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An analysis of marine debris in the US

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

NOAA

Ocean Conservancy®

How much marine debris is there on US shores?

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

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

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

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

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

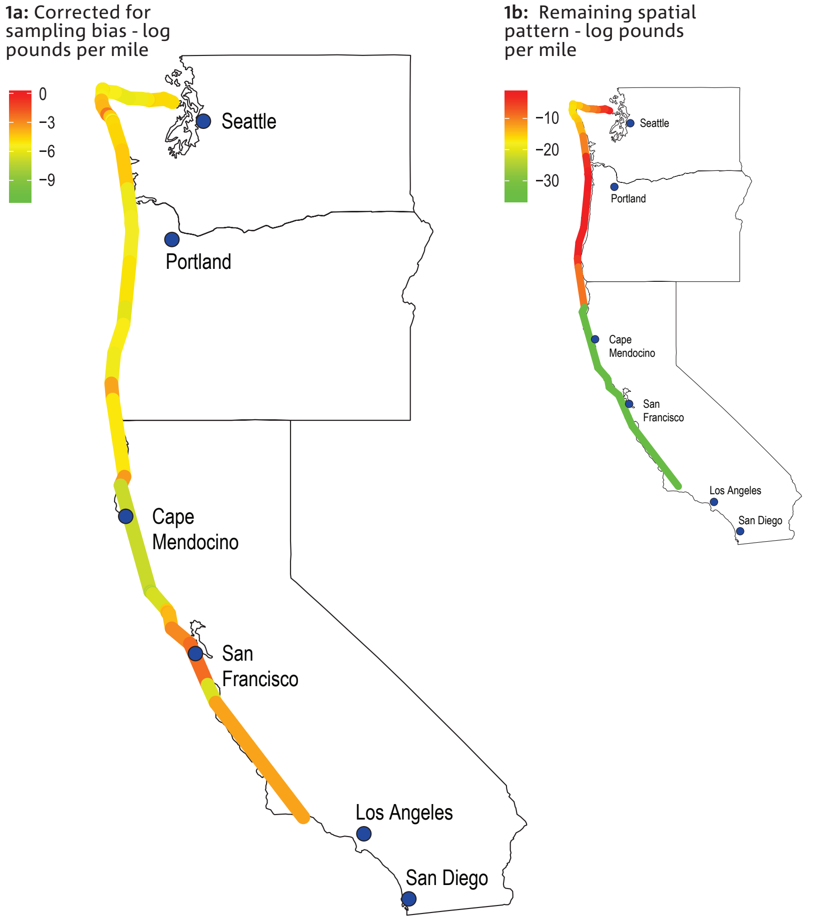
What do the data tell us?

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

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

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

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



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

Where are the national hot spots?

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

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

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

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

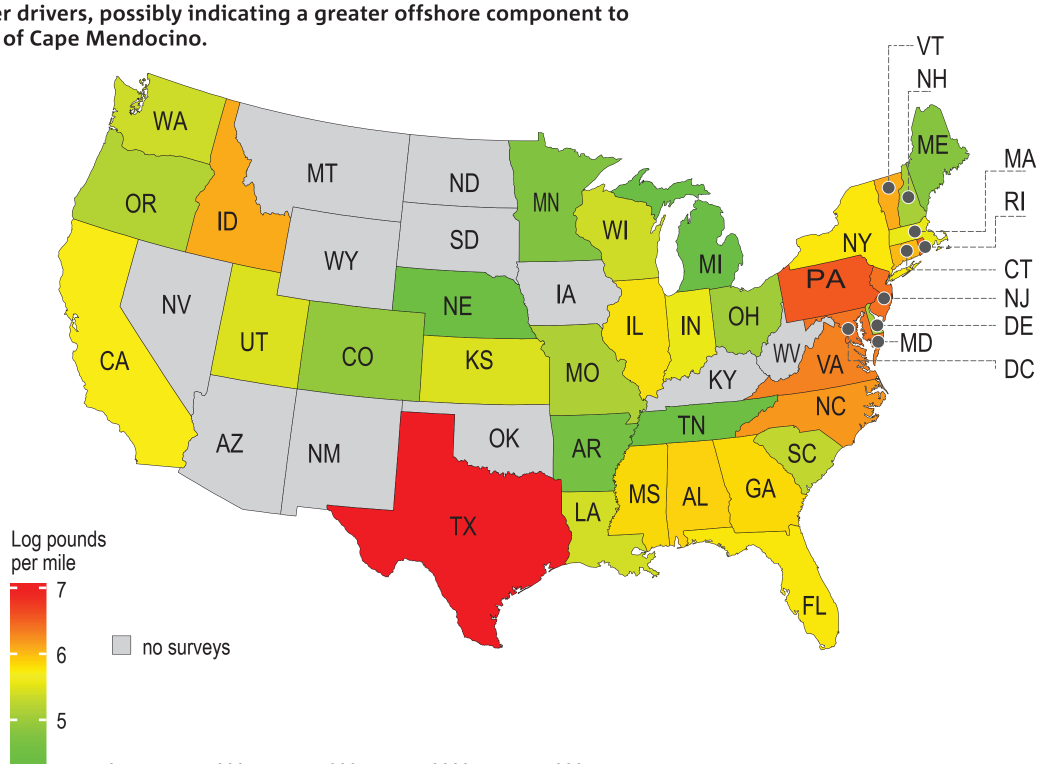


Figure 2: Statewide debris load based on ICC data after correcting for sampling bias. Values represent the average weight of debris per mile for all debris surveys across each state

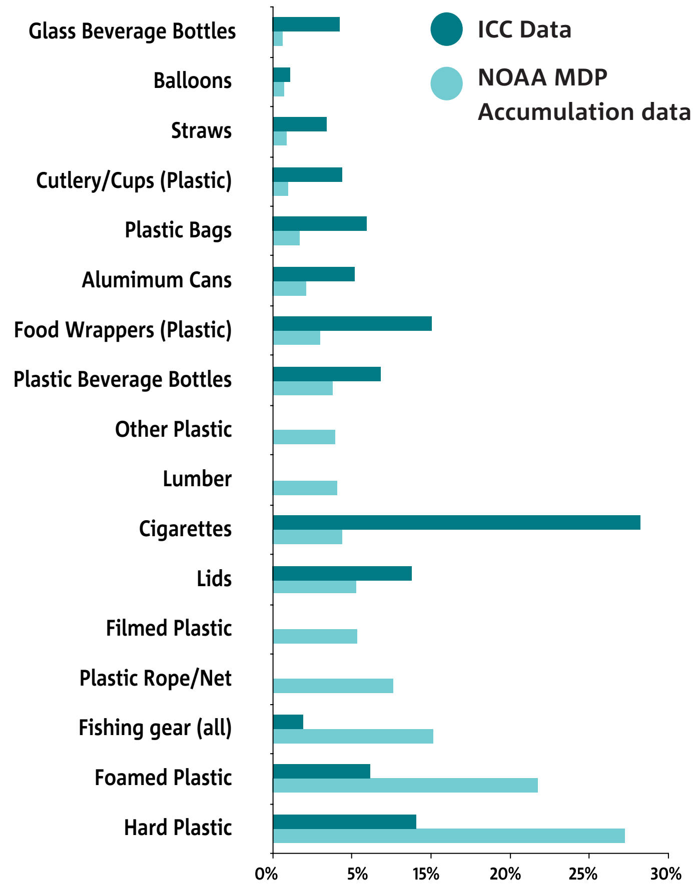
Which items were most abundant?

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

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

Why the NOAA MDP and ICC results do not match

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



Which items pose the most risk to wildlife?

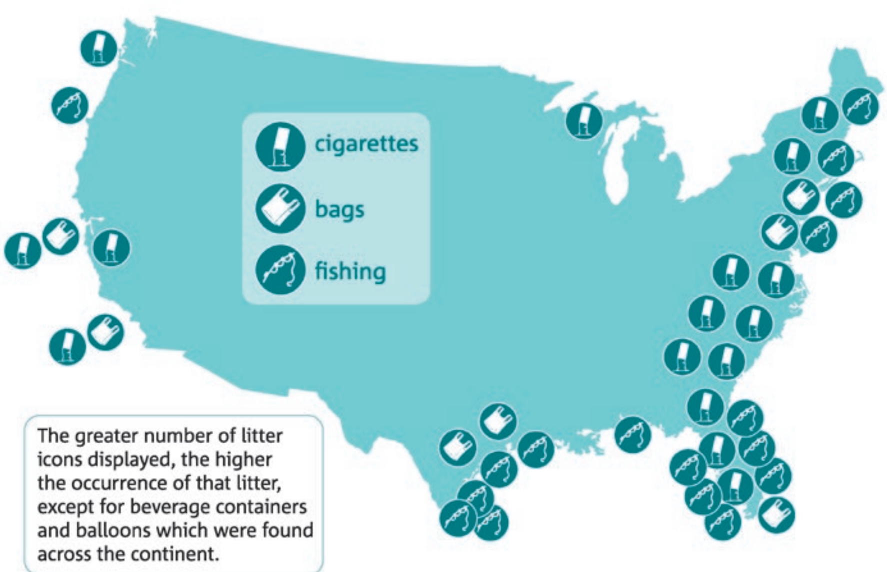
Based on recent CSIRO and OC research, fishing gear, plastic bags, balloons, plastic beverage bottles, and cigarette butts were most harmful to sea birds, marine mammals, and turtles.

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

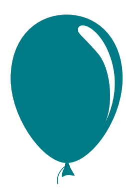
We found balloon litter was fairly constant across the whole of the continent.

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

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



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



Ballons were found across the continent.

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

How effective is legislation?

Do bottle bills work?

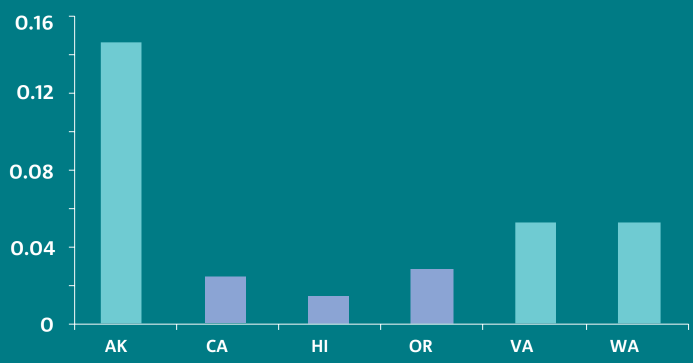
Based on NOAA MDP's data, beverage containers made up a smaller percentage of the debris collected in states that had Container Deposit Legislation (CDL) – California, Hawaii and Oregon – compared to states that do not provide a cash incentive for recovery of beverage containers – Alaska, Virginia and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

Maybe people in certain states are thirstier?

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

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

PROPORTION OF CONTAINERS



PROPORTION OF LIDS

States without CDL   States with CDL

Understanding the different sampling methods

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

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

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

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

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

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

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

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

Recommendations and next steps

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

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

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

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

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

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