Policy Routes for Marine Debris Management in the United States

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Abstract

Marine debris, particularly marine plastic pollution, is a growing pervasive global problem. This paper evaluates policy strategies for marine debris management in the United States by reviewing the literature on marine pollution, surveying U.S. experts on patterns and opinions related to marine debris, and quantifying marine debris output from US states at both state and county scales. Experts observe a lack of organization in response to policy implementation stemming from competing environmental priorities and believe states should coordinate or implement most marine debris policies. States which prioritize marine debris funding over the next five years are among the top ten contributors to marine debris. However, ocean-coastal states demonstrate clearer policy intent to reduce marine plastic debris than indicated by policy action in Great Lakes states. More detailed reporting by coastal states on self-assessments mandated by the U.S. Coastal Zone Management Act would assist in strategic marine debris policymaking.

Keywords

Marine debris, plastic pollution, United States policy, coastal zone management, survey, GIS

Introduction

Marine debris results from the consequence of intentional or unintentional and/or improperly disposed waste, litter, or dumping (Marine Debris Research, Prevention, and Reduction Act, 2006; Derraik, 2002). A review comparing studies estimating the percentage of plastic among littered items found plastic pollution compromises the majority of global marine debris (Derraik, 2002). Durable, cheap to produce, and versatile, plastics have many benefits, including providing public health benefits, and reducing food waste (Anthony L. Andrady & Mike A. Neal, 2009). The same attributes which make plastic valuable become detrimental when it enters the water and becomes marine debris (Ocean Conservancy, 2017).

Marine debris poses a serious threat to the ocean environment, causing harm to animals, impacting ocean chemistry, and disrupting the food web, with negative implications for human health (Derraik, 2002; Jambeck et al., 2015). Debris can include but is not limited to derelict fishing gear, metal, glass, and plastics categorized as macroplastics or microplastics (Cole, Lindeque, Halsband, & Galloway, 2011).

Microplastics, considered by most researchers to be particles <5mm (Andrady, 2011), disturb the composition of the ocean. When not ingested by marine animals, plastic disintegrates into particles which pollute the ocean (Cole et al., 2011) and leach hazardous chemicals such as persistent bioaccumulative toxic pollutants (PBTs) (UNEP, 2014). Plastic additives interfere with biologically important processes, potentially disrupting reproduction and development (Barnes, Galgani, Thompson, & Barlaz, 2009). Microplastics also cause damage to the food chain through

biomagnification, with humans ingesting particles through consumption of fish and other seafood. Recent studies indicate that 35% of fish in the North Pacific Central Gyre have ingested plastic, indicating problems not just for the fish themselves, but for species which feed on them (Boerger, Lattin, Moore, & Moore, 2010). Durable plastics persist 500 years in the environment (UNESCO, 1994).

Plastic materials are persistently used in society, including developing countries, where plastics are cheap and accessible (Anthony L. Andrady & Mike A. Neal, 2009) and population and per capita consumption is rising (Jambeck et al., 2015). Global plastic production in 2015 rose to 322 million tons, a 3.5% increase compared to 2014 (PlasticsEurope, 2016), increasing continuously over the last half-century and at faster rates than population growth from 2005 – 2015 (see supplemental material). Plastic usage is expected to double again in the next 20 years (Neufeld, Stassen, Sheppard, & Gilman, 2016).

Jambeck et al.'s 2015 article *Plastic Waste Inputs from Land into the Ocean* quantifies the amount of plastic debris entering the ocean annually, then breaks down these contributions by country through matching coastal populations of countries with nation-specific rates of waste generated per person per day. The study applied determined percentage of mismanaged waste per country to determine estimates of marine debris generated. The paper produced a ranking of nations responsible for marine debris input from land to sea; the United States ranked 20th. Jambeck et al., 2015 identified the need for international leadership by developed nations.

Regarding ocean governance, international success is reliant on local and national actions (Kimball, 2001). A multi-level approach should be taken for management of complex environmental issues such as climate change; doing so could guide stakeholders toward analyzing other global environmental concerns (Betsill & Bulkeley, 2006). According to Kimball, single nations cannot be solely responsible for solving an international problem and when a national issue is worsened by external sources, solutions cannot lie in that nation alone (Kimball, 2001). A 2016 bill to amend the Marine Debris Act was introduced in the U.S. Congress and focuses on international engagement, particularly US-led efforts to work with countries that contribute most to marine debris through research and investment in waste management infrastructures (Marine debris act amendments of 2016, 2016).

With respect to the literature and legislation, it is implied that marine debris policy could involve a multi-national approach, with efforts in the United States guiding developing states in policy implementation. However, there has been little research into marine debris policy in the United States. This paper explores U.S. expert opinions on marine debris matters, patterns of plastic pollution output by US state, and coastal state management practices. These findings inform a strategic portfolio of marine debris management paths, and consider structural improvement for policy development within the United States.

Materials and Methods

This paper uses three main methods: GIS maps relating coastal state and county marine debris outputs with current policy actions, a comparison of Self-Assessment and Strategy reports from the Coastal Zone Enhancement Program (Coastal Zone Management Act of 1972, 1972) and a survey of marine debris experts.

Representing marine debris generation and policy using GIS Methodology

We produce an initial estimate at the state and coastal county scales, applying the Jambeck et al. methodology to the United States, updated with state-specific waste generation rates (Jambeck et al., 2015; Shin, 2014) . We then explore state-by-state marine debris policy development. One map helps determine which states are most responsible for marine debris output from land to sea; a second map further breaks this down by coastal county. A third map identifies where marine debris policies are employed at the state level. Additional details of the methods, population data, and state-based waste generation rates are provided in supplemental material.

Data reported by States under Coastal Zone Management Act (Section 309)

Under Section 309 of the Coastal Zone Management Act, every five years coastal states provide to National Oceanic and Atmospheric Administration's (NOAA) Office of Ocean and Coastal Resource Management (OCRM) self-reported assessments detailing their coastal management program's strengths and areas of improvement[1]. OCRM then works with each state to determine strategic goals based on state priorities. When approved, NOAA may provide funding upon states' requests to carry out those plans. This is referred to as the Coastal Zone Enhancement Program, due to its focus on nine areas of "enhancement," one of which is marine debris. States report their initiatives on these areas of enhancement, then prioritize the enhancement areas which matter most to their state.

Survey Design, Development, and Sample Selection

We surveyed marine debris policy experts sought 120 experts from six different employment areas with marine debris management duties or activities: federal government, state government, city/local government, universities, businesses, and non-profit organizations. An online survey using Qualtrics® software provided national accessibility to these experts in a common survey instrument.

The survey queried experts on the following marine debris policy questions:

1) What are the biggest concerns and threats regarding marine debris?;
2) What gaps exist in current and potential policies and how can they be addressed?;
3) What they consider ideal paths for future marine debris policy management?; and
4) Which level of governance is best suited to handle marine debris policy and how does this vary?

The survey included four sections to address these questions and enable comparisons across federal, state, and local agencies and among non-agencies: (I) Demographics, (II) Opinions on Government Regulation of Marine Debris, (III) The Scale of the Problem and Potential Solutions, and (IV) Policy Initiatives and Routes. Further details on the survey development, including pilot surveys, and solicitation of experts in provided in supplemental material.

[1] The twenty-eight reports from the 2016 – 2020 Self-Assessment and Strategy cycle are cited in the references section.

Table 1 presents the number of experts identified for the survey, the number contacted, and the number that completed the survey. Potential respondents were identified through extensive searches on websites of governments, universities, non-profits, and businesses. When the appropriate contacts could not be located through independent research, phone calls to the appropriate office helped identify experts. The number of city/local experts identified was fewer than expected, because websites of many city/local agencies did not list a marine debris expert on staff and had few links beyond general recycling and refuse collection services. We contacted double the number of sought out business employees due to the anticipated difficulty in receiving a response from a corporation's general email. In engaging non-profits and universities, additional experts were contacted through referrals. Further detail on survey implementation is provided in supplemental material.

Table 1. Sample expert respondents by among agency and non-agency groups

RESPONDENT GROUP	INITIALLY IDENTIFIED FOR THE SURVEY	REQUESTED PARTICIPATION IN THE SURVEY	SURVEY RESPONDENTS
FEDERAL	15	12	12
STATE	60	120	52
CITY/LOCAL	15	6	5
BUSINESS	5	10	0
NON-PROFITS	15	30	21
UNIVERSITIES	10	26	18
OTHER		2	7
TOTAL	**120**	**206**	**115**

Results and Discussion

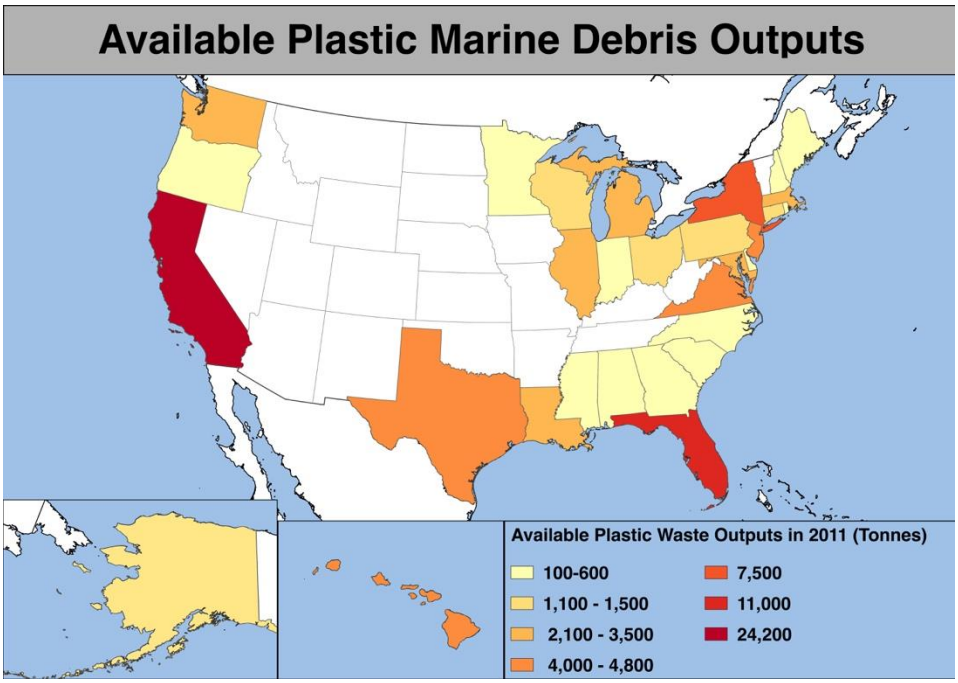
This section presents observations from review of the CZMA Section 309 data, online survey results, and GIS Data Analysis. The information obtained from these methods are analyzed and compared for trends in marine debris management.

GIS Data Analysis

GIS displays plastic marine debris output by US state and then county using the updated methods described below and in supplemental material. A third map focuses on geographic patterns from state-employed marine debris initiatives.

Plastic Marine Debris Outputs by State

Error! Reference source not found. indicates US coastal state contributions to marine debris using population data from 2010 and state-specific per capita waste generation rates. The corresponding table presents a ranking with the raw data (**Error! Reference source not found.**). The methodology used to create Figure 1 and Figure 2 is based on the findings from Jambeck et al., 2015. We calculated plastic marine debris output using coastal population data and state waste generation rates, which was determined through two papers (Jambeck et al., 2015; Shin, 2014). More information can be found in supplemental material. The data was collected from 2010 and 2011, with Figure 1 showing the results from 2011.



Note: Legend scale is discontinuous, per data in Table 2, to depict separation of clusters.

Figure 1. Plastic marine debris output from states

Table 2. Data of plastic marine debris output from states

Rank	State	Coastal Population in 2010	Waste generation rate [kg/person/day]	Mismanaged plastic waste in 2010	Middle range (tonnes) Marine plastic debris output
1	California	25,520,252	4.01	96,700	24,200
2	Florida	14,468,197	3.23	44,200	11,000
3	New York	15,691,096	2.03	30,100	7,500
4	Virginia	4,730,951	4.32	19,300	4,800
5	New Jersey	7,045,573	2.81	18,700	4,700
6	Texas	6,121,490	2.76	16,000	4,000
7	Michigan	4,680,503	3.18	14,100	3,500
8	Illinois	5,898,137	2.41	13,400	3,400
9	Washington	4,615,192	2.94	12,800	3,200

Rank	State	Coastal Population in 2010	Waste generation rate [kg/person/day]	Mismanaged plastic waste in 2010	Middle range (tonnes) Marine plastic debris output
10	Massachusetts	4,924,916	2.60	12,100	3,000
11	Maryland	4,148,642	2.41	9,500	2,400
12	Hawaii	1,360,301	6.44	8,300	2,100
13	Louisiana	2,247,053	2.88	6,100	1,500
14	Ohio	2,534,282	2.51	6,000	1,500
15	Pennsylvania	2,365,551	2.53	5,700	1,400
16	Wisconsin	2,049,934	2.25	4,400	1,100
17	Connecticut	2,219,037	2.04	4,300	1,100
18	South Carolina	1,241,048	2.15	2,500	600
19	Delaware	897,934	2.50	2,100	500
20	North Carolina	999,064	2.16	2,000	500
21	Rhode Island	1,052,567	2.00	2,000	500
22	Maine	836,502	2.42	1,900	500
23	Indiana	771,815	2.25	1,600	400
24	Alabama	595,257	2.56	1,400	400
25	Oregon	653,112	2.32	1,400	400
26	Georgia	563,967	2.46	1,300	300
27	Alaska	598,207	2.14	1,200	300
28	District of Columbia	601,723	1.74	1,000	200
29	New Hampshire	418,366	1.98	800	200
30	Mississippi	370,702	2.19	800	200
31	Minnesota	216,268	2.43	500	100

Coastal County Map

Error! Reference source not found. provides a coastal county map applying states' waste generation rate and the coastal county populations of each state to illustrate potential areas of importance as local/regional policy scales. **Error! Reference source not found.** ranks the top twenty contributing coastal counties. NOAA and the United States Census Bureau define a county to be coastal if at least 15% of its land area is in the coastal watershed, or if a county has at least 15% of a coastal cataloging unit (a coastal area between watersheds) (Crossett, Ache, Pacheco, & Haber, 2014).

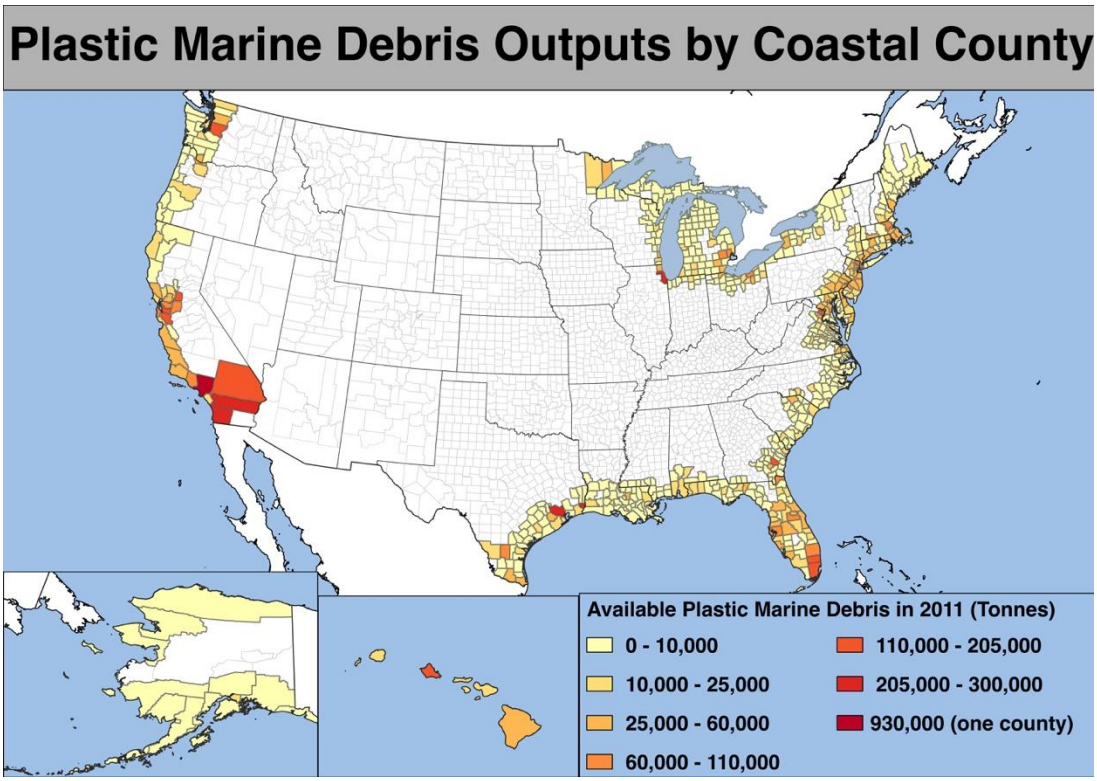


Figure 2. Plastic marine debris output from for NOAA's list of coastal counties

Table 3. Data of plastic marine debris output for NOAA's list of coastal counties

Rank	County	State	State Waste Generation Rate	Coastal Population in 2010	Mismanaged plastic waste in 2010 (tonnes)	Middle range (tonnes) Marine debris output
1	Los Angeles	CA	4.01	9,818,700	3,722,100	930,500
2	Cook	IL	2.41	5,194,700	1,183,500	295,900
3	San Diego	CA	4.01	3,095,300	1,173,400	293,300
4	Orange	CA	4.01	3,010,200	1,141,100	285,300
5	Harris	TX	2.76	4,092,400	1,067,800	266,900
6	Riverside	CA	4.01	2,189,600	830,000	207,500
7	San Bernardino	CA	4.01	2,035,000	771,400	192,900
8	Miami-Dade	FL	3.23	2,496,400	762,300	190,600

Rank	County	State	State Waste Generation Rate	Coastal Population in 2010	Mismanaged plastic waste in 2010 (tonnes)	Middle range (tonnes) Marine debris output
9	Santa Clara	CA	4.01	1,781,600	675,400	168,800
10	Honolulu	HI	6.44	953,200	580,300	145,100
11	Alameda	CA	4.01	1,510,300	572,500	143,100
12	Wayne	MI	3.18	1,820,600	547,300	136,800
13	Sacramento	CA	4.01	1,418,800	537,800	134,500
14	King	WA	2.94	1,931,200	536,800	134,200
15	Broward	FL	3.23	1,748,100	533,800	133,400
16	Kings	NY	2.03	2,504,700	480,700	120,200
17	Fairfax	VA	4.32	1,081,700	441,800	110,400
18	Queens	NY	2.03	2,230,700	428,100	107,000
19	Palm Beach	FL	3.23	1,320,100	403,100	100,800
20	Contra Costa	CA	4.01	1,049,000	397,700	99,400

For state and local legislation, these maps provide initial indication of the major population centers contributing to marine debris, and help to identify where local/regional policy action may be effective for addressing major contributors. Population is a factor of states' waste generation rate, and it may be expected that states with larger populations tend to be higher ranked. For example, California has the highest population of all coastal states (and encompasses over 20% of the total coastal population of all coastal states). However, within counties with higher waste generation rates, this is not the case. Considering counties, we can better understand the bigger picture by focusing on smaller scales of action. This also suggests value in continued work to understand the household practices and other factors that may result in higher or lower waste generation rates at a finer scale than statewide statistics.

State comparison of CZMA Section 309 reporting

Error! Reference source not found. presents a GIS map based on state responses data from 2016-2020 Coastal Zone Enhancement Program's State Self-Assessment and Strategy on the enhancement area marine debris. The National Coastal Zone Management Program asked states to "indicate if the approach is employed by the state or territory." We term these to be "state-

employed" statutes, regulations, or policies. This map reveals geographic patterns, with states with these policies being largely ocean-based, and states without on the Great Lakes.

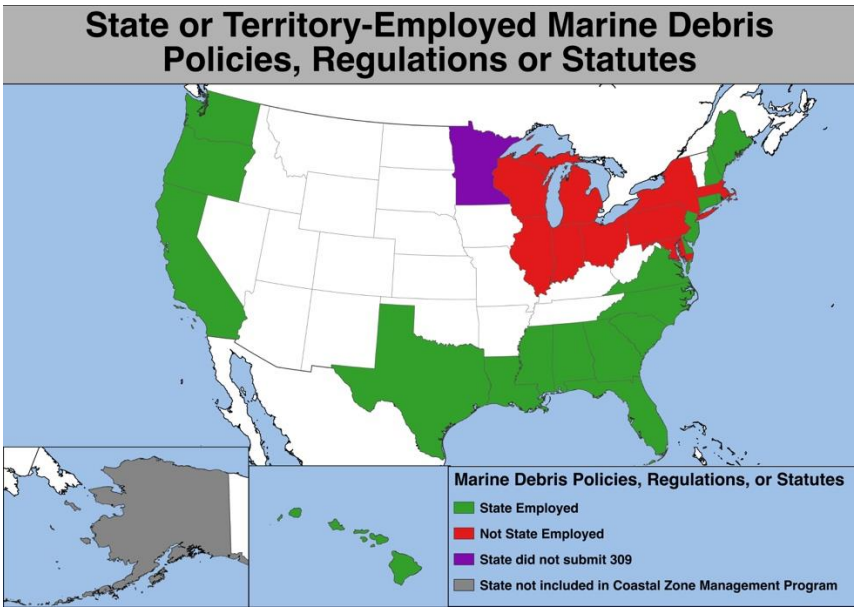


Figure 3. Coastal state-employed marine debris policies

The 2016-2020 Assessment and Strategy reports per Section 309 of the Coastal Zone Management Act provide a comparison between marine debris initiatives among coastal states. We consider four major categories as comparison points for marine debris including a) overall priority, b) state policy, c) state removal programs, and d) requests for funding through 2020.

In **Error! Reference source not found.**, states are organized per their previously generated ranking from Table 2 detailing contributions to marine debris output. The assessment reports ask the questions in **Error! Reference source not found.** to the coastal management office of the listed coastal state. California is in Table 4 twice under the same ranking because the California Coastal Management Program is divided between the California Coastal Commission and the San Francisco Bay Conservation and Development Commission (BCDC). Three states did not provide assessment and strategy findings: Alaska, Minnesota, and the District of Columbia, for the following reasons. Alaska withdrew from the voluntary National Coastal Zone Management Program in 2011 and is therefore not included. Minnesota did not develop an assessment and strategy for 2016-2020. The District of Columbia is included in these rankings of state and territory contributions to marine debris; however, since the District is not a state, it did not submit an assessment and strategy report.

Table 4. Coastal states' marine debris priorities from 2016-2020

Rank	State	Level of Priority for Enhancement of Marine Debris for Coastal Management Program	Marine debris statutes, regulations, policies, or case law interpreting these employed by state/territory (Y or N)	Marine Debris removal programs employed by state/territory (Y or N)	Funding Requested for Marine Debris through 5-Year Budget Strategies (through 2020)
1	California CCC	Medium	Y	Y	N
1	California BCDC	Low ("limited authority")	Y	Y	N
2	Florida	High	Y	Y	Y
3	New York	Medium	N	Y	N
4	Virginia	High	Y	Y	Y
5	New Jersey	Low	Y	Y	N
6	Texas	Medium	Y	Y	Y
7	Michigan	Medium	N	Y	N
8	Illinois	Medium	N	Y	N
9	Washington	Low	Y	Y	N
10	Massachusetts	Low	N	Y	N
11	Maryland	Medium	N	Y	N
12	Hawaii	Low	Y	N	N
13	Louisiana	Medium	Y	Y	N
14	Ohio	Low	N	Y	N
15	Pennsylvania	Medium	N	N	N
16	Wisconsin	Low	N	N	N
17	Connecticut	Low	Y	N	N
18	South Carolina	Medium	Y	Y	N
19	Delaware	Medium	Y	Y	N
20	North Carolina	Medium	Y	Y	N
21	Rhode Island	Low	Y	Y	N
22	Maine	Low	Y	Y	N
23	Indiana	Low	N	Y	N
24	Alabama	Medium	Y	Y	N
25	Oregon	Low	Y	Y	N
26	Georgia	Medium	Y	Y	N
27	Alaska				

Rank	State	Level of Priority for Enhancement of Marine Debris for Coastal Management Program	Marine debris statutes, regulations, policies, or case law interpreting these employed by state/territory (Y or N)	Marine Debris removal programs employed by state/territory (Y or N)	Funding Requested for Marine Debris through 5-Year Budget Strategies (through 2020)
28	District of Columbia				
29	New Hampshire	Medium	Y	Y	N
30	Mississippi	Low	Y	Y	N
31	Minnesota				

*CCC- California Coastal Commission
**BCDC- The San Francisco Bay Conservation and Development Commission

Of the 28 coastal states which submitted assessment and strategy reports (see table in supplemental material), only Florida and Virginia consider marine debris a "high" priority. Florida, Virginia, and Texas are the only states which included marine debris as an enhancement area in any of the 2016-2020 strategies. The details of these strategies are included in supplemental material.

We examined the coastal square footage of each of NOAA's 31 coastal states to determine any additional correlations between coastal area and marine debris input, and coastal area and marine debris enhancement prioritization. We found the correlation between coastal area and state contribution to marine debris is low (less than 10% with coastal area and less than 30% with coastal percent of state population).

Survey Results

The results of the survey are broken down into four areas: (1) survey response and demographics; (2) marine debris pathways; (3) barriers to policy implementation; and (4) paths for future policy management. The following results provided insight into policy effectiveness, implementation barriers, and utilization within levels of governance.

Survey Response and Demographics

The survey yielded 149 total responses, with 115 completed, 9 partially completed, and 25 not completed. Only the 115 completed surveys, i.e., response to every question, are reported below. Most respondents are employed at an intermediate position level and above, with only 3% at a junior/entry level and 15% in senior positions of Directors/Executives.

Marine debris consequences and contributions

This subsection discusses the results of two survey questions, which follow marine debris from its original source to its ultimate environmental consequence. The survey asked respondents to specify their relative concerns for the 10 most common forms of marine debris, with the total sum of all choices equal to 100 (Table 5).

Table 5. Relative Concern expressed regarding the ten most common forms of marine debris

	Average	Minimum	Maximum	Standard Deviation	Variance
Derelict fishing gear	21.43%	0	100	14.08	198.18
Macroplastics	20.27%	0	50	10.41	108.27
Microplastics (not including microbeads or microfibers)	20.02%	0	90	12.89	166.26
Microbeads	13.01%	0	50	8.81	77.70
Microfibers	11.62%	0	85	10.27	105.49
Rubber	4.25%	0	25	4.79	22.97
Metal	2.92%	0	30	4.43	19.64
Glass	2.39%	0	35	4.51	20.31
Paper and Cloth	2.13%	0	15	3.66	13.431
Wood	1.96%	0	50	5.37	28.84

Later in the survey respondents were asked about their concern for six specified consequences of marine debris (Figure 4).

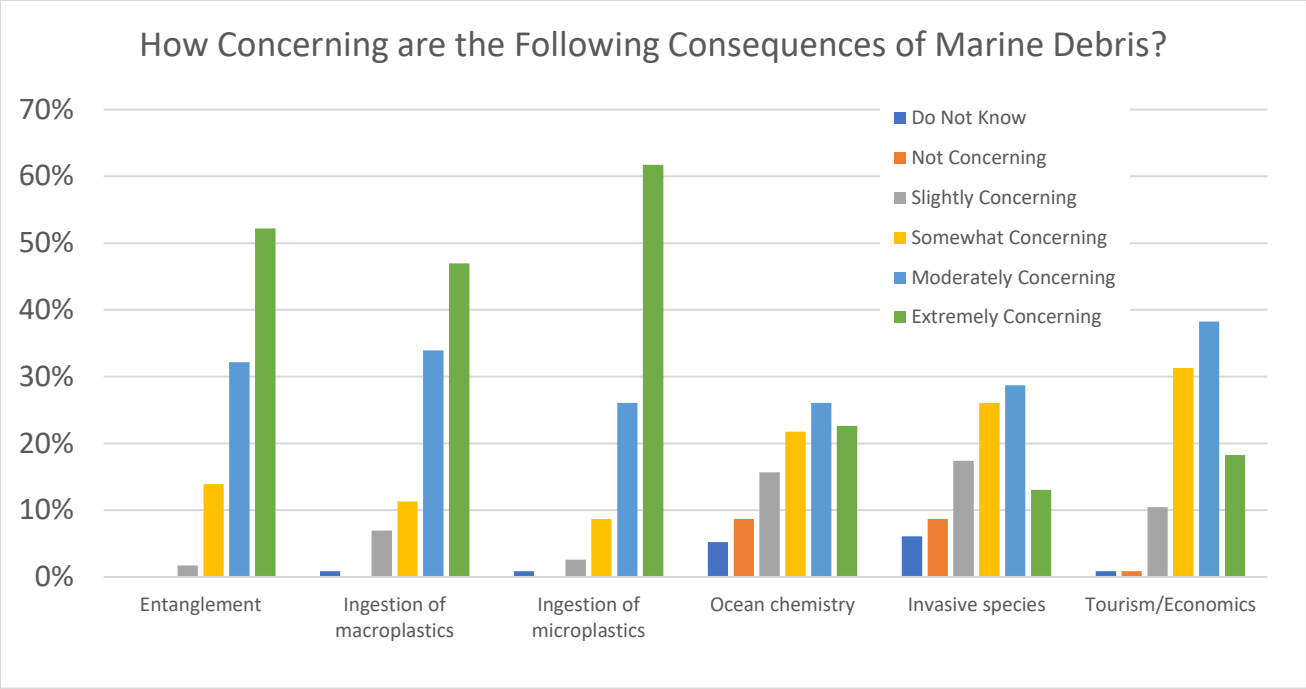


Figure 4. Opinions on concern of marine debris consequences

For the most part, consequences of marine debris which experts find most concerning originate from items by which experts also place the greatest concern. Eighty-four percent of respondents claimed entanglement, a consequence of derelict fishing gear and macroplastics, is moderately concerning or extremely concerning: Derelict fishing gear averaged as the marine debris category of most concern.

Eighty-one percent of respondents identified ingestion of macroplastics as moderately concerning or extremely concerning (Table 6). Macroplastics averaged the second most-concerning marine debris category. Survey respondents (~88% of experts) ranked ingestion of microplastics, a consequence of microbeads, microfibers, and all other microplastics, as moderately concerning or extremely concerning.

Table 6. Opinions on concern of marine debris consequences

Consequence Assessed in Survey	Do Not Know	Not Concerning	Slightly Concerning	Somewhat Concerning	Moderately or Extremely Concerning
Entanglement	0.0%	0.0%	1.7%	13.9%	84.3%
Ingestion of macroplastics	0.9%	0.0%	7.0%	11.3%	80.9%
Ingestion of microplastics	0.9%	0.0%	2.6%	8.7%	87.8%
Ocean chemistry	5.2%	8.7%	15.7%	21.7%	48.7%
Invasive species	6.1%	8.7%	17.4%	26.1%	41.7%
Tourism/Economics	0.9%	0.9%	10.4%	31.3%	56.5%

Together, the three groupings of microplastics—microbeads, microfibers, and all other microplastics—comprised approximately 45% of relative concern of experts (Table 5). Ingestion of microplastics, a consequence of all three, was found by nearly 88% of experts to be moderately or extremely concerning. However, less than half of experts found ocean chemistry, also a consequence of microbeads, microfibers, and all other microplastics, to be moderately concerning or extremely concerning. Environmental and chemical impacts on the ocean and organisms resulting from plastic's persistent, bioaccumulating and toxic substances (PBTs) are not well understood (Kershaw et al., 2011). It is possible this viewpoint may reflect expert opinions with sufficient knowledge on the subject (only 5% answered "Do not know"), or this result may indicate a need for more research on the consequences of plastic pollution on ocean chemistry per the literature.

Policy implementation barriers to addressing marine debris threats

The survey asked experts to identify the largest barriers to implementing policy among seven specified barriers and the option to write-in a barrier, with respondents asked to check all options which applied. Budget was identified by most experts (79%) as a barrier (Figure 5). Seventy-one percent of experts identified other issues taking priority as a barrier to policy implementation. To better understand barriers to marine debris within a larger context, the survey asked respondents to compare the importance of addressing marine debris with other environmental concerns (Figure 6).

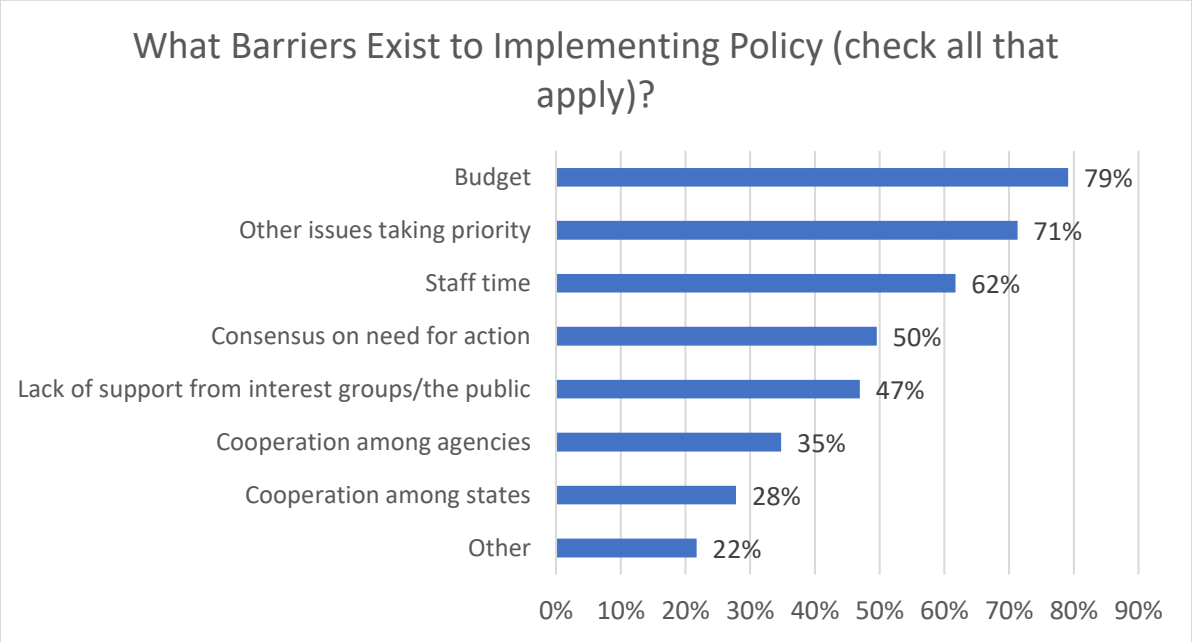


Figure 5. Barriers to implementing policy

For the majority, marine debris is just as important, or less important than other environmental concerns. In particular, between 93-95% valued drinking water quality, air pollution, and atmospheric CO2 levels to be much less important, somewhat less important, or just as important as marine debris.

Few experts find marine debris to be more important than the other listed environmental concerns. Twenty-two percent of experts view marine debris as somewhat more important or much more important than invasive species. Between 5-14% of respondents view all other environmental concerns as somewhat more important or much more important than marine debris.

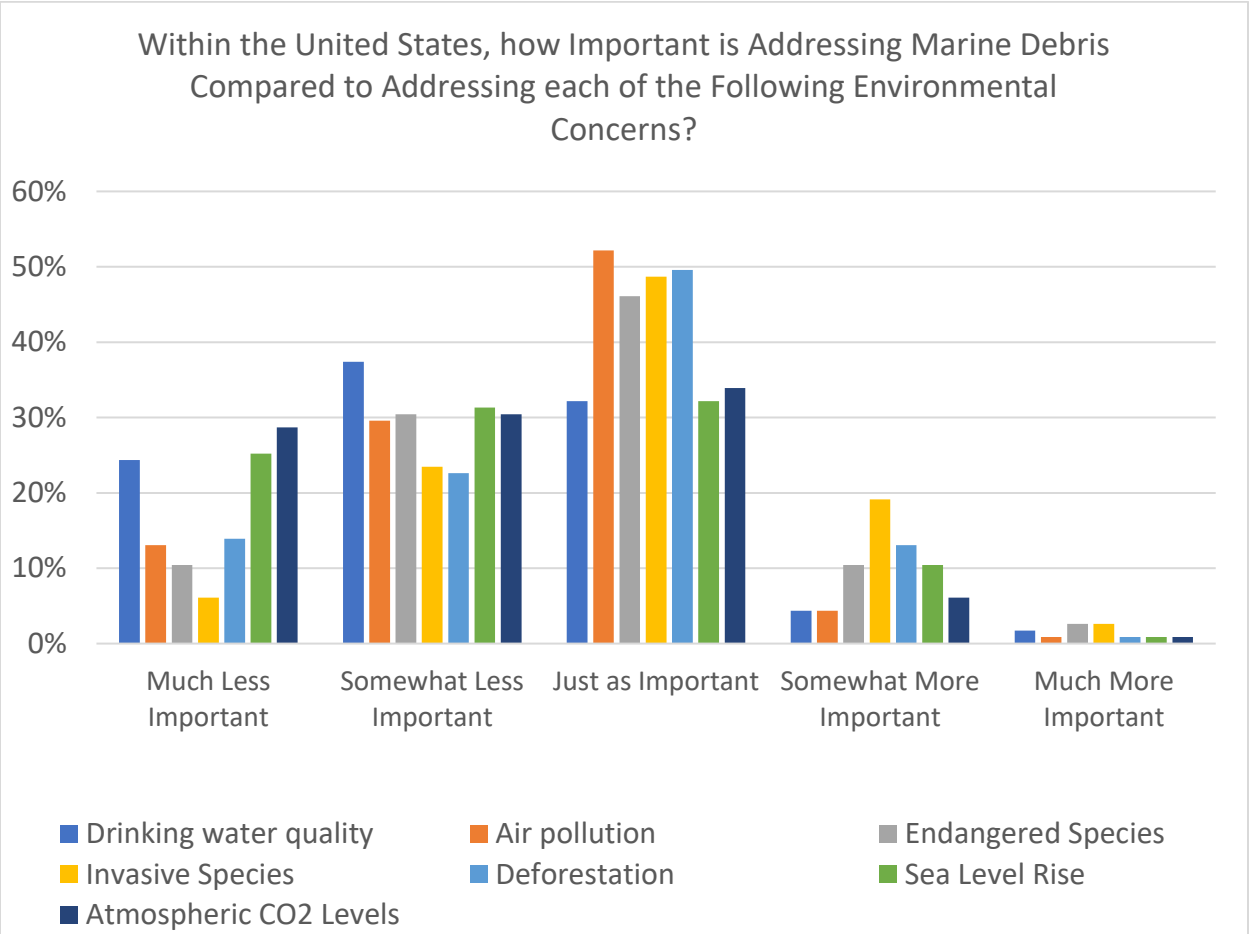


Figure 6. Addressing marine debris versus other environmental concerns

Overall, most marine debris policy professionals surveyed either view marine debris as just as important as environmental concerns, or less important. This evidences how other issues are prioritized compared to marine debris, which can unintentionally serve as a barrier to marine debris policy implementation.

Despite these barriers, should governments proceed in creating marine debris policy, responses revealed variation among levels of government in which initiatives should be undertaken. By level of government (e.g., federal) the survey asked participants what their level of government (e.g., federal) needs to do to better address marine debris threats, and respondents could check all answers which applied. Figure 7 contains the results. Across all groups, between 80-92% of respondents believe education initiatives are needed. Ninety-two percent of federal government employees believe the federal government should investigate physical science and social science

research, as well as collaborate with businesses and work with interest groups and NGOs. Education and defining policy measures, initiatives, and timeframes are most widely considered a state government issue. Local/city governments should also invest in education, in addition to working with other government agencies on these issues.

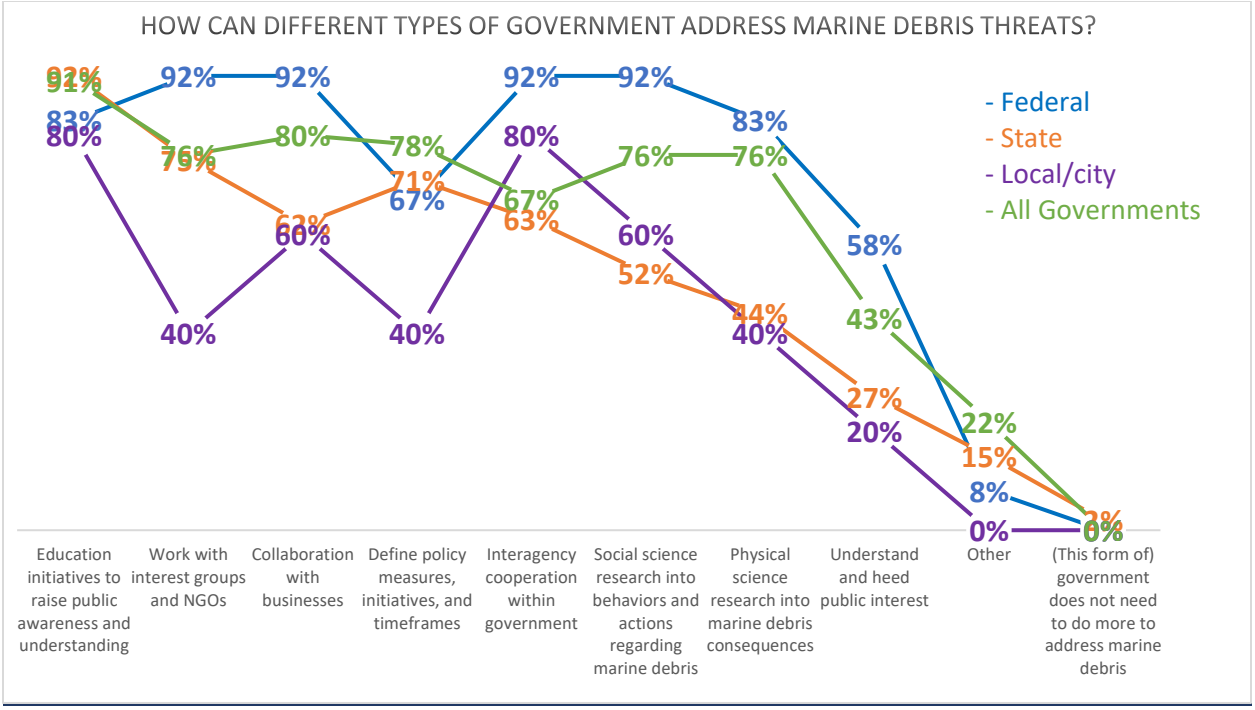


Figure 7. How government can better address marine debris, broken down by employment

Paths for future policy management

This section seeks to determine the success of certain policies and of which scale of government policy should be implemented.

Mitigating versus adaptive solutions

The survey asked respondents to compare the importance of mitigating policies versus adaptive policies (Figure 8). The results show that the highest percentage of experts, 39%, believe mitigation is much more important than adaptation. Of these individuals, less than half (47%) are government employees.

Thirty-four percent of experts view mitigation and adaptation as equally important to marine debris solutions. Most of the individuals are government employees. Between 9-10% of experts responded with one of the other options.

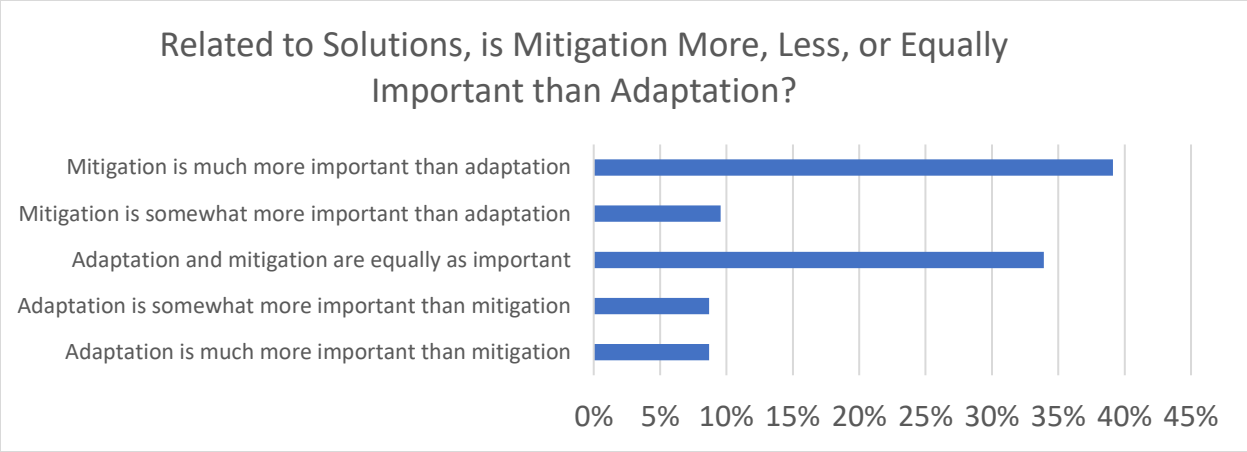


Figure 8. Comparison of the importance of mitigation versus adaptation-based solutions

The survey asked respondents to value the effectiveness of several mitigating policies. Over the past decade and across mostly city and local jurisdictions, fees and bans on certain marine debris items have been implemented in the United States. The survey solicited responses on four of them: single-use plastic bag bans, single-use plastic bag fees, Styrofoam bans in retail stores, and no-smoking bans on beaches.

The results on perceived effectiveness of each is listed in Figure 9. For single-use bag bans and Styrofoam bans, 64% and 61%, respectively, believe these policies to be effective or very effective, respectively. Slightly less than half of experts, between 46-47%, find single-use bag fees and no-smoking bans on beaches to be effective or very effective. Even so, most experts found single-use plastic bag fees and no-smoking bans on beaches as providing some effect, with only between 8-10% of experts believing these policies to be ineffective.

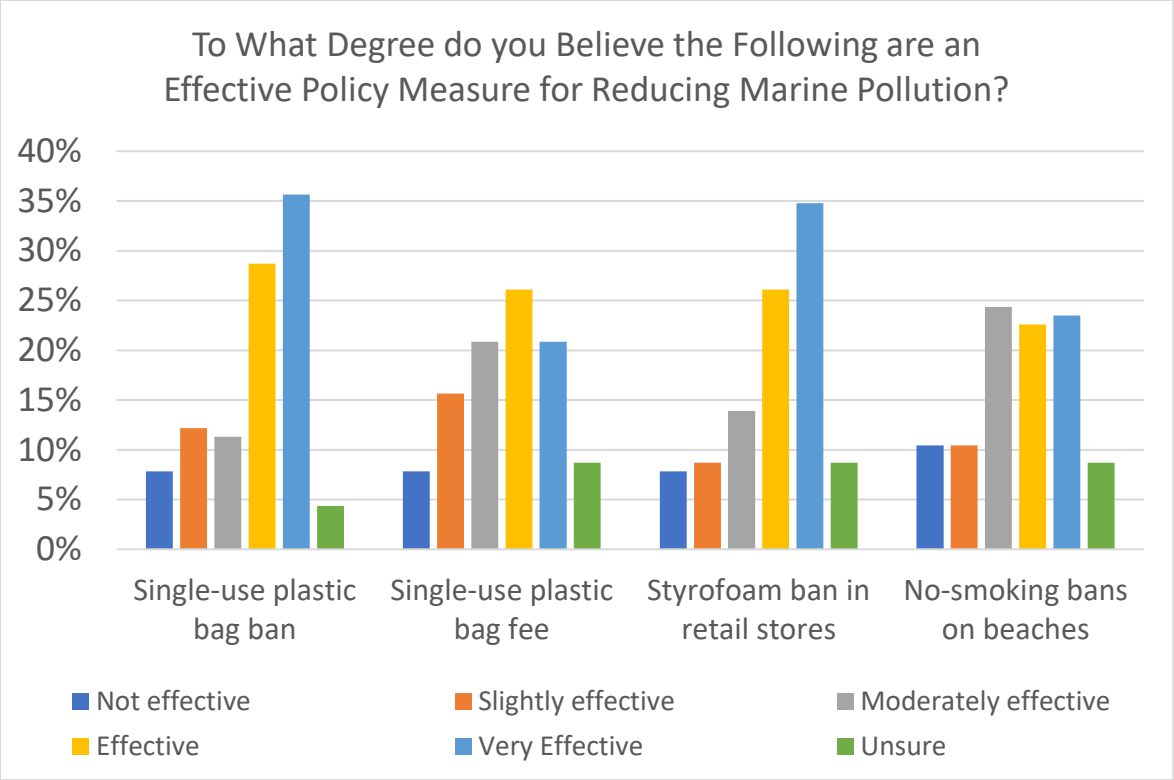


Figure 9. Effectiveness of common policies for reducing marine pollution

Although these policies are mostly viewed to be some degree of effective, these are surprising results. Given that most feel mitigation is more important than adaptation, more agreement might have been expected on the effectiveness of these policies. Perhaps experts value other mitigating policies as important to solutions, or the included policies, no matter how effective, are still more important to consider than adaptive solutions.

Scales for governing marine debris policy

In determining paths for policy management, the survey asked experts at which scale of government in the United States certain policies should be handled (Figure 10). Most experts said single-use plastic bag bans, education, regulations on littering, and clean-up mechanisms are best addressed at the state level. Respondents view single-use bag fees as a local level issue. Seventy-one percent and forty-seven percent of experts, respectively, see research-driven policy and other policies as best suited at the national level. Eighty-three percent of respondents believe education is either a state or national issue, with 48% selecting state and 35% national.

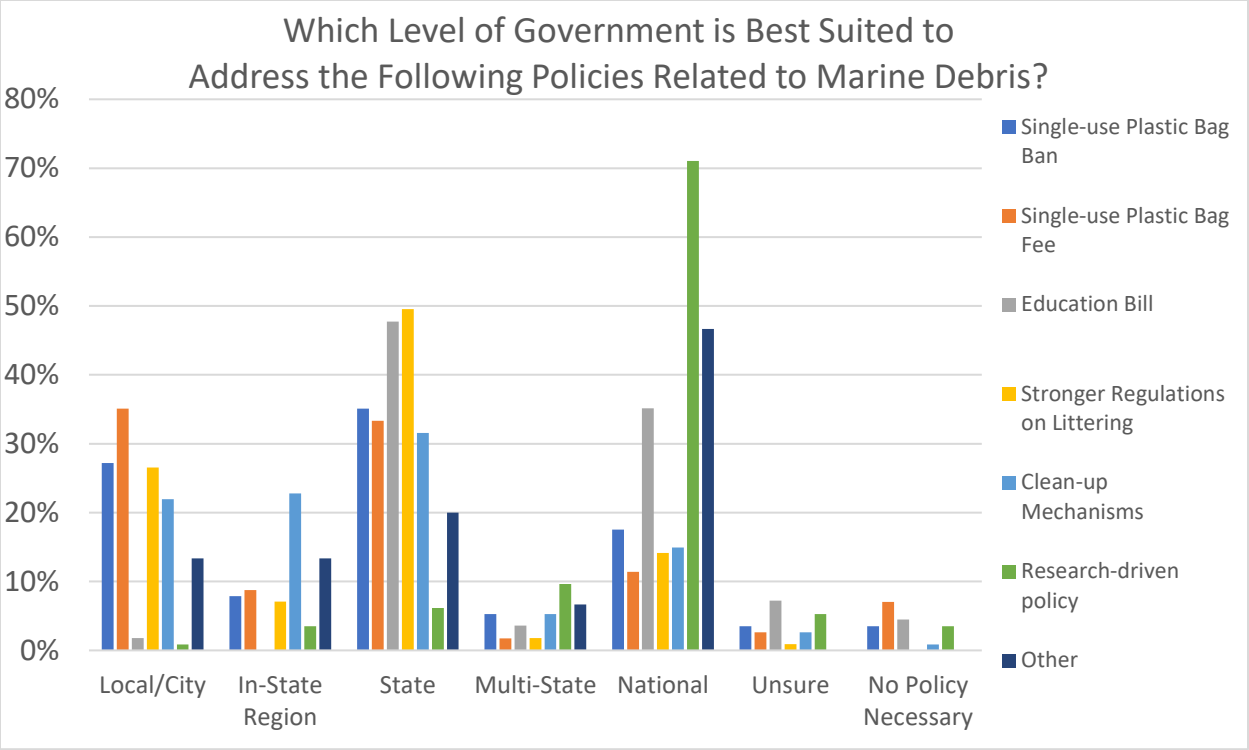


Figure 10. Scales of governance best suited to address marine debris policies

The survey asked government experts which scale would work best for a marine debris reduction plan (Figure 11). This is separate from Figure 10 as the survey only asked this question to government employees. According to most respondents (32%), state plans are considered the best scale for this plan, with twenty-six percent preferring in-state regional plans. By respondent group, most state government employees prefer a statewide plan (30%), though 26% favor an in-state regional plan. No city/local government employees support a state-wide plan, though 75% favor the in-state regional plan. Fifty-seven percent of federal employees believe a state plan is the most effective scale.

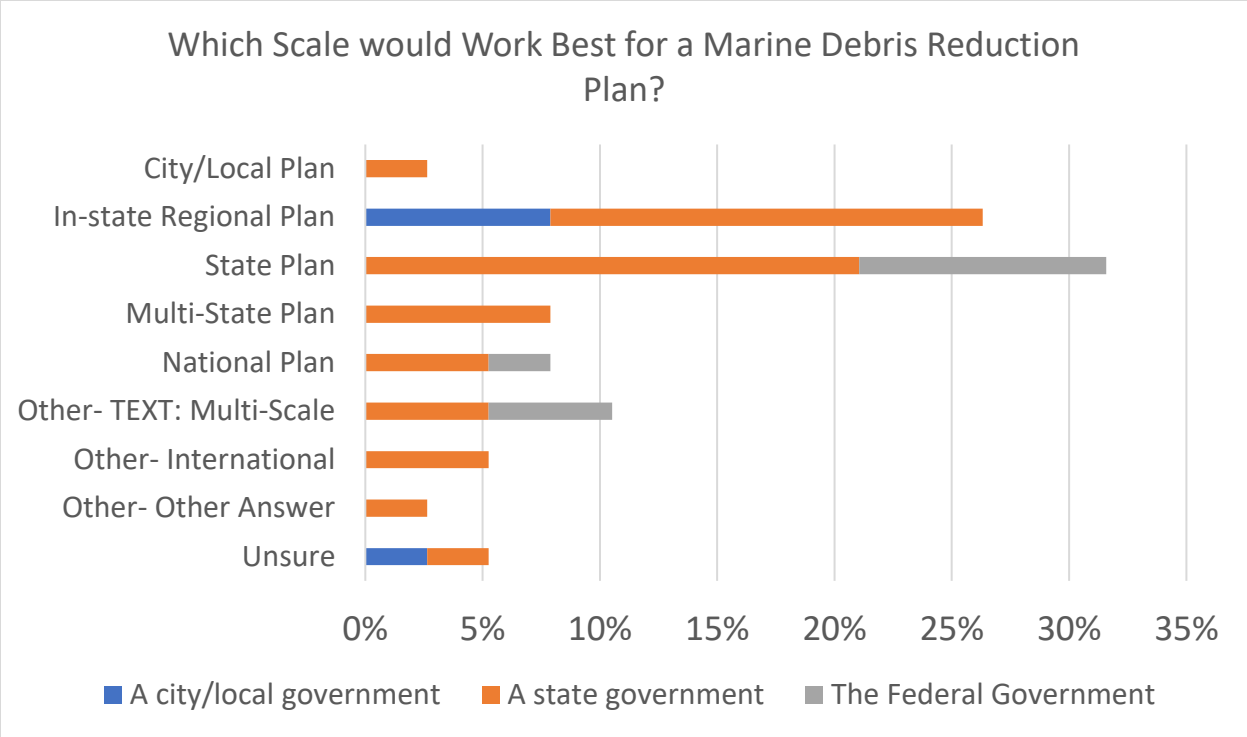


Figure 11. Marine Debris Reduction Plan Scale

Discussion

This discussion identifies and supports how the results lead to three key conclusions.

309 Assessment and Strategy Reports are Inadequate for Analyzing Marine Debris Initiatives

The Assessment and Strategy reports help shed light on state's current plans and future policy goals, but could improve in several respects regarding marine debris enhancement. The reports likely serve their purpose under the National Coastal Zone Management Program, but if specification and clarity improvements were made, the reports could also be more broadly utilized to better understand marine debris implications.

Examining the GIS data with the Assessment and Strategy reports, there are two takeaways. First, there is a connection between state responsibility for marine debris output and policy prioritization, at least from a financial standpoint, with Texas, Virginia, and Florida, which are top ten contributors to marine debris being the only states which ask for funding for marine debris enhancement. Virginia and Florida are also the only states which consider marine debris a high enhancement priority. States in the top ten were also more likely than other coastal states to evaluate marine debris as high or medium priority. All other coastal states were split evenly between medium or low priority.

Secondly, excluding Massachusetts and Maryland, ocean-based states claim to have state-employed marine debris policies, regulations, or statutes, while Great Lakes-based states identified as not having statutes, policies, or regulations. New York and Pennsylvania, which are

both on a Great Lake and on or within the basin of the Atlantic Ocean, do not have these policies, and fall within the Great Lakes group. For these states, more of their coastal territory is on the Great Lakes, although most of their population is in the Atlantic Ocean drainage basin. The Great Lakes Marine Debris Action Plan was published in 2014, meaning Great Lakes-based states are involved in addressing this issue. Of the Great Lakes states, only Illinois and Wisconsin mentioned the Plan in their reports. The reports should be edited to ask states of their involvement with any marine debris plan or initiatives.

Improvements within these reports could provide better information and more clarity in how states address and can improve upon handling marine debris. The report instructions ask states if they have "state-employed marine debris statutes, regulations, policies, or case law interpreting these," and ask for a yes or no answer. This question as phrased allows little room for specification. Some states provide more information about certain regulations or policies, but there is little uniformity between what states choose to include. The reports would be better served asking if states have specific policies which the National Coastal Zone Management Program deems to be successful in eradicating or managing marine debris. The reports instructions should then ask how effective these policies are considered by each state.

Of the 69% of states which identified as having "state employed marine debris statutes, regulations, policies, or case law interpreting these," six fell in the top 10 contributing states to marine debris, which does not infer any connection between state-employed policies and marine debris output. (A simple correlation test between states with marine debris policies showed only a ~12% correlation with inclusion in the top-ten rank.) Additionally, some states claimed other organizations, state agencies, or NOAA's Marine Debris Program as the main force behind marine debris management in their state, so their Coastal Zone Management Program doesn't need to prioritize marine debris.

The report format fails to let states demonstrate their overall effectiveness in dealing with marine debris. The enhanced prioritization levels are effective in driving states to determine which enhancement areas are most in need of funding, which presumably works for overall coastal zone area management. As we know from the survey, even among marine debris experts, more view marine debris to some degree as less important than most other environmental concerns much more than they consider marine debris to some degree to be more important than other environmental concerns. With this information, it is not surprising that 89% of coastal states valued marine debris as a medium or low priority, compared to other environmental concerns.

The Assessment and Strategy reports would be more informative if states were asked about prioritization of certain aspects of marine debris (research, education, policy, cleanup, etc.). Within these areas, there should be room for states to specialize (microplastics in the food web, persistence after introduction, etc.) Maine, for example, filled in general debris as a low priority, but derelict fishing gear as a medium priority. If the reporting requirement included more detail differentiating prioritization between components of marine debris management, stakeholders could better understand the details of how states prioritize marine debris and thereby improve focus on areas in need of enhancement.

Responses from state Assessment and Strategy reports are indicative of a states' future responses, but should also detail states' historical actions to address marine debris. This would better inform actions from states such as Hawaii, which listed marine debris as a low priority despite previously taking many actions to address this issue. The reports include a section on "significant changes since last assessment," but not all states go into the same level of detail as to what these changes are. Furthermore, this requires an understanding of what was included in previous documents. As these are public documents, they should be improved to require states to summarize past actions on marine debris in a more organized format (such as asking about specific initiatives), thus enhancing individuals' capacity to better assess a state's commitment to this issue.

If these reports are amended with the suggested changes, and states fill in reports for the next cycle with the additional information, the federal government will be taking experts advice on what they need to do to address marine debris policy. In asking for more specification from states on the self-assessment and strategy reports, the federal government is investing in research-driven policy by understanding the physical and social science needs of states, data which can be used to understand overall patterns and trends.

Marine debris policy should be largely handled by states

In the United States, policy routes for marine debris management are issue-dependent, but most experts believe state governments should carry the largest burden. Most experts view defining policy measures, initiatives, and timeframes as a state government issue. More specifically, education bills, stronger regulations on littering, clean-up mechanisms, and marine debris reduction plans should all be handled at the state level. Education, in particular, is considered by 92% of experts to be of high importance for states (for more information, see supplemental materials).

Plastic bag bans should also be a state issue, though just as many experts believe plastic bag fees are a local/city government concern. This is the only policy that experts recommend should be handled at the local level, according to experts, though 80% believe it is also the responsibility of the local governments to work with other agencies.

The federal government should be largely responsible for research-driven marine debris policy. If addressed by the federal government, 92% believe social science research is needed and 83% believe physical science research should be funded. The federal government should prioritize this work. Between 93-100% of experts found all the above stated policies to be necessary.

Important as states find addressing marine debris, there are other environmental issues which are considered a higher priority and can become a blockade to policy implementation. This is evident through the survey, in which seventy-one percent of marine debris experts responded that a barrier to marine debris policy is other issues taking priority. Between 57-62% of experts find marine debris to be much less important or somewhat less important than sea level rise, atmospheric CO2 levels, and drinking water quality. The 309 Assessment and Strategy reports also indicate competing environmental concerns by asking state Coastal Zone Management Programs to prioritize nine major zones of enhancement for improvement and funding.

Given the emphasis experts place on state-led policy initiates, the 309 Assessment and Strategy reports are of even more importance. If improved, these reports should also help illuminate findings from this study. We were surprised to find that most experts consider mitigation as much more important than adaptation. If the reports were amended to provide for state opinions on this matter, broader policy implications could be discovered.

Due to this paper's focus on United States' policy, we did not list multi-national policy as an option when we asked experts which level of government is best suited to address certain marine debris policies. But when asked more generally at which scale marine debris policy should be implemented, only 9% of experts said the state level. Most experts believe that the multi-national scale is ideal for policy, which is certainly the most comprehensive as marine debris is a global issue.

The United States should attempt to work with other nations, particularly those developing states included on the Jambeck top 20 list, but should also focus on the strides it can make on the federal, state, and local levels. The survey conducted in this study should be a resource for United States policymakers. The GIS maps on state and county contributions to marine debris should be used as a guide to dictate where policy is needed to address marine debris output. Through this bottom-up approach, localized progress can deliver global implications.

Study limitations

Figure 1 and Figure 2 use state-specific coastal population data and waste generation rates, but we held the percent of plastic waste in streams, percent of inadequately managed waste, and percent of plastic waste constant across states. This assumes individuals across states are equally likely to mismanage their waste (i.e., among urban and rural populations, coastal and non-coastal counties, etc.). This is not necessarily true; for example, counties and cities with high tourism activity may generate more solid waste or plastic debris than communities with less transient activity. Keeping these components constant also makes the results more population-driven. This also differs from how countries were examined in the Jambeck et al., 2015 paper. Though examined in Table 6, the data also do not account for percentage or amount of coastline per state, meaning there is no differentiation regarding a state's proximity to and proportion of coastal area. Either of these factors could alter the likelihood of waste becoming marine debris in the ocean or Great Lakes.

The survey did not include state employees from the two largest contributors to marine debris, California and New York. We had difficulties identifying contacts through those state's websites despite calls and emails to various agencies to identify the appropriate experts. We considered state employees as a group, rather than comparing experts between states or regions (e.g., east coast), but still sought employees from the largest contributing states to take the survey. In future surveys, expert opinions from these missing states would be highly valued.

Two questions should have been improved for clarity. In the question of which level of government is best suited to address various specific policies related to marine debris, we did not ask about better waste management systems, something that was noted as a comment (although

we did include an “other” option) by a survey respondent. Waste management might have been assumed to be part of the closest option identified in the survey as “clean-up mechanisms.” However, future surveys may explicitly include the option of waste management systems. Secondly, in Figure 4 and Table 6, “ocean chemistry” is listed as concerning consequences of marine debris, but with little explanation. Ocean chemistry was intended to mean toxic chemicals leeching into the ocean environment, but we received a comment that it was unclear if “ocean chemistry” referred to toxicity or nutrient cycling. This option should be clarified in future research.

Conclusions

This paper makes 3 key findings.

1) *Modified CZMA Section 309 reports could provide greater insight for more effective marine debris policy development.* There are some conclusions we could make based on the reports; there is a differentiation in policy between ocean-coastal states and Great Lakes-coastal states, and states which contribute more marine debris (per Table 2) are more likely to prioritize the issue. However, the reports are too broadly phrased, utilizing many yes or no questions. If improved for clarity and specification, overall effectiveness in response to marine debris (through prioritization of issues, historical responses, and future goals) can be better gauged and utilized.;
2) *Experts indicate most marine debris policies should rely upon state-level implementation or coordination.* Through the survey, we determined that state-led policy initiatives are deemed to be best suited for the listed marine debris policies and viewed by state employees as something that states should address. This state-focused conclusion makes the CZMA Section 309 reports of even more importance. By analyzing the results of state initiatives through these reports, policy paths can be identified. There are some policies which are better suited at the federal and local levels (research, plastic bag fees). Through a bottom-up approach, the US can implement policies and serve as a model for other nations to follow.
3) *The results of this paper should be used as a guide for the development of effective policy policy action as interdisciplinary science and policy knowledge improves.* A regular (perhaps annual) survey of marine debris experts will educate and inform policymakers as to opinions on marine debris threats and solutions. The GIS maps should be used by states, counties, and the federal government in assessing the scale of marine debris and its main contributors to the problem. The CZMA reports should be analyzed and compared across each state as done in this paper. Through these methods, current standings on marine debris can be determined and policy action planned based on the research.

Implications for future research

We also offer suggested implications for future research into marine debris policy development. The results of the survey question asking experts to place concern for 10 common marine debris items found that 86% of average scores for marine debris items were placed among marine plastics. Given this result, our results may provide a guide for policymakers most relevant to marine plastic debris.

Expert opinions educate which items of marine debris are most concerning, and which consequences resulting from these forms are worrisome. The survey in this study should be offered regularly to assess changes in concerns and threats. For example, microplastics were considered a popular concern, with experts viewing ingestion of microplastics as concerning, but not viewing ocean chemistry with the same degrees of concern. This further indicates a need for more research into the implications of microplastics regarding ocean chemistry. Further studies on the consequences of ocean chemistry could shape expert opinions, and should be assessed regularly. Additionally, the GIS data results represent where policy is needed, and the survey helps to answer the greatest concern regarding marine debris, what actions should be considered to address these issues, and at what level of governance.

Experts believe marine debris education is needed and should be handled by state governments. In their request for funding marine debris enhancement, Texas, Virginia, and Florida all include education initiatives in their strategies. Ninety percent of marine debris experts believe education is necessary in government-led action on marine debris. Likewise, 90% of experts found an education component to marine debris policy to be very important or extremely important. This data is found in the supplemental material section. More research should be conducted on the success of certain marine debris education initiatives to determine effective approaches, target populations, and best practices for state governments.

Most experts, 65%, view additional data on microplastics as very important or extremely important in informing marine debris policy (see supplemental materials). This would include exploring the physical science implications of marine debris, of which 61% of experts believe is a government need. Studies on microplastics should be carried out to inform scientists and policymakers about the implications of microplastics to the ocean and food web. This information would likely greatly impact survey results. Data from current undertakings, such as *Microplastics in the Delaware Bay,* can also serve as a guide to a policy creation for a shared resource between states.

According to the survey, most (39%) of experts believe mitigation is much more important than adaptation, in addressing marine debris policy solutions. We were surprised with this finding. More research should be conducted to assess why mitigating policies are perceived as more important, what these policies are, and their level of effectiveness.

Acknowledgment

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Supplemental Materials

Growth in Plastic Production is Faster than in Population

Using data from PlasticsEurope and the U.S. Census Bureau, we determined from 2002-2013, plastic production increased at a rate 3.4 times faster than the world population growth. Table 7 displays the plastic production rates and population data, and Table 8 identifies the rate of change.

Table 7. Plastic production and population rates from 2002 – 2013 (millions)

	2005	2007	2011	2012	2013	2014	2015
Plastic Production (tonnes)	230	257	279	288	299	311	322
Population	6.466	6.622	6.934	7.012	7.090	7,168	7.245

Table 8. Growth rate of plastic production compared to population

	2005 - 2007	2007 - 2011	2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2005 - 2015
Plastic Production	11.74%	8.56%	3.23%	3.82%	4.01%	3.54%	40.00%
Population	2.40%	4.72%	1.13%	1.12%	1.09%	1.08%	12.04%

GIS Mapping of Marine Debris in coastal US states

We use population data from World Bank estimates based on coastal populations within 50km of shoreline. Jambeck et al.'s findings estimate the waste generation rate of the United States at an average of 2.58 kg per person-day (kg/ppd). We extend Jambeck et al.'s methodology, updating their single national rate using state-by-state detailed rates of waste generation (Shin, 2014) . Shin estimated waste generation rates per state through per capita municipal solid waste data, including recycling, composted, combusted, and landfilled waste (Shin, 2014) . State-by-state waste generation rates vary considerably, and weighted national average rates using Shin data are higher than those used by Jambeck et al. This results in a national average 3.10 kg/ppd waste generation rate. Given that this work does not determine which rates may be most accurate, an effort is made to represent an initial range by defining an average between the two. Applying the Shin state-by-state variation to the 2.58 kg/ppd Jambeck estimate, we create a Jambeck per capita variation for each state. We then average the Shin per capita generation rate with the Jambeck per capita variation to output a waste generation rate per state. This captures the state-by-state variation, and supports our recommendation for further quantitative study that would include municipal scale estimators.

A coastal county map is produced using the statewide average rate and the coastal county populations in each state to illustrate potential areas of importance at local/regional policy scales. NOAA and the United States Census Bureau define a county to be coastal if at least 15% of its land area is in the coastal watershed, or if a county has at least 15% of a coastal cataloging unit (a coastal area between watersheds) (Crossett et al., 2014) .

To apply Jambeck's methodology to the United States, we used the following data from the study:

- Waste Generation Rate [kg/person/day] = 2.58
    - Taken from World Bank estimates based on coastal populations within 50km of shoreline
- % Plastic in Waste Stream= 13%
    - Taken from World Bank estimates based on coastal populations within 50km of shoreline
- % Inadequately managed waste = 0
    - Authors used a model developed for the study
- % Littered waste= 2%
    - From U.S. national litter study

Working through the data, we calculated the Waste Generation [kg/day] was determined by multiplying the Coastal Population by the Waste Generation Rate. For this, we used the data for coastal shoreline states (taken in 2010) from the March 2013 National Coastal Population Report from NOAA.

- WG = Coastal Population x 2.58

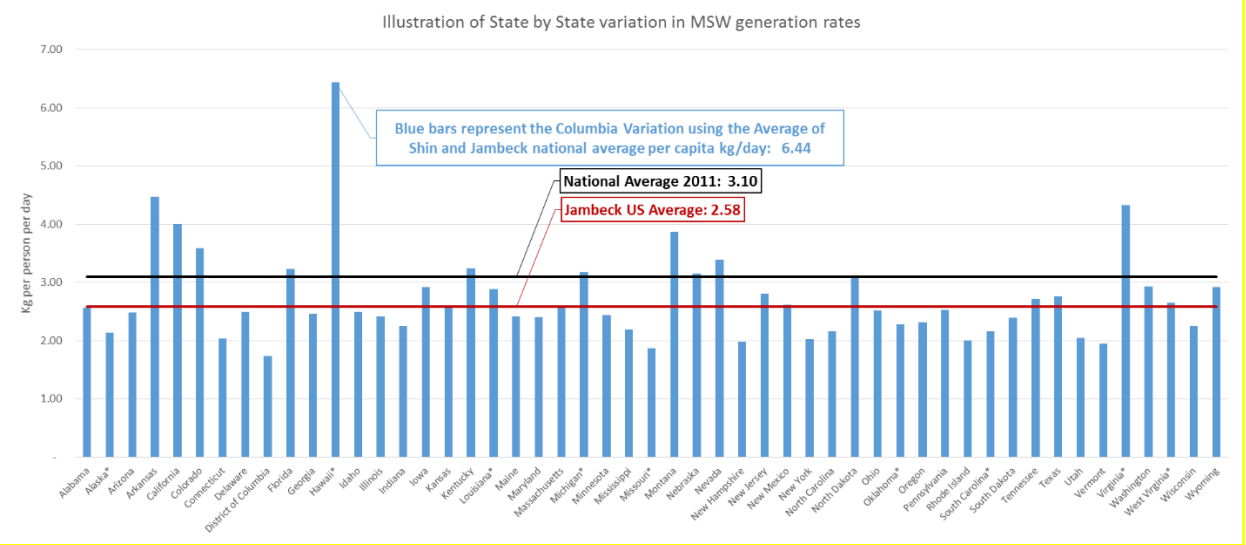
To get state-specific waste generation rates, we used the waste generation rate provided in the Shin, 2014 paper. The nationwide average in the Shin paper was 3.10, so we used both papers to create an average for each state.

- We multiplied each state's waste generation rate by the Jambeck average and then divided by the Shin average to produce a Jambeck variation
- EX: Alabama: 2.79 x 2.58 / 3.10 = 2.33
- EX: California: 4.37 x 2.58 / 3.10 = 3.64

We then took the average between the Jambeck variation and the Shin waste generation rates.

- EX: Alabama: (2.79 + 2.33) / 2 = 2.56
- EX: California: (4.37 + 3.64) / 2 = 4.01

These new state waste generation rates were then used for each state's calculation. The final results yielded the data set (Table 2) and map (Figure 1).



The Plastic Waste Generation [kg/day] was found by multiplying the fraction of plastic waste in the stream by the Waste Generation rate (kg/person/day) and Coastal Population.

- 13/100 x WG x CP

We determined the Inadequately Managed Plastic Waste [kg/day] by dividing the fraction of Inadequately Managed Waste by 100 and multiplying by the Waste Generation.

- 838 x 10^{-10} x Waste Generation

The Plastic Waste Littered [kg/day] was found by multiplying the fraction of waste comprised of Littered Waste by the Plastic Waste Generation.

- 2/100 x Plastic Waste Generation

Mismanaged Plastic Waste per capita[kg/person/day] was determined by dividing the Plastic Waste Littered by the Coastal Population

- Plastic Waste Littered / Coastal Population

To find the Mismanaged Plastic Waste in 2010 [tonnes], the rate of Mismanaged Plastic Waste per capita was multiplied by the number of days in a year, then multiplied by the Coastal Population divided by 1000 to convert to tonnes.

- 0.007 x 365 x Coastal Population/1000

Finally, given uncertainties, we sought to consider a range of waste like the Jambeck study did. In that study, the estimated conversion rates of mismanaged plastic waste to marine debris consisted of a low range of 15%, middle range of 25%, and high range of 40%. To determine the range, we multiplied the Mismanaged Plastic Waste in 2010 by each of these ranges.

- Mismanaged Plastic Waste in 2010 x.15
- Mismanaged Plastic Waste in 2010 x.25
- Mismanaged Plastic Waste in 2010 x.40

We used the data results from the middle range.

States prioritizing marine debris as an enhancement area

Of the 28 coastal states which submitted assessment and strategy reports (see table in supplemental material), only Florida and Virginia consider marine debris a "high" priority. Florida, Virginia, and Texas are the only states which included marine debris as an enhancement area in any of the 2016-2020 strategies. The details of these strategies are included in Table 9. It should be noted that *under Amount Requested*, the values indicate the total desired funding for the specified strategy title, which includes the other enhancement areas indicated. Virginia was the only state to clarify the amount allocated specifically toward marine debris.

Table 9. Coastal states including marine debris in five-year strategy

Rank	State	Number of marine debris strategies included	Strategy Title Requested	Amount Requested	Other included enhancement areas	Education Component to Marine Debris in 5-Year Strategies
2	Florida	1	Florida Keys Vessel Turn-in Program	$254,000	Ocean/Great Lakes Resources	Yes
4	Virginia	1	Ocean Resources Strategy	$823,600 ($300,000 specifically for marine debris)	Ocean/Great Lakes Resources	Yes
6	Texas	2	Incorporation of ecosystem services into grant process data collection	$141,000	Coastal Hazards, Cumulative and Secondary Impacts, Wetlands, Public Access	Yes
			Technical assistance and planning to mitigate coastal hazards	$405,000	Coastal Hazards, Ocean/Great Lakes Resources, Cumulative and Secondary Impacts,	No

					Wetlands, Public Access	

Additional GIS Maps

Much like Figure 3, the following GIS maps were created to visualize geographic patterns between states using data from the 2016-2020 Coastal Zone Enhancement Program's Self-Assessment and Strategy reports. Figure 12 shows state' significance of land-based beach/shore litter. Figure 13 depicts state's prioritization level of marine debris enhancement. Figure 14 highlights state-employed marine debris removal programs.

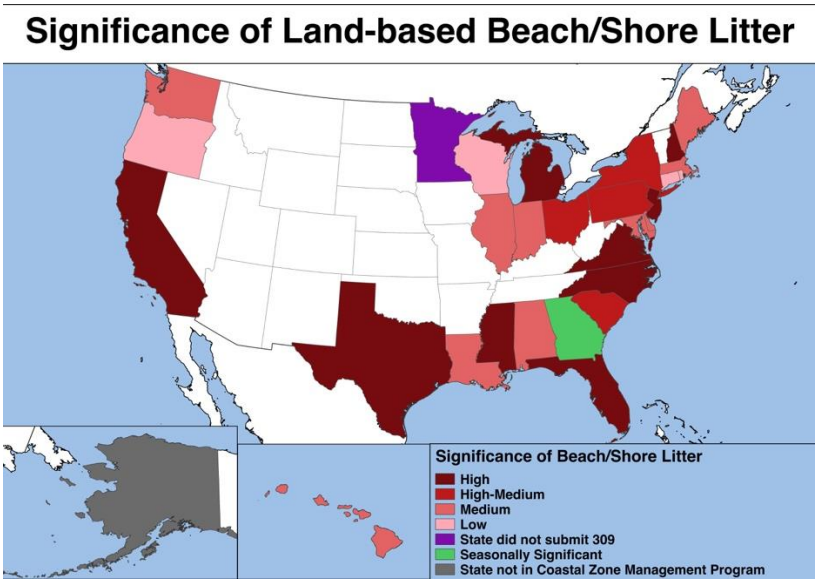


Figure 12. Significance of land-based beach/shore litter

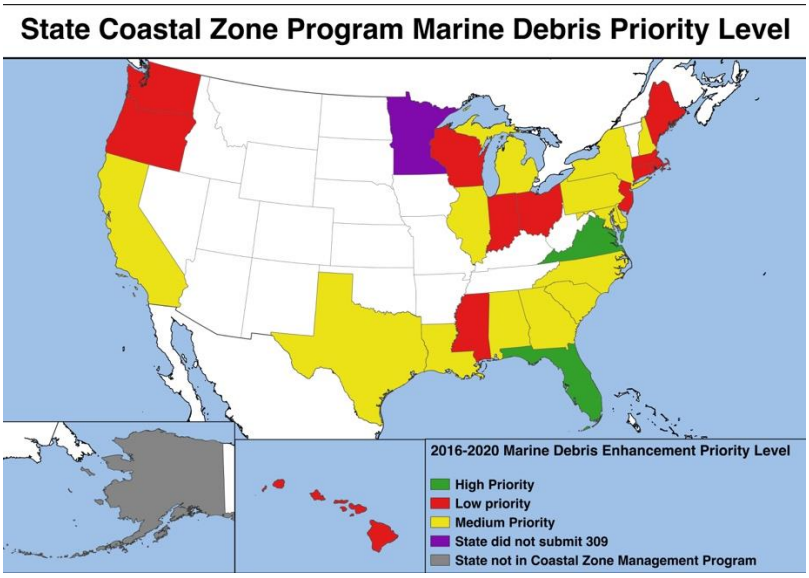


Figure 13. State coastal zone program marine debris priority level

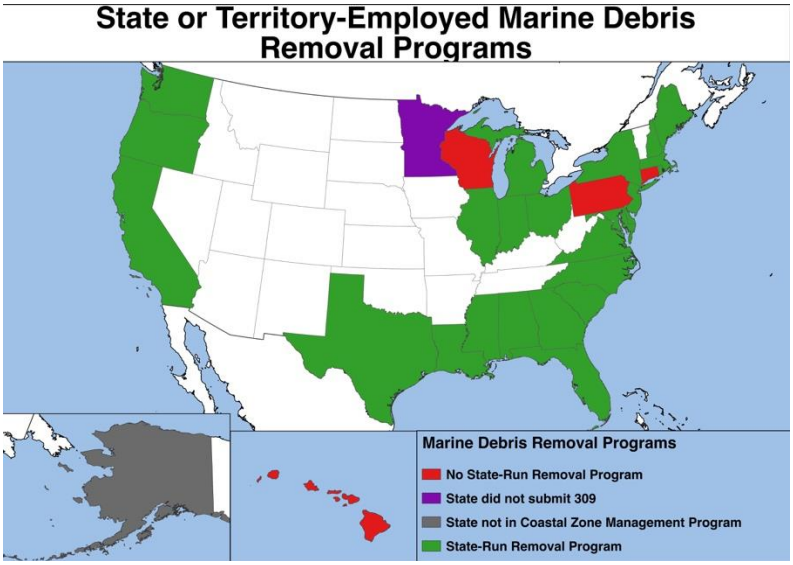


Figure 14. State or territory-employed marine debris removal programs

Additional detail on survey design and implementation

Survey questions were reviewed by the University of Delaware's Institutional Review Board, which approved a human subjects exemption. A pilot survey to 15 graduate students at UD and Drexel University provided feedback, recommendations, and suggestions which improved survey clarity, phrasing, and organization. A second pilot test ensured proper operation of the Qualtrics® survey instrument (Qualtrics, 2005) .

Invited respondents received two rounds of emails three weeks apart, with the survey open for 51 days. The first round invited 132 individuals to take the survey. The request informed experts of

the aim of the survey, how they were identified for their potential expertise given their professional duties, that the survey is anonymous, and how the results would be used. The survey request also invited experts to share the online survey link with colleagues considered to have expertise on marine debris. A few times, invited survey-takers indicated that they were not an appropriate expert contact and as a result they passed the survey along to the applicable colleague. This method proved successful, with many additional experts identified.

Federal government survey response was 100%, because of the clearly defined marine debris programs[2] and partly because contacting directly a senior management level employee in each program resulted in a list of employees who would be a good match for the survey. Experts were sought from National Oceanic and Atmospheric Administration's (NOAA) Marine Debris Program and the Environmental Protection Agency's (EPA) Trash-Free Waters program. Some of those employees were contractors to the federal government and self-identified as "other."

The methodology aimed for at least two experts from each of the thirty-one coastal states to provide comprehensive representation. The methodology aimed for at least two experts from each of the thirty coastal states to provide even representation. However, we considered state employees as a collective group rather than comparing employees from each coastal state against one another. Therefore, contact was made with 120 potential state-level experts across 31 coastal states, who were also encouraged to share the survey link with other experts in their state office(s). With a goal of 60 respondents, 43% state-level experts completed the survey. Fifty-two state-level experts from all coastal states completed the survey.

There are some groups with small sample sizes completing the survey. The survey sought fifteen local employees from different cities, each of which had enacted marine debris policy, based on a goal to include a similar number of federal and local/city experts. An online search identified six state-level experts, five of whom completed the survey. Ten experts within businesses were identified through internet searches of ocean sustainability in firms, and/or conference agendas on marine debris; all were contacted. The completion rate was zero; in future surveys, strategies should be developed to include business input.

Thirty experts from twenty-four non-profit organizations with an active marine debris component were contacted, with a 70% response rate. Twenty-four professors, researchers, and PhD students from 21 universities were contacted because they research or teach courses on marine debris. Seventy-five percent of university experts took the survey.

Two experts contacted within the federal government fit into the 'other' category as federal contractors. An additional five self-identified as such; those may have also been contractors, or experts employed in another capacity.

A second round of emails were sent, excluding those individuals who had mentioned they already completed the survey. The email stated the survey close date, reminded experts that their

[2] EPA does not refer to their "Trash-Free Waters program as a marine debris program, because their program includes the Great Lakes and they want to avoid confusing "marine" as exclusive to the ocean; this work recognizes that Great Lakes states refer to their Great Lakes Marine Debris Action Plan, so we use marine debris in all context for clarity.

results would be anonymous, and asked any individuals to indicate whether they wanted to be informed of the results. The survey closed on December 23rd.

Significance of marine debris from land-based and ocean/Great Lakes-based sources

The 309 assessment and strategy reports asks states to define the significance of marine debris from land-based sources (Table 10), and ocean/Great Lakes sources (Table 11). Pennsylvania submitted two responses to differentiate between the coastal zones of Delaware Bay (DECZ) and Lake Erie (LECZ).

Table 10. Significance of land-based marine debris sources

Note: L = Low; M = Medium; H = High, UNK = Unknown

Rank	State	Beach/ Shore Litter	Dumping	Storm drains and runoff	Fishing (e.g., line, gear)	Other
1	California CCC	H	H	H	M	
1	California BCDC	H	M	H	L	
2	Florida	H	M	M	M	Shellfish aquaculture production gear- H
3	New York	UNK- est. M-L	UNK	UNK, est. H	UNK- est. M	
4	Virginia	H	M	H	L to M	Balloons- M
5	New Jersey	H	UNK	M	L	Combined Sewer overflows- M
6	Texas	H	UNK	H	H	UNK
7	Michigan	H	L	H	M	Extreme storms- M
8	Illinois	M	L	M	L	
9	Washington	M	UNK	H	M	Creosote logs- M
10	Massachusetts	M	L	M	L	L
11	Maryland	M	UNK	H	L	
12	Hawaii	M	M	M	H	plastics marine debris- H
13	Louisiana	M	M	M	M	BP Oil Spill related debris- H
14	Ohio	M-H, by site	M-H, by site	M-H, by site and frequency/severity of storm events	M	Plastic Microbeads- M

15	Pennsylvania DECZ	H	M*	H	L	
15	Pennsylvania LECZ	M	L	M	L	Abandoned dredge pipes from historic dredging- L
16	Wisconsin	L	L	L	L	
17	Connecticut	L	L	L	L	L
18	South Carolina	M/H	UNK	H	H	
19	Delaware	M	M	L	UNK	
20	North Carolina	H	H	H	L	
21	Rhode Island	L	L	M	L	
22	Maine	M	L	M	L	UNK
23	Indiana	M	M	H	L	
24	Alabama	M	M	M	M	N/A
25	Oregon	L	L	L	L	
26	Georgia	Seasonally significant	L-M	L	L	Abandoned derelict vessels- no rating
27	Alaska					
28	District of Columbia					
29	New Hampshire	H	M	M	L	Wastewater treatment disks*- L
30	Mississippi	H	M	H	H	
31	Minnesota					

Table 11. Significance of ocean/Great Lakes-based marine debris sources

Note: L = Low; M = Medium; H = High, UNK = Unknown

		Significance of Ocean or Great Lakes-based Sources					
Rank	State	Fishing	Derelict Vessels	Vessel-based (cruise ship, cargo ship, general vessel)	Hurricane/ storm	Tsunami	Other
1	California CCC	M	M	M	L	L	
1	California BCDC	L	H	M	H (storms); L (hurricanes)	L	

2	Florida	M	H	M	M		Tire Artificial Reef- H
3	New York	UNK	UNK	UNK	UNK, estimated H	N/A	
4	Virginia	H	M	UNK	M-H	UNK	
5	New Jersey	L	L	L	H	L	Coastal currents transportin g MD from other states to NJ waters- H
6	Texas	H	H	UNK	H	UNK	N/A
7	Michigan	L	L	L	L	L	extreme storms- M
8	Illinois	L	L	UNK	L	N/A	
9	Washington	M	M	UNK	UNK, estimated H	M	
10	Massachusetts	M	L	L	L	L	L
11	Maryland	H	L	H	M	L	
12	Hawaii	H	H	M	M	M	
13	Louisiana	M	M	M	H	N/A	
14	Ohio	L	L	M	M		
15	Pennsylvania DECZ	L	L	L	M		
15	Pennsylvania LECZ	L	L	L	L		
16	Wisconsin	L	N/A	N/A	L	N/A	
17	Connecticut	L	L	L	L		
18	South Carolina	H	H	L	L	L	
19	Delaware	UNK	L	L	M	L	
20	North Carolina	L	L	L	L	L	
21	Rhode Island	M	L	UNK	L (event dependent)	N/A	
22	Maine	H	UNK	UNK	Episodic	N/A	
23	Indiana	L	L	L	H		Derelict dredge equipment- M
24	Alabama	M	L	L	H	N/A	N/A

25	Oregon	M	M	L	L	M	
26	Georgia	L-M	M-H	M	M-H	L	H- Water quality from sewage release
27	Alaska						
28	District of Columbia						
29	New Hampshire	H	L	L	M-H	N/A	N/A
30	Mississippi	H	M	M	M-H		
31	Minnesota						

These tables were created using data taken from the Section 309 reports from the 2016 – 2020 cycle. The results were used in the analysis of the Section 309 reports. We recommend that the reports are improved for specificity and clarification to enhance comparison in the future.

Education Implications

Between 84-94% of experts at all levels of governance believe that education is either a very important or extremely important component to marine debris policy (Figure 16). Within that margin, more state employees and university employees selected 'very important' other than experts sampled, yet the majority of federal employees, city/local employees, non-profit employees, and others still said education is an 'extremely important' component to marine debris policy. No experts found education 'not important.'

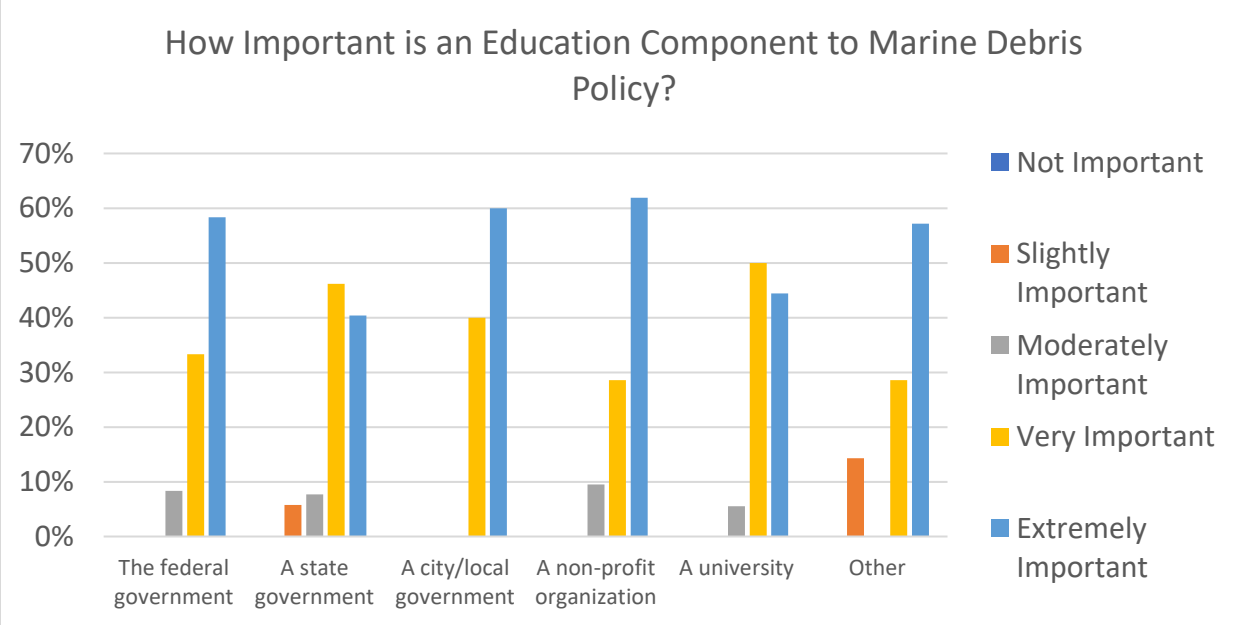


Figure 15. The importance of education to marine debris policy

Additional research on microplastics

Between 58-83% of experts at all levels of governance consider the collection of additional data on microplastics as 'very important' or 'extremely important,' and 80-100% of experts said 'moderately important,' 'very important,' or 'extremely important.' Full results can be found in Figure 16.

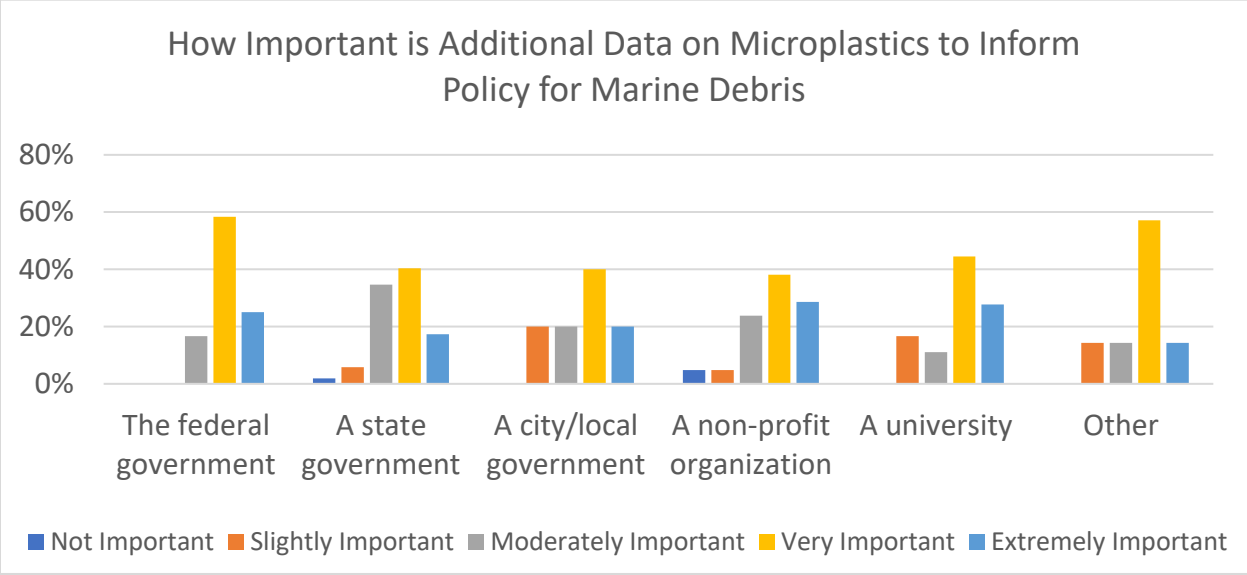


Figure 16. Importance of additional data on microplastics