Marine Biodiversity Hub

National Environmental Science Programme

Emerging Priorities Project - EP1

Assessing the effectiveness of waste management in reducing the levels of plastics entering Australia's marine environment

Britta Denise Hardesty, Kathryn Willis, Qamar Schuyler,
TJ Lawson and Chris Wilcox

Milestones:

- *2 - Preliminary Report*
- *3 – Maps of national debris land-based, coastal, and at-sea floating debris hotspots*

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Enquiries should be addressed to:

Denise Hardesty
denise.hardesty@csiro.au

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THE PROJECT

Assessing the effectiveness of waste management in reducing the levels of plastics entering Australia's marine environment This preliminary report and plain English summary for this emerging priorities project is intended to be a high-level document that synthesises existing knowledge on the relationship between debris in the marine environment and litter data from nearby sites, and the pathways through which litter moves into the marine environment.

Maps showing leakage points and litter or debris concentrations (e.g. hotspots) are also provided.

1. PROJECT OUTPUTS

1. A written report and plain English summary for use by state, territory and local governments, which:
    a. Synthesises existing knowledge on the relationship between debris in the marine environment and litter data from nearby sites, the types of litter and the pathways through which litter moves into the marine environment.
    b. Summarizes existing coastal debris/litter survey methodologies with discussion of applications of each.
2. A list of activities and programs associated with plastic waste reduction (including facilities, policies and outreach),
3. A publically accessible analysis and summary of different survey methods aiming to reduce debris inputs to the marine environment.
    a. The relative cost of activities and programs;
    b. A relative ranking of activities and programs regarding their effectiveness in reducing plastic waste in the marine environment.
4. Conclusions on where marine debris hot spots are in Australia's marine environment and effective mitigation strategies.
5. Recommendations on where more information (such as scientific, policy, infrastructure, community engagement) is required to obtain a better understanding of the problem and possible solutions. This may include identifying knowledge gaps and needs for further analysis.

2. AN OVERVIEW OF SOURCES AND PATHWAYS FOR MARINE DEBRIS ENTERING THE MARINE ENVIRONMENT, WITH A DISCUSSION OF SURVEY METHODOLOGIES

Marine debris (or marine litter) is a growing issue of international concern. Defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment (UN Environment Program, 2009), it results in a multitude of impacts in coastal and marine environments. Not only does debris impact wildlife, have detrimental economic consequences, result in navigation hazards and transport invasive species, but it also has aesthetic and toxicological impacts on communities and wildlife, respectively. Common items that end up as marine debris include plastic bottles, food packaging, fishing nets or gear, food packaging, cigarette butts and plastic bags (ICC 2016).

Marine debris and its upstream source, land-based litter, is a growing environmental, economic and social issue that spans council, state, national and international boundaries. Addressing this complex issue and reducing litter inputs to the marine environment is a challenging undertaking. Managing the issue will benefit from understanding the plastic pollution problem from a large-scale, holistic perspective. This involves conceptualizing the sources and drivers, the distribution and dynamics of debris in the environment as well as identifying or quantifying the impacts on wildlife and humans, and identifying and assessing a suite of potential management responses (Hardesty and Wilcox 2017). The remit is conceptually broad and includes topics as widespread and diverse as littering and human behaviour, oceanography and physics, economics and ecology, and toxicology and metabolic physiology (Hardesty and Wilcox 2017).

Research on marine litter has been ongoing for decades, with studies in the 1970's initially addressing the topic. There has, however, been a recent explosion of work addressing the marine debris topic, and it has increasingly been in the public eye. In 2015, the first recent estimate of how much mismanaged waste enters our global ocean was published, suggesting that 4.8-12.7 million metric tonnes of plastic enters the ocean from the 192 countries around the world considered, and including people living within 50 km of the coastline (Jambeck et al. 2015). It has also been estimated there are more than five trillion pieces of floating plastic in the ocean (Eriksen et al. 2014).

In terms of impacts on wildlife, a recent review estimates around 700 species interact with marine debris (Gall and Thompson 2015). That number is undoubtedly climbing as further research into additional species and their interactions with debris are explored. Plastic debris is ubiquitous; it is found not only on the coastlines of countries around the world, but it has also been found from the most remote corners of the Arctic (Obbard et al. 2014; Lusher et al. 2015) to the deepest depths of the ocean (Woodall et al. 2014).

With an estimated 80% of debris entering the oceans coming from land-based sources and the remaining 20% from at-sea activities (Derraik 2002; Jambeck et al. 2015), understanding the movement of litter on land is fundamental to addressing the issue *before* it reaches the ocean, and is the focus of this project. Litter or debris moves in the environment through a variety of pathways. The primary pathways through which litter moves include human movement and behaviour (littering or dropping items), vehicular transport, wind and water (along rivers, creeks, streams and stormwater outfalls). We address this in our work. As a case study, we examine watersheds in the Sydney region to identify the key sources and drivers of litter moving from land to the ocean (see Figures 3, 4).

The topics of how, where and why to monitor debris are wrought with implications. These questions have implications for how data can be analysed, what we can learn from it, how we can estimate or

make predictions or projections for areas we have not been able to sample, and many other questions we may wish to address. From the 1990s through to the present day, peer-reviewed studies have summarized marine litter monitoring programs, focusing on methods and national-scale surveys (Rees and Pond, 1995; Ribic et al. 1992) with a variety of recommendations for guidelines and approaches to monitoring marine litter on land (see Cheshire and Adler, 2009; Galgani et al. 2010; Opfer et al. 2012; NOAA 1992, 2011; others) and at sea (Directive 2013; Ryan et al. 2009; Mace et al. 2012).

There are myriad ways in which people carry out clean-up activities, surveys and monitoring programs around the world. To date, however, there has been no global consensus reached on a single survey method, nor has there been a robust comparison of survey methods (other than a recently completed project by CSIRO; see Hardesty et al. 2016). Hence, this is a significant knowledge gap and is a topic considered in this emerging priorities project. Indeed, before 2018, a global working group through the Group of Experts on Scientific Aspects of Marine Protection (GESAMP) will have commenced to address this topic specifically. The working group specifically will be working on harmonization of monitoring methods (beginning September 2017), and will include experts from around the world.

Why has the standardization of methodologies proven so difficult? One of the fundamental challenges of standardization comes back to the question(s) being asked. If someone asks a question as seemingly straightforward as 'How much debris do we find on the coast of New South Wales?' we might then ask do we mean how many pieces of litter? How much does it weigh? What is the volume of that litter? What proportion of litter is made of what kind of material? How big an area are we going to sample? How many people are collecting information, and how big an area are we considering? What do we consider coastline? Is it only sandy beaches or are rocky slabs or other coastal areas considered? What about mangroves? How far from the waterline do we sample? Do we sample big items, small items, and how do we decide? How can we get an estimate if we can't survey every meter of the coastline?

As is apparent, what seems like a simple question quickly can become quite challenging. Is it fair to compare the coastal litter in New South Wales to that of coastal South Australia (given how many people live in each state, not to mention the length of coastline and infrastructure and resources in each of the two states)? How do we account for the difference in the number of people in a state – is that something we need to consider when we present our results? All these (and many other) questions come in to consideration as one considers design and implementation of monitoring programs. If we want to ask if there has been a change in time, is it fair to compare count (or weight or volume) differences between years, or do we need to account for the fact that more people live in a survey region now than they did when an area was surveyed 10 years ago?

There are a number of goals or reasons for carrying out marine debris monitoring. Monitoring or cleanups may take place to increase community engagement and raise awareness, to quantify the amounts of debris, to predict hotspots, to identfy sources to reduce loss rates, to determine sinks or debris accumulation areas, to identify interdiction points, to determine the cost effectiveness of litter bins and signage; and many other reasons. Not all of these are mutually exclusive, some methodogies can address a number of goals. To contextualize the topic and provide a framework for considering how one might establish a monitoring program (or relevant components to consider), we developed a structure to think about marine debris from survey design through to analysis and interpretation (Figure 1). When we identify what we want to know, we can then determine how and/or what we measure – and the appropriate approach or method to employ. If the goal is to have a monitoring system in place which addresses particular questions, assesses changes through time

(and is statistically robust and appropriate), there could be significant benefit in the development of such a monitoring system at the national scale.

This project addresses many of these questions. Critically, and perhaps most importantly, we provide a framework the conversation and a structure that laypeople, citizen scientists and policy makers may want to consider as any group sets out to design and conduct surveys (see Figure 1 for details and description of questions, types of data that may be collected, and appropriate analyses that can be applied to address specific questions).

Australia is well-poised to take a leadership role as a key country in the Asia Pacific region. As highlighted by Jambeck and colleagues (2015), many of the countries with significant waste management that makes its way to the ocean, are within in the Asia Pacific region (Figure 2, below). It is clear that regulations, economic and market based instruments and community-based solutions all have a role to play (Vince and Hardesty 2016). By better understanding the types of litter and the pathways through which it moves before it reaches the ocean, we will be better able to manage litter before it reaches the ocean. The landscape is dynamic and changing rapidly in Australia, particularly as policies such as bag bans, container deposit legislation (CDL) and other governance arrangements are being considered at state and national levels. There is much to be learned about successes, challenges, and opportunities to reduce land-based litter inputs to the ocean.

Figure 1. Description of what questions might be asked of data (1, 2 in orange and purple), how or what is measured, with how the data may be collected, described or arranged and what questions and analyses that can be conducted to address particular questions of different types of data.

*At one extreme, the data can be aggregated up into a total count of items across all categories or a total weight (**Error! Reference source not found.**lower left). The advantage of this approach is that by using a single category of data, modelling efforts can focus on the full complexity of space and time patterns, incorporating both driving variables, such as local population size, and nuisance variables, such as sampling effort. At the other extreme, one might model the abundance of items in each category, across the tens of categories that are recorded in various data collections. The challenge in taking this approach is that models describing the abundances in each category may differ, leading to a very complex interpretation of the data (lower right). Furthermore, categories may be positively or negatively correlated so the direction of the link between items and abundance may be difficult to interpret. Intermediate tools such as richness curves or rank order distributions, as typically used in fields like community ecology (**Error! Reference source not found.**central bottom) do not seem to be particularly linked to useful questions in this context, though this is something we considered and explored.*

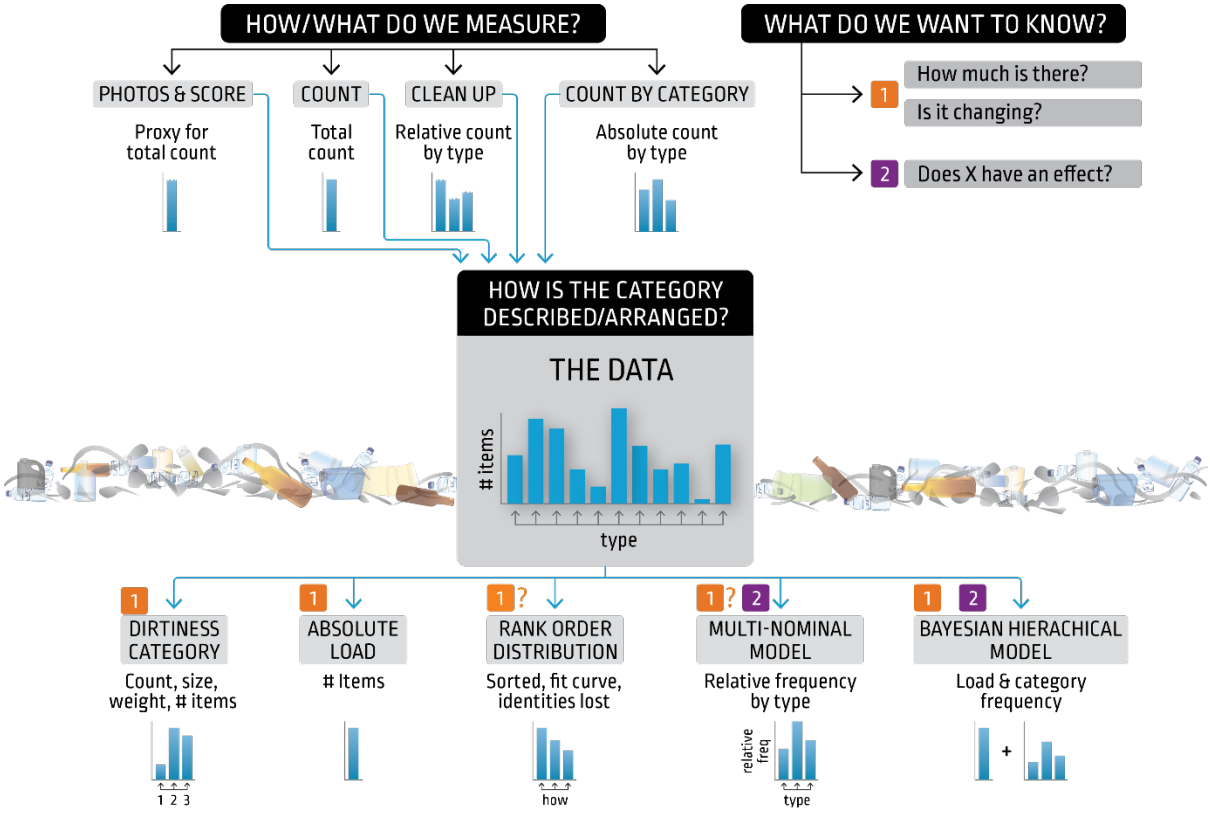


Figure 2. Waste estimates based on 2010 World Bank data for the top 20 countries ranked according to waste mismanagement (by mass; in units of millions of metric tons per year).

Mismanaged waste is considered the sum of inadequately managed waste plus 2% littering and includes populations within 50 km of the coast in the 192 countries considered. Economic classification is UMI, upper middle income; LMI, lower middle income; and LI low income). Figure adapted from Jambeck et al. 2015.

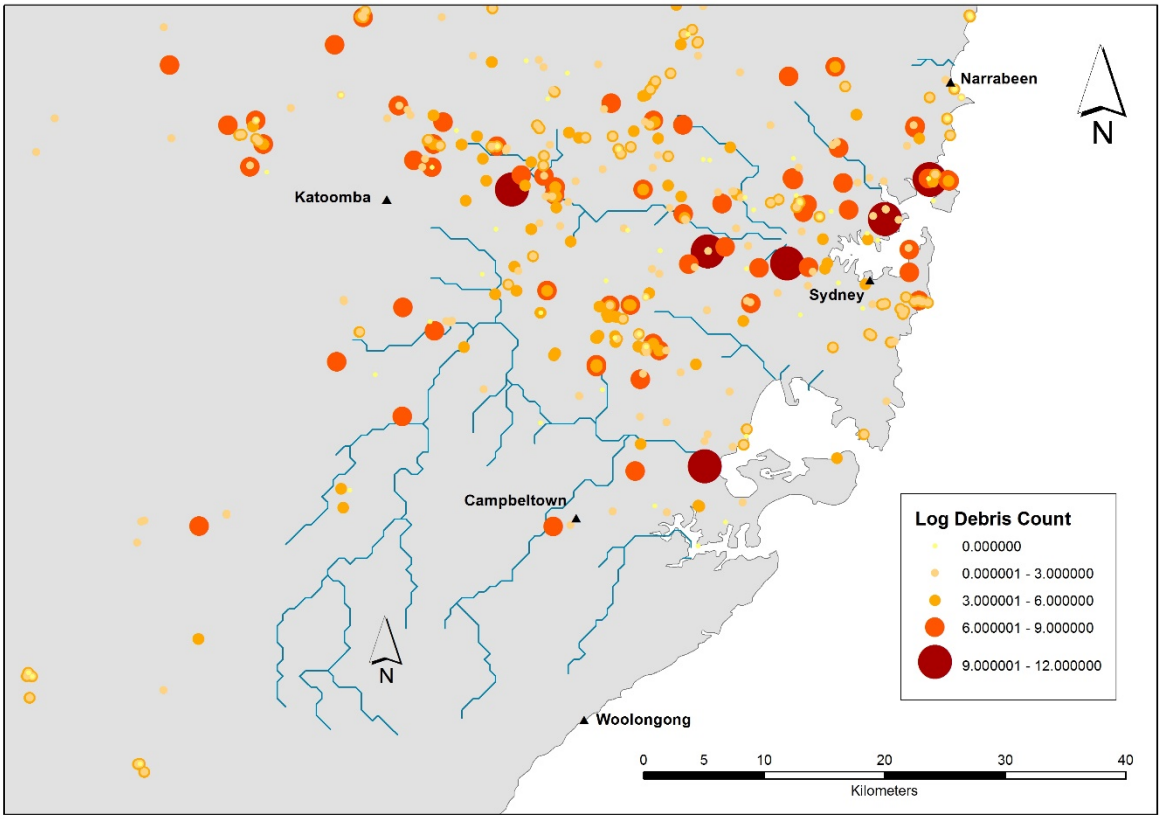
Rank	Country	Econ. classif.	Coastal pop. [millions]	Waste gen. rate [kg/ppd]	% plastic waste	% mismanaged waste
1	China	UMI	262.9	1.10	11	76
2	Indonesia	LMI	187.2	0.52	11	83
3	Philippines	LMI	83.4	0.5	15	83
4	Vietnam	LMI	55.9	0.79	13	88
5	Sri Lanka	LMI	14.6	5.1	7	84
6	Thailand	UMI	26.0	1.2	12	75
7	Egypt	LMI	21.8	1.37	13	69
8	Malaysia	UMI	22.9	1.52	13	57
9	Nigeria	LMI	27.5	0.79	13	83
10	Bangladesh	LI	70.9	0.43	8	89
11	South Africa	UMI	12.9	2.0	12	56
12	India	LMI	187.5	0.34	3	87
13	Algeria	UMI	16.6	1.2	12	60
14	Turkey	UMI	34.0	1.77	12	18
15	Pakistan	LMI	14.6	0.79	13	88
16	Brazil	UMI	74.7	1.03	16	11
17	Burma	LI	19.0	0.44	17	89
18*	Morocco	LMI	17.3	1.46	5	68
19	North Korea	LI	17.3	0.6	9	90
20	United States	HIC	112.9	2.58	13	2

*If considered collectively, coastal European Union countries (23 total) would rank eighteenth on the list

3. MAPS OF NATIONAL DEBRIS LAND-BASED, COASTAL, AND AT-SEA FLOATING DEBRIS HOTSPOTS

Below, we present a series of hotspot maps at multiple scales. First, we present two watershed level debris maps for the Sydney watershed, one based on observed data (Figure 3) and the other based on predicted data from our watershed-scale modelling (Figure 4). We also present national hotspot maps for land-based debris from Clean Up Australia data (Figures 5, 8); Keep Australia National and Keep South Australia Beautiful data (Figure 6, 8); and CSIRO coastal debris surveys (Figures 7, 8). The at-sea distribution of floating plastic litter based on CSIRO surveys is shown in Figure 9.

Figure 3. Litter and debris densities in the Sydney watershed region based on surveys conducted by Clean Up Australia, Keep Australia Beautiful, and CSIRO 2007-2015). Data are shown on a log 10 scale with darker, larger circles depicting areas of higher debris loads.



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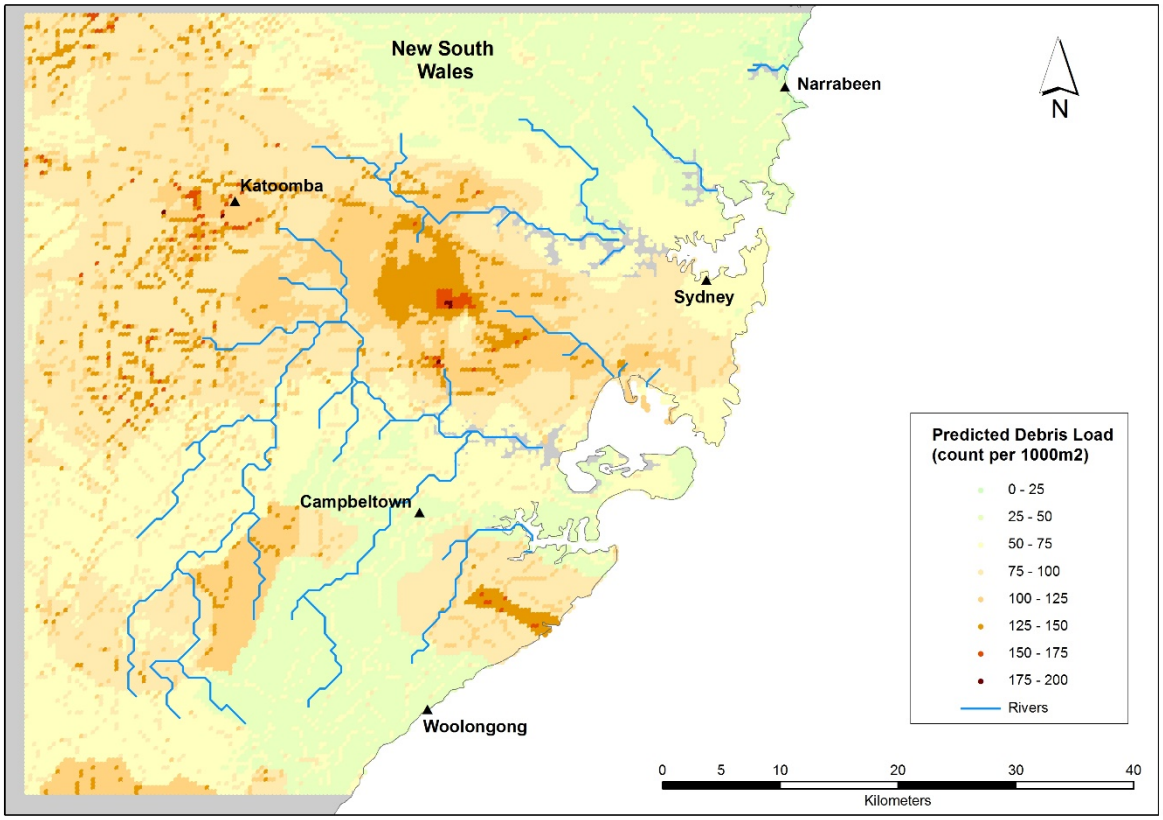
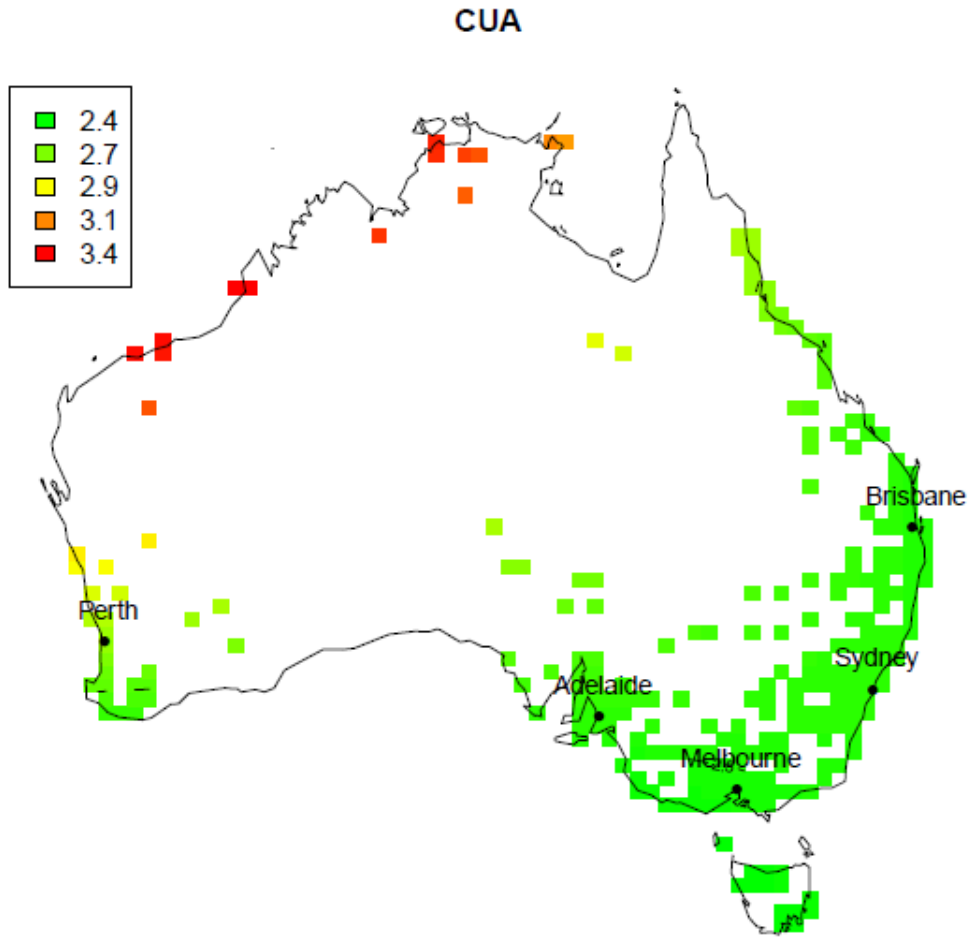


Figure 5. The relative debris density across Australia based on Clean Up Australia (2007-2016) data. Green indicates less debris, with red indicating highest debris counts recorded.



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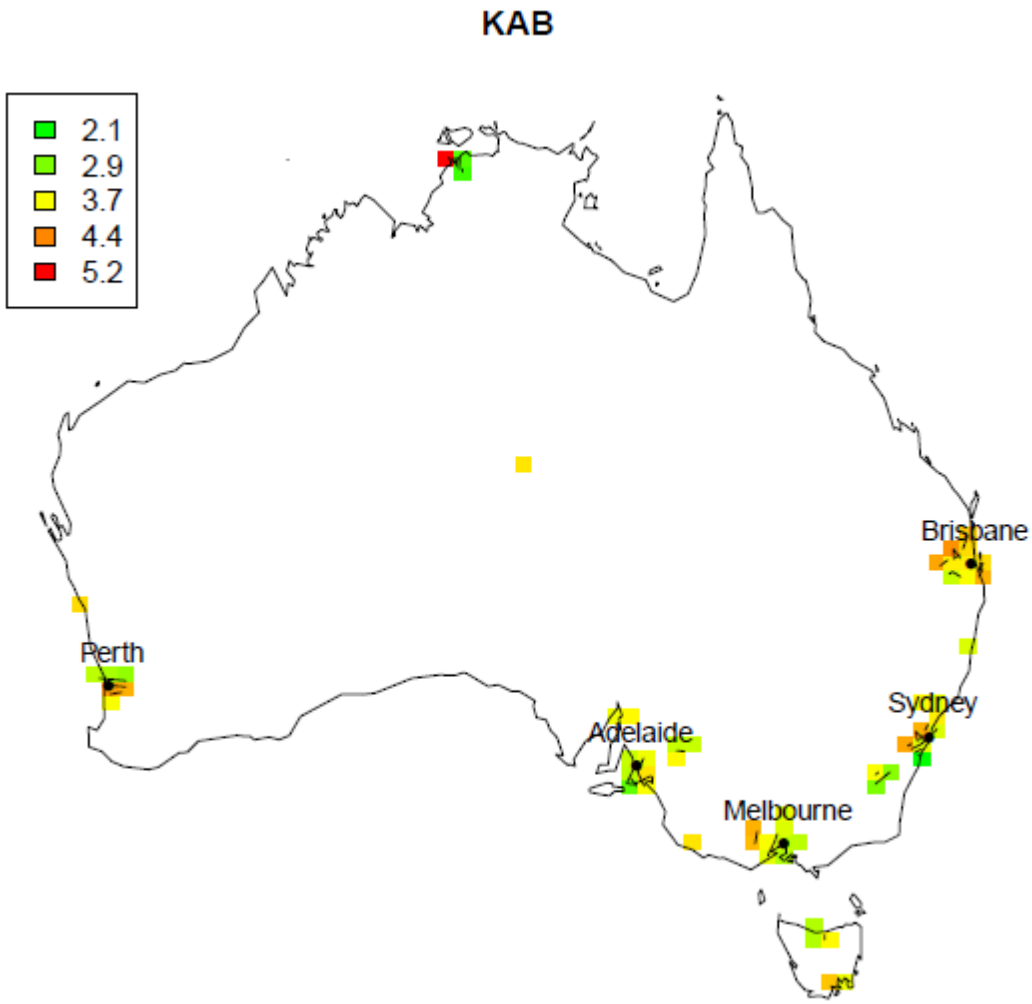


Figure 7. Relative debris density on Australia's coastline based on CSIRO national coastal debris survey data (2011-2016). Surveys were carried out following a stratified random sampling approximately 100 km apart, with minimum of three (maximum of six) transects per site. Green indicates less debris, with red indicating highest debris counts recorded.

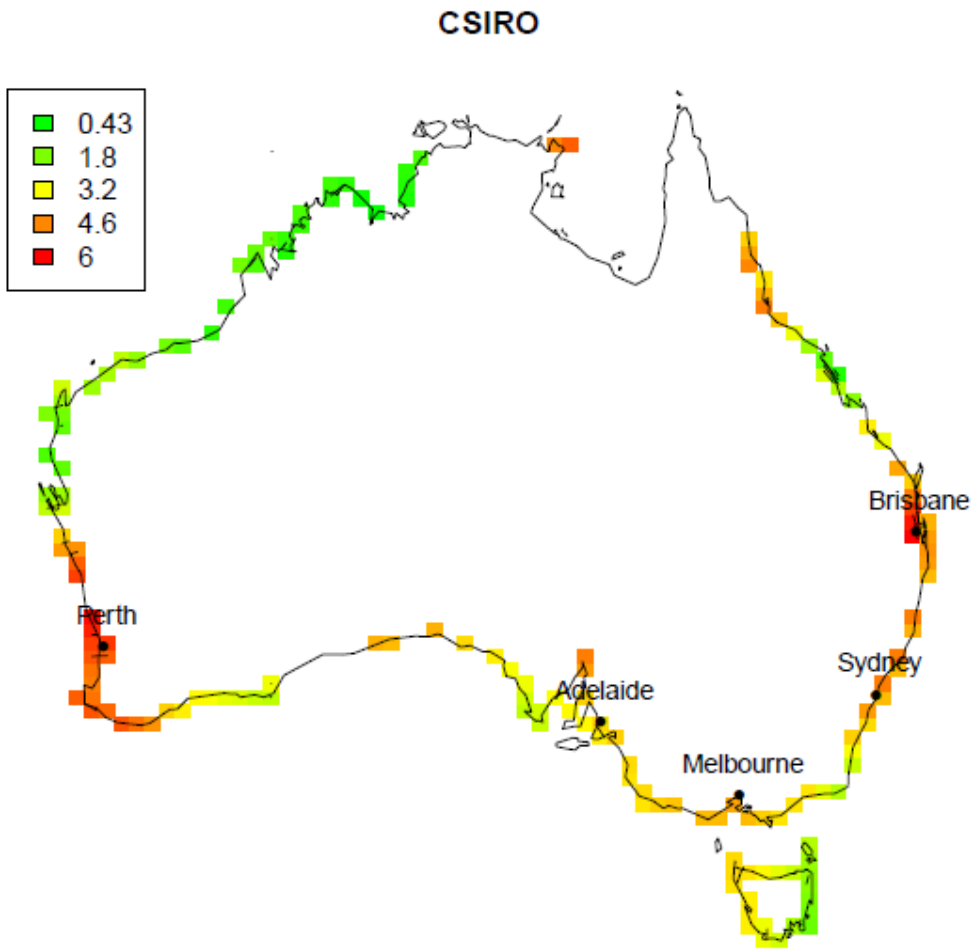
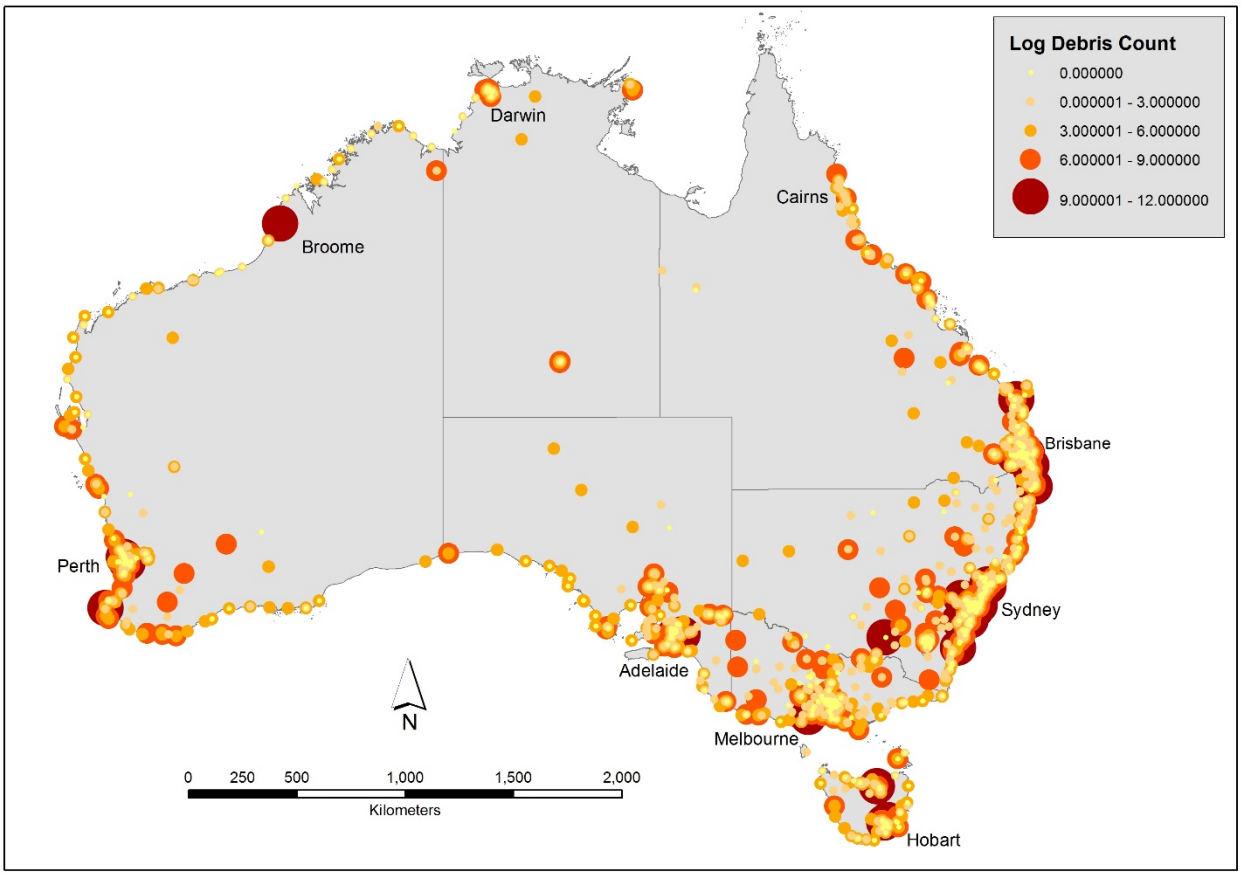


Figure 8. Map of debris hotspots based on all survey data from CSIRO, CUA and KAB. Note higher debris loads in urban cities around Australia's coastline. Survey methods are dissimilar among organizations, but this provides a general depiction of relative debris loads based on data provided by all three groups. Data are reported as the log base 10 of the total amount of debris per 1000m2. Figure taken from CSIRO APC report, 2016.



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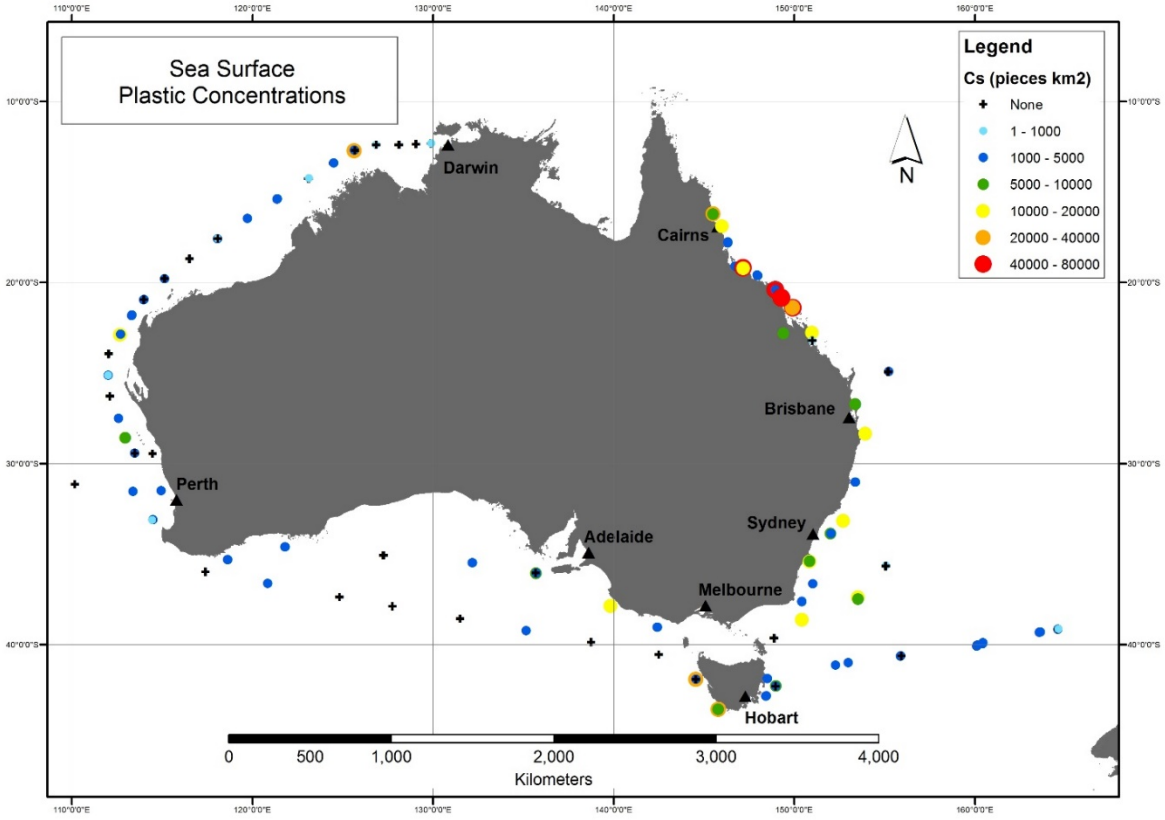

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www.nespmarine.edu.au

Contact:

Denise Hardesty

CSIRO

Castray Esplanade, Hobart TAS 7001

denise.hardesty@csiro.au | tel +61 3 6232 5276