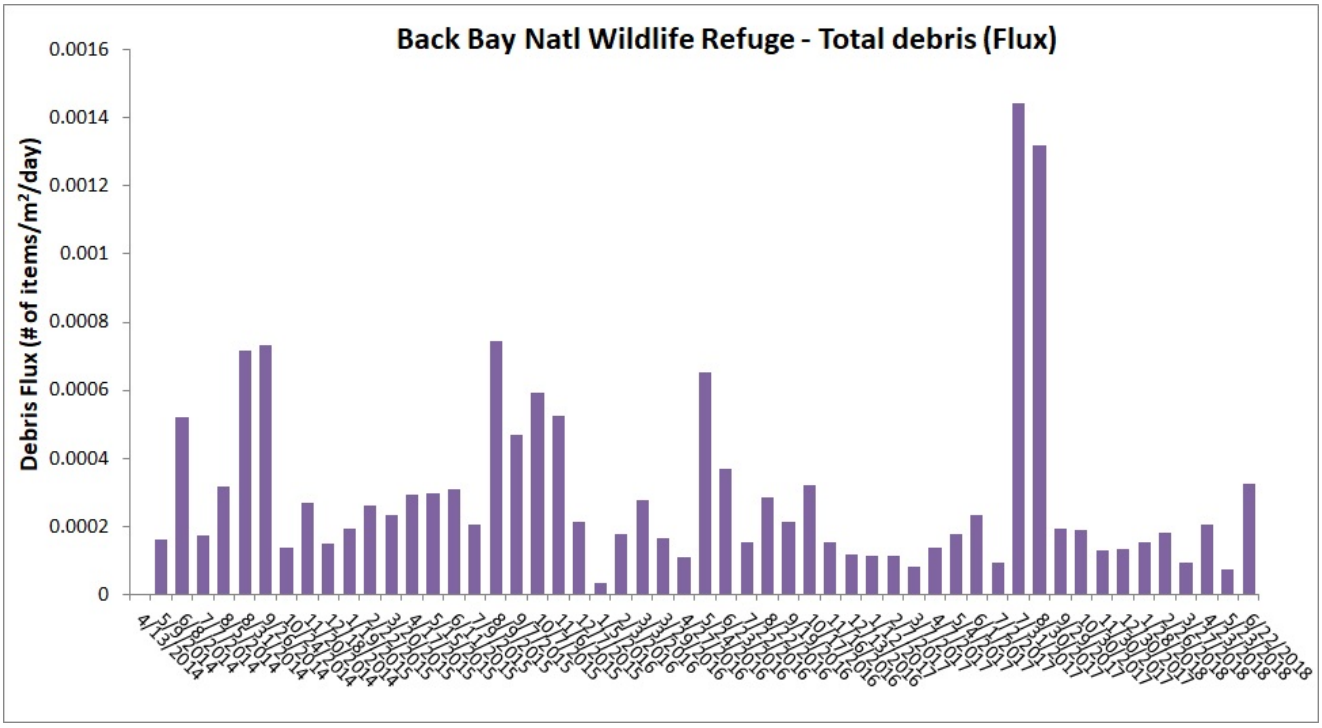

Figure 56. Total debris flux (number of items/m^2/day) for Back Bay National Wildlife Refuge.

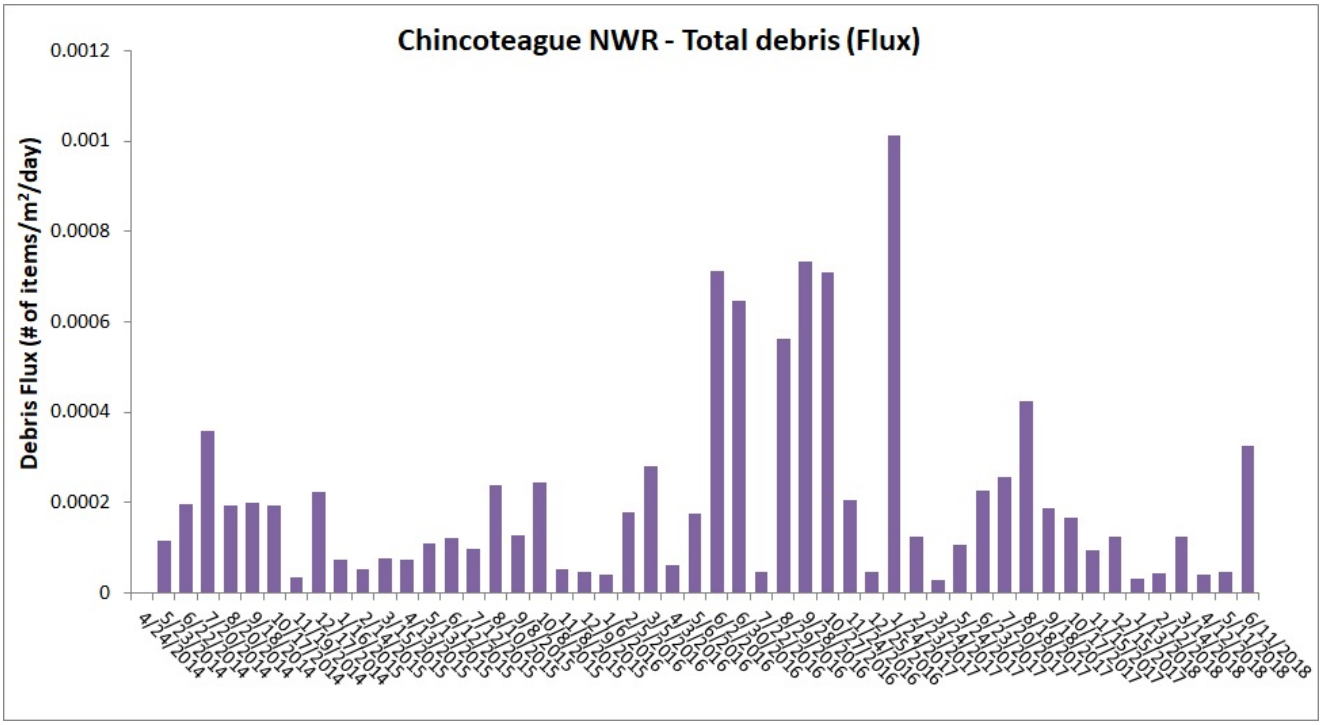

Figure 57. Total debris flux (number of items/m^2/day) for Chincoteague National Wildlife Refuge.

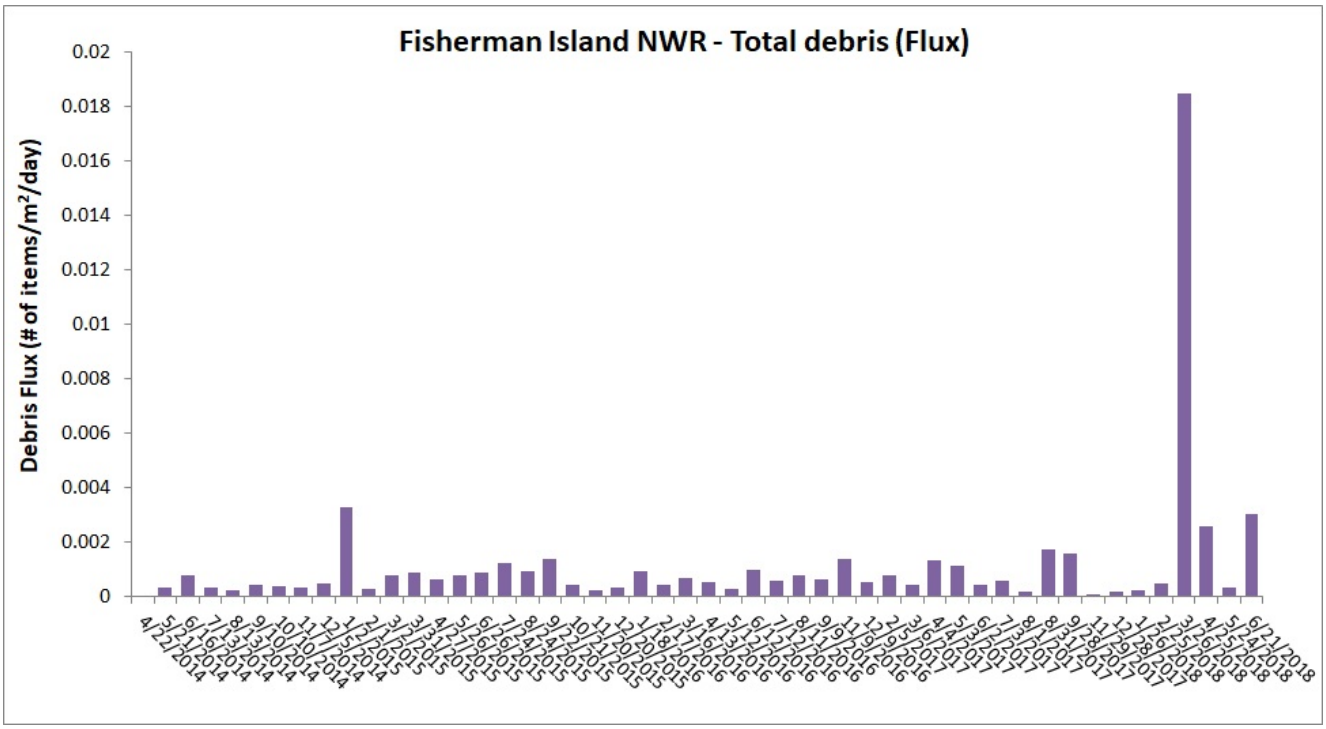

Figure 58. Total debris flux (number of items/m^2/day) for Fisherman Island National Wildlife Refuge.

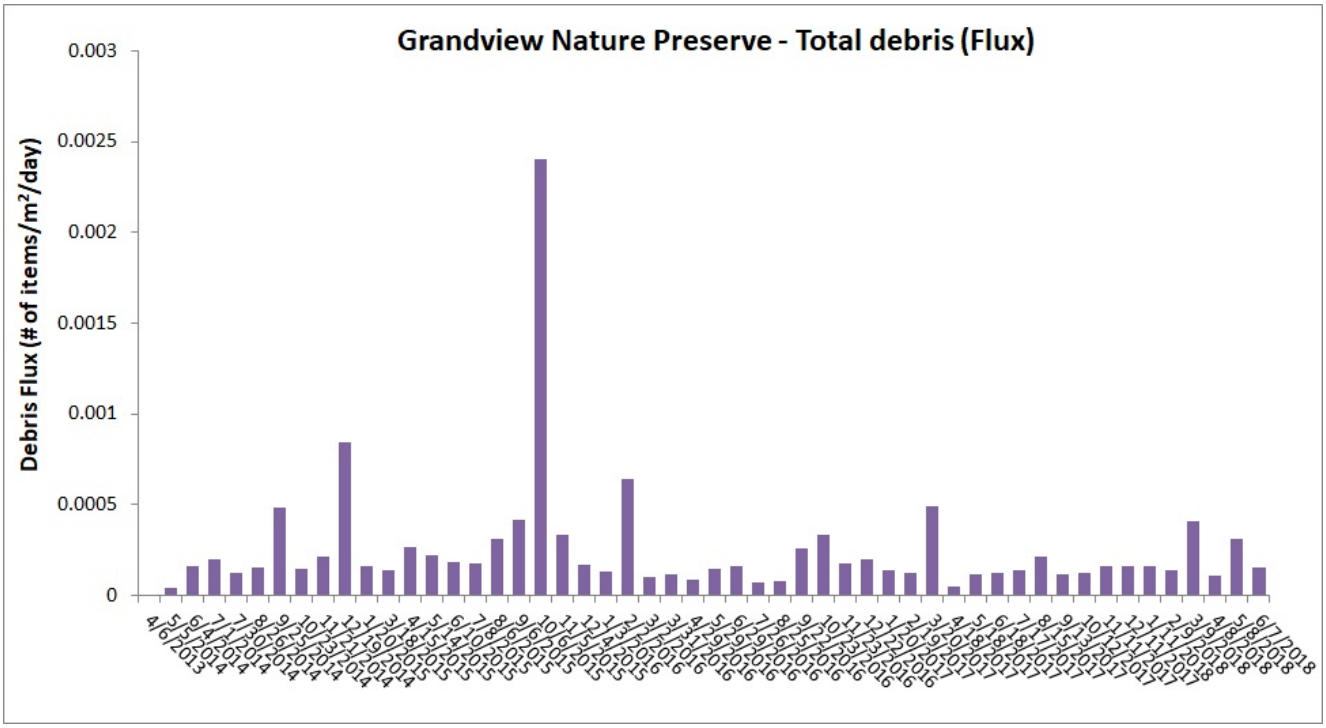

Figure 59. Total debris flux (number of items/m^2/day) for Grandview Nature Preserve.

Total Debris by Material Type (Flux)

Figures 60 through 63 illustrate the flux or deposition rate of debris items by material type. The figures show how much debris accumulated on the shoreline monitoring site between Accumulation Surveys for the various material types. Note that there is no flux value for the first survey.

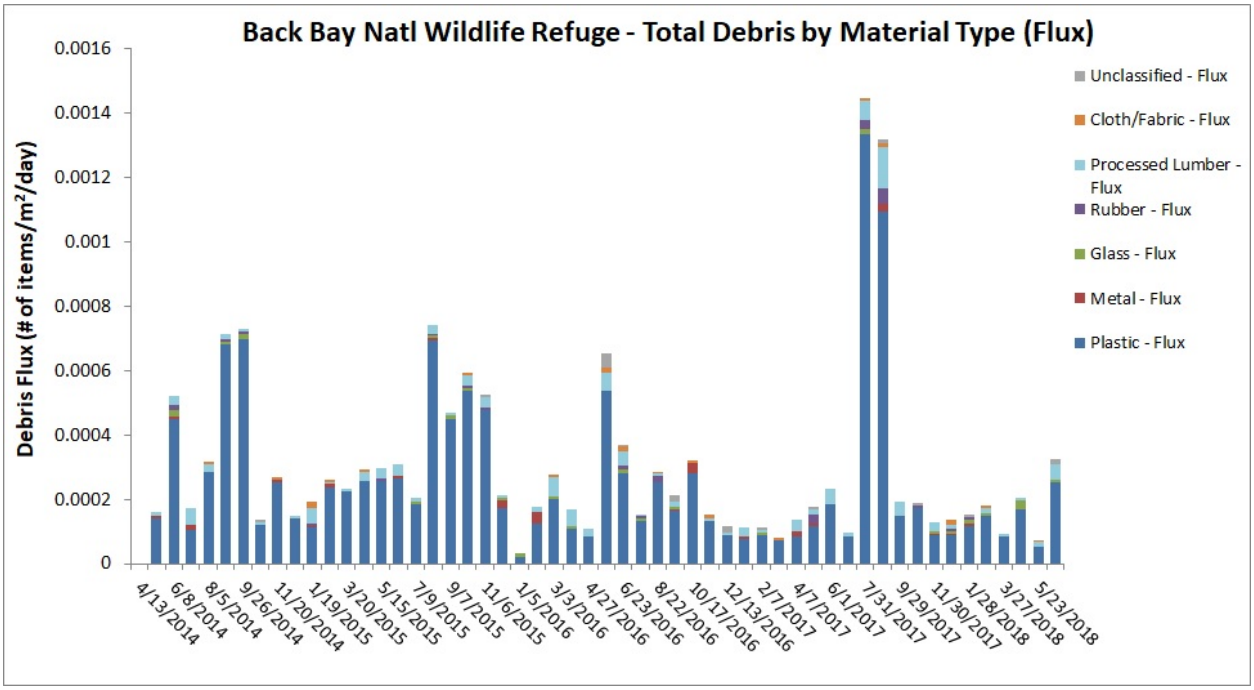

Figure 61. Debris flux (number of items/m^2/day) by material type (plastic, metal, glass, rubber, processed lumber, cloth/fabric, and other/unclassified) for Back Bay National Wildlife Refuge.

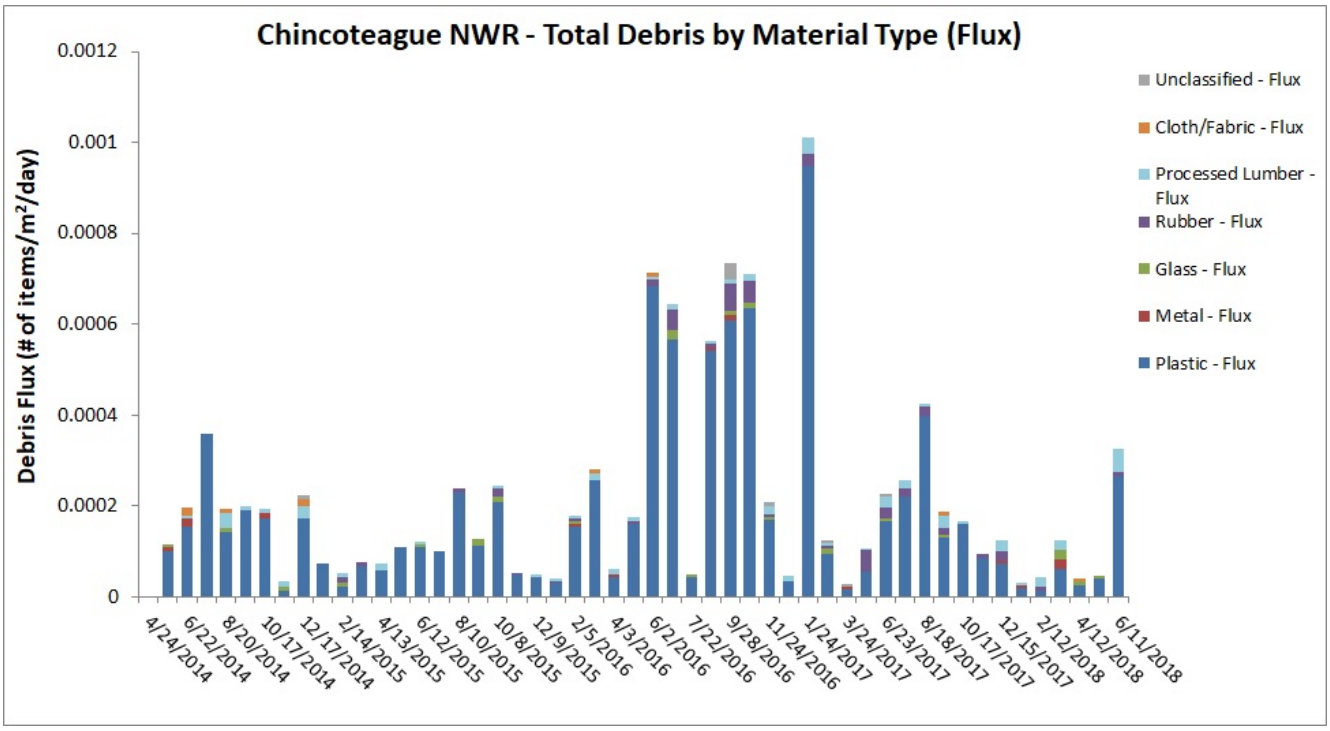

Figure 62. Debris flux (number of items/m²/day) by material type (plastic, metal, glass, rubber, processed lumber, cloth/fabric, and other/unclassified) for Chincoteague National Wildlife Refuge.

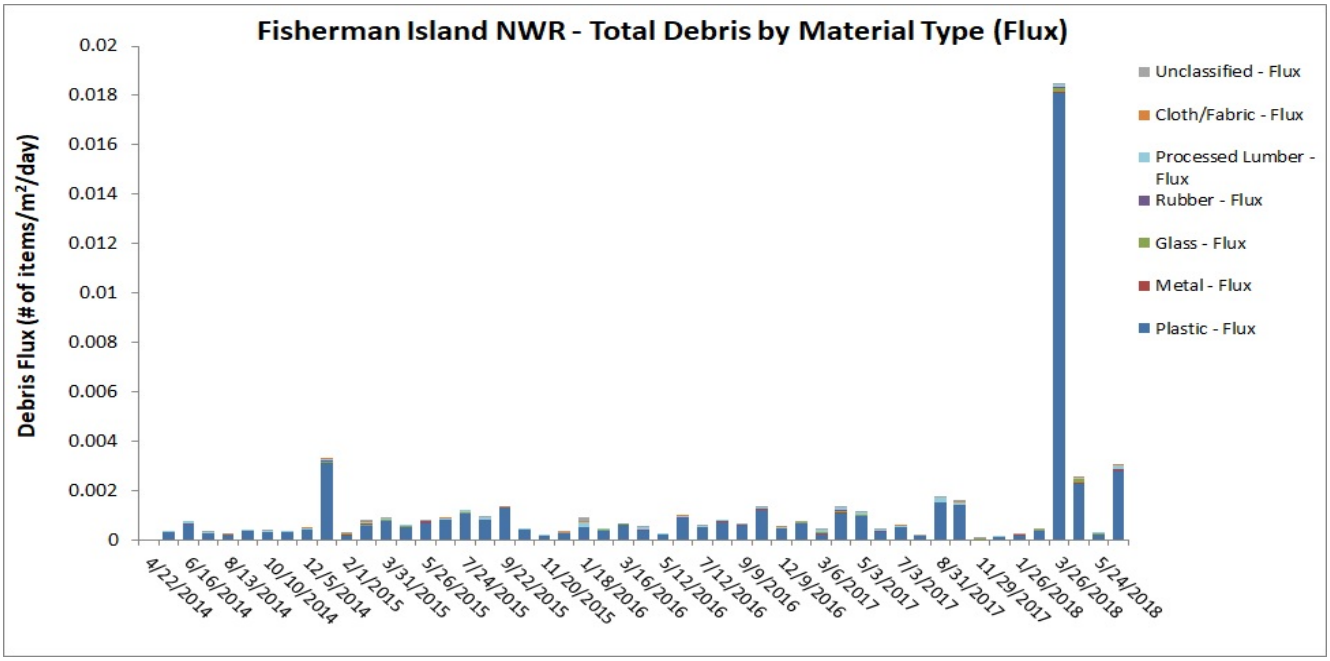

Figure 63. Debris flux (number of items/m²/day) by material type (plastic, metal, glass, rubber, processed lumber, cloth/fabric, and other/unclassified) for Fisherman Island National Wildlife Refuge.

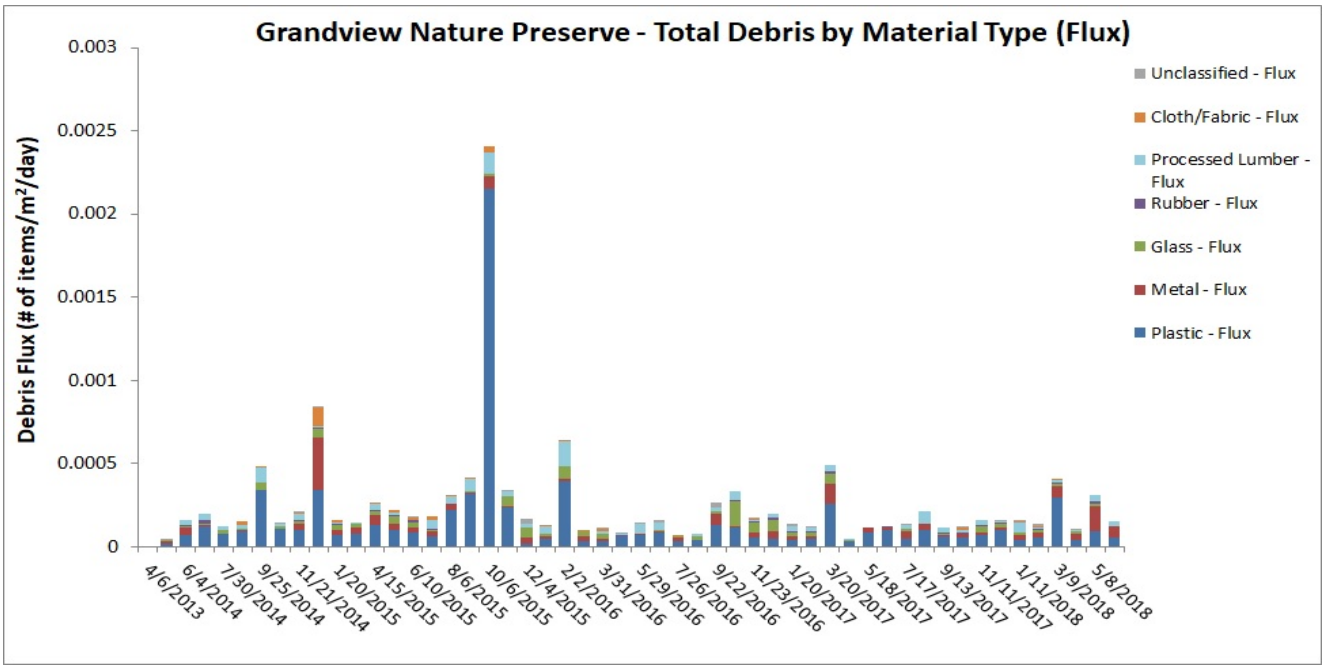

Figure 64. Debris flux (number of items/m^2/day) by material type (plastic, metal, glass, rubber, processed lumber, cloth/fabric, and other/unclassified) for Grandview Nature Preserve.

Total Plastic Debris Grouped by User Category (Flux)

Figures 65 through 68 show the flux or deposition rate of plastic debris items by user group category. The figures show how much plastic debris accumulates on the shoreline monitoring site between surveys for the various user group categories: plastic consumer products, plastic smoking products >2.5 cm, and plastic fishing related products. Note that there is no flux value for the first survey.

Plastic consumer products include: food wrappers; plastic beverage bottles; other jugs/containers; bottle/container caps; 6-pack rings; bags; cups; plastic utensils; straws; balloons; and personal care products. Smoking Products >2.5 cm include: cigar tips; cigarettes; and disposable cigarette lighters. Fishing-related products include: plastic rope/net; buoys & floats; and fishing lures & line.

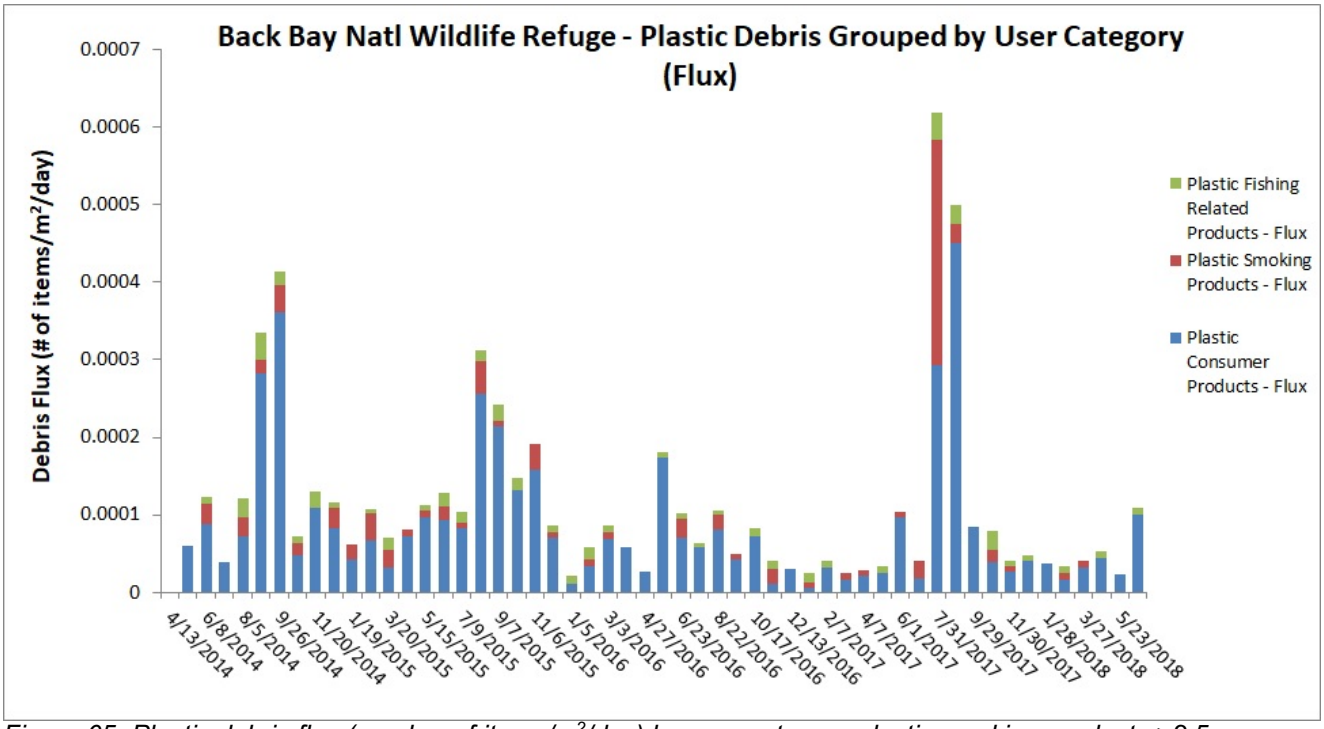

Figure 65. Plastic debris flux (number of items/m²/day) by user category plastic smoking products >2.5cm, and plastic fishing related products) for Back Bay National Wildlife Refuge.

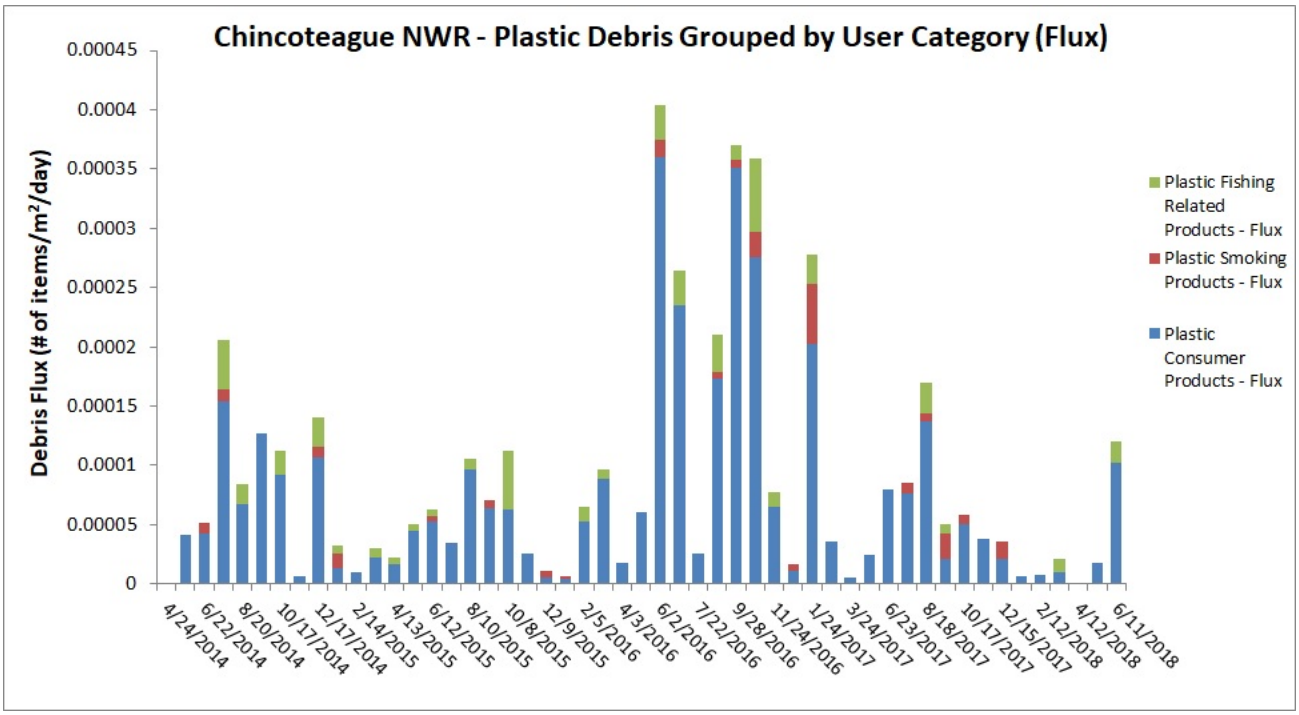

Figure 66. Plastic debris flux (number of items/m^2/day) by user category (plastic consumer products, plastic smoking products >2.5cm, and plastic fishing related products) for Chincoteague National Wildlife Refuge.

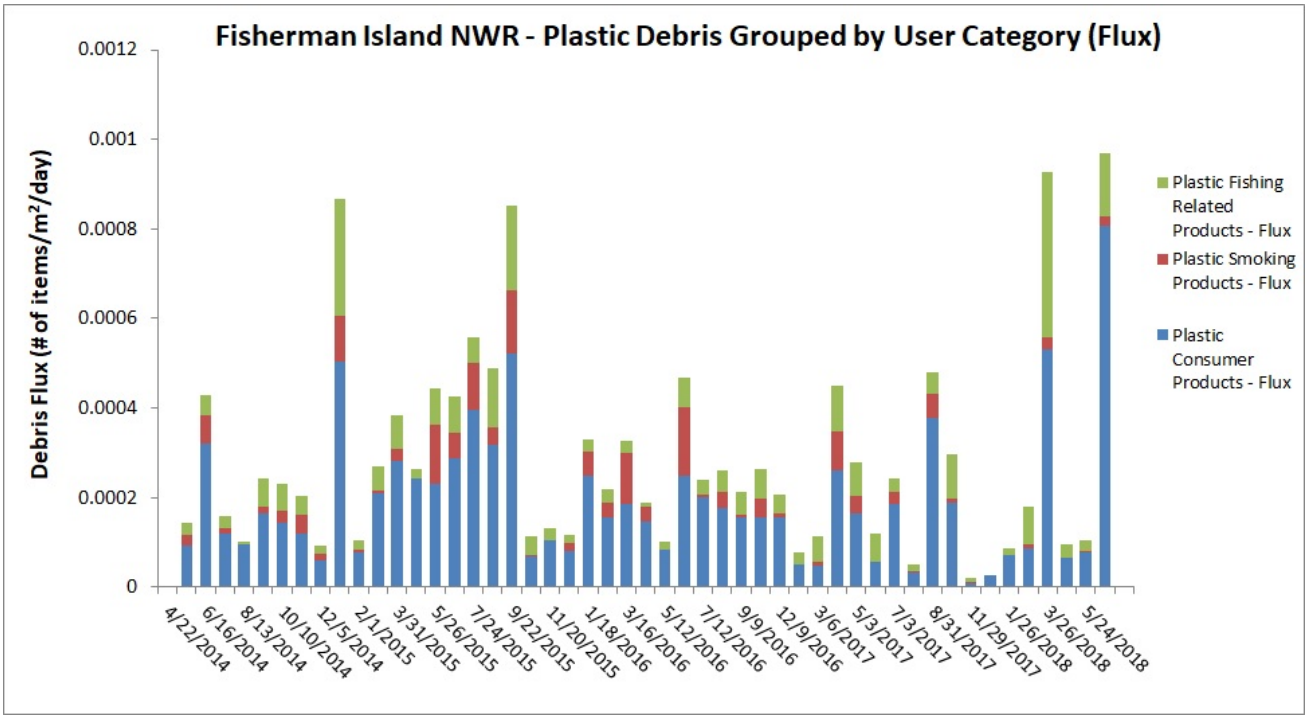

Figure 67: Plastic debris flux (number of items/m^2/day) by user category (plastic consumer products, plastic smoking products >2.5cm, and plastic fishing related products) for Fisherman Island National Wildlife Refuge.

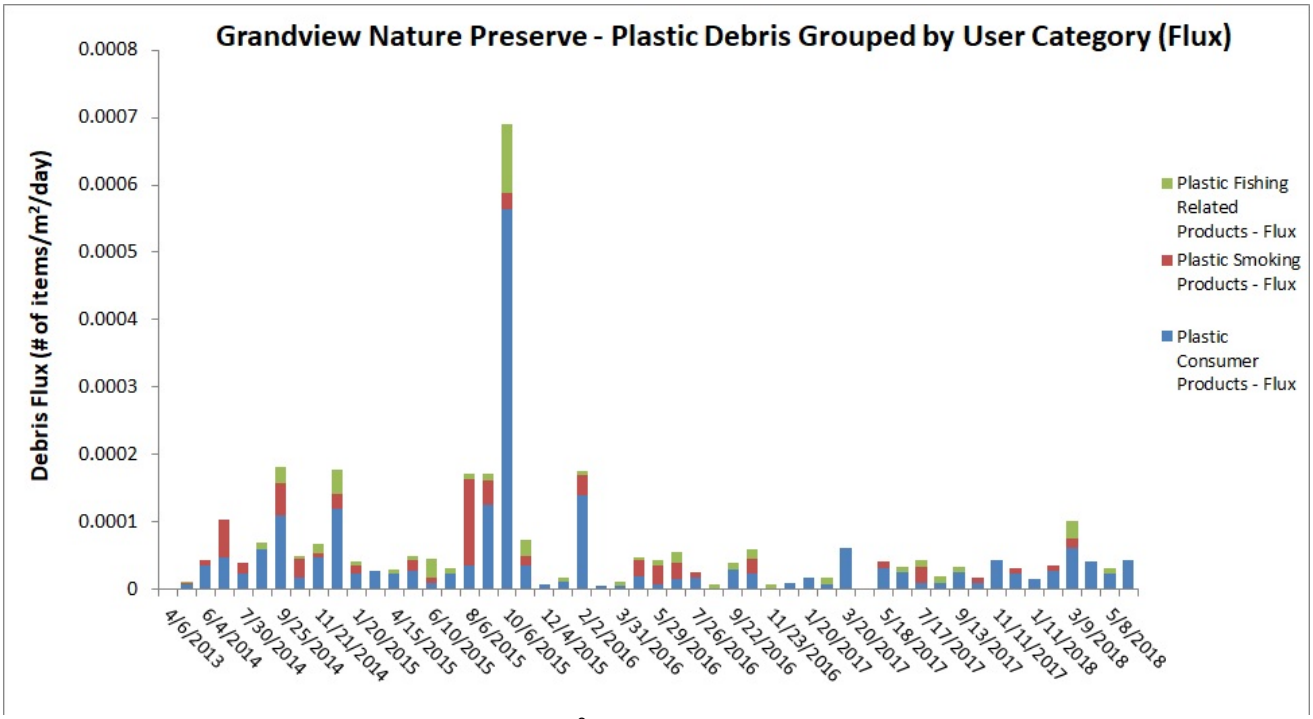

Figure 68. Plastic debris flux (number of items/m^2/day) by user category (plastic consumer products, plastic smoking products >2.5cm, and plastic fishing related products) for Grandview Nature Preserve.

Appendix III

Concentration (Density) of Debris Items Based on Standing-Stock Survey Data

Standing-Stock Surveys are used to **determine debris density (number of items per square meter**). During these surveys, all debris items greater than or equal to 1 inch (2.5cm) within a survey area were recorded, but they were not removed from the area. Each survey area is 328 ft (100 meters) in length and varies in width based upon the beach profile.

The following figures illustrate the **concentration** of debris items (# of items/m2) recorded at each monthly survey. This figure is best used to display how the debris density (loads) changes for a site between surveys.

According to Lippiatt *et al.* (2013):

> *"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."*

Total Debris (Concentration) for Each Monitoring Site (Standing-Stock Survey Data)

Figures 69 through 72 illustrate the **concentration** of debris items (# of items/m2) recorded at each monthly survey for all debris items recorded during the Standing-Stock Surveys. These figures are best used to display how the debris density (loads) changes for a site between surveys.

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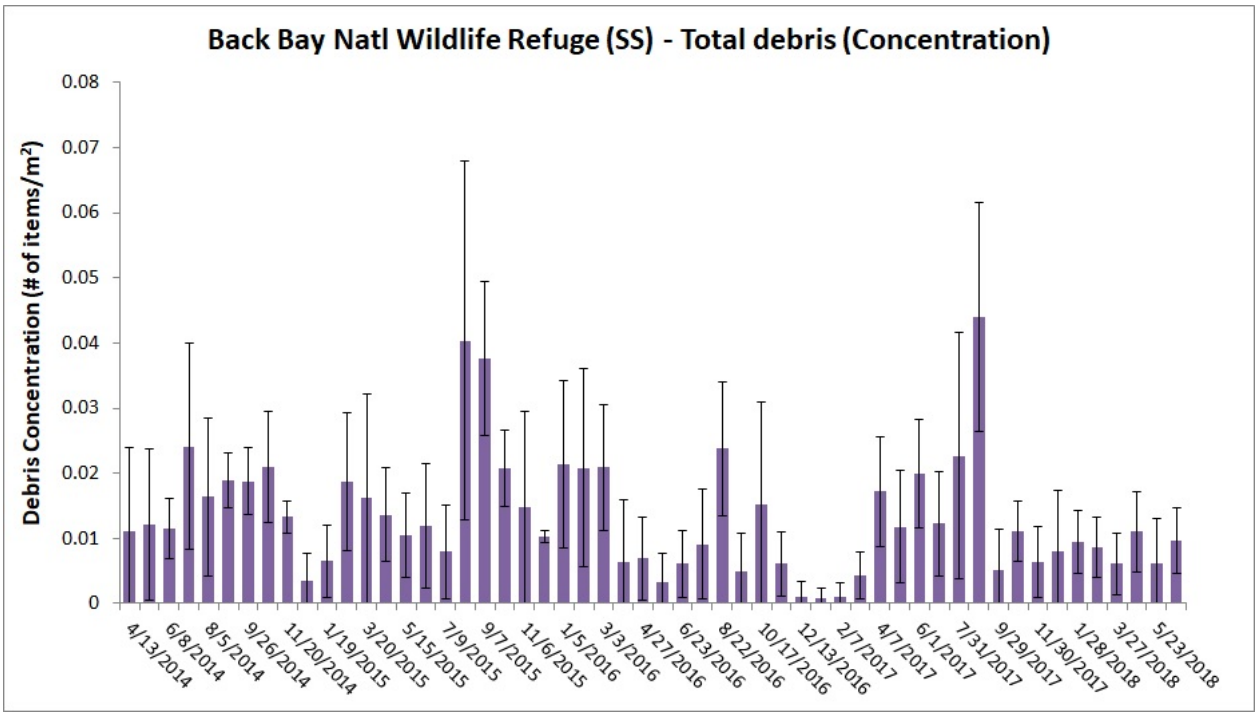

Figure 69. Total calculated debris concentration per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge. Error bars represent standard deviations.

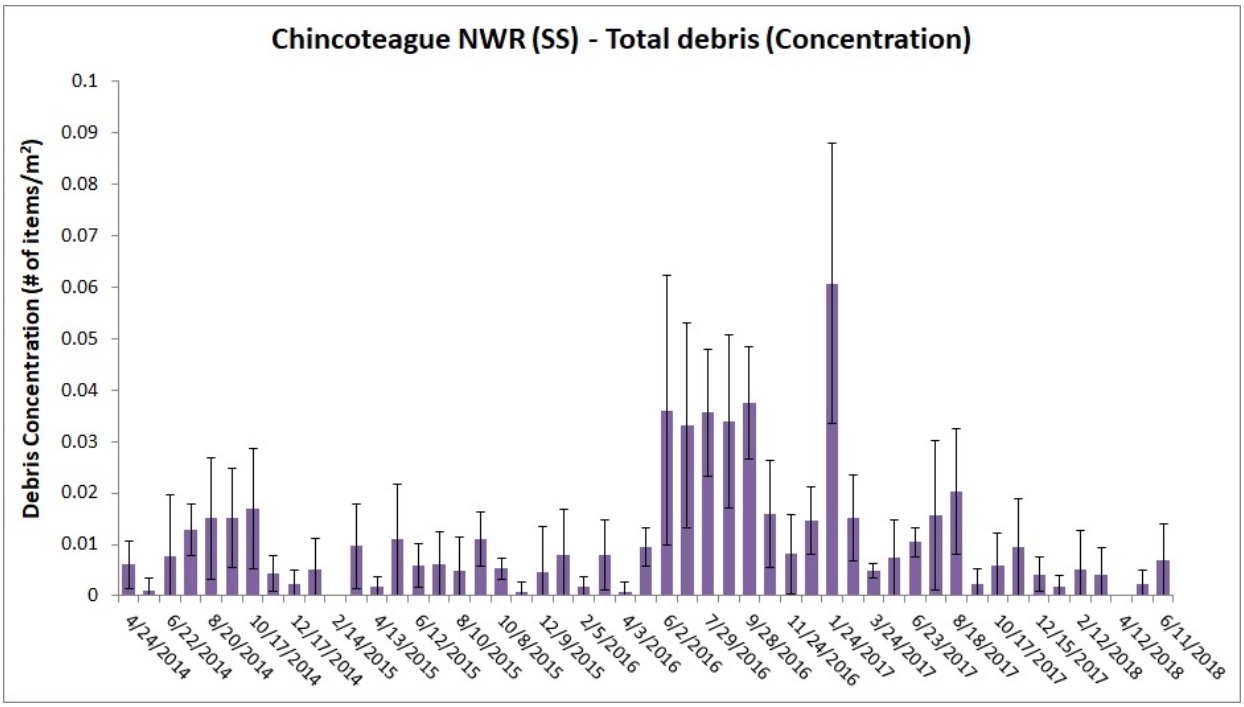

Figure 70. Total calculated debris concentration per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge. Error bars represent standard deviations.

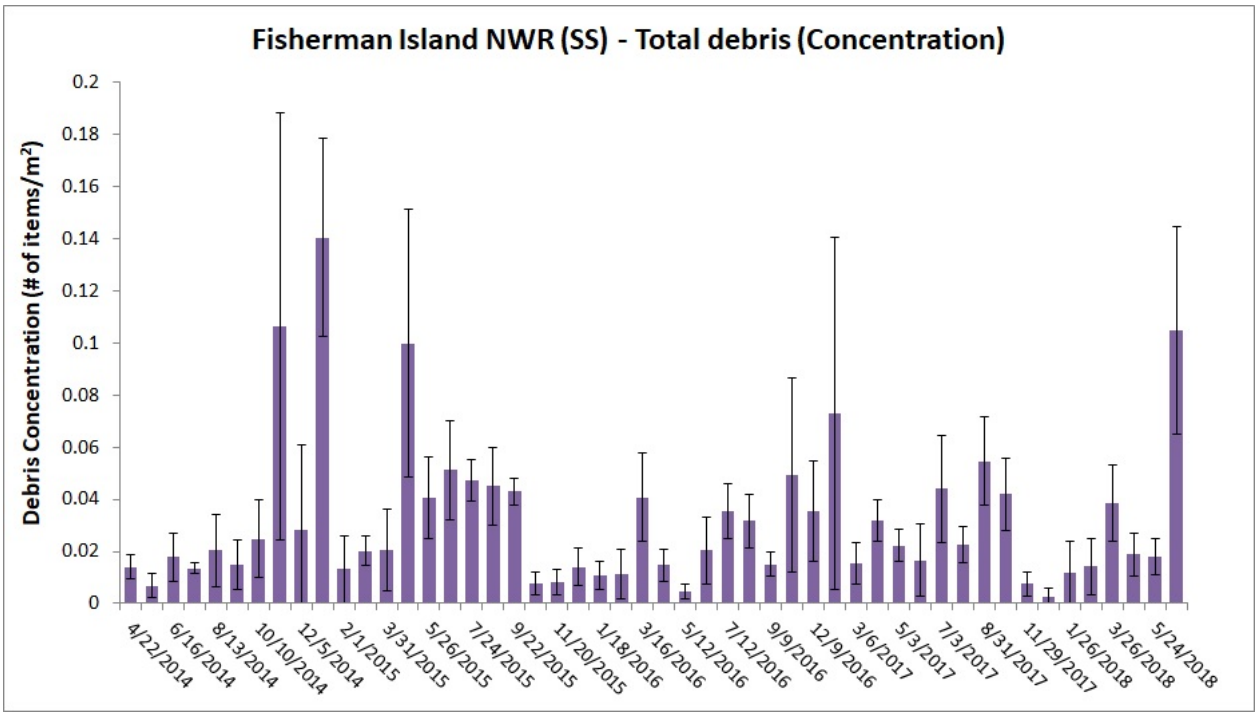

Figure 71. Total calculated debris concentration per monthly Standing-Stock Survey on Fisherman Island National Wildlife Refuge. Error bars represent standard deviations.

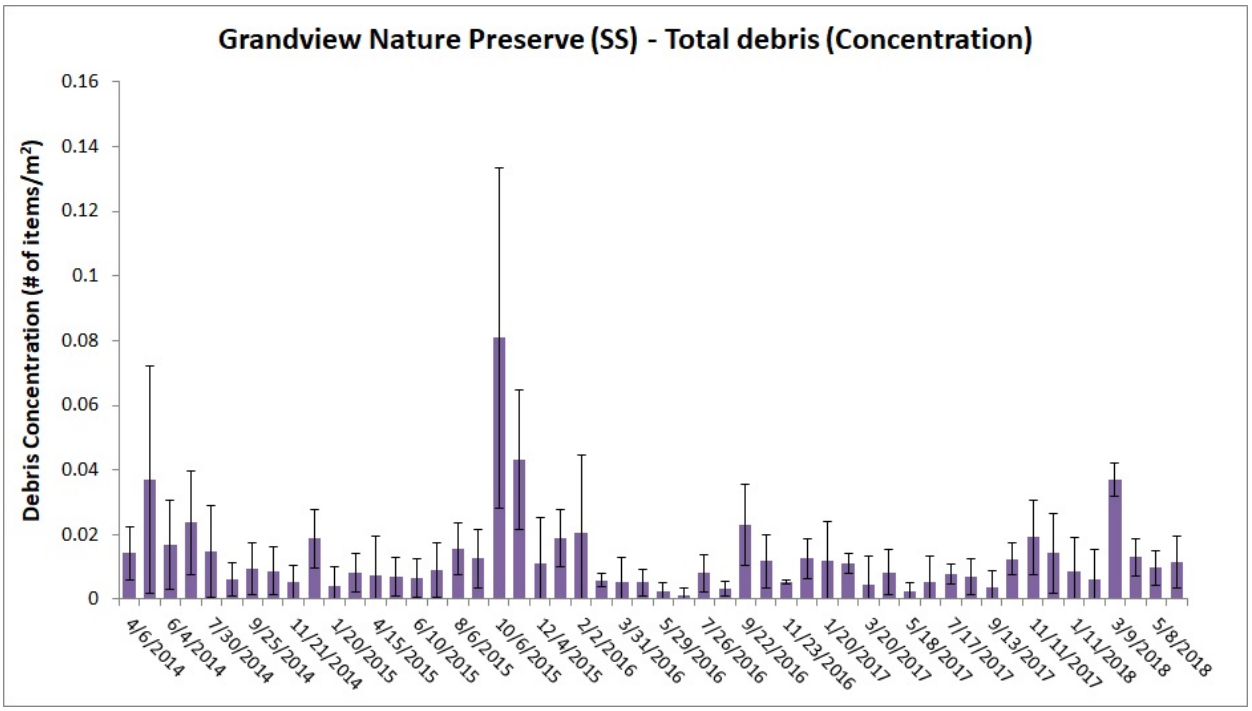

Figure 72. Total calculated debris concentration per monthly Standing-Stock Survey on Grandview Nature Preserve. Error bars represent standard deviations.

Total Debris by Material Type (Concentration) for Each Monitoring Site (Standing-Stock Survey Data)

Figures 73 through 76 illustrate the **concentration** of debris items (# of items/m2) recorded at each monthly survey for all debris items by material type. These figures are best used to display how the debris density (loads) changes for a site between surveys.

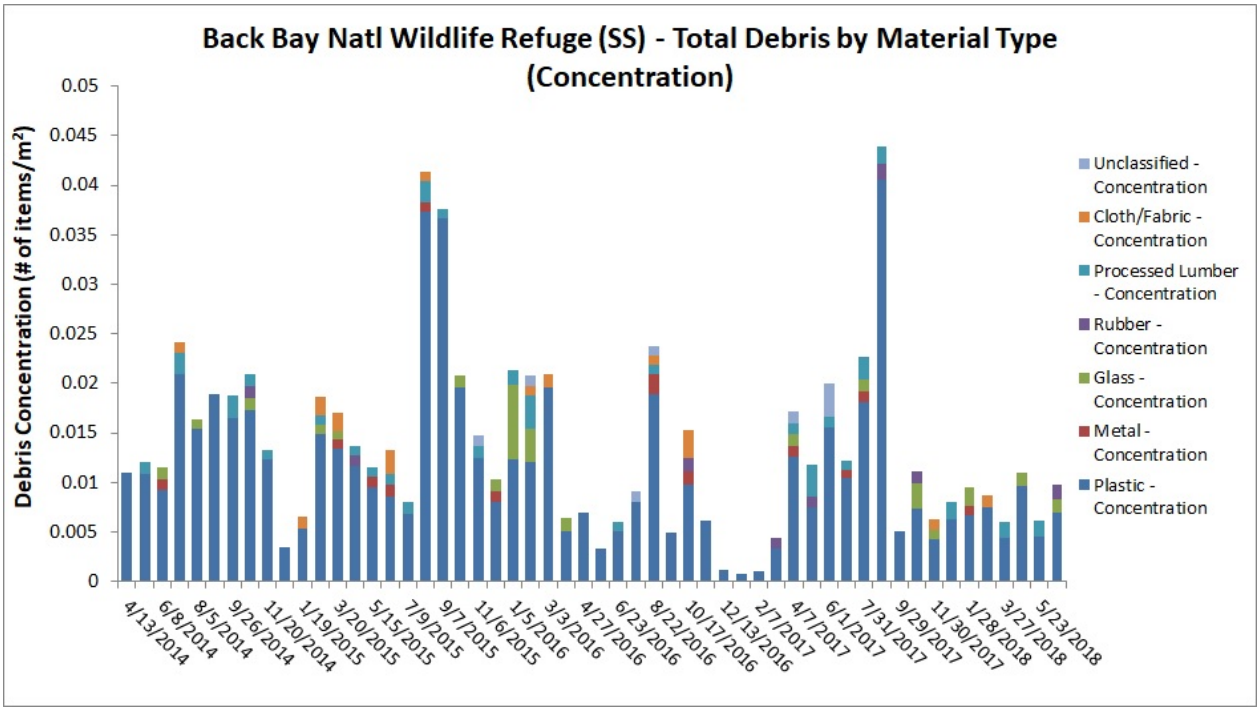

Figure 73. Total calculated debris concentration by material type per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge.

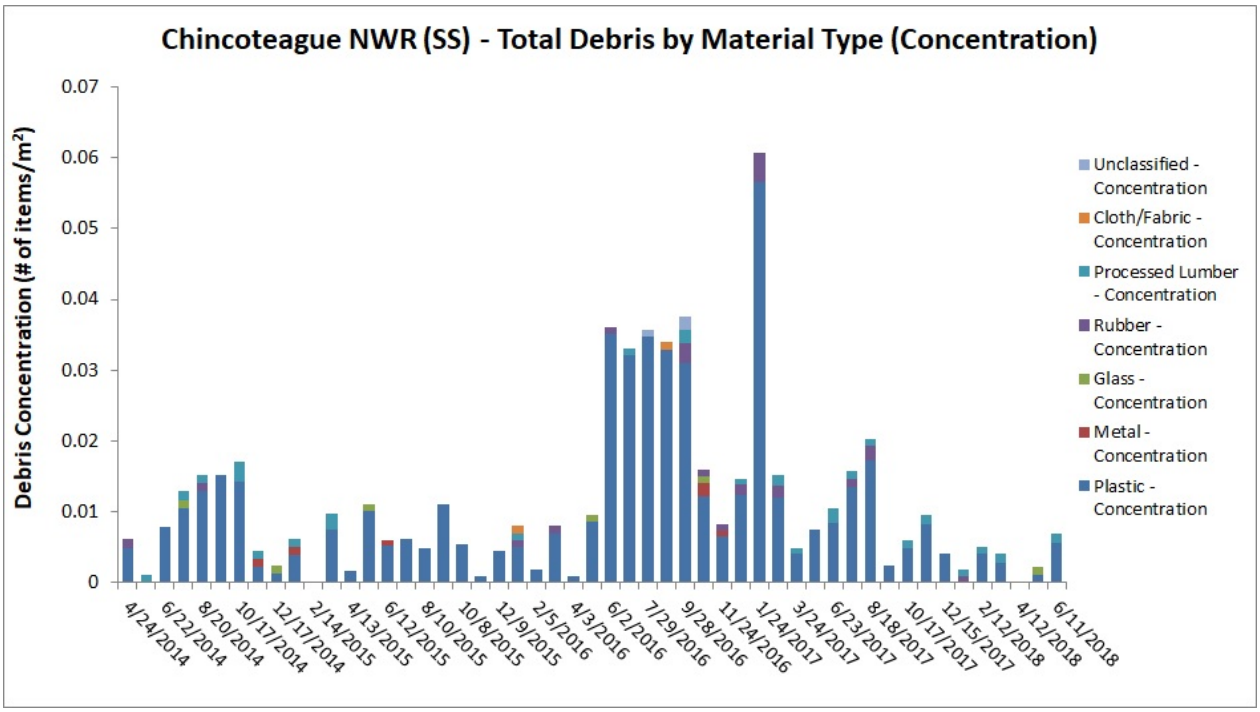

Figure 74. Total calculated debris concentration by material type per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge.

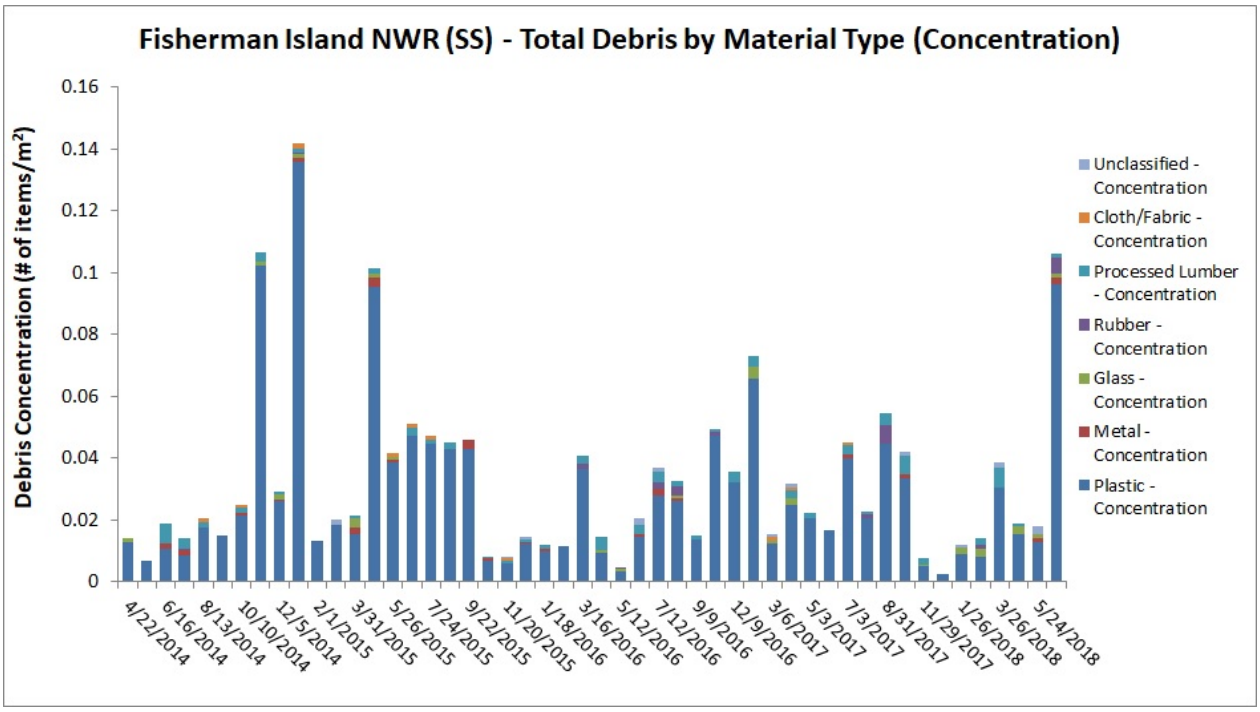

Figure 75. Total calculated debris concentration by material type per monthly Standing-Stock Survey on Fisherman Island National Wildlife Refuge.

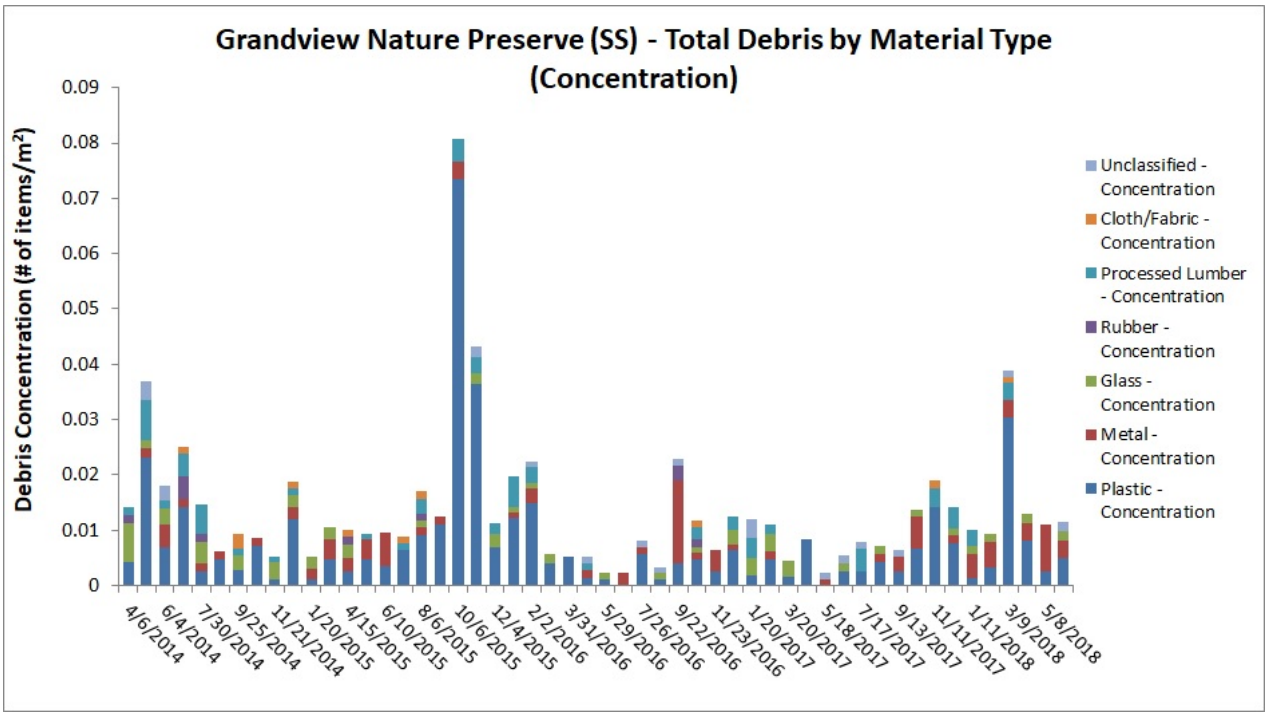

Figure 76. Total calculated debris concentrations by material type per monthly Standing-Stock Survey on Grandview Nature Preserve.

Plastic Debris Grouped by User Category for Each Monitoring Site (Standing-Stock Survey Data)

Figures 77 through 80 illustrate the **concentration** of plastic debris concentrations for the four transects by user category (plastic consumer products, plastic smoking products >2.5 cm, and plastic fishing related products).
Plastic consumer products include: food wrappers; plastic beverage bottles; other jugs/containers; bottle/container caps; 6-pack rings; bags; cups; plastic utensils; straws; balloons; and personal care products. Smoking Products >2.5 cm include: cigar tips; cigarettes; and disposable cigarette lighters. Fishing-related products include: plastic rope/net; buoys & floats; and fishing lures & line.

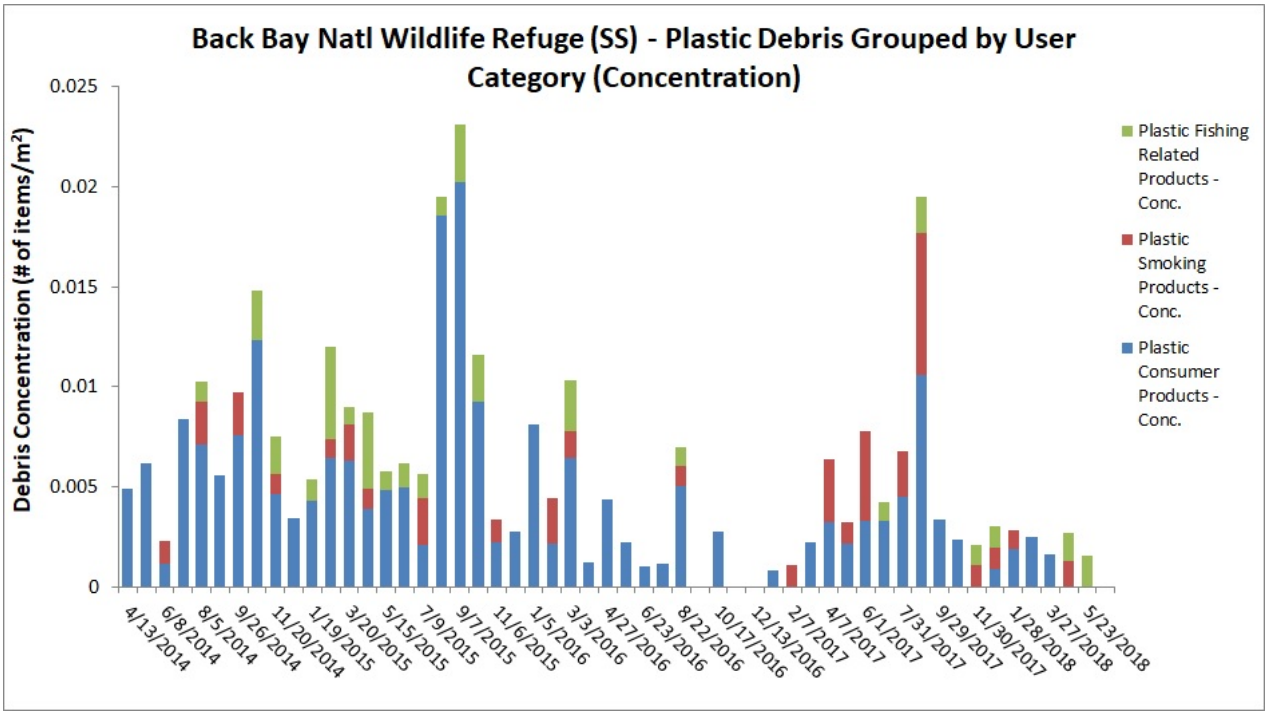

Figure 77. Total calculated plastic debris concentration by user category per monthly Standing-Stock Survey on Back Bay National Wildlife Refuge.

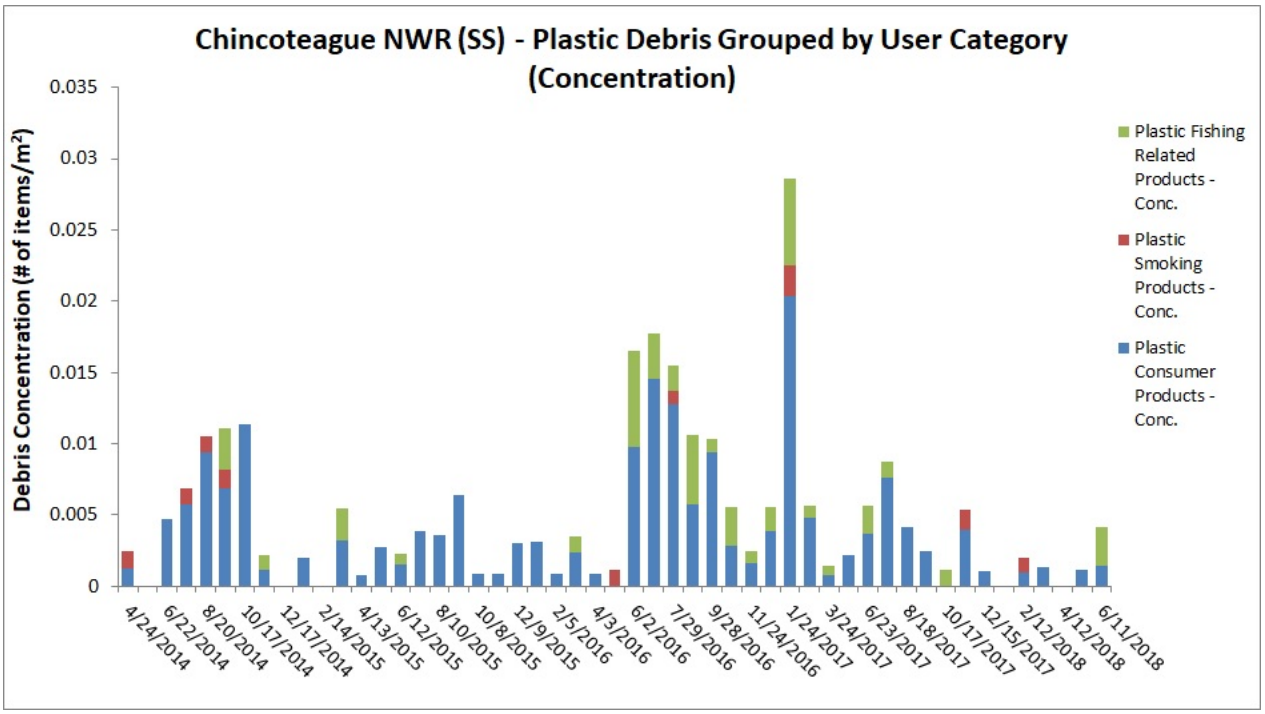

Figure 78. Total calculated plastic debris concentration by user category per monthly Standing-Stock Survey on Chincoteague National Wildlife Refuge.

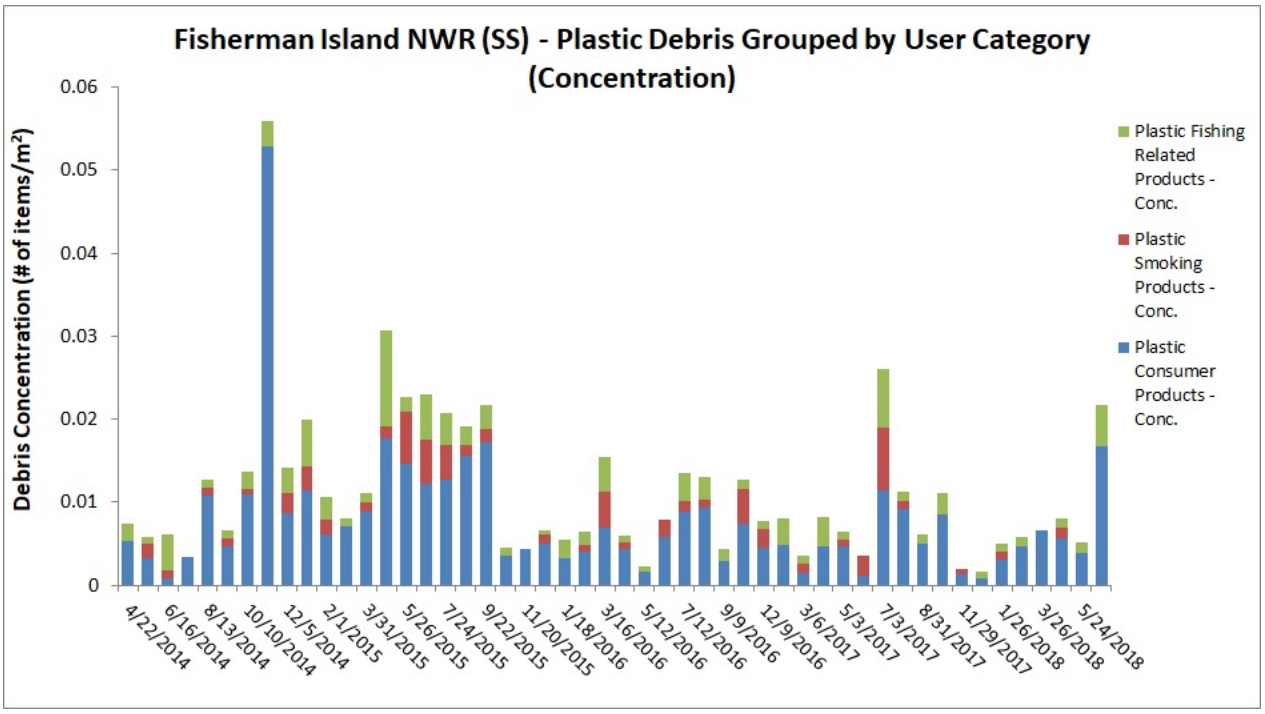

Figure 79. Total calculated plastic debris concentration by user category per monthly Standing-Stock Survey on Fisherman Island Wildlife Refuge.

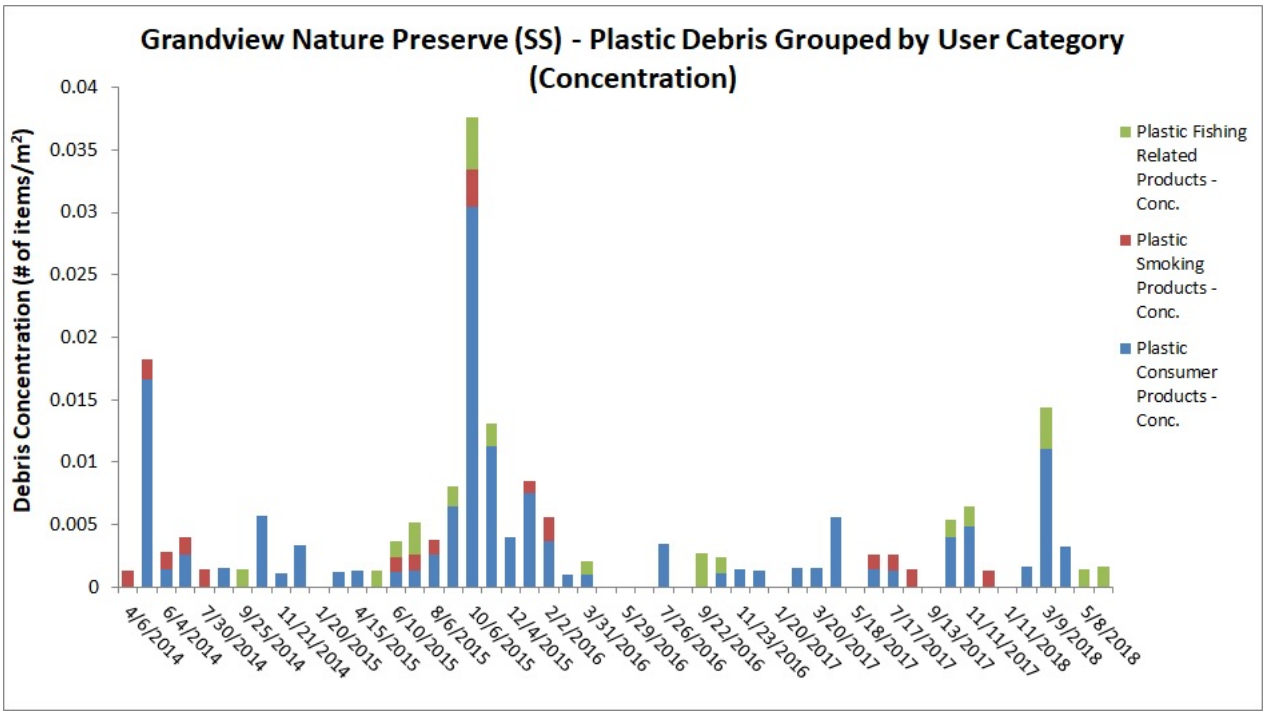

Figure 80. Total calculated plastic debris concentration by user category per monthly Standing-Stock Survey on Grandview Nature Preserve.