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Quantifying the Financial Costs to Communities of Managing Trash in the Hudson-Raritan Estuary

Columbia Marine Debris Research Team

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Prepared for the New York Department of Environmental Conservation and the U.S. Environmental Protection Agency, Region 2

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Executive Summary

Marine debris poses an ecological hazard to wildlife and an economic burden to coastal communities tasked with managing it. While marine debris is typically considered trash in waterways, a significant portion of it originates on land. The U.S. Environmental Protection Agency started the Trash Free Waters Program as a collaborative approach to address the issue at all levels. A first step of the program was a study conducted on the West Coast, quantifying the costs of managing marine debris.

The New York State Department of Environmental Conservation asked a team of graduate students at Columbia University's School of International and Public Affairs, to replicate this study in New York and New Jersey. The study area is defined as the Hudson-Raritan Estuary, and cost data was collected from municipalities within this area for the following waste management activities.

- Beach and Waterway Cleanup
- Street Sweeping
- Storm Drain Cleaning and Maintenance
- Stormwater and Runoff Capture Devices
- Manual Debris Cleanup
- Public Education

Officials from 121 municipalities were contacted and 34 responded—including New York City—for a 28.1% response rate, representing 71.2% of the population in the Hudson-Raritan Estuary. In total, these municipalities spend $59,063,285 million dollars a year on marine debris waste management activities. This translates to a per capita cost of $6.16, and $75,407 per square mile.

These data demonstrate the direct economic costs of marine debris and make an argument for the importance of managing waste effectively before it enters our waterways. Policymakers can use this to make the case that reducing our trash stream makes sense not only ecologically, but also economically.

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I. INTRODUCTION

i. What is Marine Debris?

Trash that accumulates in the ocean can cause serious ecological, economic, and public health issues. Many types of trash, such as plastic and glass, do not break down easily, if at all. This is becoming a larger problem as the amount of these materials in trash increases. Trash becomes marine debris when it enters waterways from one of two sources: water or land.

Water-based marine debris is trash that originates from commercial fishing vessels; merchant, military, and research vessels; recreational boats and cruise ships; and offshore petroleum platforms and associated supply vessels.[1] The Marine Plastic Pollution, Research and Control Act (MPPRCA) of 1987 requires the Environmental Protection Agency (EPA), in consultation with the National Oceanic and Atmospheric Administration (NOAA), to study the adverse effects of improper disposal of plastics on the environment, on waste disposal, and on various methods to reduce or eliminate these adverse effects.[2] The MPPRCA applies to ship-generated garbage, and it aims to reduce the amount of garbage—both plastics and other persistent wastes—that ships dump into the oceans. It also prohibits all ships from dumping plastics into the sea.

Land-based marine debris is trash that originates from land and is carried into waterways via runoff, or through combined sewage overflows that discharge trash directly into waterways during heavy rainfall or snowmelt events.[3] Additionally, visitors often leave trash on the beach, which is carried into the ocean with the tide or precipitation.[4] For the purposes of this study, we have focused on land-based marine debris.

ii. The Effects of Marine Debris on the Environment

Some marine debris, such as wood and paper, break down quickly. However, other types of marine debris can persist for long periods of time and take many years to biodegrade. Glass and plastic have the highest likelihood of persisting and causing long-term damage to the marine environment.[5]

Marine debris negatively impacts humans, wildlife, habitats, and the economic health of coastal communities. Beach visitors can be harmed by broken glass and exposed to diseases from solid waste transported from sewers to the coastal area.[6] Marine debris harms the wildlife in marine environments, with repercussions throughout the ecosystem. Animals can ingest marine debris, interrupting important biological processes, and they can also become entangled in debris, such as plastic rings.[7] In addition to these public health and ecological issues, visitors are less attracted to dirty and damaged beaches, which can lead to loss of tourism revenue for communities.

[1] Sheavly, S. B., 2007
[2] Marine Plastic Pollution Research and Control Act of 1987
[2] Marine Plastic Pollution Research and Control Act of 1987
[3] Sheavly, S.B., 2007
[4] Environmental Protection Agency, "Marine Debris", 2009
[5] Marine Debris Research, Prevention, and Reduction Act of 2005
[6] Sheavly, S.B., 2007
[7] Santos, I. R., Friedrich, A.C., Sul, J.A., 2009

iii. Trash Free Waters Initiative

According to a nation-wide EPA study, 49% of marine debris originated from land-based sources in comparison to 18% from water-based sources. The remaining 33% originated from undetermined sources.[8]

The EPA started the Trash Free Waters Initiative[9] to address this urban-coastal connection and reduce the amount of land-based trash that enters streams, rivers, and ultimately the world's oceans. This initiative is a collaborative approach, involving research, public education, outreach, and new program partnerships.

EPA's Region 9 (Arizona, California, Hawaii, Nevada, and the Pacific Islands) was an early implementer of Trash Free Waters. The EPA Region 9 office contracted Kier Associates to conduct a study quantifying the cost to West Coast communities of managing actual and potential marine debris.[10] The study attempted to quantify the costs that coastal communities in California, Oregon, and Washington incur in their management of litter. The study found that on average, communities on the West coast spend $16.21 per capita on an annual basis.[11] These findings highlight the costs to communities and the potential benefits of managing trash at the source—point of production—rather than after disposal.

EPA's Region 2 is following Region 9's lead to advance Trash Free Waters, along with the New York State Department of Environmental Conservation (DEC) and a number of other regional stakeholders. To date, there have been two meetings, which were attended by local, state, and federal officials, along with non-profit organizations and academic institutions. This represents the collaborative nature of the initiative. The meetings established five working groups, based on the most common types of marine debris known as the five B's: Bags, Bottles, Bins, [cigarette] Butts, and [micro]Beads. These working groups are assessing the possibility of managing these materials before they become litter and marine debris using bans, fees, and extended producer responsibility.

iv. Purpose and Scope of the Study

As a part of the Trash Free Waters Initiative in New York and New Jersey, the DEC asked the Columbia Marine Debris Research Team from Columbia University's School of International and Public Affairs, to replicate the study of marine debris cleanup costs on the West Coast.[12] The DEC plans to use this analysis to help identify cost-effective source-reduction strategies. These findings can also be used to demonstrate that marine debris carries both economic and environmental costs. By identifying the problem and the costs associated with it, the DEC can prioritize prevention and control measures.

[8] Environmental Protection Agency, "National Marine Debris Monitoring Program", 2012
[9] Environmental Protection Agency, "Trash Free Waters", 2015
[10] Stickel, Jahn & Kier, 2012
[11] Stickel, Jahn & Kier, 2012
[12] Stickel, Jahn & Kier, 2012

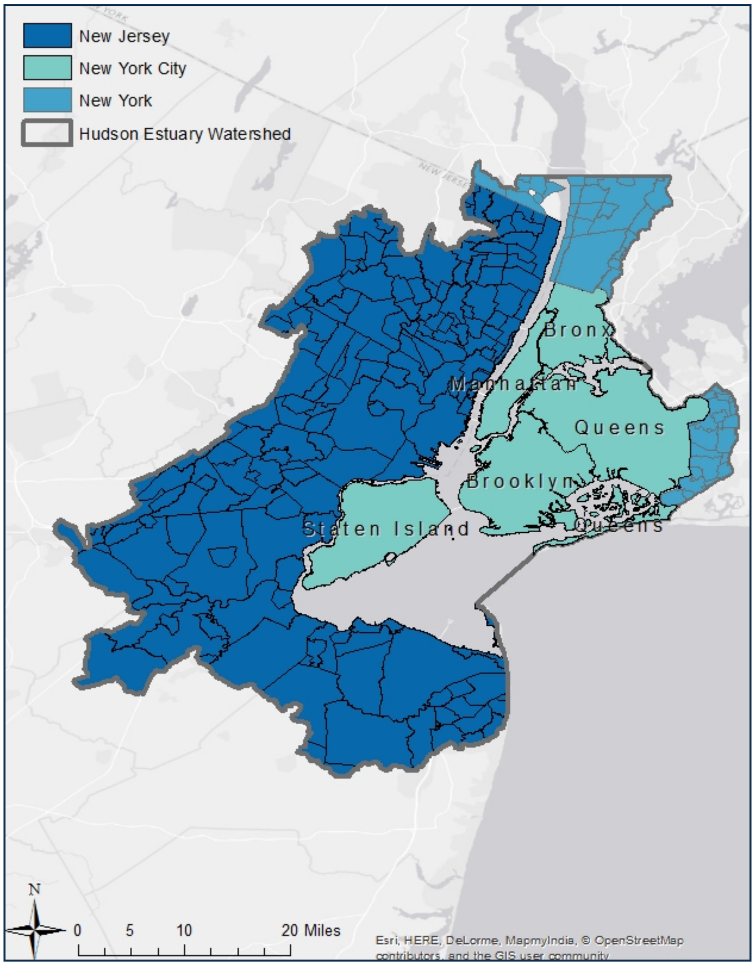


Figure 1. Map of the Hudson-Raritan Estuary, the study area.

The goal of this study is to quantify the overall direct costs of managing trash in the Hudson-Raritan Estuary, shown in Figure 1. The Hudson-Raritan Estuary includes New York City, parts of Westchester and Nassau Counties in New York, and parts of New Jersey. To collect the necessary primary data, we contacted municipalities and requested information about costs of specific trash management activities.

In this report, we also analyze California's recent efforts to reduce marine debris in their region.[13] Following that analysis, we identify potential policy strategies for the Hudson-Raritan Estuary, located in EPA Region 2 (New York, New Jersey, Puerto Rico, Virgin Islands, and eight tribal nations).[14]

[13] California Ocean Protection Council, 2008
[14] Environmental Protection Agency, "EPA Region 2", 2015

II. METHODOLOGY

i. General Methodology

The study area boundary is the Hudson-Raritan Estuary. The Hudson-Raritan Estuary includes the following units of government: (1) New York City, (2) municipalities from Westchester and Nassau counties in New York State, and (3) municipalities from New Jersey. In total there are 179 cities, boroughs, townships, and villages in the Hudson-Raritan Estuary. This includes 158 municipalities in New Jersey, 10 each in Westchester and Nassau counties, and New York City.

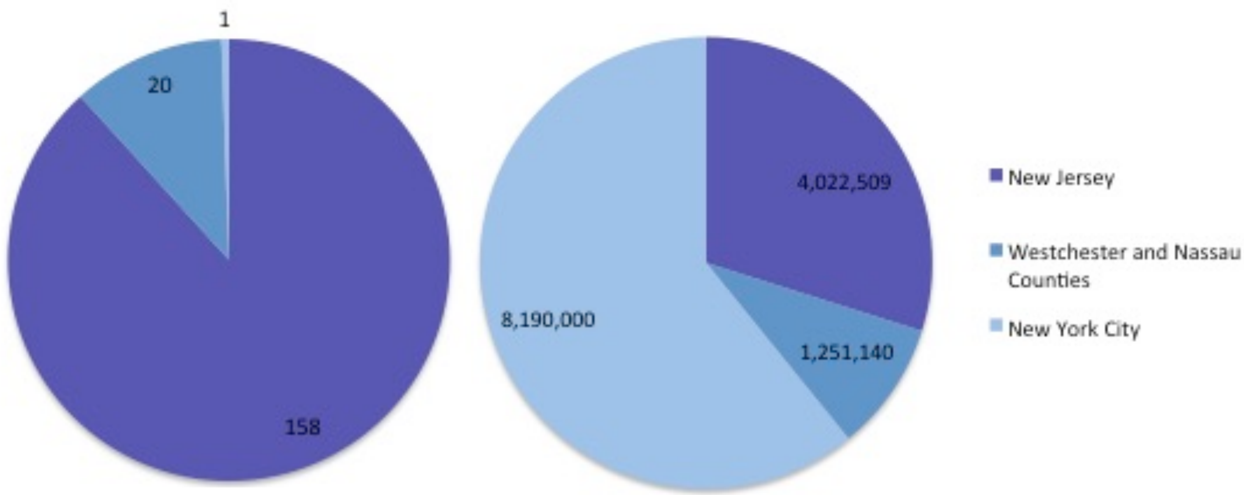


Figure 2. These pie charts illustrate the number of municipalities in the Hudson-Raritan Estuary in each region (left), and the population that resides in the Hudson-Raritan Estuary within each region (right).

When possible, we analyzed annual marine debris-related budgets for these areas. However, these documents were not always readily available, and we relied heavily on the expert estimates of local government officials. We collected these data via emails and phone calls.

Due to the short timeframe of this study, it was not possible to contact all of the New Jersey municipalities. Therefore, we created a method to randomly sample municipalities from this region. In order to ensure that the selected municipalities in the New Jersey sample were representative, we created a sampling methodology to minimize geographic and demographic representation bias. This methodology is explained in detail in the next section. In total, we contacted 121 municipalities in the study area, including 100 municipalities (out of 158) from New Jersey, 20 municipalities in Westchester and Nassau counties, and New York City. Of the municipalities contacted, 34 responded and provided cost data. These 34 municipalities are listed in Table 1.

Table 1. List of municipalities that provided cost data, ranked by population size

City, State	Population	City, State	Population
Largest	**Over 30,000**	Metuchen, NJ	13,574
New York City, NY	8,190,000	Guttenberg, NJ	11,176
Hempstead, NY	759,757	**Smaller**	**Less than 10,000**
Paterson, NJ	146,199	Matawan, NJ	8,810
Union, NJ	56,642	North Haledon, NJ	8,417
Bloomfield, NJ	47,315	Closter, NJ	8,373
Sayreville, NJ	42,704	Haledon, NJ	8,318
Montclair, NJ	37,669	Kenilworth, NJ	7,914
Fair Lawn, NJ	32,457	Hastings-on-Hudson, NY	7,857
Larger	**20,000 – 29,999**	Fanwood, NJ	7,318
Paramus, NJ	26,342	Mountainside, NJ	6,685
South Plainfield, NJ	23,385	Tuckahoe, NY	6,493
Roselle, NJ	21,085	Little Silver, NJ	5,950
Hazlet, NJ	20,334	Elmsford, NY	4,670
Mid-sized	**10,000 – 19,999**	Harrington Park, NJ	4,664
Palisades Park, NJ	19,622	Monmouth Beach, NJ	3,279
Hawthorne, NJ	18,791	East Newark, NJ	2,406
South River, NJ	16,008	Stewart Manor, NY	1,907
Highland Park, NJ	13,982	Sea Bright, NJ	1,412

To ensure a high level of accuracy we chose to focus on the direct costs of managing trash in local municipalities. Indirect costs such as the negative impact of trash on beach tourism were not included in this study. Mirroring the West Coast study, there were six trash management activities listed in the Request for Information form sent to municipalities.[15] The complete Request for Information form is provided in Appendix A.

Table 2. The Request for Information form Sent to Municipalities

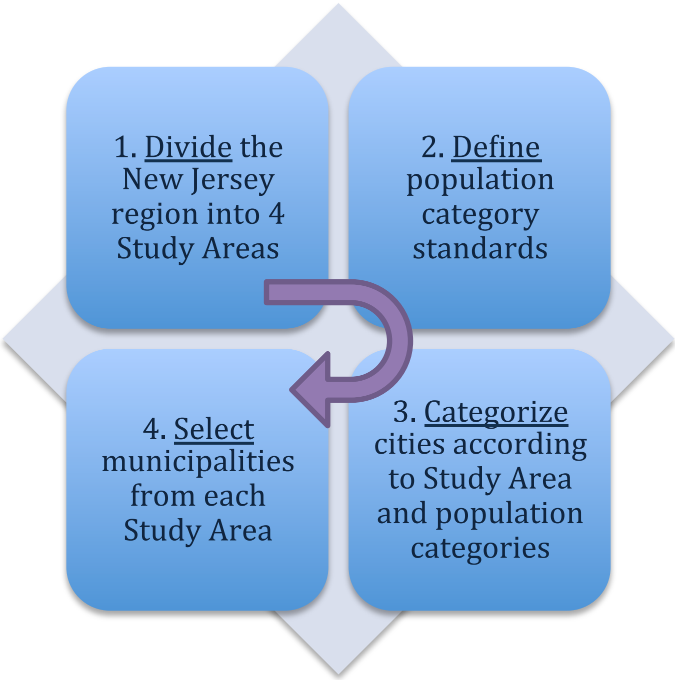
Activity	Best Estimates of Annual Cost (can be a range)
1. **Beach and waterway cleanup** – costs associated with removing litter from beaches and waterways, including skimming and any other costs incurred from participating in volunteer efforts.	
2. **Street sweeping** – costs of operating street sweepers and disposal of litter.	
3. Storm drain cleaning and maintenance	
4. **Stormwater and runoff capture devices** – cost of purchase, installation and maintenance of these devices.	

[15] Stickel, Jahn & Kier, 2012

5. **Manual debris cleanup** – any cost associated with picking up trash in areas like parks and roadsides that has not previously been covered above.	
6. **Public education** – costs of public campaigns against littering and improper disposal that could impact management of runoff (this includes costs of participating in larger programs like the Harbor & Estuary Program).	

ii. New Jersey Sampling Methodology

The previously mentioned sampling methodology for New Jersey municipalties consisted of the following steps:



1. We divided the New Jersey region into four Study Areas (A, B, C, and D) with similar land area shown below in Figure 3. The dots in each municipality represent the geographic center of the municipality. This was necessary because there are municipalities that are only partly in the Hudson-Raritan Estuary. If the dot was outside of the estuary boundary, it was not included. These municipalities are colored in dark gray in Figure 3.

   By region, Study Areas A, B, C, and D have 26, 29, 35, and 68 municipalities, respectively.

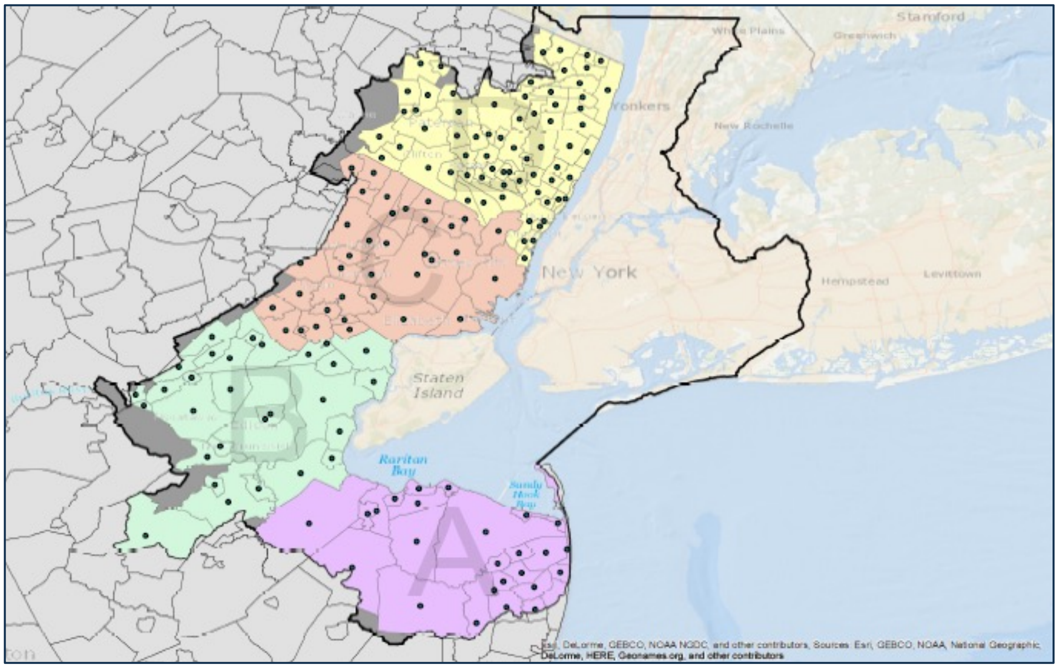


Figure 3. Map of the New Jersey area in the Hudson-Raritan Estuary split into the 4 Study Areas (A, B, C, and D).

2. We then analyzed the populations of the various municipalities under review, and defined the population categories to achieve an even distribution of municipalities in each category. The population categories are defined in Table 3 below.

Table 3. The determined population categories for this study.

City Size	Population Range
Smaller	0 - 9,999
Mid-sized	10,000 - 19,999
Larger	20,000 - 29,999
Largest	30,000 or more

3. Next, we classified the cities in each Study Area by their population category (largest, larger, mid-sized, and smaller).

Table 4. Number of New Jersey municipalities by population category and by Study Area

ENTIRE POPULATION					
Population Category	**Study Area A**	**Study Area B**	**Study Area C**	**Study Area D**	**TOTAL**
Smaller	14	8	6	28	**56**
Mid-Sized	7	6	8	23	**44**
Larger	1	5	7	5	**18**
Largest	4	10	14	12	**40**
TOTAL	**26**	**29**	**35**	**68**	**158**

By population category, there are 40 *largest* municipalities, 18 *larger* municipalities, 44 *mid-sized* municipalities, and 56 *smaller* municipalities.

4. We selected approximately 60% of municipalities from each Study Area to make up the sample. For example, Study Area C had a population of 35, so Study Area A will have a sample of 21. Then, we randomly selected a proportional number of municipalities in each population category. For example, 6 municipalities out of the 35 in Study Area C were in the "Smaller" population category. This is 17.1% of the municipalities in Study Area C. So the "Smaller" sample was 17.1% of the 21 municipalities in the Study Area C sample. This leads to a Study Area C "Smaller" population category of 4 municipalities.

Table 5. Randomly sampled New Jersey municipalities by population category and by Study Area.

SAMPLE POPULATION					
Population Category	**Study Area A**	**Study Area B**	**Study Area C**	**Study Area D**	**TOTAL**
Smaller	9	5	4	17	**38**
Mid-Sized	4	3	5	14	**27**
Larger	1	3	4	3	**10**
Largest	2	6	8	7	**25**
TOTAL	**19**	**19**	**21**	**41**	**100**

Using this method, the numbers of municipalities selected by population category are 25 *largest* municipalities, 10 *larger* municipalities, 27 *mid-sized* municipalities, and 38 *smaller* municipalities. By region, Study Areas A, B, C, and D samples contain 19, 19, 21, and 41, respectively.

III. Data Analysis

i. Data Collection

We contacted 121 municipalities in the Hudson-Raritan Estuary. Of these, 34 municipalities responded with their annual estimates of marine debris cleanup costs for a 28.1% response rate (including New York City).

Table 6. Sample response rate by area

Area	Number of Municipalities	Sampled	Responded	Response Rate
NJ State	**158**	**100**	**28**	**28.0%**
Smaller	56	38	12	31.6%
Mid-sized	44	27	6	22.2%
Larger	18	10	4	40.0%
Largest	40	25	6	24.0%
NY State	**20**	**20**	**5**	**25.0%**
Westchester	10	10	3	30.0%
Nassau	10	10	2	20.0%
New York City	**1**	**1**	**1**	**100.0%**
TOTAL	**179**	**121**	**34**	**28.1%**

The total population of the Hudson-Raritan Estuary is approximately 13,463,670 based on 2010 Census data. 71.2% of the total population (9,591,515 people) resides in municipalities that provided cost estimates of their marine debris management efforts.

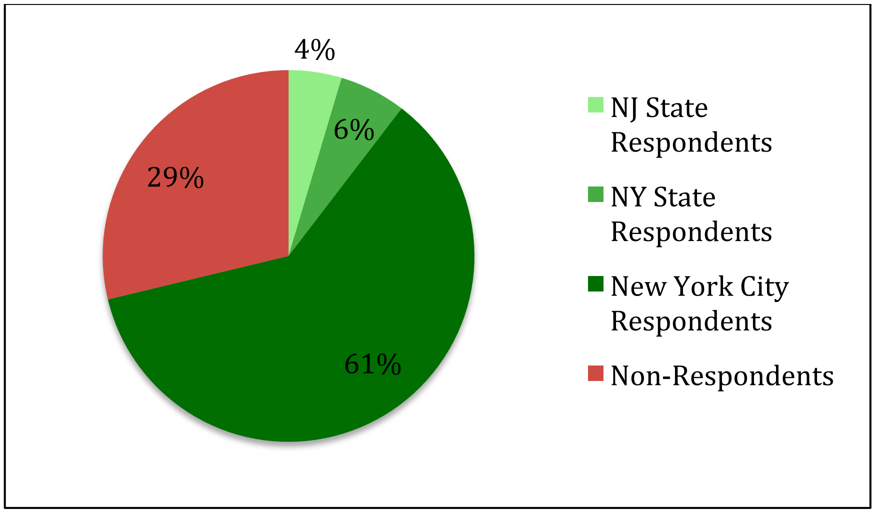


Figure 4. Hudson-Raritan Estuary population by respondents (separated by area) and non-respondents.

We contacted 100 municipalities in New Jersey and 28 provided cost data, giving us a 28% response rate. Among the population categories (smaller, mid-sized, larger, and largest), response rates were 24%, 40%, 22.2%, and 31.6%, respectively. In New York State, we contacted 20 municipalities in Nassau and Westchester counties, in addition to New York City. A total of 6 municipalities responded, for a 25% response rate.

Prior to comparing and analyzing the collected data, we made several assumptions to standardize the data, listed and explained in the following section.

ii. Assumptions

In order to facilitate data analysis, several simplifying assumptions were made to the dataset:

- All data requested and collected are on an annual basis from 2014 budgets
- When exact expenditure data was not available, municipalities were asked to provide their best estimates or a range
- If the cost data of an item is provided in a range, the mid-point value is used for further analysis
- When a budget item cost is not available, or an exact number cannot be extracted from a larger expenditure, the team treated that cost item as $0
- Due to the large size of New York City in terms of square miles and population, New York City is discussed and analyzed separately, instead of being included in the *Largest* city population category

iii. Findings

Beach and Waterway Cleanup

Figure 5. A member of the team, Tianhua Gao, participating in a beach cleanup event at Jamaica Bay, NY (Photo taken by Siyi Sun).

Special beach and waterway cleanup events are often organized and managed by non-governmental agencies (NGOs) and non-profit agencies. Volunteers attend these organized cleanup events to pick up litter from affected areas in an effort to decrease the amount of trash on beaches and in waters.[16] Some municipalities routinely conduct beach cleanups. Most of the costs incurred by beach and waterway cleanup events come from employing administration, purchasing materials, and event advertisement. The data reported in this study only reflects expenses of local governments for these activities and not those of NGOs involved.

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for beach and waterway cleanup is $8,563 and it is 2.4% of the total cost of activities related to marine debris cleanup. The average per capita cost is $0.15. For New York City, the annual cost for beach and waterway cleanup is $2,719,500 and the per capita cost is $0.33.

[16] Stickel, Jahn & Kier, 2012

Table 7. Cost data for beach and waterway cleanup

BEACH AND WATERWAY CLEANUP				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	\$0 - \$75,000	\$14,638	\$0.15
Smaller	Under 10,000	\$0 - \$10,000	\$4,444	\$0.42
Mid-sized	10,000 - 19,999	\$0 - \$2,000	\$500	\$0.02
Larger	20,000 - 29,999	\$0 - \$20,000	\$9,625	\$0.42
Largest	Over 30,000	\$0 - \$75,000	\$17,857	\$0.11
New York City	8,190,000	-	\$2,719,500	\$0.33

Street Sweeping

Figure 6. Mechanical street sweeping in Vineland, NJ (Source: City of Vineland, New Jersey).

Street sweeping activities rely on mechanical vehicles to physically remove solids and other pollutants from impervious surfaces.[17] It prevents debris from being carried to waterways by runoff. Costs associated with street sweeping include using truck-powered street sweepers, and the cost of equipment, labor, and litter disposal.[18]

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for street sweeping is \$67,031 and it is 25.3% of the total cost of activities related to marine debris cleanup. The average per capita cost is \$2.09. For New York City, the annual cost for street sweeping is \$11,965,872 and the per capita cost is \$1.46.

Table 8. Cost data for street sweeping

STREET SWEEPING				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	\$0 - \$835,000	\$52,759	\$1.53
Smaller	Under 10,000	\$0 - \$53,066	\$21,162	\$3.58
Mid-sized	10,000 - 19,999	\$60,250 - \$90,924	\$48,182	\$2.59
Larger	20,000 - 29,999	\$23,462 - \$85,482	\$55,611	\$2.44
Largest	Over 30,000	\$0 - \$835,000	\$191,864	\$1.20
New York City	8,190,000	-	\$11,965,872	\$1.46

[17] Idaho Transportation Department, 2014
[18] Stickel, Jahn & Kier, 2012

Storm Drain Cleaning and Maintenance

Figure 7. Storm drain facility cleaning (Source: Anne Arundel County, Maryland).

Stormwater drains help to slow drainage and redirect runoff into wastewater facilities where it is cleaned and treated before being discharged into water bodies. This prevents runoff carrying trash and other contaminants from directly entering nearby waterways. Stormwater drains can become clogged with trash, debris, sediment and mud, or other materials carried by runoff. Regular maintenance prevents stormwater drains from developing structural cracks and leaks over time.[19] The costs of stormwater drains are primarily incurred from cleaning and maintenance.[20]

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for storm drain cleaning and maintenance is $176,281 and it is 48.7% of the total cost of activities related to marine debris cleanup. The average per capita cost is $3.77. For New York City, the annual cost for storm drain cleaning and maintenance is $14,081,000 and the per capita cost is $1.72.

Table 9. Cost data for storm drain cleaning and maintenance

STORM DRAIN CLEANING AND MAINTENANCE				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	$0 - $4,400,000	$115,369	$3.77
Smaller	Under 10,000	$0 - $50,000	$12,343	$1.96
Mid-sized	10,000 - 19,999	$10,000 - $15,000	$11,741	$0.50
Larger	20,000 - 29,999	$25,000 - $100,000	$54,156	$2.38
Largest	Over 30,000	$0 - $4,400,000	$691,386	$4.31
New York City	8,190,000	-	$14,081,000	$1.72

[19] Montgomery County, Department of Environmental Protection, 2015
[20] Stickel, Jahn & Kier, 2012

Stormwater and Runoff Capture Devices

Figure 8. Stormwater capture device (Source: Stormwater Maintenance & Consulting).

Stormwater capture devices help to filter trash out of urban stormwater runoff by trapping trash in the storm drain system. They can be part of large centralized facilities or small-scale decentralized devices.[21] For the purposes of this report, we will be referring to small-scale systems when discussing these devices. The costs incurred by these devices are primarily from purchase, installation, and maintenance.[22]

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for stormwater capture and runoff devices is $112,748 and it is 31.1% of the total cost of activities related to marine debris cleanup. The average per capita cost is $2.17. For New York City, the annual cost for stormwater and runoff capture devices is $70,000 and the per capita cost is $0.01.

Table 10. Cost data for stormwater and runoff capture devices

STORMWATER AND RUNOFF CAPTURE DEVICES				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	$0 - $2,650,000	$112,748	$2.17
Smaller	Under 10,000	$0 - $50,000	$6,654	$0.85
Mid-sized	10,000 - 19,999	0	$0	$0.00
Larger	20,000 - 29,999	$0 - $50,000	$18,588	$0.82
Largest	Over 30,000	$0 - $2,650,000	$412,857	$2.57
New York City	8,190,000	-	$70,000	$0.01

[21] Baerenklau, Cutter, DeWoody, Sharma & Lee, 2015
[22] Stickel, Jahn & Kier, 2012

Manual Debris Cleanup

Figure 9. Manual litter pick up (Source: Mahoning County).

Manual debris cleanup is the act of physically removing litter from streets, parks, and roadsides.[23] These activities occur regularly as a part of park maintenance and in response to complaints. Each local government handles this differently. Some municipalities have formal and routine litter collection programs, while others have volunteer collection programs. Municipalities with formal manual litter cleanup programs sometimes spread the responsibility among multiple departments. Costs of these activities are incurred mainly from employing personnel and equipment purchases.

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for manual debris cleanup is $12,370 and it is 3.4% of the total cost of activities related to marine debris cleanup. The average per capita cost is $0.26. For New York City, the annual cost for manual debris cleanup is $18,531,621 and the per capita cost is $2.26.

Table 11. Cost data for manual debris cleanup

MARINE DEBRIS CLEANUP				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	$0 - $96,000	$12,370	$0.26
Smaller	Under 10,000	$0 - $20,000	$5,633	$0.89
Mid-sized	10,000 - 19,999	$0 - $20,000	$5,000	$0.21
Larger	20,000 - 29,999	$9,500 - $20,000	$16,397	$0.72
Largest	Over 30,000	$0 - $96,000	$28,714	$0.18
New York City	8,190,000	-	$18,531,621	$2.26

[23] Stickel, Jahn & Kier, 2012

Public Education

Figure 10. NOAA marine debris prevention through education and outreach program (Source: NOAA).

Public education activities aim to increase public awareness about the issue of marine debris. These programs: (1) encourage changes in behavior to reduce and address marine debris; (2) increase public knowledge on the impacts of marine debris; and (3) engage the public in active, personal participation in volunteer cleanup activities.[24] Public education activities can be implemented through the internet, billboards, public transit posters, school programs and television. Costs of public education include personnel, materials, holding events, advertising space, and potentially contractors to develop public awareness campaigns.[25]

For cities and boroughs in New Jersey and New York State (except New York City), the average annual cost for public education is $3,615 and it is 1% of the total cost of activities related to marine debris cleanup. The average per capita cost is $0.08. For New York City, the annual cost for public education is $529,000 and the per capita cost is $0.06.

Table 12. Cost data for public education

PUBLIC EDUCATION				
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**
NJ and NY State	1,401,515	$0 - $23,750	$3,615	$0.08
Smaller	Under 10,000	$0 - $5,750	$930	$0.15
Mid-sized	10,000 - 19,999	$0 - $3,500	$900	$0.05
Larger	20,000 - 29,999	$1,500 - $6,700	$3,844	$0.17
Largest	Over 30,000	$0 - $23,750	$11,179	$0.07
New York City	8,190,000	-	$529,000	$0.06

[24] National Oceanic and Atmospheric Administration, 2015
[25] Stickel, Jahn & Kier, 2012

All Cleanup Activities

For cities and boroughs in New Jersey and New York State (except New York City), the average annual total cost of activities related to marine debris cleanup is $338,372, the average per capita cost is $7.97 and the average cost per square mile is $35,533. For New York City, the annual total cost is $47,896,993, the per capita cost is $5.85, and the average cost per square mile is $102,126. For New Jersey State alone, the per capita cost is $17.23. The total cost of all study areas is $59,063,285, the per capita cost is $6.16 and $75,407 per sq mile.

Table 13. Cost data for total costs by population and square mile

TOTAL COSTS BY POPULATION					
Area	**Population**	**Range of Annual Costs**	**Average Annual Costs**	**Annual Per Capita Costs**	**Annual Cost per Square Mile**
NJ and NY State	1,401,515	$0 - $8,045,000	$338,372	$7.97	$35,533
Smaller	Under 10,000	$0 - $130,000	$46,377	$7.85	$23,730
Mid-sized	10,000 - 19,999	$1,000 - $105,000	$52,396	$3.37	$25,353
Larger	20,000 - 29,999	$110,697 - $197,200	$158,219	$6.94	$23,336
Largest	Over 30,000	$2,000 - $8,045,000	$1,353,858	$8.44	$38,926
New York City	8,190,000	-	$47,896,993	$5.85	$102,126

iv. Discussion

For New Jersey and New York State, 48.7% of the total cost of activities related to marine debris cleanup is storm drain cleaning and maintenance and 31% of the total cost was spent on stormwater and runoff capture devices. The cost of beach and waterway cleanup is only 2% of the total cost annually. Although there is no significant relationship between a city's proximity to a coastline with a beach and the cost for beach and waterway cleanup (See Appendix B2a), there are only five cities in the response sample that have beaches in the region. This may well have affected the results. City size and population also have an effect on the scale of costs: there is a significant relationship between the population and average per capita cost (See Appendix B2b).

Compared to the costs observed in the West Coast study, the total cost for the Hudson-Raritan Estuary area ($59,063,285) is slightly lower than the total cost of the West Coast ($60,131,679).[26] For all of the activities, except storm drain cleaning and maintenance, the cost of activities related to marine debris cleanup for West Coast area have a higher average per capita cost than New Jersey and New York State study area (See Appendix B1). For New York City, the cost of manual debris cleanup is higher than the West Coast study area. Differences in costs could be due to a number of factors: (1) the New Jersey and New York area, especially New York City, has a much higher population density than the West Coast study area; (2) due to seasonal differences, the winter period (during which some cleanup activities may not be performed) in New York and New Jersey area is longer than the West Coast; (3) only five cities/towns in the New York and New Jersey study area are along the coastline; and (4) due to the shorter time frame of the study, the cost of related activities from NGOs and other volunteer organizations was not included. In addition, New Jersey alone has a much higher per capita cost than other areas. This may be because the selected New Jersey municipalities are mostly small and mid-sized towns or villages.

[26] Stickel, Jahn & Kier, 2012

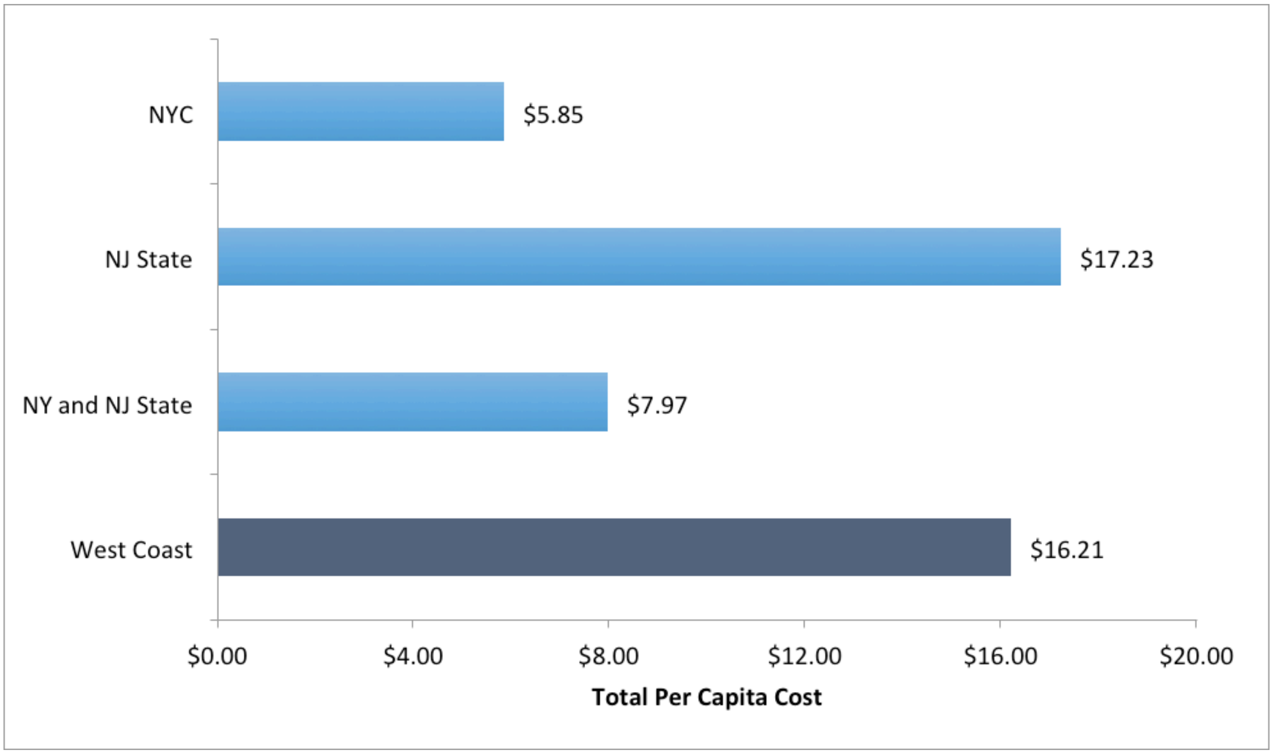


Figure 11. Total per capita cost for West Coast, New Jersey, New York City and NY&NJ States

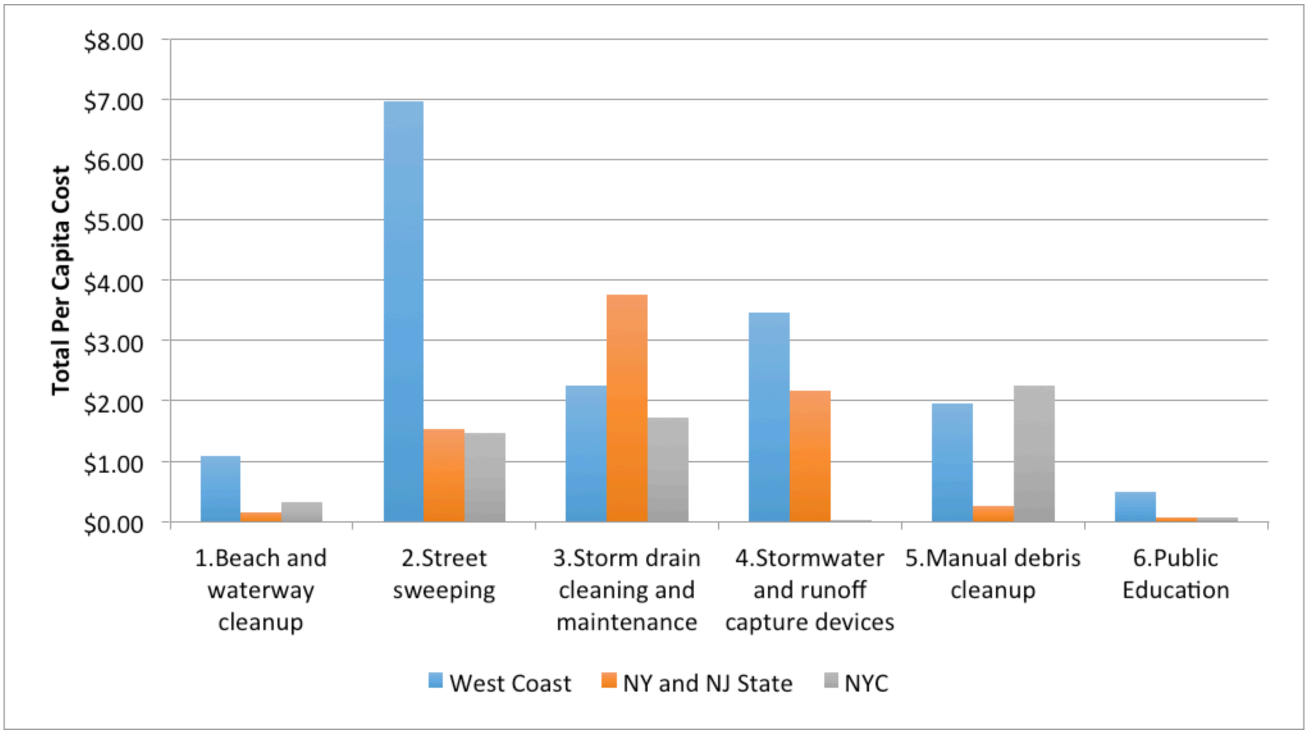


Figure 12. Per capita cost for West Coast, NJ, NYC and NY&NJ States by cleanup activity

IV. LIMITATIONS OF THE STUDY

While we drew a random sample of municipalities, we did not obtain data from all the municipalities we contacted. The municipalities that responded may not be fully representative of the wider Hudson-Raritan Estuary population.

Moreover, marine debris management or cleanup activities are not a line item in all municipal budgets; some municipalities provided ranges, or estimates. An example of this type of complication is manual litter cleanup. Some municipalities reported that the money spent on manual litter cleanup is often in the form of a salary to city employees. However, municipalities do not know exactly how much time these employees spend on manual litter cleanup, making it difficult to precisely calculate how much of the employee's salary to include in the cost data. Therefore, we often relied on estimates of labor costs.

We asked municipalities to provide cost data on stormwater runoff and capture devices. Some municipalities contacted us and stated that it was difficult to quantify an annual cost for this item because they do not purchase stormwater runoff and capture devices on an annual basis. For the purpose of this study, the upfront costs of capital required to manage marine debris, were not included in the cost data. This includes not only stormwater runoff and capture devices, but also other equipment that may be necessary for marine debris management, or other budgetary items that are not representative of annual operations. For example, Hurricane Sandy caused a great deal of marine debris that New York City had to manage, and the City was given one-time marine debris removal grant from NOAA. However, that cost was not included in the study as it is not representative of their annual operations. Despite these limitations, we believe that our study provides a useful estimate of the annual costs of local marine debris cleanup.

V. POLICY LANDSCAPE

We now turn to a brief overview of existing marine debris management policies that have been implemented through the Trash Free Waters program in California. We have analyzed these policies and discuss options for marine debris management in EPA Region 2.

i. California Case Study

In 2007, California's Ocean Protection Council (OPC) adopted a resolution titled "Reducing and Preventing Marine Debris". Following that resolution, the OPC formed the Marine Debris Steering Committee to oversee implementation of this resolution.[27]

The Marine Debris Steering Committee identified three priority actions for reducing and preventing litter: Extended Producer Responsibility, Single-Use Product Bans, and Fees for Commonly Littered Items.

Priority Action #1: Extended Producer Responsibility

Extended Producer Responsibility (also known as a producer take-back program) places the responsibility for collection and disposal of packaging waste on: (1) the manufacturers of these packaging materials, and (2) the manufacturers of products using that packaging. Extended responsibility can be internalized by producers as an operating cost or by arranging a recovery program with distributors and retailers. In an interview, Amanda Hong (EPA Region 9, Environmental Protection Specialist) and Molly Martin (EPA Region 9, Coastal Watersheds Coordinator), reported that although take-back programs are effective, it tends to be a long and drawn out process.

Extended Producer Responsibility programs have been implemented in at least 33 countries. In the United States, state and local entities have implemented Extended Producer Responsibility programs despite the lack of a national program. Most of these programs are voluntary such as the Rechargeable Battery Recycling Corporation (RBRC) program that recycles batteries and cell phones. Another example is California law AB2449, which mandates take-back of bags and films by all large grocery stores and pharmacies in the state.

Priority Action #2: Single-Use Product Bans

In California, single-use plastic bags and other packaging such as polystyrene food take-out containers are increasingly being targeted for bans by coastal communities. California's Marine Debris Steering Committee has focused on two specific measures: (1) polystyrene food packaging prohibition and (2) plastic bag fee or ban.

Lightweight and insulating materials like foamed plastic, expanded polystyrene, and Styrofoam™ have historically been used in food packaging. However, due to the harmful environmental effects of these materials, seven California jurisdictions including San Francisco, Los Angeles, and Monterey counties have prohibited the use of both polystyrene and foam plastic food container packaging. When San Francisco did a litter audit in 2007, one year after the ban, they found a 36% reduction in polystyrene litter.

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[27] California Ocean Protection Council, California Marine Debris Steering Committee, Gordon Environmental Consulting. (2008)

In 2007, the Ocean Conservancy found that plastic bags were one of the most frequently collected trash items during beach cleanup events. That same year, San Francisco enacted a plastic bag ban in major supermarkets and pharmacies. Currently, California has a pending statewide bag ban on the ballot. Washington D.C.'s plastic bag fee went into effect in 2010, with success. Although many municipalities have implemented these types of bans or fees, recently there have been some moves to repeal them.[28]

Priority Action #3: Fees for Commonly Littered Items

For items unsuitable for Extended Producer Responsibility programs, California's Marine Debris Steering Committee determined that a viable policy option could be adding fees. Cigarette butts, for example, are one such item where this policy can have a great effect. Fee revenues could be used to clean up litter, so that the costs of cleanup activities are transferred to those that use the products. To be effective, this option will also have to overcome manufacturer resistance due to potential customer loss.[29]

ii. Policy Options for the Hudson-Raritan Estuary

Extended Producer Responsibility

Some programs promoting extended producer responsibility have already been implemented in New York and New Jersey. Examples of this are: product stewardship programs; and regulating the recycling of items such as electronic waste, rechargeable batteries, and mercury thermostats.[30] In 2009, the State of New York passed the Plastic Reduction, Reuse, and Recycling Act. Under this act, retail stores with 10,000 square feet or more, and chains that operate five or more stores with an area of 5,000 square feet or more, are required to place plastic bag recycling bins throughout the store, and establish their own plastic recycling programs.[31] This is meant to reduce the number of plastic bags that become litter.

New Jersey already has take-back requirements applying to nickel-cadmium batteries and rechargeable batteries, but has no Extended Producer Responsibility programs on plastic bags or food containers.[32] One policy option would be to expand Extended Producer Responsibility programs in New York and New Jersey, involving manufacturers and producers of packaging. The ideal Extended Producer Responsibility program would not just involve plastic bags, but would be extended to other products that commonly become marine debris. As the California case study suggests, food packaging would be the main target of this policy. Rhode Island recently passed a possible model. Rhode Island House Bill 5508 calls on packaging producers to develop a plan aimed at reducing at least 80% of packaging sold in the state by 2020.[33]

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[28] Amanda Hong (EPA Region 9 Environmental Protection Specialist) and Molly Martin (EPA Region 9 Coastal Watersheds Coordinator), personal communication, April 9, 2015.
[29] Amanda Hong (EPA Region 9 Environmental Protection Specialist) and Molly Martin (EPA Region 9 Coastal Watersheds Coordinator), personal communication, April 9, 2015.
[30] New York Department of Environmental Conservation, "Product Stewardship", 2015
[31] New York Department of Environmental Conservation, "NYS Plastic Bag and Film Plastic Reduction", 2015
[32] Van Rossem, Tojo, Lindhqvist, 2006
[33] State of Rhode Island, "House Bill 5508", 2015

Single-Use Items Bans

Recently, New York City enacted legislation (going into effect on July 1, 2015) preventing food service establishments, stores, and manufacturers from selling single use expanded polystyrene (EPS) foam articles—the ubiquitous clamshell takeout boxes—or polystyrene loose fill packaging.[34] The city of Rahway, NJ, implemented a similar policy, banning food containers and utensils made from PVC and polystyrene in December 1996.[35] This measure has also been implemented in numerous cities on the West Coast. The 2008 San Francisco Litter Audit revealed a 36% reduction in polystyrene since the material was banned in 2007.[36] While a state level ban might be ideal, no state in the U.S. has been able to pass such legislation. A gradual expansion of this measure might be a more feasible solution. New York State and New Jersey could focus on implementing this policy at the city and/or county level, aiming to enact a statewide policy once this measure has spread through the region.

Plastic Bag Fee

An annual volunteer beach cleanup event organized by the Ocean Conservancy and funded by the U.S. EPA revealed that during the survey period from 2001-2006 the amount of items from unidentified sources (including plastic bags, bans, plastic beverage bottles, plastic food bottles, plastic bleach/cleaner bottles, and other plastic bottles) increased 5.4% each year. New Yorkers use 5.2 billion carryout bags per year, the vast majority of which are not recycled. Plastic bags get stuck in storm drains, exacerbating flooding and sewage discharges into waterways and are the fourth most commonly found type of litter on U.S. beaches. [37] According to the nonprofit organization, BagItNYC, New York City pays an estimated $10 million to transport 100,000 tons of plastic bags to landfills in other states each year. Shopping bags jam expensive machinery at recycling plants and contaminate the recycling stream, increasing costs.

New York State created a voluntary plastic bag take-back recycling system, but this voluntary effort has failed to produce a demonstrable impact in reducing plastic bag waste. Some retailers in New York are already leading the way on eliminating bag waste, demonstrating receptiveness among both retailers and consumers. Whole Foods Market eliminated plastic bags in 2008, offering only 100% recycled paper bags for free or reusable bags for purchase. The policy requires stores to charge for plastic or paper bags to make the cost of single-use bags clear to the consumer.[38]

Fees on Common Litter Items

The California report highlighted the efficacy of imposing fees on common litter items that are more difficult to capture through Extended Producer Responsibility programs or bans. Food packages and cigarettes are the most obvious examples that fit this policy mechanism. It’s not possible to ban purchase of those goods. However, fees put on certain items, taking into account their economic cost and the environmental impact, some consumers may change their purchasing behaviors. Eventually, those commonly littered items may decrease on the beach and coastal areas. In addition, fee revenues can be

[34] City of New York, 2015
[35] Clean Water Action, 2015
[36] California Ocean Protection Council, California Marine Debris Steering Committee, Gordon Environmental Consulting, 2008
[37] Bag it NYC, 2013

[38] Bag it NYC, 2013

used to clean up litter so that the costs are borne by those who choose to consume the products that contribute most to marine debris.

Total Maximum Daily Loads (TMDL)

According to the Clean Water Act, states are required to identify water bodies that don't meet water quality standards. For these "impaired waters", states need to develop a Total Maximum Daily Load (TMDL), the maximum amount of a certain pollutant that a water body can receive while still meeting water quality standards. Once this assessment is made, states are required to reduce the amount of excess pollutants, in order to restore the quality of the water.[39]

Total Maximum Daily Load assessments can be developed not only for chemicals, but also for other types of pollutants, such as marine debris. In 2001 the State of California adopted an amendment to the Water Quality Control Plan for the Los Angeles Region (Basin Plan), establishing a Total Maximum Daily Load for trash in the Los Angeles River Watershed.[40] The Total Maximum Daily Load implementation plan was aimed at a progressive reduction of the trash in the Los Angeles River Watershed to be achieved by September 2016.

A similar resolution was adopted in September 2001 for the Ballona Creek and Wetland, also in California. The main goal of establishing a marine debris TMDL for this water body was to achieve a progressive reduction of trash by September 30, 2015.[41] This policy could serve as a model for New York and New Jersey. Even if a Total Maximum Daily Load plan doesn't focus on preventing trash from entering water bodies, it still can be taken into consideration as a complementary measure, combining it with the prevention policies described above. An ideal plan would focus on major water bodies in New York and New Jersey. Because these plans are already in place for chemicals, it might be feasible to develop a similar plan for trash.

[39] New York Department of Conservation, "Clean Water Blueprints", 2015

[40] State of California, 2015

[41] State of California, 2015

VI. CONCLUSION

Marine debris affects wildlife as well as communities on and near coastlines. Despite the fact that marine debris is found in waterways, a significant proportion of the trash originates on land. The EPA's Trash Free Waters program aims to address this urban-coastal connection by emphasizing a collaborative approach to solving the problem.

This study is an effort to contribute to that goal by highlighting the amount of money municipalities in the Hudson-Raritan Estuary spend on managing actual and potential marine debris. The budgetary data makes an economic argument for reducing costs by managing waste materials before they are able to enter waterways.

In addition to estimating the economic costs of managing marine debris, the study also highlighted some actions taken elsewhere in the country that could be implemented in New York and New Jersey. These include: extended producer responsibility, bans and fees on single use items, and adopting total maximum daily loads for trash in waterways.

This report adds to the ongoing dialogue of managing marine debris in EPA Region 2. We hope that the economic costs of marine debris management in the Hudson-Raritan Estuary will illuminate the importance of addressing this issue and inform policy decisions on how best to do so.

Bibliography

Amanda Hong (EPA Region 9 Environmental Protection Specialist) and Molly Martin (EPA Region 9 Coastal Watersheds Coordinator), Personal communication, April 9, 2015.

Baerenklau, K., Cutter, W., DeWoody, A., Sharma, R., & Lee, J. (2015). Capturing Urban Stormwater Runoff: A Decentralized Market-Based Alternative. *Policy Matters*, *2*(3). Retrieved from: http://policymatters.ucr.edu/pmatters-vol2-3-water.pdf

BagItNYC. (2013). *About BagItNYC.* Retrieved from http://bagitnyc.org/about/

California Ocean Protection Council, California Marine Debris Steering Committee, Gordon Environmental Consulting. (2008). *An Implementation Strategy for the California Ocean Protection Council Resolution to Reduce and Prevent Ocean Litter*. Retrieved from http://www.opc.ca.gov/webmaster/ftp/pdf/opc_ocean_litter_final_strategy.pdf

City of New York. (2015). De Blasio Administration Bans Single-Use Styrofoam Products in New York City Beginning July 1, 2015. Retrieved from http://www1.nyc.gov/office-of-the-mayor/news/016-15/de-blasio-administration-bans-single-use-styrofoam-products-new-york-city-beginning-july-1-2015

Clean Water Action. (2015). Phase Out Foam: Additional Information on Foam. Retrieved from http://www.cleanwateraction.org/feature/phase-out-foam-additional-information-foam.

Environmental Protection Agency. (2009). *Marine Debris*. Retrieved from http://water.epa.gov/type/oceb/marinedebris/upload/2009_05_11_oceans_debris_marine_debris_final.pdf

Environmental Protection Agency. (2012). *National Marine Debris Monitoring Program*. Retrieved from http://water.epa.gov/type/oceb/marinedebris/nmdmp.cfm

Environmental Protection Agency. (2015). *EPA Region 2*. Retrieved from http://www2.epa.gov/aboutepa/epa-region-2

Environmental Protection Agency. (2015). *Trash Free Waters*. Retrieved from http://water.epa.gov/type/oceb/marinedebris/

Idaho Transportation Department. (2014). *Best Management Practices – Street Sweeping and Vacuuming.* Retrieved from http://itd.idaho.gov/enviro/stormwater/BMP/PDF%20Files%20for%20BMP/Chapter%202/SC-4%20Street%20Sweeping%20and%20Vacuuming.pdf.

Marine Debris Research, Prevention, and Reduction Act of 2005, Pub Law No. 109-449, § 362 (2005).

Marine Plastic Pollution Research and Control Act of 1987, Pub. Law No. 109 – 449, § 33 U.S.C. 1901. (1987).

Montgomery County, Department of Environmental Protection. (2015). *Stormwater Facility Maintenance and Inspections*. Retrieved 25 April 2015, from http://www.montgomerycountymd.gov/DEP/water/stormwater-facilities.html

National Oceanic and Atmospheric Administration. (2015). *OR&R's Marine Debris Program*. Retrieved from http://marinedebris.noaa.gov/funding/funding-opportunities

New York Department of Environmental Conservation. (2015). *Clean Water Blueprints*. Retrieved from http://www.dec.ny.gov/chemical/23835.html

New York Department of Environmental Conservation. (2015). *NYS Plastic Bag and Film Plastic Reduction*. Retrieved from http://www.dec.ny.gov/chemical/50034.html

New York Department of Environmental Conservation. (2015). *Product Stewardship*. Retrieved from http://www.dec.ny.gov/chemical/66746.html

Santos, I. R., Friedrich, A.C., Sul, J.A. (2009). Marine debris contamination along undeveloped tropical beaches from northeast Brazil. Environ Monitoring Assessment. 148:455–462.

Sheavly, S. B., Register. E. K. M. (2007). Marine Debris & Plastics: Environmental Concerns, Sources, Impacts and Solutions. J Polym Environ (2007) 15:301–305.

State of California. (2015). *Resolution NO. R15-XXX*. Retrieved from http://www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/107_new/TentativeResolutionBCandLARTrashReconsideration3Apr15.pdf.

State of Rhode Island, “House Bill 5508,” Introduced February 12, 2015

Stickel, B. H., A. Jahn and W. Kier. (2012). The Cost to West Coast Communities of Dealing with Trash, Reducing Marine Debris. Prepared by Kier Associates for U.S. Environmental Protection Agency, Region 9, pursuant to Order for Services EPG12900098, 21 p. + appendices.

Van Rossem C., Tojo N., Lindhqvist T. (2006). Extended Producer Responsibility: An examination of its impacts on innovation and greening products. Retrieved from http://www.greenpeace.org/international/PageFiles/24472/epr.pdf

APPENDIX A: Request for Information

REQUEST FOR INFORMATION

To: _______
From: Columbia Marine Debris Research Team
Subject: Quantifying the Costs of Marine Debris in the Hudson-Raritan Estuary
Date: March 5, 2015

Dear City Officials,

My name is Bo Ra Kim and I am contacting you on behalf of the Columbia Marine Debris Research Team – a group of Columbia University graduate students working in conjunction with the Environmental Protection Agency and the New York Department of Environmental Conservation.

As a part of an effort to reduce the overall quantity of marine debris in the Hudson-Raritan Estuary, the DEC has asked us to collect information on the costs associated with preventing and removing trash that can enter surrounding water bodies. We understand that these numbers may not be easily accessible, so any estimate that you can provide will be helpful. If you feel more comfortable, a range based on your expertise would be helpful.

Activity	Best Estimates of Annual Cost (can be a range)
1. **Beach and waterway cleanup** – costs associated with removing litter from beaches and waterways, including skimming and any other costs incurred from participating in volunteer efforts.	
2. **Street sweeping** – costs of operating street sweepers and disposal of litter.	
3. Storm drain cleaning and maintenance	
4. **Stormwater and runoff capture devices** – cost of purchase, installation and maintenance of these devices.	
5. **Manual debris cleanup** – any cost associated with picking up trash in areas like parks and roadsides that has not previously been covered above.	
6. **Public education** – costs of public campaigns against littering and improper disposal that could impact management of runoff (this includes costs of participating in larger programs like the Harbor & Estuary Program).	

If you have any questions or concerns, please do not hesitate to contact Bo Ra Kim at xxx-xxx-xxxx or xxxxxx@columbia.edu. Thank you in advance for your help!

APPENDIX B: Data Analysis

B1. West Coast Data

BEACH AND WAERWAY CLEANUP				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$0-$1,837,398	422185	0.83
Larger	75,000-249,999	$0-$17,500	3329	0.03
Mid-Sized	15,000-74,999	$0-$112,459	12746	0.28
Smaller	Under 15,000	$0-$114,005	6418	1.28

STREET SWEEPING				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$245,000-$8,104,857	4084492	5.36
Larger	75,000-249,999	$180,000-$1,224,210	641298	5.58
Mid-Sized	15,000-74,999	$25,685-$1,300,000	272715	7.06
Smaller	Under 15,000	$0-$160,301	36314	5.48

STORM DRAIN CLEANING AND MAINTENANCE				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$0-$6,400,000	1943260	1.85
Larger	75,000-249,999	$0-$1,098,000	261449	1.73
Mid-Sized	15,000-74,999	$0-$538,778	47320	1.07
Smaller	Under 15,000	$0-$85,000	10533	2.32

STORMWATER AND RUNOFF CAPTURE DEVICES				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$0-$2,508,000	630755	1.32
Larger	75,000-249,999	$0-$640,000	223105	2.04
Mid-Sized	15,000-74,999	$0-$1,100,000	164499	4.12
Smaller	Under 15,000	$0-$560,000	27382	2.21

MANUAL DEBRIS CLEANUP				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$48,000-700,000	2371903	2.58
Larger	75,000-249,999	$0-$150,000	50141	0.48
Mid-Sized	15,000-74,999	$0-$200,000	46188	1.09
Smaller	Under 15,000	$0-$81,000	11166	2.11

PUBLIC EDUCATION				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$0-1,945,531	602208	0.59
Larger	75,000-249,999	$5,000-$72,000	32200	0.29
Mid-Sized	15,000-74,999	$0-$80,000	14127	0.35
Smaller	Under 15,000	$0-$25,000	3532	0.46

TOTAL COST BY POPULATION AND BY AREA				
City Size	**Population Range**	**Range of Annual Costs**	**Average Annual Cost**	**Average Per Capita Cost**
Largest	Over 250,000	$2,877,400-$20,672,266	10054805	12.54
Larger	75,000-249,999	$342,000-$2,057,500	1211522	10.15
Mid-Sized	15,000-74,999	$37,500-$2,330,000	557596	13.97
Smaller	Under 15,000	$0-$890,000	95345	13.85

B2. Hudson-Raritan Estuary Regression Outputs

a. Regression output for city location vs. cost of beach and water cleanup activities

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.01777370602							
R Square	0.000315904625							
Adjusted R Squa	-0.03193196942							
Standard Error	15676.81453							
Observations	33							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	2407523.511	2407523.511	0.009796138039	0.9217950284			
Residual	31	7618637931	245762513.9					
Total	32	7621045455						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	6327.586207	2911.111376	2.173598117	0.03749349577	390.3355262	12264.83689	390.3355262	12264.83689
Location	-827.5862069	8361.530836	-0.09897544159	0.9217950293	-17881.04045	16225.86803	-17881.04045	16225.86803

b. Regression output for population vs. cost per capital for all locations

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.7840869301
R Square	0.6147923139
Adjusted R Squa	0.6023662596
Standard Error	876077.9267
Observations	33

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	37973502426865	37973502426865	49.47606816	0.000000067414
Residual	31	23792888541080	767512533583		
Total	32	61766390967945			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	-556476.303	198601.7009	-2.801971486	0.008675923692	-961527.1345	-151425.4714	-961527.1345	-151425.4714
cost per capital	101552.6978	14437.56245	7.033922672	0.000000067414	72107.09566	130998.3	72107.09566	130998.3

c. Regression output for population vs. total cost for all locations

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.1475628185
R Square	0.02177478541
Adjusted R Squa	-0.009780866672
Standard Error	1396094.103
Observations	33

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1344949908993	1344949908993	0.6900439057	0.41250175
Residual	31	60421441058953	1949078743837		
Total	32	61766390967945			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	272144.0948	255772.1576	1.064009849	0.2955423781	-249506.6497	793794.8394	-249506.6497	793794.8394
population	1.559409985	1.877249288	0.830688814	0.412501755	-2.269265107	5.388085077	-2.269265107	5.388085077