Marine Policy 96 (2018) 243–249

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

How successful are waste abatement campaigns and government policies at reducing plastic waste into the marine environment?

Kathryn Willis[a,b,*], Clémentine Maureaud[c], Chris Wilcox[a], Britta Denise Hardesty[a]

[a] Commonwealth Scientific and Industrial Research Organisation, Oceans and Atmosphere Business Unit, Hobart, Tasmania 7000, Australia
[b] University of Tasmania, School of Social Sciences, College of Arts and Law, Hobart, Tasmania 7000, Australia
[c] Supagro University of Advanced Agricultural Science Agronomy and Rural Management, Montpellier Supagro, France

ARTICLE INFO

Keywords:
Abatement campaigns
Litter
Policy
Local government
Waste effectiveness

ABSTRACT

Plastic production is increasing globally and in turn there is a rise of plastic waste lost into the coastal and marine environment. To combat this issue, there is an increase in policies that target specific types of plastic waste (such as microbeads and plastic shopping bags). Given that such anthropogenic waste have environmental impacts, reduce the tourism income of an area and result in human health issues, identifying effective abatement policies is imperative to reducing waste and litter before it enters the ocean. Within Australia, state and local governments employ a plethora of policies, campaigns and strategies to target abatement and reduce litter and waste inputs to the environment. Waste managers were interviewed from 40 local councils around Australia on waste abatement strategies and investments implemented in their council. Generalised linear models (GLMs) were used to compare outreach programs (such as 'Don't be a Tosser', Clean Up Australia and Bin your Butts cigarette campaign) and state-enacted policies (e.g. Plastic Shopping Bag Ban, Zero Waste Strategy and Recycling Strategy) aimed at targeting human behaviour to reduce waste. Investments in campaigns led to larger reductions of waste in the environment than did investment in policies. Illegal dumping, litter prevention, recycling, education and Clean Up Australia programs all significantly reduced waste along a council's coastline. Additionally, councils that invested in a coastal waste management budget had fewer littered or waste items on the coastline within their jurisdictions.

1. Introduction

Littering (i.e. discarding any material intentionally or unintentionally into the environment), is a relatively common form of illegal behaviour which creates an enormous cost to society and environments at local, regional, national and global scales. Land-based waste, such as litter, pollutes the shores and waters of oceans [1], rivers [2–4], estuaries [5,6] and lakes [7,8]. Such waste has been shown to reduce tourism revenue of regions [9,10] and is a threat to human health, via flooding, increase in disease risk and potential transfer of chemicals [11–14]. Plastic waste, in particular, entangles and is ingested by aquatic and terrestrial species which can result in starvation and mortality [15,16]. Seventeen percent of species affected by plastic waste entanglement and ingestion are listed as threatened or near threatened [15] and it is estimated by 2050 99% of all sea bird species will ingest plastic [17]. In Ethiopia and Nigeria numerous cattle, sheep and goats have plastic in their stomachs [18,19] and there are increasing cases of terrestrial birds dying from plastic waste ingestion [20–22].

With an estimated 8.4 million tonnes of plastic waste entering the oceans per year [23], the global problem of plastic waste is a significant environmental concern for governments and the public. To combat the damage from plastic waste, government and non- government organisations invest in numerous waste abatement infrastructure, policies and outreach programs (Fig. 1). Waste abatement strategies intervene at different stages along the plastic waste pathway from production to coastal deposition (Fig. 1). The conceptual map (Fig. 1) illustrates that waste abatement policies commonly target plastic production and use i.e. before the plastic becomes waste. Policies do not target plastic waste once it has entered the environment; instead they aim to reduce the quantity of plastic production and use, before it is likely to enter the environment. In contrast, waste abatement outreach programs and infrastructure commonly target plastic waste before and after it has entered the environment. These strategies try to prevent and remove plastic waste from entering the environment and prevent coastal deposition.

Anti-litter campaigns such as 'Do the Right Thing' [24] and 'Neat Streets' [25] educate and encourage the public to improve their waste disposal behaviour. Community programs such as the International

* Corresponding author at: Commonwealth Scientific and Industrial Research Organisation, Oceans and Atmosphere Business Unit, Hobart, Tasmania 7000, Australia.
E-mail address: Kathy.willis@csiro.au (K. Willis).

https://doi.org/10.1016/j.marpol.2017.11.037
Received 2 August 2017; Received in revised form 22 November 2017; Accepted 29 November 2017
Available online 08 December 2017

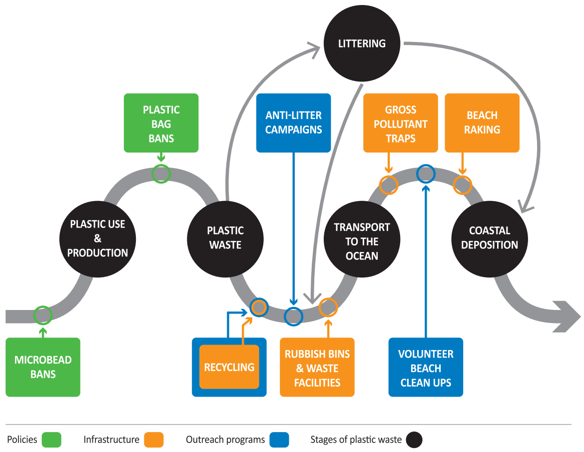

Fig. 1. The type and point of waste abatement interventions along the plastic waste pathway. Thin arrows indicate the point of intervention, shapes indicate the type of intervention and large arrows indicate the pathway flow.

Coastal Cleanup [26] and Keep America Beautiful [27] and citizen science projects like Bravo et al. [28] encourage local community members to be custodians of their environment by involving them in beach clean up activities.

Waste management policy frameworks such as the National Waste Policy in Australia and the EU Waste Framework Directive set guidelines and regulations that control varying waste and recycling streams and minimise environmental pollution. More recently grass-root campaigns such as 'Beat the Microbead' [29] and 'Bye Bye Plastic Bags' [30] have pushed for legislation to focus on individual litter items that are in high frequency in the environment. In Canada, the US, the UK and the Netherlands legislation is underway to ban the manufacture of microbeads, commonly found in cosmetics [31]. Globally plastic bag consumption has been progressively levied, such as in Ireland and Australia, or completely banned, such as in Germany, India and numerous countries in Africa [31,32].

Waste infrastructure focuses on containing waste before or whilst transported through the environment. The placement of rubbish bins in popular public areas, such as beaches and shopping malls, provides the public with containers to dispose of their rubbish correctly. Gross pollutant traps (GPTs) catch large litter items flowing along waterways such as storm water drains and rivers. In the Derwent Estuary, Australia, GPTs capture 136 t of litter per year [33] and in San Francisco Bay GPTs capture 44% of litter [34]. To remove large litter items from popular beaches, councils often use large mechanical rakes towed by tractors. For example, Cape Town runs an extensive beach raking program [35] and an average of fifteen tonnes of litter per week is raked off Bondi Beach in Sydney, Australia [36].

Since the 1970s littering has been illegal in all Australian states and territories. Recently, litter and waste in the marine environment (i.e. marine debris) has become a major concern for the Australian government. In 2003, marine debris was identified as a key threatening process under the Australian *Environment Protection and Biodiversity Conservation Act 1999*. In 2016, a Senate inquiry was conducted on the threat of marine plastic waste in Australia [37]. Australian waste and litter is managed by state governments in accordance with their respective legislation, policies and programs. However, the local governments are responsible for implementing and managing their respective state waste strategies i.e. the collection of waste and recycling, management and operation of landfill, delivery of awareness programs and providing and maintaining waste infrastructure [38].

There are 560 local governments in Australia [39] who each implement waste strategies to suit their socio-economic status, population and geography. The diversity in local governments has led to their investment in a variety of waste abatement strategies to prevent plastic waste. Unfortunately, the success of each strategy in preventing or removing plastic waste from the coastline is unknown. The clean up of litter costs Australia over one billion dollars annually, with approximately 80% of those costs paid by local and state governments [40]. Given these costs, efficient targeting of waste management funds towards the most effective strategies will be a key feature in determining their success in reducing plastic pollution.

To evaluate how effective various strategies are at reducing plastic waste into the environment, the analysis compared the level of investment, and type of waste abatement policies and programs implemented by local governments in Australia. The study asked: 1) What level of investment of council budget reduces plastic pollution along coastlines by the greatest amount; 2) What waste abatement strategies reduce plastic pollution along coastlines by the greatest amount; and 3) What specific waste abatement strategies are most effective at reducing plastic pollution along Australia's coastline.

2. Materials and methods

2.1. Site selection

Questionnaires were carried out at the local council level drawn from regions around Australia where coastal debris surveys took place (Fig. 2). Sites were selected to span a wide range of debris densities and council regions. Initially 52 councils were contacted, however interviews were completed with 40 councils around the country. Six sites were chosen in New South Wales (NSW), Victoria (VIC), South Australia (SA), Queensland (QLD) and Tasmania (TAS). Seven sites were chosen in Western Australia (WA) to geographically represent the length of Western Australia's coastline. Due to restricted access three sites were surveyed in the Northern Territory (NT) [41]. Two of those sites in the NT were subsequently removed from the study as they were situated in the same council. One site in Tasmania was also removed. Hence, a total 37 councils completed the questionnaire. Questionnaire results were compared with debris densities from a national dataset on plastic pollution loads along the coast at 100 km intervals from 2011 to 2013 [41].

2.2. Questionnaire

The waste manager from each focal council was contacted. Waste managers were chosen based on the presumption that the person in this role would provide the most accurate information on waste management, council activities and waste abatement strategies in their council. Managers were interviewed over the phone using the questionnaire (see Supplementary information). The questionnaire was divided into three sections. The first section covered general information about the council (e.g. council population, surface area, coastline length). The second section focused on information about waste management on beaches within the council (e.g. number of rubbish bins at the beach, frequency of beach cleaning, are there active clean up groups in the council), any partnerships with other state associations or councils and finally the amount of funding the council puts towards general waste management and waste management specifically for coastlines. The third section listed a series of legislations and policies, waste facilities and outreach programs and asks whether they are present in the council, if so, what are their names. All interviews were recorded and kept for reference and to clarify any uncertainties. To enable prompt responses, answers in the third section of the questionnaire were pre-filled, where possible, based on information from the council website. Interviewees checked pre-filled answers and modified or corrected where required.

2.3. Statistical analysis

Council policies and programs were compared against patterns of

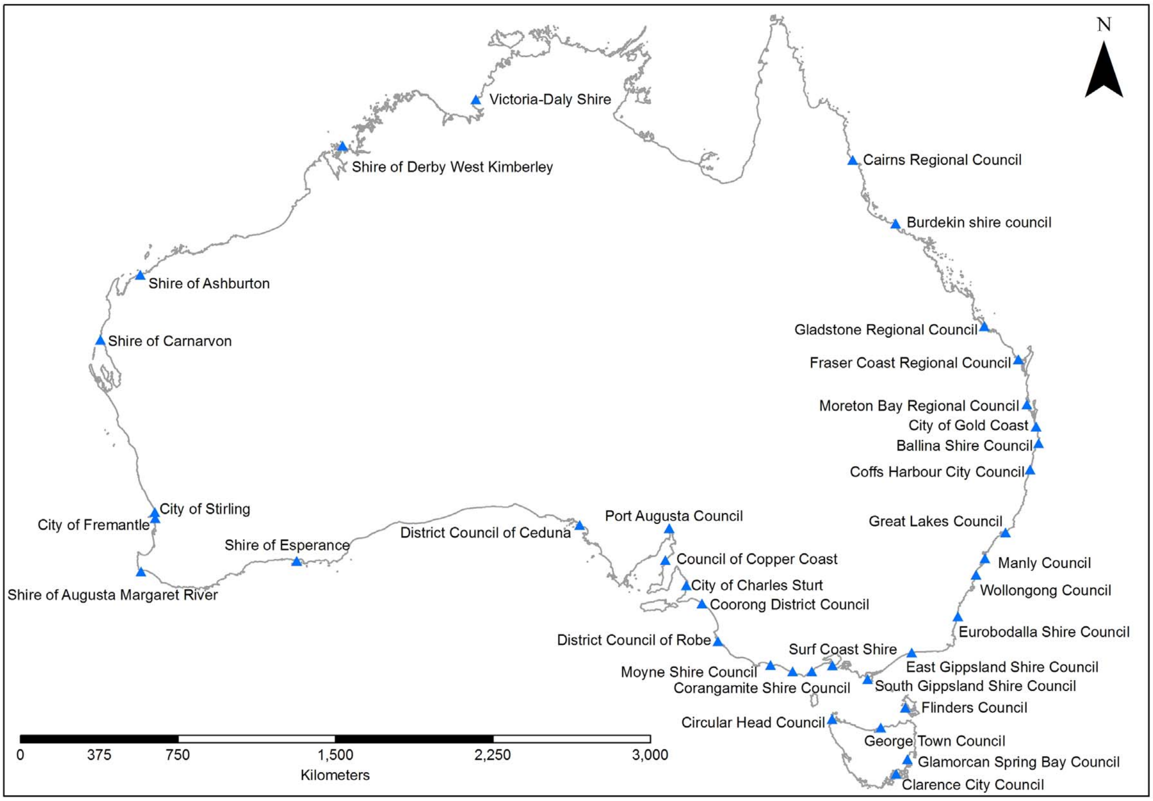

Fig. 2. map showing location of the local councils in which survey sites are situated.

coastal debris. The generalised additive model (GAM) developed in Hardesty et al. [41] was used to correct for the beach transect characteristic covariates: shape, substrate, gradient, backshore type. All subsequent analyses in this study were conducted on the residuals resulting from the GAM used in Hardesty et al. [41], which in effect measure the unexplained variation in coastal debris density.

Generalised linear models (GLMs) implemented in the R statistical language (R Core Team 2013) were used to determine whether the level of local council investment in waste management influences the amount of debris found along the Australian coastline and whether the type of investment (i.e. policies, facilities or outreach programs) is more effective at reducing debris. A combination of GLMs and linear models were used to determine which policies or programs explain the greatest amount of variation in debris.

General 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.

The GLM for type of investment included the terms: total number of outreach programs in each council, total number of waste facilities in each council and total number of policies (state and local) within each council. The model was run with every possible combination of terms. To determine the most parsimonious model, AIC scores were compared with the null model.

The linear model for which local council outreach program works included: the presence of recycling programs, packaging programs, plastic recycling programs, Clean Up Australia programs, electronic waste programs, chemical waste programs, 'Love Food, Hate Waste' programs, National Recycling week, general clean-up program, reduce reuse recycle program, plastic bags program, Keep Australia Beautiful program, education program, illegal dumping program, litter prevention program, REDcycle program, 'Get it Sorted' campaign, 'Bin your Butts' campaign, home composting program, worm farming at home program and the number of any campaigns/programs not listed in the questionnaire. The StepAIC function in R was used to determine the most parsimonious model.

3. Results

3.1. Questionnaire response success

All 37 councils were initially contacted with 34 councils (92%) successfully responding to the questionnaire. Three councils (8%) did not answer the phone or return any calls. For the three councils that did not respond, data was taken from their website and latest report.

3.2. Waste management investment

The final investment model included the terms waste management budget as a proportion of total council budget and the presence of a specific coastal waste management budget per capita dollar (AIC = 372.9). Waste management budget as a proportion of total council budget explained a greater variation in the data than coastal waste management investment (Mean Effect Size in Table 1). This indicates that the proportion of total budget spent on waste management in a council will have a greater effect on reducing coastal pollution than having a council budget specifically for coastal waste. The same results were also shown in the single term GLMs with waste management budget as a proportion of total council budget having a larger estimate (Mean Effect Size = – 1.774; Table 1) than the coastal waste management budget per council population (Mean Effect Size = – 0.565;

Table 1
Results from the GLM analysis of the council budget investment in coastal waste management and general waste management; and the final council waste management budget model (in bold). Models are listed according to AIC score. The final model (i.e. most parsimonious) includes the terms coastal waste budget per council population and waste management budget as a proportion of total council budget. Significant terms are indicated with a *.

Model terms	Estimate	Mean effect size	Pr (> |t|)	AIC	Data ranges
Coastal Waste Budget ($)/Council population +	**−1.010**	**−0.802**	**0.059**	**369.7**	
Waste Budget as % of Council Budget	**−0.332**	**−2.753**	**0.024***		
Coastal Waste Budget ($)/Council population	−0.712	−0.565	0.172	395.2	$1.22–4.10
Coastal Waste Budget ($)/(Council population * Coastline length)	−4.328	−0.282	0.329	396.1	0.006–0.556
Coastal Waste Budget ($)	−1.957e−06	−0.296	0.359	396.2	$28,000–1,200,000
Coastal Waste Budget ($)/Coastline length	−2.315e−05	−0.192	0.435	396.4	$62–114,615 per km
Coastal Waste Budget as % of Waste Budget	−0.069	−0.155	0.503	396.6	0–29%
Presence of Coastal Waste Budget	−2.520	−0.775	0.094	410.5	0–1
Waste Budget as % of Council Budget	−0.214	−1.774	0.049*	529.4	0–22%
Waste Budget ($)	−2.899e−08	−0.336	0.290	532.2	$19,000–93,200,000
Waste Budget ($)/(Council population * Coastline length)	−0.061	−0.234	0.327	532.4	$0.02–37
Waste Budget ($)/Coastline length	−4.525e−07	−0.155	0.394	532.6	$86–5,384,615
Waste Budget ($)/Council population	−0.003	−0.503	0.488	532.8	$5–795
Null model	1.832			911.1	

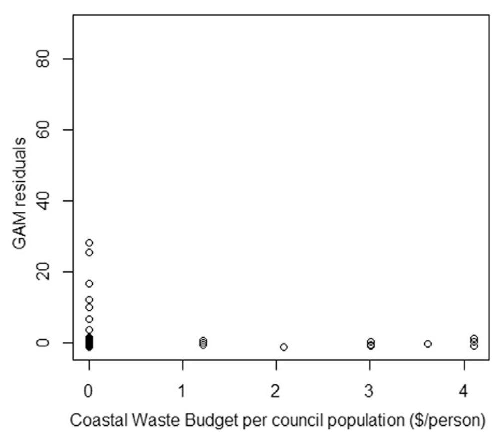

Fig. 3. The effect of a coastal waste budget (corrected for council population) on debris observed on the Australian coastline. Each point represents one debris survey site.

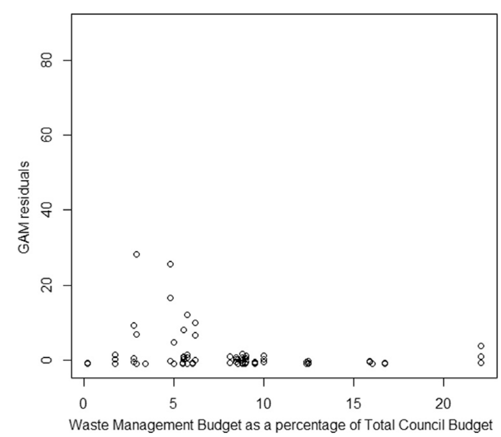

Fig. 4. The effect of council waste management budget as a percentage of total council budget on debris observed on the Australian coastline. As the waste management percentage increases the amount of debris observed decreases. Each point represents one debris survey site.

Table 1). It is important to note that there was no effect of the amount of coastal budget as either a proportion or as whole dollar value. Any investment in a coastal waste budget showed a decrease in debris found along a council's coast (Fig. 3).

We found waste management investment as a proportion of total council budget led to a significant decrease in debris ($p = 0.02$). As the waste management proportion of total council budget increased the amount of debris along a council's coast decreased (Fig. 4). Additionally, if a council waste management budget was greater than 8% of the total council budget the amount of debris along their coast would be less (Fig. 4). Interestingly, there was little change in debris densities when investments were greater than 8% (Fig. 4). The coastal waste management investment term was not significant ($p = 0.059$).

3.3. What waste abatement strategies work?

The best model included the total number of outreach programs and waste facilities (AIC = 344.2; Table 2). The model was more parsimonious than the model that included total number of government waste policies, facilities and programs. (Table 2; Ranges: Facilities = 1–17, Policies = 3–15, Programs = 1–17). The number of outreach programs explained a greater amount of variation in the data than the number of waste facilities and both terms led to a decrease in plastic pollution along a council's coastline. (Mean Effect Size: Outreach = −2.504, Facilities = −1.391, Table 2). This suggests that outreach programs will lead to a greater decrease in plastic pollution than will waste facilities, however a combination of both is best (Table 2). Neither term is significant in the best model (Facilities $p = 0.609$ and Outreach $p = 0.095$), however, outreach programs was significant in the single term model ($p = 0.045$). This could be due to insufficient degrees of freedom to detect a significant result in the best model.

Table 2
Results from the GLM analysis of what type of waste abatement strategy (i.e. outreach programs, policies or waste facilities) councils should invest in. Models are listed according to AIC score. The final model (i.e. most parsimonious) includes the terms total number of waste facilities and total number of outreach programs per council. Significant terms are indicated with a *.

Term combinations in model	Estimate	Mean effect size	Pr (> |t|)	AIC
Waste Facilities	−0.044	−1.391	0.609	344.2
Outreach programs	−0.191	−2.504	0.095	
Waste Facilities	−0.044	−1.391	0.619	345.9
Outreach programs	−0.147	−1.927	0.318	
Waste policies	−0.136	−1.146	0.638	
Waste Facilities	−0.167	−5.279	0.074	406.7
Waste Facilities	−0.174	−5.500	−1.848	408.6
Waste policies	0.095	0.801	0.403	
Outreach programs	−0.524	−6.869	0.045*	504.7
Outreach programs	−0.765	−10.029	0.029 *	505.5
Waste policies	0.778	6.556	0.297	
Waste policies	0.101	0.851	0.698	912.9

Table 3a
Most parsimonious model from StepAIC. The final model includes the terms; recycling program, illegal dumping program and litter prevention program. Significant terms are indicated with a *.

Model equation	Terms	Estimate	Pr (> |t|)	AIC
lm(formula = GAM.S.residuals ~ recycling program + illegal dumping program + litter prevention program, data = PolicyDataFull)	Recycling	−7.620	0.003509*	493.080
	Illegal Dumping	−6.118	0.032817*	
	Litter Prevention	14.081	0.000383*	

3.4. In which specific outreach program strategy should councils invest?

The results from StepAIC showed a final model with the terms recycling programs, illegal dumping programs and litter prevention programs was the most parsimonious (AIC = 495.02) (Table 3a). Recycling programs and illegal dumping programs each significantly reduce waste along a council's coastline (Table 3a), with recycling having a slightly greater effect than illegal dumping (Estimates in Table 3a). Estimates for all terms in the model are directly comparable as their covariate data is binary (i.e. 1 or 0). The estimate for litter prevention programs was positive and double that of recycling and illegal dumping (Table 3a). Litter prevention programs was also significant (Litter Estimate = 14.08, P value = 0.00). This does not indicate that litter prevention programs increase waste loads on a council's coastline, rather it suggests that litter prevention programs occur in areas where waste accumulates (i.e. dirty areas).

The single term linear models all had higher AIC scores than the final model presented in StepAIC (Table 3b). However, education programs and Clean Up Australia (CUA) programs were significantly correlated with waste reduction (Education p value = 0.006, CUA p value = 0.012, Table 3b). The education program estimate was negative (–7.615) indicating education programs reduce waste along a council's coastline. The estimate for CUA was positive (6.719). Similar to litter prevention programs, a positive estimate does not indicate CUA programs increase waste loads along a council's coastline. It suggest, however that CUA programs only occur in areas with high levels of waste mismanagement (dirty areas).

Table 3b
Results from the single term linear model analyses on the different kind of outreach programs implemented across the interviewed councils. Significant terms are indicated with a *. Models are ordered according to AIC score, with the most parsimonious model first. 'Other Outreach programs' include any program implemented by a council that was not listed in the questionnaire.

Type of outreach program	Estimate	Pr (> |t|)	AIC
Plastic Recycling	−4.117	0.228	507.374
Home Composting	−4.384	0.246	507.484
Worm Farming at Home	−4.089	0.415	508.196
Packaging	−3.423	0.447	508.290
Keep Australia Beautiful	−1.406	0.682	508.713
REDcycle	−2.805	0.705	508.739
Recycling	−2.805	0.705	508.740
Get it Sorted	0.484	0.940	508.882
Bin your Butts	0.484	0.940	508.882
General Clean up	−4.544	0.128	527.129
National Recycling Week	−4.064	0.195	527.769
Plastic Bags Ban	−2.806	0.309	528.458
Education	−7.615	0.006 *	542.527
Clean Up Australia	6.719	0.012 *	543.682
Illegal Dumping	−5.394	0.062	546.415
Litter Prevention	6.715	0.055	548.148
Love Food, Hate Waste	−3.837	0.225	548.559
Reduce, Reuse, Recycle	−4.299	0.131	554.670
Chemical Waste	−2.506	0.129	588.484
Electronic Waste	−2.981	0.056	594.037
Other Outreach programs	−1.014	0.301	616.783
Null	1.832	0.032 *	911.109
Total number of Programs	−0.027	0.902	913.090

4. Discussion

Councils that invest in waste management and have a budget specifically for coastal waste management had less debris on their coastline. However, the size of the coastal investment does not make a difference. Generally speaking, councils that apply 8% or more of their total budget towards waste management have lower waste loads on their coastline. Providing funds for coastal waste management suggests those councils are aware of the marine debris issue and are actively trying to prevent it. In this study, investment in outreach programs in combination with waste facilities was associated with a larger and more predictable reduction in waste than investment in policies. For example, educating a community on recycling and providing each household with a recycling bin and kerbside collection service could be affiliated with a reduction in coastal waste mismanagement.

Programs that target specific waste streams are effective in reducing coastal waste. The study showed that implementing the combination of recycling, litter prevention and illegal dumping (i.e. litter > 200 L) programs into a council is the best at reducing waste on a coastline. Recycling and litter prevention programs target the removal of waste before it enters the environment (Fig. 1). The programs focus on educating the individual user on why and how to dispose of their waste correctly. The results showed that councils who provide litter education programs, have significantly less waste on their coastlines. Raising public awareness through education programs is an effective way of reducing marine debris as it creates a sense of environmental responsibility in participants [28,42]. Education programs have shown to successfully reduce waste in Europe [43,44], Malaysia [45] and the USA [46]. For example, in the European initiative MARLISCO five of the top eleven best practices included marine debris awareness programs [47].

Littering directly (via beach visitors) and indirectly (via transport by wind and water) increases waste loads on a beach (Fig. 1). Hence, it is expected that an anti-litter campaign, such as litter prevention, would have a strong effect on reducing coastal waste loads. Illegal dumping programs target waste disposed in the environment, typically far away from coastal sites. Illegal dumping is suggested as a major indirect driver of high coastal waste loads via transport by wind and water to the coast [48]. Wetlands and creeks in urban margins in low socioeconomic regions have high waste loads [49], relative to other sites, suggesting that material littered or dumped in these sites may be easily transported to the coast during flooding events. This is supported by Hardesty et al. [41] who found high levels of coastal debris near isolated areas at urban margins, which they associated with illegal dumping. The inclusion of both litter prevention and illegal dumping programs by StepAIC indicates they are independent. Hence councils that implement both an illegal dumping and litter prevention program will see larger reductions in coastal waste than a council that just implements one of the programs.

The presence of a clean up program was also significant (CUA p = 0.0129). Interestingly the model showed that the clean ups only happen in dirty areas as the coefficient value was positive (6.719) i.e. councils and groups target their clean ups on beaches that have high waste loads. Clean ups have immediate aesthetic results however they routinely focus on areas where waste accumulates i.e. a sink, not where waste enters the coastal environment i.e. the source. The action of picking up waste does not yield a net reduction in waste reaching the marine system from the source. Hence, a dirty beach will need perpetual cleaning unless the source of waste is reduced. This selection of dirty beaches as sites for clean ups can also have implications if clean ups are being used as a monitoring tool. When dirty sites are chosen for clean ups, actual waste loads will be over-estimated. This is not to say clean ups are not a useful tool. The waste collected from clean ups can be used to identify the potential pollution sources [50–52]. Clean ups also create a sense of beach custodianship and encourage participants question their littering behaviour by educating them on the issue of marine debris [28,53]. For example, the damage plastic waste causes to the environment and local businesses and the money it costs councils to remove the waste. Unfortunately, clean ups can also have a contrary effect on the public. If the public witness their local beach routinely cleaned they may continue to litter as there is someone cleaning up after them [54].

5. Conclusion

This study demonstrates that integrated solutions are best at reducing coastal waste loads in Australia. A model including recycling, litter prevention and illegal dumping programs was better at reducing waste loads than any single term model. The inclusion of recycling, litter prevention and illegal dumping in the final model could indicate the major sources of waste along Australian coastlines. Councils with illegal dumping programs, litter prevention programs and recycling programs had significantly less waste along their coasts than councils without those programs. Additionally, councils who invest at least 8% of their budget towards waste management and focus a proportion of that budget towards coastal waste management will also have less waste on their coastline.

Acknowledgements

We thank council staff from the many councils around the country who contributed information used in the analyses herein. We thank Louise Bell Graphic Design and TJ Lawson for assistance with figures and we acknowledge the clean-up activities of the many volunteers who contribute to Clean Up Australia efforts around Australia.

Ethics

The data in this study was obtained under the Commonwealth Scientific and Industrial Research Organisation Human Ethics Approval “Understanding the effects of marine debris on wildlife” (058/14) granted for the period 12/06/14 – 31/12/15.

Funding

This work was supported by the NESP Marine Biodiversity Hub and by Oceans and Atmosphere, CSIRO, Tasmania, Australia.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2017.11.037.

References

[1] K.L. Law, S. Moret-Ferguson, N.A. Maximenko, G. Proskurowski, E.E. Peacock, J. Hafner, C.M. Reddy, Plastic accumulation in the North Atlantic subtropical gyre, Science 329 (5996) (2010) 1185–1188.
[2] R.A. Castañeda, S. Avlijas, M.A. Simard, A. Ricciardi, R. Smith, Microplastic pollution in St. Lawrence River sediments, Can. J. Fish. Aquat. Sci. 71 (12) (2014) 1767–1771.
[3] D. Morritt, P.V. Stefanoudis, D. Pearce, O.A. Crimmen, P.F. Clark, Plastic in the Thames: a river runs through it, Mar. Pollut. Bull. 78 (1–2) (2014) 196–200.
[4] L.C. Lebreton, J. van der Zwet, J.-W. Damsteeg, B. Slat, A. Andrady, J. Reisser, River plastic emissions to the world's oceans, Nat. Commun. 8 (2017).
[5] S.S. Sadri, R.C. Thompson, On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England, Mar. Pollut. Bull. 81 (1) (2014) 55–60.
[6] S. Sruthy, E. Ramasamy, Microplastic pollution in Vembanad Lake, Kerala, India: the first report of microplastics in lake and estuarine sediments in India, Environ. Pollut. 222 (2017) 315–322.
[7] H.K. Imhof, N.P. Ivleva, J. Schmid, R. Niessner, C. Laforsch, Contamination of beach sediments of a subalpine lake with microplastic particles, Curr. Biol. 23 (19) (2013) R867–R868.
[8] P.L. Corcoran, T. Norris, T. Ceccanese, M.J. Walzak, P.A. Helm, C.H. Marvin, Hidden plastics of Lake Ontario, Canada and their potential preservation in the sediment record, Environ. Pollut. 204 (2015) 17–25.
[9] A. McIlgorm, H.F. Campbell, M.J. Rule, The economic cost and control of marine debris damage in the Asia-Pacific region, Ocean Coast. Manag. 54 (9) (2011) 643–651.
[10] Y.C. Jang, S. Hong, J. Lee, M.J. Lee, W.J. Shim, Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea, Mar. Pollut. Bull. 81 (1) (2014) 49–54.
[11] C.M. Rochman, A. Tahir, S.L. Williams, D.V. Baxa, R. Lam, J.T. Miller, F.C. Teh, S. Werorilangi, S.J. Teh, Anthropogenic debris in seafood: plastic debris and fibers from textiles in fish and bivalves sold for human consumption, Sci. Rep. 5 (2015) 14340.
[12] L. Van Cauwenberghe, C.R. Janssen, Microplastics in bivalves cultured for human consumption, Environ. Pollut. 193 (2014) 65–70.
[13] M.L. Campbell, C. Slavin, A. Grage, A. Kinslow, Human health impacts from litter on beaches and associated perceptions: a case study of ‘clean’ Tasmanian beaches, Ocean Coast. Manag. 126 (2016) 22–30.
[14] R.C. Thompson, C.J. Moore, F.S. vom Saal, S.H. Swan, Plastics, the environment and human health: current consensus and future trends, Philos. Trans. R. Soc. B: Biol. Sci. 364 (1526) (2009) 2153–2166.
[15] S.C. Gall, R.C. Thompson, The impact of debris on marine life, Mar. Pollut. Bull. 92 (1–2) (2015) 170–179.
[16] M.R. Gregory, Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions, Philos. Trans. R. Soc. Lond. B Biol. Sci. 364 (1526) (2009) 2013–2025.
[17] C. Wilcox, E. Van Sebille, B.D. Hardesty, Threat of plastic pollution to seabirds is global, pervasive, and increasing, Proc. Natl. Acad. Sci. USA 112 (38) (2015) 11899–11904.
[18] I.O. Igbokwe, M.Y. Kolo, G.O. Egwu, Rumen impaction in sheep with indigestible foreign bodies in the semi-arid region of Nigeria, Small Rumin. Res. 49 (2) (2003) 141–146.
[19] S. Nugusu, R. Velappagounder, C. Unakal, R. Nagappan, Studies on foreign body ingestion and their related complications in ruminants associated with inappropriate solid waste disposal in Gondar Town, North West Ethiopia, Int. J. Anim. Vet. Adv. 5 (2) (2013) 67–74.
[20] P.-Y. Henry, G. Wey, G. Balança, Rubber band ingestion by a rubbish dump dweller, the White Stork (Ciconia ciconia), Waterbirds 34 (4) (2011) 504–508.
[21] J.C. Torres-Mura, M.L. Lemus, F. Hertel, Plastic material in the diet of the Turkey Vulture (Cathartes aura) in the Atacama Desert, Chile, Wilson J. Ornithol. 127 (1) (2015) 134–138.
[22] D.C. Houston, A. Mee, M. McGrady, I.G. Warkentin, Why do condors and vultures eat junk?: the implications for conservation, J. Raptor Res. 41 (3) (2007) 235–238.
[23] J.R. Jambeck, R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, K.L. Law, Plastic waste inputs from land into the ocean, Science 347 (6223) (2015) 768–771.
[24] Keep Australia Beautiful, Do the Right Thing, 2016. ⟨http://kab.org.au/do-the-right-thing-this-keep-australia-beautiful-week/⟩. (Accessed 21 June 2017).
[25] Neat Streets, Neat Streets, 2017. ⟨http://neatstreets.co/⟩. (Accessed 21 June 2017).
[26] Ocean Conservancy, International Coastal Cleanup, 2017. ⟨https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/⟩. (Accessed 27 June 2017).
[27] Keep America Beautiful, Keep America Beautiful, 2017. ⟨https://www.kab.org/⟩. (Accessed 27 June 2017).
[28] M. Bravo, M. de Los Angeles Gallardo, G. Luna-Jorquera, P. Nunez, N. Vasquez, M. Thiel, Anthropogenic debris on beaches in the SE Pacific (Chile): results from a national survey supported by volunteers, Mar. Pollut. Bull. 58 (11) (2009) 1718–1726.
[29] Beat the Microbead, Beat the Microbead, 2017. ⟨http://www.beatthemicrobead.org/⟩. (Accessed 21 June 2017).
[30] Bye Bye Plastic Bags, Bye Bye Plastic Bags, 2017. ⟨http://www.byebyeplasticbags.org/⟩. (Accessed 27 June 2017).
[31] D. Xanthos, T.R. Walker, International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): a review, Mar. Pollut. Bull. (2017).
[32] Global Press Journal, Bag Bans Are Widespread in Africa, But it’s Uncertain How Much Good They're Doing for Ocean, 2015. ⟨https://globalpressjournal.com/africa/bag-bans-are-widespread-in-africa-but-it-s-uncertain-how-much-good-they-re-doing-for-oceans/⟩. (Accessed 2 August 2017) .
[33] J. Whitehead, C. Coughanowr, J. Agius, J. Chrispijn, U. Taylor, F. Wells, State of the Derwent Estuary 2009: A Review of Pollution Sources, Loads and Environmental Quality Data from 2003 to 2009, DPIPWE, Tasmania, Derwent Estuary Program, 2010.
[34] K. Schlining, S. von Thun, L. Kuhnz, B. Schlining, L. Lundsten, N. Jacobsen Stout, L. Chaney, J. Connor, Debris in the deep: using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA, Deep Sea Res. Part I: Oceanogr. Res. Pap. 79 (2013) 96–105.
[35] Beach Clean SA, Beach Clean Services, 2013. ⟨http://www.beachclean.co.za/project.html⟩. (Accessed 27 June 2017).
[36] Keep NSW Beautiful, New South Wales Residents Exposed as Litterbugs, 2013. ⟨http://knswb.org.au/new-south-wales-residents-exposed-as-litterbugs/⟩. (Accessed 21 June 2017).
[37] Commonwealth of Australia, Ea.C.R. Committee (Ed.), Toxic Tide: The Threat of Marine Plastic Pollution in Australia, Senate Printing Unit, Parliament House, Canberra, 2016.

[38] Department of the Environment, Overview – Policies and Governance for Waste, National Waste Reporting Department of the Environment, 2013.
[39] Australian Local Government Association, About ALGA, 2013. 〈http://alga.asn.au/?ID=42)〉. (Accessed 26 June 2017).
[40] Queensland Litter Prevention Alliance, What is Litter, 2014. 〈http://www.keepqueenslandbeautiful.org.au/what-is-litter〉. (Accessed 20 June 2017).
[41] B.D. Hardesty, T.J. Lawson, T. van der Velde, M. Lansdell, C. Wilcox, Estimating quantities and sources of marine debris at a continental scale, Front. Ecol. Environ. 15 (1) (2017) 18–25.
[42] P. Uneputty, S.M. Evans, E. Suyoso, The effectiveness of a community education programme in reducing litter pollution on shores of Ambon Bay (eastern Indonesia), J. Biol. Educ. 32 (2) (1998) 143–147.
[43] J.M. Veiga, T. Vlachogianni, S. Pahl, R.C. Thompson, K. Kopke, T.K. Doyle, B.L. Hartley, T. Maes, D.L. Orthodoxou, X.I. Loizidou, I. Alampei, Enhancing public awareness and promoting co-responsibility for marine litter in Europe: the challenge of MARLISCO, Mar. Pollut. Bull. 102 (2) (2016) 309–315.
[44] B.L. Hartley, R.C. Thompson, S. Pahl, Marine litter education boosts children's understanding and self-reported actions, Mar. Pollut. Bull. 90 (1–2) (2015) 209–217.
[45] S. Pudin, Development of an Environmental Education Programme for Waste Management with Local Communities in Sabah, Malaysia, University of Waikato, Hamilton, New Zealand, 2015.
[46] S. Hasan, Public awareness is key to successful waste management, J. Environ. Sci. Health, Part A 39 (2) (2004) 483–492.
[47] X.I. Loizidou, M.I. Loizides, D.L. Orthodoxou, A novel best practices approach: the MARLISCO case, Mar. Pollut. Bull. 88 (1–2) (2014) 118–128.
[48] K. Glanville, H.-C. Chang, Mapping illegal domestic waste disposal potential to support waste management efforts in Queensland, Australia, Int. J. Geogr. Inf. Sci. 29 (6) (2015) 1042–1058.
[49] B.D. Hardesty, Q. Schuyler, T.J. lawson, K. Opie, C. Wilcox, Identifying Debris Sources, Understanding Transport to the Ocean and Evaluating Policy Responses, Final Report to the National Packaging Covenant Industry Association, CSIRO, 2016 (EP165651).
[50] B.H. Grumbles, EPA's marine debris program: taking action against trash, Sea Technol. 49 (1) (2008) 23–24.
[51] B.D. Hardesty, C. Wilcox, T. Lawson, M. Lansdell, T. van der Velde, Understanding the Effects of Marine Debris on Wildlife: A Final Report to Earthwatch Australia, 2014.
[52] A. Abu-Hilal, T. Al-Najjar, Marine litter in coral reef areas along the Jordan Gulf of Aqaba, Red Sea, J. Environ. Manag. 90 (2) (2009) 1043–1049.
[53] K.L. Storrier, D.J. McGlashan, Development and management of a coastal litter campaign: the voluntary coastal partnership approach, Mar. Policy 30 (2) (2006) 189–196.
[54] Beverage Industry Environment Council, Littering Behaviour Studies VII: National Benchmark, Pyrmont, Sydney, Australia, 2004.