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Policy and Practices Analysis to Reduce Debris Inputs to the Environment

Draft Final Report to the National Packaging Covenant Industry Association

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Australian Packaging Covenant
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Table of Contents

Tables

Figures

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Executive Summary

This report represents Phase II of a two-part body of work undertaken by CSIRO for the Australian Packaging Covenant. As noted in the Phase I report, marine debris is defined as any persistent solid material that is manufactured or processed and, directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment. As with the initial project, this work focused on what is called ‘marine debris,’ though it might be more accurately termed ‘debris’ to encompass all anthropogenic litter. The data collected and the results presented herein focus on data derived from land-based surveys and, accordingly, the land-based sources of the debris or litter recorded.

CSIRO’s Policy and Practices Analysis, Phase II project supported by the Australian Packaging Covenant was similarly ambitious to the Phase I project. This body of work extended the research carried out in the previous project, addressing identified knowledge gaps in greater detail and providing new analyses around waste management or abatement campaigns and government policies in reducing land-based waste inputs to the environment. The project specifically focused on the following main questions: 1) how do designed surveys compare to clean-up activities? 2) What types of interventions (activities, infrastructure or programs) are associated with lower debris loads around coastal Australia? And 3) Is container deposit legislation effective?

The project achieved its aims of addressing each of the main questions. In Section 1 of the report we provide some context for this work, including discussing the aim, rationale and approach we took in the project. In the next chapter (Section 2) we discuss some of the key considerations for designing surveys. We also discuss differences and challenges between designed surveys and clean-up activities in terms of data quality, questions that can be addressed, and utility. We also provide an example case study, comparing Clean Up Australia data and CSIRO’s designed surveys.

In Section 3 we turn our attention to legislative instruments at the state and regional level (as implemented by councils), investments in facilities such as coastal waste receptacles, and investments in programs including community awareness and outreach. We find that councils do significantly differ in their budgets overall, as well as in their allocation to waste management. Councils spend an average of 8% of their annual budget on waste management, though there is considerable variability (Section 3.1). Overall, councils that invest more in waste management as a fraction of their total budget tend to have coastlines with lower loads of debris. Importantly, the proportion invested is a better predictor of the ‘cleanliness’ of the local coastline than the total investment in waste management.

We also found that five particular policies appeared to have the strongest effects with regards to coastal litter loads, when considered singly. These were Education, Clean Up Australia Activities, Litter Avoidance, Illegal Dumping and Electronic Waste policies (Section 3.2). Evaluating the best overall combination of factors in explaining debris densities at local sites found that a suite recycling, illegal dumping programs, and litter abatement programs most strongly reduced debris densities along a council’s coastline (Section 3.2). These policies may act relatively independently, affecting different load sources, as they are chosen in combination as the 'best set' from a much larger overall list of possible programs (detail in Section 3.2).

In section 3.3 we discuss the results of an incentives analysis which specifically addressed the effectiveness of container deposit legislation (CDL). This is particularly timely as several states will soon to enact state-based legislation which requires cash incentives for beverage containers (e.g. New South Wales and Queensland will each be enacting statewide CDL legislation in the coming months). We found strong evidence that container deposit legislation may not only increase the return rates of beverage containers, but, perhaps more importantly, reduce the number of beverage containers that end up in the environment through leakage from the waste stream. The two states with CDL (South Australia and the Northern Territory) had a significantly lower proportion of containers than states without CDL. We also found a higher proportion of lids to containers, another measure of incentive effectiveness (discussed in detail in Section 3.3).

We know from previous work, including the Phase I report, that debris data and information is increasingly available from many parts of Australia and the rest of the world (see Hardesty et al. 2016 b and c). In Australia, this information has been recorded and collated from a number of local, regional, state and nationally associated clean-up activities such as those run by Clean Up Australia, Keep Australia Beautiful, Surfrider, Tangaroa Blue Foundation, the International Coastal Cleanup, and many others. Ultimately, with sufficient data (and sometimes making minimal changes to data collection record keeping for clean-up activities), the various datasets available on waste and litter can be used to help inform the amounts, types, and locations of litter losses into the environment. Scientists, industry, and NGOs working together, will result in an enhanced understanding of loss rates, litter movement through the environment, hotspots and ways to most effectively reduce land-based waste inputs to the marine environment.

1 Introduction

1.1 Aim

Through recent coastal debris surveys and coastal clean-ups, there is now reasonable information about the amounts and types of rubbish that accumulate in our coastal regions. From volunteer clean-up activities (Clean Up Australia, Keep Australia Beautiful as well as local council and volunteer coastal clean-ups), we further have information about high and low deposition sites and their relationship to population density, geography and myriad other factors. What has been less well understood however, is where in the supply chain items are being lost, and a quantification of the factors associated with higher and lower loss rates into the environment. We now have better information on factors associated with higher and lower loss rates into the environment. These data allowed us to focus on our aim to address questions about where investments in facilities, policies and outreach may be effective.

1.2 Rationale

To significantly reduce litter and increase recycling at local, regional and national levels requires robust analyses to identify loss points as well as to identify simple, manageable responses to reduce loss rates into the environment. Critically, we need solid data and information to ensure evidence-based learning underpins management actions. This will help to identify which on-ground activities will be best positioned to achieve environmental targets.

1.3 Approach

To follow up on the Phase I project ('Understanding debris sources and transport from the coastal margin to the ocean'), we explored more fully the question 'Are there particular investments in facilities, policies or outreach that are most effective in reducing the amount of debris that reaches coasts or oceans'?

For the analysis in Phase II we utilized datasets already in hand from Phase I of the project, representing sources of litter and other rubbish at a wide range of sites, including data from plastic debris on the coastline. We also used existing volunteer-collected data available from Clean Up Australia and Keep Australia Beautiful activities from 2007-2015, as both organisations provided permission for the continued work on this project.

In Phase II, we analysed the effect of state, regional, and council activities on the amount of debris observed at each study site. We evaluated the influence of three different types of government activities on littering or coastal debris: 1) investment in infrastructure and facilities, 2) development of policies, 3) outreach and other action programs.

To meet the goals of the project, CSIRO staff identified, sourced and secured relevant geospatial information from around the country including population, highway/road maps, socio-economic data, and other potentially important spatially related data (see Phase I for more details). KAB and CUA datasets were amalgamated and systematically checked for errors. Once the datasets were 'cleaned,' models were run that targeted specific questions. The approach we applied included a combination of analytical and modelling approaches such as general linear models and generalised mixed models to carry out a number of analyses (see detail in section 3).

In this project we used a variety of data sources including:

1. Structured interview data with councils from around the country (see below);
2. Statistically designed coastal debris survey data (from CSIRO);
3. Volunteer collected clean-up data (from CUA); and
4. Structured designed surveys at multiple site types (from KAB).

We also utilised data from a CSIRO-conducted survey of coastal councils from around the country. The survey was designed to learn about resources, policies, activities, and governance structures in place to aid in litter abatement. The data in this component of the project was obtained under the CSIRO Human Ethics Approval "Understanding the effects of marine debris on wildlife" (058/14) granted for the period 12/06/14 – 31/12/15.

1.4 Issues confronted in completing the project

Ensuring steps to maintain effective communication internally and externally has been of utmost importance in this project. The risk of data sharing had been identified in the earlier phase work of this project, and we continued to have agreement to work with both Clean Up Australia and Keep Australia Beautiful data for this continuation project.

2 Comparison of designed surveys and volunteer clean-up activities

One important component of this project was to estimate, quantify and compare debris amounts and types based upon different survey methods. Comparing among methods (essentially clean-ups and designed surveys) provides an opportunity to evaluate the relative power of each method to uncover pattern and process in marine debris at local, regional and national scales. We first discuss some of the sampling design considerations relevant for marine debris surveys. We consider clean-ups and statistically designed surveys with respect to data quality, concerns and constraints and extent of data. From this, we illustrate some issues to consider for various survey methods. Based on our experience and analyses undertaken, we also provide recommendations to improve statistical power, reduce data collection effort and associated costs, improve scientific inference, and maximise scientific and policy insights related to marine debris monitoring and clean-up efforts going forward.

The first thing to consider in developing a quality data set is the survey design (Table 2.1). This, however, may be largely driven by the purpose of the activity. For example, if the goal of a clean-up (such as Clean Up Australia Day Activities, Tangaroa Blue Foundation WA beach clean-up, or the International Coastal Cleanup (organised by the Ocean Conservancy)) is to increase public awareness, increase community involvement in local activities or remove litter or debris from particular areas, data recording may be for different purposes than for a designed survey. Hence, it can be important to consider design at a number of levels. First, at an overall level, surveys should be balanced across any variable for which inference is to be made. As an example, for understanding temporal trends, surveys would need to be carried out over the time period in question. Similarly, for evaluating spatial trends, ideally all locations will be covered consistently. If effects of river outlets are of interest, sampling should be structured according to river mouth locations and balanced across factors that could affect their effects, such as the population in the watershed. Deviations from a balanced sampling design (e.g. variations in sampling over time or space), can create confounding in the data, and results more challenging to interpret.

Analysis of different data types requires a multitude of statistical tools. Clearly identifying the main questions or goals of the project at the outset allows for appropriate analysis and interpretation of data. For example, if one wants to identify the baseline level of litter on the coastline and the goal is to make projections outside of where litter was collected or reported at sites, it is important to stratify the sampling such that various coastal types are sampled in proportion to their occurrence. If survey sites only encompass one substrate type or are of one shape, aspect, or slope, it is difficult to make predictions about the amounts of debris that occur at other sites within the region. However, if that is not a goal of the monitoring, such factors need not be incorporated into the survey design.

It is worth noting that site characteristics (type, aspect, slope, substrate, etc.) can vary widely, not only between sites, but even within sites. Hence, it is valuable to have replication *within* survey sites. Coastal locations vary significantly in their debris load levels, even at small spatial scales. Replication at the site level, and stratification of these replicates across the conditions at each site can assist in reducing variability at each site. This allows an improved estimation of the variables that drive variation where it appears.

Table 2.1 Survey design characteristics for data collection efforts analysed in this report

Issue	Clean Up Australia	Keep Australia Beautiful	CSIRO Surveys
Stratification of sites	No	Partial	Yes
Randomization of site location	No	No	Yes
Replication within sites	No	No	Yes
Stratification within sites	No	Partial?	Yes
Randomization within sites	N/A	N/A	Yes
Control of survey effort	No	Yes	Yes
Control of detection probability	No	Yes	Yes

Next, it is important to control *bias* in site sampling. This is particularly true in a situation where there is correlation between the chance of choosing a site and the variables affecting the site. For instance, access to coastal sites might be part of the survey location choice, but is also likely to affect visitation rates by the public, which in turn can impact debris deposition rates. Another example of site selection bias is selecting clean-up sites based on choosing the dirtiest site in the area. While this may address goals of a clean-up, it will certainly bias the predictive capability of designed surveys. Applying tools such as randomization can help avoid these biases to the extent possible.

Finally, at the finest level, controlling *survey effort* and *observation error* is a key consideration. Ideally, any item in a survey should have an equal probability of detection, irrespective of size, shape, location, and observer. This is clearly an impossible task, thus it is important to control observer effort and detection probability to the extent possible. This can be done through standardizing search area, search time, and search speed. Recording information on the size and colour of items can help with standardizing observations for detection error, particularly when considered in the context of survey conditions like substrate type and colour. Finally, if the study goal includes predicting outside the observed conditions, it is essential that the sampling hierarchy described above covers the range of conditions for which predictions will be made.

2.1 A case study example for clean-up and statistically designed surveys in Australia

To better understand the differences between designed surveys (e.g. CSIRO surveys) and clean-up activities, we compared debris survey results from CSIRO surveys with debris survey results from CUA clean-ups located within 5km of a CSIRO site. CSIRO surveys are all conducted along the coastline, so in order to minimize site-level differences, we selected only that subset of CUA clean-ups conducted in coastal areas. Because KAB surveys are conducted in many inland areas and there would have been insufficient data for a reasonable direct comparison between survey methods, we did not conduct such an analysis.

We used data from a total of 28 matching site pairs located in QLD, NSW, SA, TAS, and WA (Figure 2.1). At each site, there were between 3-6 CSIRO surveys (completed during the time window of September 2011 – July 2016; see detailed methods description in Hardesty et al. 2016c). Corresponding CUA sites had one CUA survey completed each, between March 2007 – March 2015. The single exception to this was one site in Adelaide which had two clean-ups, one in 2009 and one conducted in 2013.

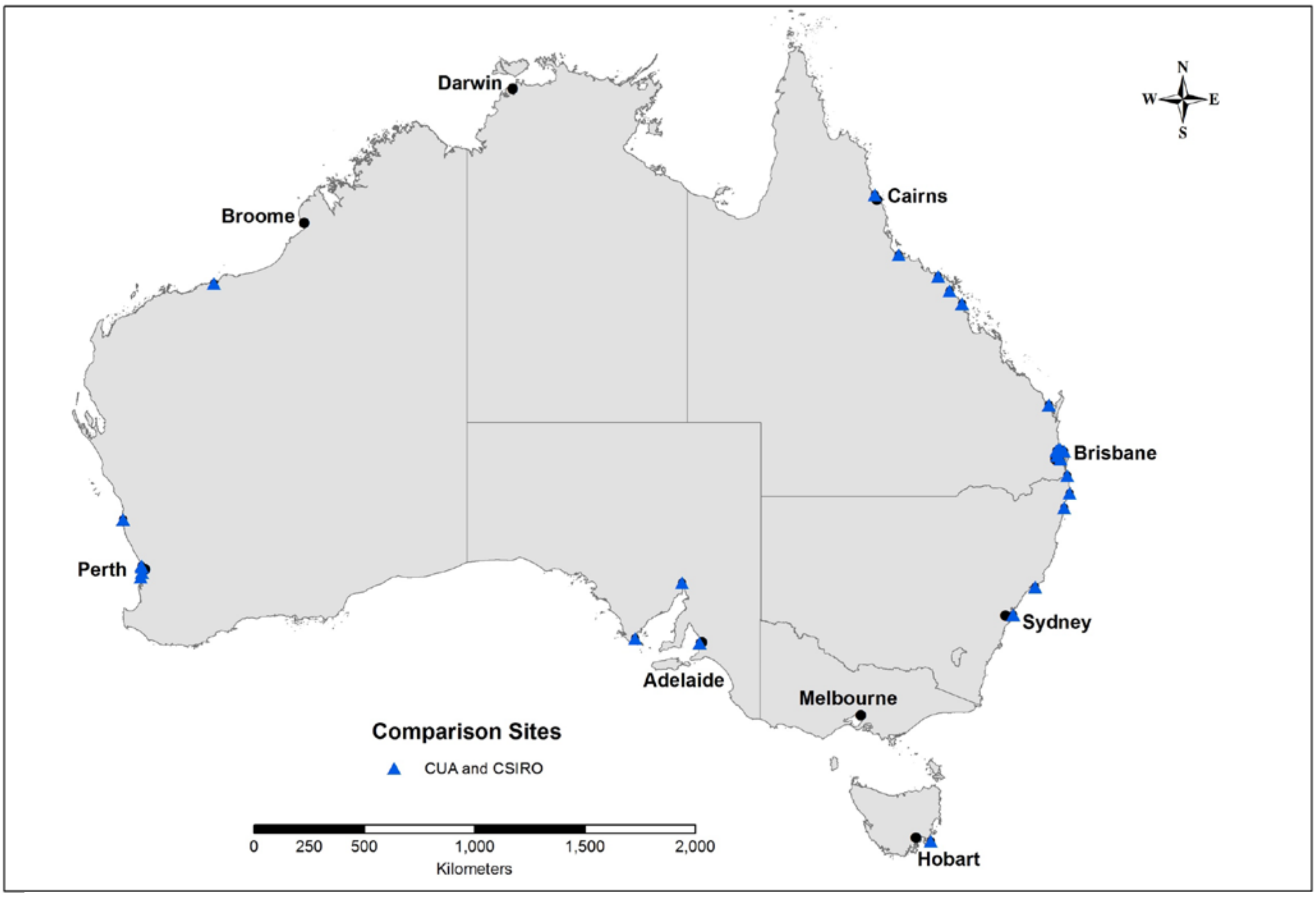

Figure 2.1 CSIRO sites around Australia with a corresponding CUA beach clean-up site within 5km.

For each site, we standardised for area and effort by calculating the total number of pieces of debris per 1000m^2 per person conducting the survey. Because the survey methodology differs between the two data sets, we also calculated the rank order of the cleanliness of the beach, in terms of the standardised amount of debris. Beaches with less debris have a lower rank than those with more debris. Therefore we can compare the relative dirtiness of the beaches as quantified by the two different methodologies, even if the magnitude of the debris amounts varies between survey methods.

Comparing the standardised debris amounts (Figure 2.2), a few things stand out. First, CSIRO surveys find significantly more debris per unit area than CUA clean-ups. This is likely because the CSIRO methodology does not specify a minimum size of debris to record (minimum size recorded can be as small as 2-3 mm). Surveyors actively seek out all pieces of debris found on a transect (down to the smallest size that can be detected by the human eye from standing position). Because there is typically a smaller area to cover for each transect, surveyors can spend as much time as necessary to find even the smallest debris items. In contrast, CUA clean-up volunteers do not focus on collecting or reporting items down to a specific minimum size. Because the event is held as a clean-up, participants are more likely to target larger items, and try to cover (or sample) as large an area as possible. This can result in focusing on larger items which are easier to observe or detect, though it may result in an overall lower count of debris items at a site.

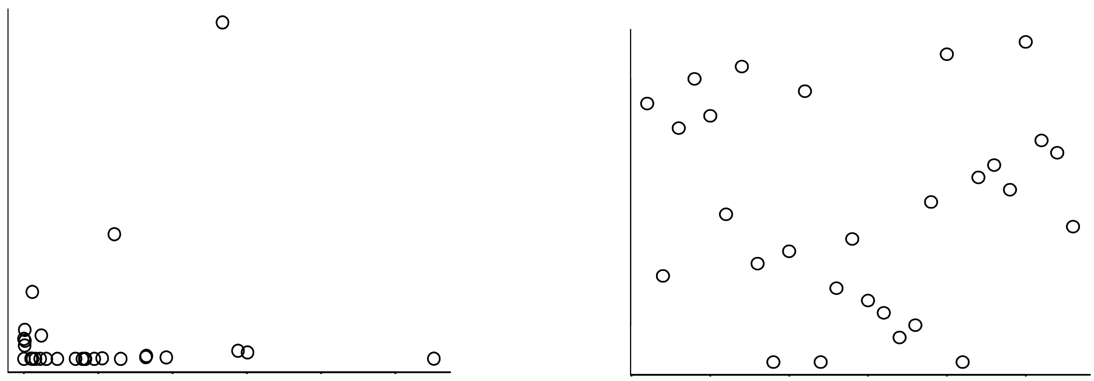

Figure 2.2 A (left) compares the standardised amount of debris (per 1000m2 per participant) in CSIRO surveys with the standardised amount of debris (per 1000m2 per participant) in nearby CUA surveys. B (right) plots the rank order of CSIRO sites against the rank order of CUA sites. Lower ranks indicate cleaner beaches.

The second item of note in Figure 2.2A is that there seems to be very little correlation between the total amount of debris found on CSIRO sites as compared to nearby CUA sites. Due to the scale of the graph, and a couple of outliers on the CUA data points, it is possible that a trend is being obscured. We therefore compared the rank order of CSIRO sites with the rank order of

CUA sites (Figure 2.2B) We also ran a Spearman's rank correlation test to assess whether there is a correlation between the standardised debris amounts found by the two methodologies. The results of this test indicate no significant correlation (rho = -0.0241, p = 0.9031).

Why might this be the case? There are many possible confounding factors which make direct comparisons extremely difficult. First, marine debris can be very patchy, both spatially and temporally. There is, on average, 2.19km between CUA and CSIRO sites (range of 0.081 – 4.913 km). While each of the 3-6 surveys at the CSIRO sites were all collected on the same date, there could be several years between the CUA data and the CSIRO data (hence, there is a confounding temporal aspect to the data). Data are often not collected during the same time period between the two sampling strategies, so differences in weather and wind patterns can result in varying debris quantities reported between the two methodologies.

In addition to spatial and temporal differences, there are also survey design differences. As previously mentioned, the size of debris collected on the two surveys is likely very different. Some sites have an abundance of small, fragmented debris, and not have a lot of the land based larger items of litter. A site like this could be ranked very high in the CSIRO methodology, but low in a CUA study.

Furthermore, biases can enter the data set even before data collection commences. CSIRO sites are chosen at random, and are designed to capture information from a range of habitats. In contrast, CUA sites are chosen by clean-up coordinators and are designed to maximise volunteer effort. Consequently, it is often the "dirtiest" sites that are selected for clean-up activities. Therefore, a CSIRO site chosen at random closely located to a CUA clean-up site, might have characteristics that are quite different from the nearby CUA site (e.g. there can be high heterogeneity at even at local spatial scales).

Finally, although we did attempt to correct the data for effort, we only had enough information to standardise by the number of people participating in the survey or clean-up. At the time of this report, we were unable to capture the total number of hours conducting each clean-up activity at the paired sites. By way of example, a three hour clean-up in a certain area might yield substantially more debris than a one hour clean-up in the same area.

Ultimately it is useful to understand the differences between site selection, methodology, and effort at any survey site. To glean useful information about the debris load at a site, the more of these variables that we can account for, the more useful insights analyses of the data can yield.

3 Analysis of legislation effectiveness

We investigated interventions by local councils to evaluate their effectiveness in reducing coastal debris. We evaluated three general types of interventions, 1) legislative instruments at the state and regional level, as implemented by councils, 2) investments in facilities, such as coastal waste receptacles, and 3) investments in programs including community awareness and outreach. We used the CSIRO dataset to evaluate the patterns of high and low debris densities along coastal survey sites in each council's area as a measure of the load of coastal waste, incorporating both directly deposited materials from sources such as littering and dumping, and ocean-transported materials (Hardesty et al. 2016a). We incorporated local characteristics such as coastal shape and foreshore slope, which could affect the level of debris deposition at a site, into a spatial statistical model at the national scale (Hardesty et al. 2016a). We then investigated whether council regulations, facilities, or programs could explain higher or lower than expected debris loads on their coastlines, after correcting the data for coastal conditions.

3.1 An analysis of waste management budget

Councils differed significantly in their budgets, their allocation to waste management, and their allocation across possible investments within waste management. In general, councils with larger populations have larger waste management budgets, although there is significant variation in budgets as council populations increase in size (Figure 3.1A). Councils on average spend 8% of their annual budget on waste management, although again there is significant variation among councils (Figure 3.1B). This variation in the allocation of budget translates to substantial differences among councils in per capita funding for waste management, particularly for small councils (Figure 3.1C). Within these bounds, councils also differ significantly in their investments across possible waste management activities. For instance, across the possible facility and program types that we included in our surveys (see Appendix for survey form), councils differed substantially in their investment patterns (Figure 3.1D).

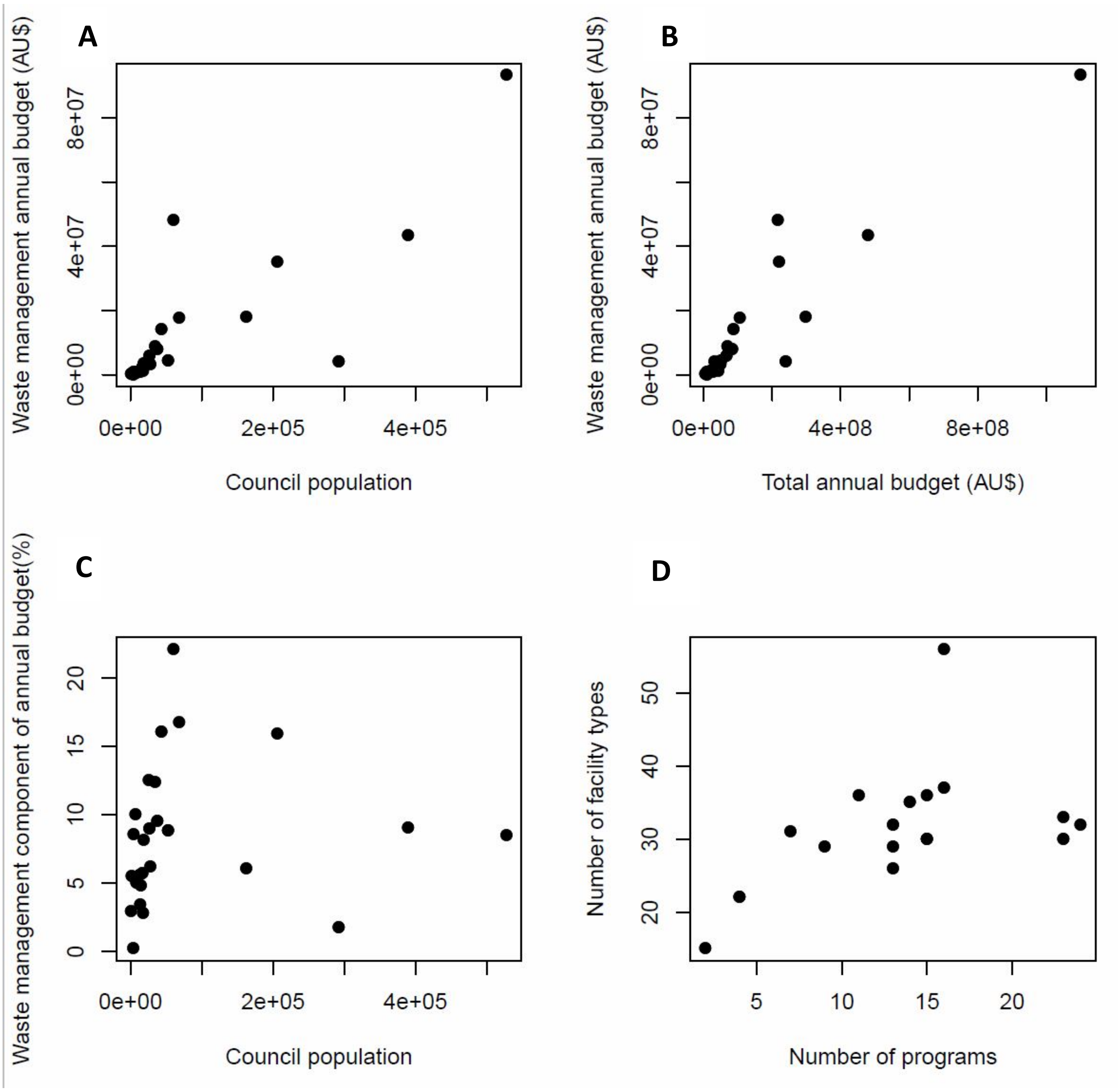

Figure 3.1 Relationships between council budgets, waste management budget, council size, and investment priorities.

We evaluated a range of measures of investment by councils to understand the relationship between debris loads on their coastlines and the investment in waste management by councils. We used general linear models (GLMs) to investigate the relationship between debris loads on the coastline and patterns of council investment, as implemented in the R statistical language (R Core Team 2013). Generalized linear models for level of local council investment in waste management per council's population and length of coastline included the terms: annual waste management budget (AU$), annual waste management budget as a percentage of total annual council budget, whether there is a specific waste management budget for coastlines (absent or present), coastline waste management budget as a percentage of total waste management budget, annual coastline waste management budget (AU$), council population and length of coastline within the council (km). To determine the most parsimonious model the Akaike's Information Criterion (AIC) scores were compared with the null model.

We found that as councils invest more in waste management as a fraction of their budget, their coastlines have lower loads of debris (Table 3.1). Importantly, the proportion invested is a better predictor of the cleanliness of their coastline than their total investment in waste management. Notably, their allocation of a specific coastal waste management budget also significantly decreased the debris load on their coastline. The best measure of this effect was the coastal waste management budget per capita. Comparing the two effects, the level of waste management investment overall had a much stronger effect, although the per capita coastal waste management budget was important in explaining the load of debris on council coastlines.

Table 3.1 Best fitting statistical model of debris loads on council coastlines and council investment.

	Estimate	Mean Effect Size	Pr (>|t|)	AIC
Coastal Waste Budget ($)/Council population +	-1.010	-0.802	0.059	369.7
Waste Budget as % of Council Budget	-0.332	-2.753	0.024*	
Null model	1.832			911.1

3.2 Where is best to invest? An analysis of activities, infrastructure and programs associated with littler reduction

The interview covered three general types of investments by councils: policies, facilities, and activities. In each category, we quantified the investments made by councils, based on whether they implemented a particular category of investment or not. For instance, some councils provide green waste collection. This category would fall under the general category of facilities, with councils having green waste scored as 1s and those without scored as 0s (e.g. presence or absence of green waste collection). For each set of investments within a category, we used a linear regression to evaluate the relationship between that intervention and the density of debris on the coastline in the council area. In addition, for each overall category of investments we used a stepwise model search to identify the best combination of categories for predicting the density of debris on the coastline of the council. This multiple variable approach is intended to identify possible combinations of investments that will lead to the largest reduction in debris if councils should implement them.

Policies

There were five policies that appeared to have the strongest effects when considering council options in isolation from each other: education (Ed), Clean Up Australia (Cl), litter avoidance (Li), illegal dumping (Il), and electronic waste (El), based on significance tests (Table 3.2). Education, illegal dumping, and electronic waste programs were related to decreases in loads at the coastline, based on the sign of their coefficient (Table 3.2). Of these models, education explained the largest variation in the data, with illegal dumping and electronic waste programs explaining roughly half as much, based on R square values (Table 3.2). Clean-ups and litter reduction programs were associated with councils that had higher densities of coastal debris (Table 3.2). This is potentially due to these types of programs being targeted at areas with high debris loads. However, the positive association suggests that while councils might implement these programs where debris loads are high, they ultimately do not result in lower coastal debris loads in comparison with other sites. Clean-ups and litter abatement programs might still reduce levels below what they would otherwise be at the sites where they are implemented, they are just not effective enough to reduce the level below that at other sites.

When we evaluated the best combination of factors in explaining debris densities at local sites, we found that a combination of recycling, illegal dumping programs, and litter abatement programs were most strongly related to debris densities on the council coasts. This suggests that these three policies act relatively independently, affecting different sources, as they are chosen in combination as the best set of variables from the overall list of possibilities. Litter abatement programs again have a positive coefficient, suggesting that they are associated with areas that are relatively high in debris. Again, this does not mean that they do not result in a decrease, but that the councils are implementing them in areas with particularly high loads. It is not clear what the load in these same areas would be in their absence, but it could quite possibly be higher.

Table 3.2 Relationship between policies implemented by local councils and debris densities on their coasts. Section A gives results for single variable models, section B gives those for the overall best model considering all possible combinations.

A. Single factor models				B. Best fit overall model			
Model	**R square**	**Coefficient**	**Significance**	**Term**	**Estimate**	**Std. Error**	**Pr(>|t|)**
Ed	0.102	-7.62	0.0069	(Intercept)	8.198	2.375	0.001028
Cl	0.088	6.72	0.0129	recycling	-7.62	2.507	0.003509
Li	0.056	6.71	0.0547	Illegal dump	-6.118	2.8	0.032817
Il	0.05	-5.39	0.0621	litter	14.081	3.742	0.000383
El	0.048	-2.98	0.0564				
Gc	0.035	-4.54	0.1282				
Rr	0.033	-4.3	0.1306				
Ch	0.031	-2.51	0.1294				
Nr	0.026	-4.06	0.195				
Pls	0.023	-4.12	0.2278				
Co	0.022	-4.38	0.2455				
Lo	0.022	-3.84	0.2246				
Plb	0.016	-2.81	0.3092				
O	0.014	-1.01	0.3014				
Wo	0.011	-4.09	0.4147				
Pa	0.009	-3.42	0.4471				
Ka	0.003	-1.41	0.6821				
Re	0.002	-2.8	0.7054				
Re	0.002	-2.8	0.7054				
St	0	-0.03	0.9021				
Ge	0	0.48	0.9404				
Bu	0	0.48	0.9404				

Facilities

There were three different facility variables that were associated with significant effects on coastal debris densities in council areas: the presence of green waste facilities (Gw), recycling facilities in schools (rSc), and the number of waste recycling stations (rWr) based on the single factor analysis. Considering the possible combinations of facilities, the best combination was a significant improvement over a null model (AICs: null model - 911, best model - 391).

Considering all possible combinations, the best fitting model included the following: kerbside collection, the number of waste transfer stations (wd.nb), the presence of waste recycling station(s, wr.wrs), the number of waste recycling stations (wr.wrsnb), the availability of plastic recycling (wr.plastic), and the availability of plastic bag recycling (wr.plasticbags), and the presence of a waste hotline (hotline) (See Table 3.3b).

All of the coefficients in the best model are significant, indicating that they make a discernible contribution to the model overall, with the exception of the wr.plastic, the availability of plastic recycling. All the remaining terms, with the exception of the number of waste recycling stations, have negative coefficients, indicating that their presence or abundance is associated with lower loads of coastal debris. The number of waste recycling stations has a positive relationship with coastal debris loads, which is in the opposite direction to what might be expected. One explanation is that waste recycling stations might be added in areas with relatively high waste production, and therefore be associated with areas of high coastal load. This is a similar explanation to that for the positive relationship between the presence of clean-ups and coastal debris loads. Essentially, we interpret this finding as suggesting that clean-ups are potentially targeted in 'dirty' areas. Thus, while they do result in the removal of waste or litter, it is not enough to completely compensate for the total load in the locations.

Table 3.3 Relationship between facilities provided by local councils and debris densities on their coasts. Section A gives results for single variable models, section B gives those for the overall best model considering all possible combinations. The best model is significant improvement over a null model (AIC null model – 911, best model – 489).

A. Single factor models				**B. Best fit overall model**			
Model	**R square**	**Coefficient**	**Significance**	**Term**	**Estimate**	**Std. Error**	**Pr(>|t|)**
Gw	0.106	-7.34	0.0006	(Intercept)	20.6015	3.8705	1.86E-06
rSc	0.043	-5.09	0.0839	wc.kerside	-13.7973	3.6756	0.000416
rWr	0.037	-2.64	0.0595	wd.nb	-0.8075	0.2352	0.001126
cKb	0.025	-9.61	0.0923	wr.wrs	-8.8176	2.593	0.001247
cHo	0.025	-9.57	0.098	wr.wrsnb	1.2399	0.3497	0.000798
rKb	0.025	-9.53	0.099	wr.plastic	4.2006	2.7501	0.132273
rIr	0.019	-4.86	0.239	wr.plasticbags	-2.882	1.5893	0.075135
Ht	0.019	-3.34	-3.3389	hotline	-5.4825	1.9313	0.006299
rPb	0.013	-2.77	0.2428				
rGd	0.011	-1.46	0.2907				
rWb	0.008	-0.11	0.4194				
cId	0.006	-2.1	0.4674				
rMk	0.006	-3.29	0.4444				
r3b	0.005	2.6	0.4866				
dNb	0.005	-0.16	0.4457				
rPl	0.004	-2.58	0.4993				
rGw	0.002	1.23	0.6527				

Activities

Only two of the potential actions that could be implemented by councils were associated with a drop in debris densities on the council coastline, when considered in isolation: education (Ed) and the presence of Clean Up Australia events (Cl). Education had a clear effect on the debris densities, explaining 11% of the variation in the data (Table 3.4). The presence of an active education program resulted in a significant reduction in debris densities on local council coastlines, as indicated by the negative coefficient and a significance term less than 0.05 (Table 3.4). As with councils having policies supporting clean-ups, those with active clean-up programs had higher levels of coastal debris, as can be seen from the positive coefficient and significance term (Table 3.4). This is similar to the patterns noted above, and likely due to the presence of active clean-up programs in areas with particularly high debris levels.

The best model considering all possible combinations of the policies was able to explain a significant amount of the variation in the data, and was an improvement over a null model (AIC: null model – 911, best model - 490). When considered in combination, there were a number of actions that were associated with lower debris densities on council coastlines (Table 3.4b), including plastics recycling (plastic), electronic waste (elec), illegal dumping (illegaldump), and home composting (compost). The remaining terms in the best model all had significant positive coefficients with respect to debris density on the council coastline. In some cases these could be indicators of activities that are targeting areas of high waste density, such as Clean Up Australia (cleanup) or the “Get it Sorted” advertising campaign (getit).

Table 3.4 Relationship between actions and programs implemented by local councils and debris densities on their coasts. Section a gives results for single variable models, section B gives those for the overall best model considering all possible combinations.

a. Single factor models				b. Best fit overall model			
Model	**R square**	**Coefficient**	**Significance**	**Term**	**Estimate**	**Std. Error**	**Pr(>|t|)**
Ed	0.114	-8.06	0.0256	(Intercept)	-7.735	5.273	0.14842
Cl	0.094	6.99	0.0436	plasticsr	-13.305	5.887	0.028048
Il	0.061	-5.95	0.1179	cleanup	9.759	3.499	0.007368
El	0.057	-3.26	0.1113	elec	-18.19	4.859	0.000455
Li	0.054	6.63	0.1379	chemic	13.669	3.512	0.000284
Gc	0.041	-4.93	0.2101	lovefood	33.45	9.507	0.000911
Rr	0.038	-4.66	0.213	kab	19.684	6.372	0.003221
Ch	0.036	-2.72	0.2039	educ	9.972	4.46	0.02968
Nr	0.029	-4.32	0.2951	illegaldump	-27.021	5.921	3.10E-05
Pls	0.027	-4.46	0.3187	litter1	24.442	6.206	0.000245
Co	0.024	-4.63	0.3583	getit	41.061	10.761	0.000363
Lo	0.024	-4.04	0.3312	compost	-9.727	4.028	0.019311
Plb	0.018	-2.98	0.4062				
O	0.015	-1.08	0.406				
Wo	0.012	-4.3	0.5222				
Pa	0.011	-3.7	0.5251				
Ka	0.003	-1.58	0.7273				
Re	0.003	-3.02	0.7516				
Re	0.003	-3.02	0.7516				
St	0	-0.04	0.9004				
Ge	0	0.27	0.9761				
Bu	0	0.27	0.9761				

We found a suggestive pattern in terms of investments at the local council level that can reduce debris densities in the coastal environment. For instance, prosecution of illegal dumping and education programs are consistently associated with lower levels of debris. However, some policies such as clean-ups and advertising campaigns appear to have a positive association with coastal debris loads. This is likely due to two factors: they are targeted at areas that have high loads, and they are potentially not effective enough to reduce those loads below the level that would be expected otherwise. However, one key consideration to keep in mind when evaluating the results presented here is that this policy analysis is based on an observational study, not a designed experiment. This is an important caveat, as it means that while we can test for associations among policies and debris loads, we cannot be sure the relationships we detect are causal. In fact, many of the more confusing results may be due to causality flowing in the opposite direction – dirty sites attract clean-ups, as opposed to clean-ups resulting in less debris at a site.

Interestingly, some investments that are associated with increased awareness through direct action at the individual level also seemed to be associated with reductions in debris loads on council coastlines. For instance, home composting programs, school recycling programs and home green waste collection all were associated with lower debris levels. One would not necessarily expect green waste collection to drive changes in debris loads, but it is possible that these individual level direct actions result in increased awareness, and through that altered behaviour around waste disposal.

Finally, provision of waste disposal facilities and their active promotion by councils does seem to reduce coastal debris loads. Plastic bag collection programs, kerbside recycling, and the provision of waste transfer stations and recycling centres all are associated with reduced coastal loads of debris. These may indicate the role of access to waste disposal facilities is an important moderator of individual and community level waste management behaviour.

3.3 Is Container Deposit Legislation (CDL) effective?

CDL is one of the more widely implemented legislative incentive approaches aimed at reducing waste in the environment. Whilst there has been substantial scholarship on the economic benefits of such programs, both theoretical and practical (e.g. Lavee 2010, Walls 2011), fewer studies have demonstrated the effectiveness of such programs.

In Australia, two out of the eight states and territories currently have some form of CDL; the Northern Territory (implemented in 2012) and South Australia (initiated in 1977). Western Australia, Queensland, and New South Wales are planning to implement CDL in 2017 and 2018. While each state has slightly different wording in the incentive legislation, typically a 10-cent surcharge is placed on glass, aluminium and plastic beverage bottles. This cash refund is returned when the consumer brings the container back to an appropriate facility. Often dairy bottles are excluded, and sometimes wine or spirits.

Keep Australia Beautiful and Keep South Australia Beautiful hereafter referred to as KAB collectively) provided data from 2007-2015. For more details on the data, see Hardesty et al. 2016c. We analysed these data to determine whether we could detect the effects of the container deposit schemes in South Australia and the Northern Territory. We chose to use KAB data because of its high level of accuracy and large volume of survey data. Unfortunately, we could not conduct a similar analysis with the CSIRO data, because CSIRO methodology does not identify the original function of the discarded material (e.g. water bottle, bucket, etc.); rather it focuses on material types. For each of the 983 individual sites in the KAB data set, we collected additional geospatial data to determine which site characteristics had the most influence on the prevalence of containers in the environment. These additional variables included measures of socio-economic status, population, year, site type, and land use at each site. For more details on the site characteristics, see Hardesty et al. 2016c.

We summed the total number of items within each KAB survey that would fall under the rules of the container deposit scheme. A total of 25 categories would be able to be returned under the scheme. We also counted lids separately (a total of 2 categories in the KAB data), as they should occur in equal proportion to the containers, but do not attract a deposit. Due to this difference, they are what is known as a control group in statistics. That is, they are otherwise identical to the variable of interest, with the exception of the phenomena being investigated.

We fit binomial linear regressions to both the proportion of containers compared to the total amount of debris collected, as well as the proportion of lids compared to the total number of containers. In order to determine whether any additional variables might affect the proportion of containers found in the environment, we incorporated measures of socio-economic status, population, year, site type, and land use at each site. To determine whether there was any difference in the effect of socio-economic status in states with and without CDL, we also incorporated an interaction term between state and the index of economic advantage.

We found that the two states with CDL had a significantly lower proportion of containers than the states without CDL (Figure 3.2), and a higher proportion of lids to containers (Figure 3.3). Overall, there is a negative relationship between the index of economic advantage and the number of containers in the environment, indicating that there are fewer containers in more affluent neighbourhoods. However, in states with a CDL, this is reversed, and there are fewer containers in the less affluent neighbourhoods (Table 3.5).

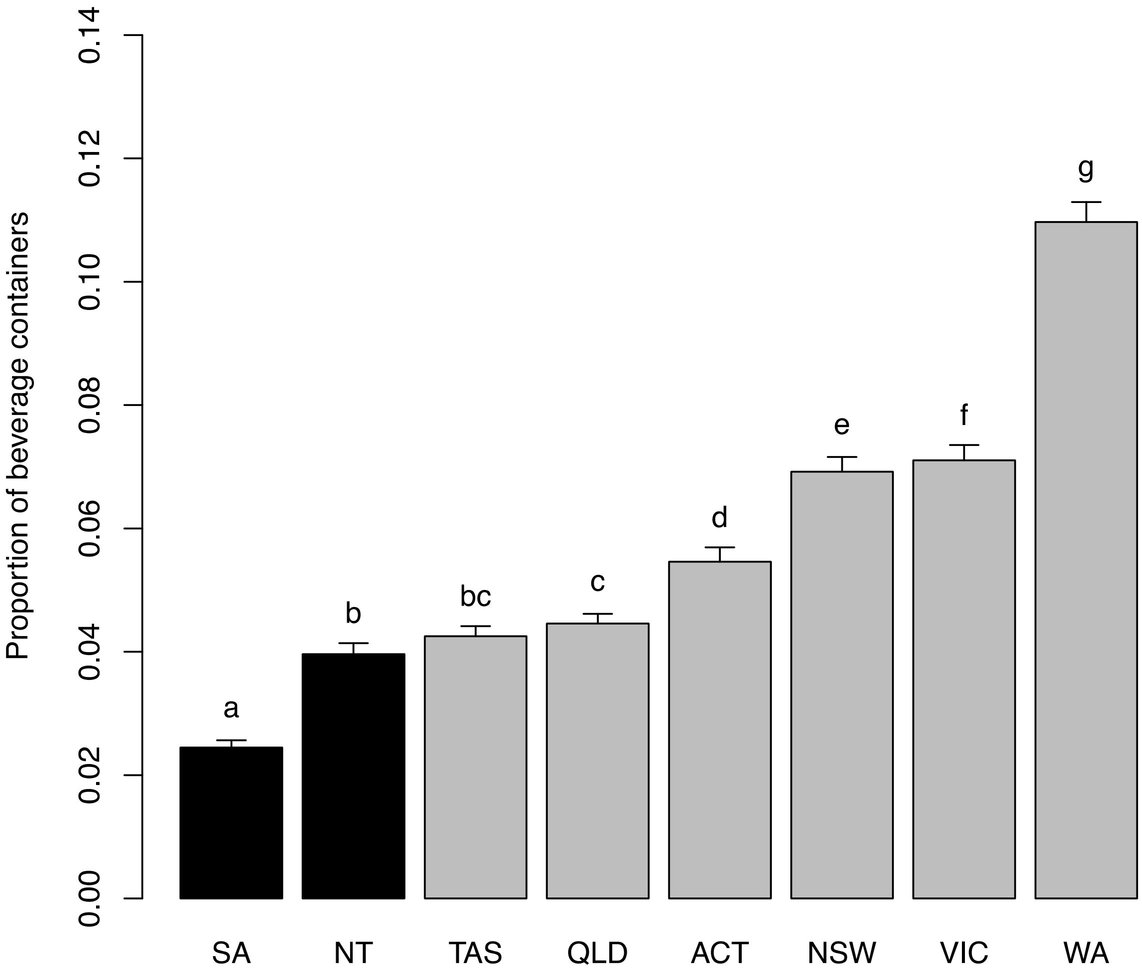

Figure 3.2 Mean proportion of lids to containers from Keep Australia Beautiful surveys in Australia. Error bars are the standard error of the mean. Black bars are states with container deposit legislation in place, grey bars denote states without CDL.

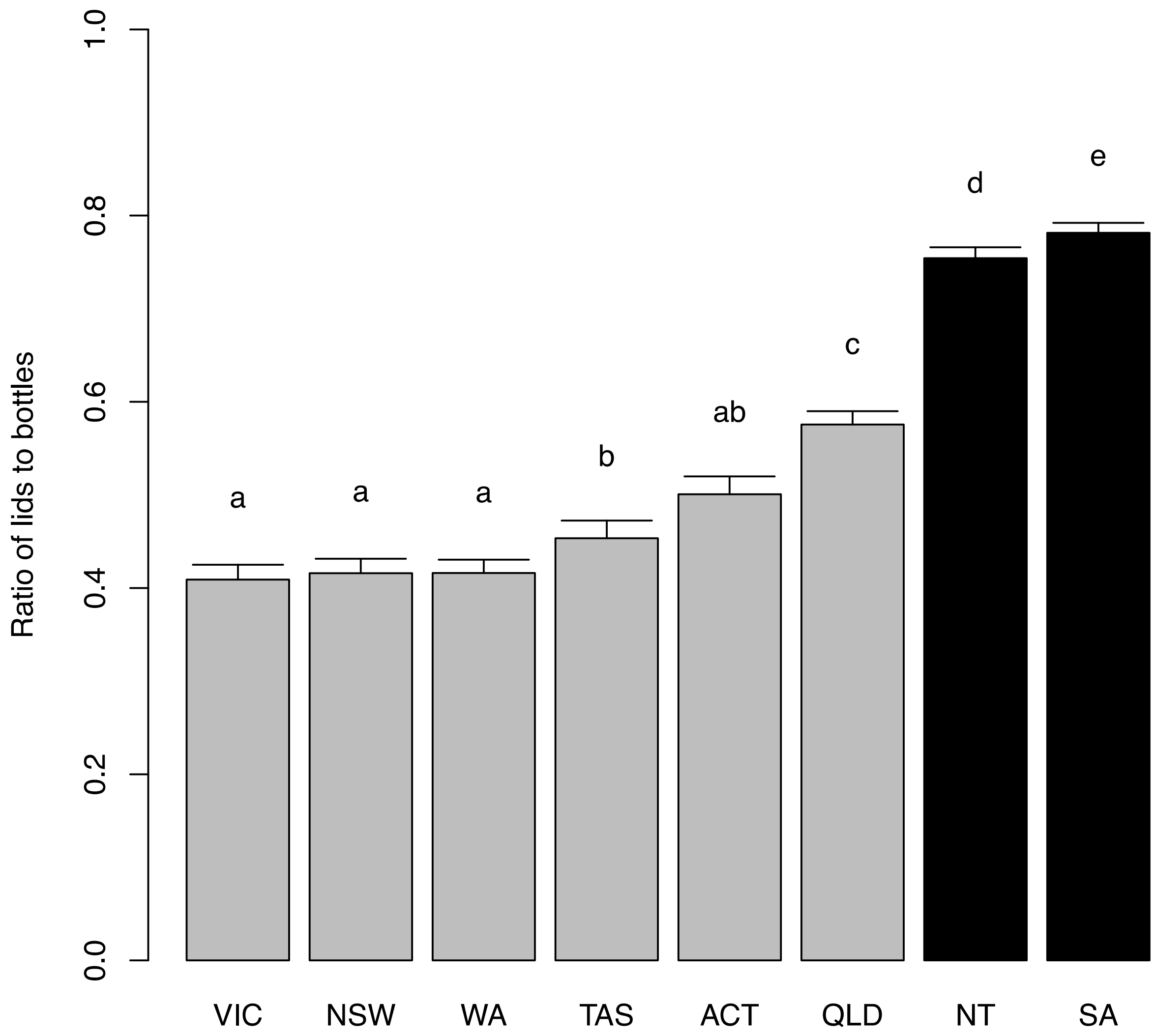

Figure 3.3 Mean ratio of lids: containers based on data from Keep Australia Beautiful surveys in Australia. Error bars are the standard error of the mean. Black bars are states with container deposit legislation in place, grey bars denote states without CDL.

Table 3.5 Coefficients for best model, incorporating population within 5km, residuals from Education/economic advantage, Year, Site type, Primary land use, and an interaction term between State and the index of Economic advantage.

	Est/	Std. Error	Pr(>|z|)	Med value	Effect size	Rank
(Intercept)	-61.2633	3.5388	0.0000*	1	61.2633	1
State						
NSW	2.8319	0.8129	0.0005*	1	2.8319	5
NT	-2.8420	1.0569	0.0072*	1	2.8420	4
QLD	-0.2083	0.8234	0.8003	1	0.2083	17
SA	-2.4179	0.8345	0.0038*	1	2.4179	6
TAS	-1.0328	0.8805	0.2408	1	1.0328	10
VIC	-2.3778	0.8260	0.0040*	1	2.3778	7
WA	5.4196	0.8048	0.0000*	1	5.4196	3
Eco_advan_5km	-0.0014	0.0007	0.0664+	1009.63	1.3703	8
Pop_5km	0.0000	0.0000	0.0000*	53726.06	0.1937	18
Edu.Adv.resid	0.0007	0.0002	0.0000*	1.02	0.0007	29
Year	0.0299	0.0017	0.0000*	2011	60.0721	2
Site Type						
Car Park	-0.1020	0.0266	0.0001*	1	0.1020	20
Highway	1.1682	0.0247	0.0000*	1	1.1682	9
Industrial	0.8198	0.0264	0.0000*	1	0.8198	12
Recreational Park	0.0864	0.0312	0.0056*	1	0.0864	22
Residential	0.6058	0.0277	0.0000*	1	0.6058	15
Retail Strip	-0.7985	0.0315	0.0000*	1	0.7985	13
Shopping Centre	-0.8980	0.0351	0.0000*	1	0.8980	11
Primary land use						
Prod. – rel. natural environments	0.0912	0.0317	0.0040*	1	0.0912	21
Prod. – dryland agric & plantations	-0.0100	0.0232	0.6667	1	0.0100	23
Prod. – irrigated agric & plantations	0.1616	0.1994	0.4177	1	0.1616	19
Intensive uses	-0.5835	0.0207	0.0000*	1	0.5835	16
Water	-0.7438	0.0401	0.0000*	1	0.7438	14
Interaction terms						
NSW:Eco_advan_5km	-0.0023	0.0008	0.0027*	1	0.0023	27
NT:Eco_advan_5km	0.0024	0.0010	0.0176*	1	0.0024	26
QLD:Eco_advan_5km	-0.0001	0.0008	0.9014	1	0.0001	31
SA:Eco_advan_5km	0.0016	0.0008	0.0451*	1	0.0016	28
TAS:Eco_advan_5km	0.0006	0.0008	0.4467	1	0.0006	30
VIC:Eco_advan_5km	0.0027	0.0008	0.0004*	1	0.0027	25
WA:Eco_advan_5km	-0.0047	0.0007	0.0000*	1	0.0047	24

Overall, there is strong evidence that container deposit legislation not only increases the return rates of beverage containers, but more importantly, reduces the number of beverage containers that end up in the environment through leakage from the waste stream. This reduction can result from consumer behaviour, subsequent removal by scavengers, or some combination of the two. However, in either event, the outcome is similar (e.g. a reduction in containers in the environment).

By incorporating measures of socio-economic status into the model, we gain additional clarity on the factors driving this reduction of containers in the environment. In most of the states without CDL, there are fewer containers in more affluent neighbourhoods. There are several possible explanations for this result. People with more money may be more likely to recycle, less likely to litter, or perhaps simply don't drink as many beverages! In contrast, in states with CDL, the trend is reversed, and there are fewer containers in less affluent neighbourhoods. The reason for this difference is that the 10-cent deposit has a higher marginal value to poorer people. It makes a bigger difference to their bottom line than it does to more wealthy consumers. By attaching even a small monetary value to containers, they become a commodity. Monetizing containers decreases their prevalence in the environment across the board (Figure 3.2), but reduces them more in poorer communities as opposed to wealthier communities. Whether individuals are returning purchased containers for a deposit, or gleaning containers from the environment in order to return, there are significantly fewer containers in the environment.

One possible interpretation of Figure 3.2 is that people in South Australia and the Northern Territory simply drink fewer beverages than in other states, relative to the total amount of debris generated. In order to test which hypothesis is more accurate, we fit another binomial regression comparing the number of lids to the number of containers (Figure 3.3). Under current container deposit legislation, containers have value; lids do not. We would generally expect that every plastic or glass bottle would have a corresponding lid, and it is likely that lids and containers would be discarded together. Aluminium cans are, of course, slightly different, with the pull tab typically remaining with the container. The container calculations incorporate all beverage containers, both aluminium cans as well as plastic bottles. Therefore we would not expect to see a 1:1 ratio of lids to containers, but would still expect a difference in the ratio of lids to containers between CDL and non-CDL states, because a significant proportion of containers are either plastic or glass. The results in Figure 3.3 indicate that South Australia and the NT have higher proportions of lids to bottles than in other states. This lends support for the hypothesis that there are fewer containers littered into the environment in South Australia in comparison with other states because a container deposit scheme is in place, not because South Australians drink fewer beverages.

It is notable that even in Australia, a highly developed country, where there is not only significant waste and resource recovery infrastructure, but also a well-developed social environmental ethic, small incentives are still effective at reducing waste mismanagement. The incentive does not need to be large; even a 10-cent value on containers significantly reduces mismanaged beverage waste. Similarly, economic disincentives can be small and still be effective. In Ireland, a

15 euro cents levy was placed on plastic bags, and this levy reduced their use by 90% within less than a year (Convery et al. 2007). In less developed countries or those with poorer waste management infrastructure, incentives can potentially be even smaller, because the materials themselves (PET bottles, aluminium cans) have a commodity value, and are therefore inherently of value to the informal sector.

4 Stakeholder Outreach in course of this work

The main direct outreach and engagement for this work was carried out under Phase I of this project. In Phase I we engaged in the following:

1. Informal conversations with members of the public regarding litter and loss rates in their communities;
2. Direct conversations with those involved in litter awareness campaigns, clean-up activities, waste management and educational/outreach as part of their jobs and/or community volunteer activities;
3. Discussions with the key staff members at the department of the environment regarding the relationship between coastal litter and impacts on marine wildlife;
4. Providing input to the federal government (at their request) to inform decisions regarding the revision of the marine debris Threat Abatement Plan (TAP);
5. Participating in the department organized TAP working group meeting regarding revision of the TAP;
6. Participating in monthly meetings with multiple state litter teams to identify and coordinate litter efforts and to better understand key issues, questions, and activities underway in various jurisdictions (particularly New South Wales, Queensland and Victoria);
7. Organization of a national litter workshop which includes invited participants from all states and territories, includes special interest groups, volunteers, industry partners and federal government personnel;
8. Development of a web-based survey tool targeted to stakeholder groups from around the country.

The process by which stakeholder engagement took place included identification of key stakeholders with whom to engage, reaching out to broader networks, web-based searching to identify any programs, activities or key stakeholder who might otherwise have been missed, and directly contacting colleagues and potential collaborators who have been working in the field that CSIRO staff have met while engaged in litter related research projects for the past 7+ years.

Furthermore, in the Phase I project we carried out:

9. A web-based survey which targeted a broad audience engaged in litter management, reduction and removal (in final stages of development and trial); and
10. A national litter workshop with a limited number of stakeholder participants.

Subsequent engagement, outreach and participation with stakeholders

In the Phase II project, CSIRO team members have represented Australia at G7 and G20 meetings, to share information about the state of knowledge within Australia with the broader international community. We have also had frequent discussions with the Department of the Environment (specifically in relation to the Federal Threat Abatement Plan on marine debris as a key threatening process to threatened marine vertebrates) and the Department of Foreign

Affairs and Trade (DFAT) regarding our work with the Australian Packaging Covenant and our research on marine debris. Multiple conversations with these important stakeholders ensures communication lines are open, stakeholders are kept aware of key research being carried out in this area, and helps to avoid duplication of efforts. CSIRO staff have also discussed some of the work we are undertaking at recent ASEAN and Stimson Center organized meetings where marine debris was a focal point of conversations.

As in Phase I, this Phase II project directly addresses key knowledge gaps outlined in the federal Threat Abatement Plan and CSIRO expects to provide a copy of the final report to the appropriate department staff after final delivery of this project.

Staff have also presented keynote presentations at several national and international conferences, have interacted extensively with state EPA (or their equivalent) staff in Victoria, New South Wales, Queensland and Tasmania.

5 Recommendations and Conclusions

This project focused more on analyses of information available than identifying opportunities for waste diversion. The analysis of the effectiveness of legislative actions such as container deposit incentives provides strong evidence that such incentives are successful and provide an opportunity for waste diversion. Increasing recycling capacity in some states, councils and regions may provide economic opportunities within communities. Furthermore, there may be investment opportunities if or as options such as automated depots or reverse vending machines are implemented. Such opportunities are reportedly being trialled in Victoria (by Wyndham City Council, for example). Comparing data from designed surveys carried out before and after the initiation of incentives (such as bag bans or cash for containers) would undoubtedly prove useful in terms of increasing our understanding of the effectiveness of various types of incentives.

Working with industry data from various parts of the supply chain could also prove useful to better understand where leakage may be occurring (for example, are loss rates higher near manufacturing sites, during transport, at the shop level, or associated with individual consumers?). Identifying consumer items that may be leaked into the environment can then provide an opportunity to consider the implementation of incentives or disincentives for other products that may be likely to be leaked -- or those which may be identified as resulting in significant or disproportionate harm to biodiversity (see Wilcox et al. 2015).

Working together with industry towards a circular economy approach (rather than linear economy associated with single use plastic items) would also be useful in terms of reducing plastic waste (whether lost into the environment or ending up in landfill).

Focusing on a national standard for data collection, and a shared repository or archive location for data storage or mirroring could be an excellent next step towards harmonizing various data collection methods and gaining a more holistic national picture of coastal and inland debris losses to the environment. Through time, the longitudinal data collected could provide insights to how human behaviour shifts in conjunction with local activities, education, awareness raising, and legislative tools aimed at reducing waste inputs to the environment. Some organizations (such as KAB and CUA) already have longitudinal datasets which can be used to address such questions at state and national levels (though there are some challenges in data analyses which have been mentioned). Furthermore, increasing sampling in areas away from urban centres would help to fill important knowledge gaps, given that most clean ups and surveys by volunteer groups take place in more heavily populated areas (with some exceptions). Furthermore, providing resources to conduct designed surveys alongside or simultaneously with clean-up activities would allow us to better understand how to interpret results from clean-up activities.

Finally, investing a larger portion of local waste budgets into those programs that have been shown to be effective (such as plastics recycling, electronic waste, illegal dumping and home composting) would like continue to be beneficial.

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7 Appendix

Questionnaire: Integration of the local waste management around the marine coastal debris in Australia

Presentation of the action

This project is a part of a national marine debris project aimed to identify the threats marine debris poses to wildlife. Our goal is to determine a potential link between the density of the marine debris on the coastlines all around Australia and the hotspots and effectiveness of local, regional and state policies, thanks to a model. A survey has been done all around Australia, on the beaches every 100 km in order to count and to identify types of marine debris. One of these sites is located in your council and we are asking people to provide us with more details about the waste management within your council.

General information about the council

Name of Council:

Name of respondent:

Role:

Tel:

Email address:

Date:

Population of the council:

Surface area:

Length of the council along the coast:

Region:

Population of the region:

General information about the waste management within the council on the beaches

Considering the waste management legislation and policies within your state, your council could adopt several attitudes and run different programs dealing with the coastal debris issues, how relevant do you think coastal debris issues are to your council/region?

1: No attention and concerns

2: Minor attention, but not active programs

3: Ongoing attention, but active programs not running at this time

4: Major attention and active programs running at this time

5: Really active programs, excellent management

Name of the site CSIRO have seen within your council:

Identification of the place: latitude: longitude:

These questions are relevant to see what is done concretely within your council on the beaches to avoid marine debris:

- Presence of bins on the beaches (on the sand or on the car parks)? Yes No

If yes, how many per beach?

Or [0;5[[5;10[[10;15[[15;20[[20;25]

Is there is one defined, what is the distance between 2 bins?

- Presence of recycling bins on the beaches? Yes No

If yes, how many per beach?

Or [0;5[[5;10[[10;15[[15;20[[20;25]

Is there is one defined, what is the distance between 2 bins?

- Is there cleaning days on the beaches within your council? Yes No

If yes, what is the frequency?

- Is there any active coastal cleaning group?
- Are there river traps within your council? Yes No

Partnerships

- Do you work in collaboration with some state associations? Yes No
- If yes, which one(s)?

- Do you work in collaboration with other councils? Yes No
- If yes, which one(s)?

- Are you a council member of a regional association/organization? Yes No
- If yes, which one(s)?

Funding for the waste management within the council

- What is the fraction of the budget within your region/council area which goes towards waste management?

.....AUS$? or .....%?

- Is there something for the coastlines especially?

- If yes, how much? (this would include river traps and bins at beaches both)

........AUS$? or ....%?

We have tried to find the legislations, actions and programs within your council concerning the waste management. The information collected is presented in the following table, have we missed anything? Is there any gap?

Legislation and policies

Example of policies and strategies	**Name of the legislation, the strategy or the policy**	**Description, document or link, if new**
Waste Legislation		
Regional's waste and recycling strategy		
Council's waste management strategy		
Zero waste strategy		
Container deposit legislation		
Litter strategy		
Marine Litter Strategy		
Others		

Waste facilities

Waste facilities		**Within the council level**
Waste collection	Household waste collection	
	Commercial, Industry waste collection	
	Kerbside collection	
	Waste management calendar	
	Purchased bins	
	Rubbish fees	
	Street bins	
Waste Disposal	Waste transfer station, how many?	
	Waste pass/fees	
Waste Recycling	Waste Recycling Station, how many?	
	Waste pass/fees	
	Kerbside Recycling collection	
	Domestic recycling	
	School recycling	
	Industry/Commercial	
	3 bins, colours...	
	Paper and cardboard recycling	
	Plastic recycling	
	Glass recycling	
	Cans recycling	
	Milk and Juice cartons	
	Plastics Bags collected	
	Green waste	
	Guide for recycling	
Green Waste, Composting and Worm Farming		
Waste Hotline		
Other facilities		

Programs and actions

Programs	Presence of the program or the action within the council	Name of the program or the action	Description, document or link, if new
Recycling program			
Packaging program			
Plastics Recycling			
Clean Up Australia Day			
Electronic waste			
Chemical Waste			
Love food, hate waste			
National recycling week			
General Clean-up			
Reduce, reuse, recycle			
Plastic bags			
Keep Australia Beautiful			
Education			
Illegal dumping (information, surveillance, active enforcement)			
Litter avoidance			
REDcycle program			
Other campaigns			

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