

2013

Tracking Trash: An Analysis of Marine Debris from the Olympic Coast Clean-up

Rebekah Paci-Green

Western Washington University, rebekah.paci-green@wwu.edu

Pamela Griswold

Western Washington University

Kassandra Grimm

Western Washington University

Follow this and additional works at: https://cedar.wwu.edu/envs_facpubs



Part of the [Environmental Studies Commons](#)

Recommended Citation

Paci-Green, Rebekah; Griswold, Pamela; and Grimm, Kassandra, "Tracking Trash: An Analysis of Marine Debris from the Olympic Coast Clean-up" (2013). *Environmental Studies Faculty and Staff Publications*. 30.

https://cedar.wwu.edu/envs_facpubs/30

This Article is brought to you for free and open access by the Environmental Studies at Western CEDAR. It has been accepted for inclusion in Environmental Studies Faculty and Staff Publications by an authorized administrator of Western CEDAR. For more information, please contact westerncedar@wwu.edu.

Tracking Trash: An Analysis of Marine Debris from the Olympic Coast Clean-up

Rebekah Green, Huxley College of the Environment (Rebekah.Paci-Green@wwu.edu)

Pamela Griswold, Huxley College of the Environment

Kassandra Grimm, Huxley College on the Peninsulas

Summary

Researchers at Western Washington University (WWU) assessed whether the estimated 1.5 million tons of mobile debris from the 2011 Japan tsunami has affected the proportion of debris types removed from Washington coast beaches during annual cleanup events. WWU researchers used historical data from 2009-2012 provided by the Washington CoastSavers to establish a baseline for common marine debris trends and compared these baselines with cleanup data obtained from the 2013 CoastSavers cleanup and WWU in-depth assessments of debris removed from four beaches during this 2013 event.

Debris from the tsunami, like debris from local sources, can have a significant impact on marine species. Noteworthy harmful effects of certain debris types, including polystyrene on marine biota include ingestion, entanglement, and accumulation along the ocean floor and surface. Debris from the tsunami event can have added impacts as tsunami debris has been suspended in the water for multiple years and can harbor invasive species.

An analysis of historical CoastSavers beach cleanup data cards indicates shoreline debris is the most abundant category of debris, followed by oceanic debris. The former ranged between 53% to 65% of the total debris (by piece count) between 2009 to 2012; the latter ranged from 24% to 35% of the debris by piece count during the same period. These two categories of debris remained the highest proportion of piece counts in the 2013 data. CoastSavers volunteer data showed shoreline debris piece counts increased to 74% in 2013, while oceanic debris piece counts decreased to 21%.

Despite the continued prevalence of shoreline and oceanic debris in 2013, data score cards from CoastSavers volunteers and the piece counts from WWU researchers analyzing four representative beaches shows considerable disagreement. WWU volunteer counts show that debris removed by CoastSavers was dominated by oceanic debris, ranging from 35% to 74% across the selected beaches.

The difference in the percentage of oceanic debris in 2013 between CoastSavers and WWU counts can be attributed to the treatment of polystyrene. WWU researchers found that polystyrene, a prevalent type of debris along the coast, had not been consistently recorded by CoastSavers volunteers in any category because it is not a debris type listed on the CoastSavers debris data card. WWU volunteers recorded polystyrene in the oceanic category, and fully counted these pieces of debris.

An analysis of CoastSavers volunteer comments about debris of interest found an increase in comments regarding polystyrene debris before and after the tsunami. From 2009 to 2011, polystyrene was mentioned in 24-29% of the debris of interest comments; in 2012 it was mentioned in 41% of the comments. In 2013, the percentage increased further still to 50%, possibly suggesting a quantitative rise in this type of debris, likely attributable tsunami debris from floatation and housing insulation.

WWU researchers concluded that many factors influence the accuracy of the CoastSavers debris data card entries. A lack of a polystyrene category has led to inconsistent tracking of this debris type before and after the tsunami. Other tsunami debris such as lumber may also be inconsistently tracked because the CoastSavers data form did not include lumber as a data category and volunteers may or may not have lumped lumber in the “building materials” section of the Dump category. In some cases, volunteers may also lack the capacity to carry waterlogged lumber to dump stations. Finally, CoastSavers volunteers vary in the degree of meticulousness in recording debris pieces on debris data cards. On one analyzed beach, CoastSavers volunteers fairly accurately tallied the types of debris found in varying categories, but only recorded 6% of the pieces they actually picked up within the categories.

Future research and consistent documentation while collecting debris data is recommended for further analysis. To better track debris pieces cleaned up off of beaches, training a specific subset of CoastSavers volunteers to tally debris before cleanup may be worth consideration and discussion.

Keywords: marine debris, polystyrene, Washington coast, tsunami

Funding: This project received funding from the North Pacific Marine Resources Committee, working in partnership with the National Oceanic and Atmospheric Administration (NOAA)’s Olympic Coast National Marine Sanctuary (OCNMS) and Washington SeaGrant using data from the Washington CoastSavers and OCNMS.

Introduction

On March 11, 2011, a M9.1 earthquake shook the east coast of Japan, creating the event the Japanese Government titles the “3.11 tsunami.” During the event, the 3.11 tsunami swept an estimated five million tons of debris into the Pacific Ocean. Some of the debris washed up along the coast, while other debris was collected or sank to the ocean floor. However, 1.5 million tons of the debris remained mobile in the water, eventually being dispersed around the Pacific Ocean via currents and wind (NOAA, 2013).

Ninety percent of the debris created by the 3.11 tsunami is estimated to originate from collapsed houses and drift wood (Government of Japan, 2013). Debris originating from these sources often does not sink. The Japanese Ministry of the Environment and National Oceanic and Atmospheric Administration (NOAA) are cooperating to model when and where the 3.11 tsunami debris will flow. The models developed by NOAA and the Japanese Ministry of the Environment use created using the speed of the ocean current and the speed of winds to determine the drifting speed of the debris (Government of Japan, 2013). A substantial amount of debris is projected to reach the Washington Coast.

When items appear along the U.S. and Canadian coasts depends on their size and “windage.” Windage is a term describing how easily debris is transported in water, related to buoyancy. Items with more buoyancy have larger surface area above the water and are therefore more easily blown by winds, effecting how quickly items move. Model forecasts suggest the heaviest pulse of tsunami debris will make landfall along the North American Pacific coast occur between April and October, 2013 (Ministry of the Environment, Gov’t of Japan 2013; NOAA, 2013).

The United States received five million dollars from Japan to support debris cleanup. In spring 2013, the five western states affecting by the tsunami (Alaska, California, Hawaii, Oregon and Washington) received part of this money, which is being distributed by NOAA. The first increment was \$250,000, divided among the five states. How far the five million dollars for cleanup efforts will stretch is unknown, raising debate amongst officials.

Within Washington State, NOAA is cooperating with federal, state, tribal and local partners to collect and analyze the debris as it lands on shorelines. The Washington coast is 375 miles long, including beaches and tidal lands bordering the Pacific Ocean. On the Pacific Coast, Washington State coastlines are managed by many different entities, including the Hoh Indian Tribe, Makah Nation, Quileute Indian Tribe, Quinault Indian Nation, Shoalwater Bay Tribe, Washington State Parks and Recreation Commission, Washington State Department of Natural Resources, Olympic National Park, the U.S. Fish and Wildlife Service and the Olympic Coast National Marine Sanctuary.

Debris from the tsunami, like debris from local sources, can have a significant impact on marine species. It has been estimated that 10% of plastics produced globally eventually enter the world’s oceans (Cole, 2013). The fourth most commonly produced polymer in the world is polystyrene (Cole, 2013), commonly known by its brand name “Styrofoam.” The most noteworthy harmful effects of polystyrene on marine biota include ingestion, entanglement, and accumulation along the ocean floor and surface. Polystyrene is easily ingested because it breaks down into small pellets animals often mistake for food. Ingestion of plastics, like polystyrene, can reduce the storage volume of organism’s stomachs which hinders them from consuming as much food as normal. This reduces organisms overall fitness because it reduces the ability to build



Figure 1 Biological colonization on a large polystyrene piece collected at Moclips beach

fat deposits (Derraik, 2002). Polystyrene can also block digestion pathways, like the intestines, causing organism fatalities.

Tsunami debris has an added potential impact on Washington beaches. The suspended long-range debris from the 3.11 tsunami has the potential to host organisms from Japan, bringing non-native and invasive species to Washington's coast (Carlton, 2013). Evidence of invasive organisms appearing along Washington's coast has already occurred on some Japanese debris. For example, a dock was found near Mosquito Creek within Olympic National Park, Washington and later traced back to Misawa, Aomori Prefecture, Japan. Officials have confirmed this dock as debris from the 3.11 tsunami. On the dock, 67 species were identified, twelve of which are known to have successfully established outside of Japan.

Invasive species compete with native species for food and resources, causing damage to local organisms and ecosystems when they establish themselves. Studying the influence of invasive species that have been found from Japan on the Washington coast, as well as others that may be found in the future, will provide important knowledge for officials to use, making decisions about mitigation and cleanup strategies.

Research Focus

Cleanup costs and invasive species are tangible and specific concerns related to responding to 3.11 tsunami debris in Washington State. In order to make decisions about these issues, response entities need accurate documentation of how, if at all, the 3.11 tsunami debris affects the Washington coast. To measure the impacts of the debris, historical data provided by the Washington CoastSavers, and OCNMS, was organized and analyzed, providing a baseline for comparison with 2013 data.



Figure 2 CoastSaver marine debris cleanup sites along the Washington coast

CoastSavers is a program compiled of a spectrum of 22 non-profit organizations, community groups, and public agencies. CoastSavers started collecting debris data in 2002 by asking volunteer citizens participating in their annual April beach cleanup to fill out a Debris Data Card (See Appendix 1). The annual April beach cleanup occurs all along the Washington coast, as shown in Figure 2.

The Debris Data Card has five sections for volunteers to complete. The first section is an introduction, explaining the importance of beach cleaning and asking volunteers to record their findings on an online debris database on the CoastSavers website after the cleanup. The second section of the Debris Data Card is comprised of cleanup site information. For example, how many people the data card is reporting for, the distance cleaned, how many trash bags were filled, time spent cleaning, and a weight estimate. The third section asks volunteers to fill out their personal contact information. The fourth section is for listing entangled animals found during the cleanup, including the type of animal, whether it is alive, and what kind of debris it was entangled in.

The fifth section of the Debris Data Card (adapted from the International Coastal Cleanup) is for volunteers to categorize the items collected during the beach cleanup. Most pieces of debris ideally fits into one of the five categories including debris from shoreline recreational activities, ocean and waterway activities, smoking-related activities, dumping activities, and medical or personal hygiene activities. Each category has different lines for specific items volunteers collect (for example, plastic beverage bottles). Volunteers are asked to keep a count of items collected using tally marks

during the cleanup, totaling the items at the end of the event.

Baseline data from historical CoastSavers cleanup data cards provides a potential method for assessing whether 3.11 tsunami debris is reaching the Washington State coastline. Specifically, it was hypothesized that an influx of tsunami debris could increase the proportion of debris in some CoastSavers debris categories in comparison to historic proportions. WWU researchers predicted that Oceanic and Dump debris would become a larger proportion of the total debris pieces collected by CoastSavers volunteers compared to historical data due to an influx of tsunami-related lumber and coastal fisheries debris. Potentially countering this trend, plastic bottles and household items could increase the Shoreline debris category.

Methods

To assess 2013 debris with historic CoastSavers data, our team first organized the 2002 through 2012 historic data provided by past CoastSavers volunteers who filled out data cards. The team then compared these data with new data card data from the 2013 cleanup. To better assess the accuracy of CoastSavers volunteers in filling out data cards and to better characterize the relationship between volume, weight and piece count in each of the CoastSavers debris categories, the research team also selected four beaches for in-depth assessment. During the 2013 April cleanup event, WWU researchers and volunteers collected debris from CoastSavers volunteers on the four selected beaches and cataloged and photographed the debris before it was collected for disposal. Each of these steps is described in more detail below.

Cleaning the historic data proved more difficult than initially anticipated. The databases CoastSavers and OCNMS provided included many inconsistencies over time. CoastSavers has been collecting beach debris from citizen volunteers since 2002. Since then however, four years of data are missing entirely. The oldest data from 2002 and 2003 use one set of debris categories, data from 2004 to 2008 is inaccessible, and then a new format of data collection with different categories was used from 2008 forward.

The oldest available data, which is from 2002 and 2003, was input differently than the newer data ranging from 2009 to 2012. Initially, WWU researchers tried to convert the older data to the newer format to create one cohesive data entry method. However, the earlier years catalogued different variables and were unable to be converted to the new format. As a result, WWU researchers decided to focus on the most recent year's data, ranging from 2009 to 2012.

Each year of data was compiled by CoastSavers into an excel database, including a column for each question on the Debris Data Card. One limitation to the data is the cleanup sites. Many beaches participate in the CoastSavers annual beach cleanup but debris data is not always collected. The large historical gaps made these beaches difficult to examine. Furthermore, many coastal beaches go by different names and span great distances, making it difficult to verify that the exact same stretch of beach is being compared each year. A table was created to visualize which beaches had consistent longitudinal data from 2009 to 2012. These beaches included Hobuck, Third, Moclips, Twin Harbors, and Ruby. The data for these five beaches was then extracted from the original files and cleaned more thoroughly.

During the 2013 April cleanup, WWU researchers and their recruited WWU volunteers coordinated with CoastSavers better characterize debris CoastSavers volunteers removed from beaches. WWU volunteers met CoastSavers volunteers when they returned from picking up debris and then proceeded to sift and categorize every piece of the debris. WWU volunteers recorded which trash was from volunteer groups who filled out a CoastSavers Debris Data Card and which trash was returned from volunteers without a Debris Data Card.

Once sorted by debris with data cards and without, WWU volunteers sorted the debris into the five different CoastSavers categories: Dump, Medical, Smoking, Oceanic and Shoreline. These categories were adapted from the International Coastal Cleanup.

- The Dump category is comprised of debris such as building materials, car parts, tires and appliances. WWU researchers predicted the Dump category to grow as a result of the 3.11 tsunami because so many building materials were left suspended after the event.
- The Medical category includes all medical supplies, ranging from tampon applicators to diapers. The Smoking category is comprised of all smoking paraphernalia such as cigarette lighters, cigar



Figure 3 WWU research sites for the 2013 CoastSavers beach cleanup

tips and tobacco packaging. Medical and Smoking debris are very small, and historically do not comprise a significant portion, by weight or volume, of the debris found on Washington beaches. However, it is important to note that the beaches vicinity to an urban area influences the size of the Medical and Smoking categories. Beaches closer to urban areas experience more Medical and Smoking debris.

- The Oceanic debris category is historically one of the larger debris categories, with more pieces collected than Medical and Smoking debris combined. This category is made up of items like buoys, floats, rope, wooden pallets, and bait packaging.
- The Shoreline category, also large, is comprised of items that beach goers leave on the beach. For example, six-pack holders, plastic bags, food packaging and beverage bottles.



Figure 4 Oceanic Debris, Twin Harbors Beach



Figure 5 Shoreline Debris, Twin Harbors Beach



Figure 6 Smoking Debris, Twin Harbors Beach



Figure 7 Medical Debris, Twin Harbors Beach



Figure 8 Dumping Debris, Twin Harbors Beach

After all of the debris was sorted into the five categories, WWU volunteers separated each category into three more subcategories based on estimated distance the debris traveled. The first subcategory was short-range debris originating from local sources. Any item with a United States label on it, or that looked

as though it had not been in the water for a long time (due to overall wear, biological colonization, etc.) was sorted into this category.

The next subcategory was long-range Asian debris. Debris in this category often had biological colonization on it and looked as though it had been in the water a long time. WWU volunteers were trained to identify different Asian characters. Russian, Japanese, Korean and Chinese languages were focused on due to tidal patterns suggesting that debris may have originated from these areas. The long-range Asian debris was then sorted through to find debris with Japanese writing, creating a new Japanese category of debris within each five (Dump, Medical, Smoking, Ocean and Shoreline) debris subcategories. Overall, the short-range piles were significantly larger than the long-range and Asian origin piles.

All of the categories were photographed. The long-range Asian and the Japanese subcategories were photographed more carefully, taking macro images of any organisms and characters on them. All categories were also counted by piece, weighed using hanging scales, and the total volume of the debris category was estimated in cubic feet.

Out of the seven beaches WWU volunteers visited, four beaches had consistent piece and weight data from 2009-2013. These beaches include Hobuck, Third, Moclips, and Twin Harbors. The data collected in the 2013 cleanup was then entered into an Excel database to graph and analyze compared to the historical data. WWU volunteers at Ruby beach did not collect adequate data to analyze and so were excluded from analysis.

Analysis of Piece Count

Upon analyzing the historic data for the four selected beaches, trends emerged regarding the proportion of certain debris categories to the total debris collected. For example, dump and medical categories remain consistently small from 2009 through 2012. From 2009 through 2012, oceanic pieces were 33 percent on average of the total collected at the selected sites, as seen in Figure 10. In addition, shoreline pieces averaged 61 percent of the total debris collected. During this analysis, averages were used rather than medians to better account for the mid-range values.

Similar patterns occur while analyzing the CoastSavers data from

each year including all participating beaches, not just the four WWU researchers selected. Figure 9 is a graph demonstrating the proportions of categories at all beaches participating in the CoastSavers cleanup each year. Figure 10 demonstrates the shoreline and oceanic categories are regularly the largest proportion of debris each year at the four selected beaches. It is important to note that the number of beaches represented varies each year. For example, in 2009, 16 beaches had volunteers who returned Debris Data Cards. In 2010, it was 24 beaches (Table 1). In addition to the change in numbers, which beaches participated is also different. As a result, different sections of the coast may be more represented some years compared to others.

Table 1 Number of beaches participating in the CoastSavers cleanup

Year	Number of Beaches Where Data Was Reported
2009	16
2010	24
2011	19
2012	23
2013	17

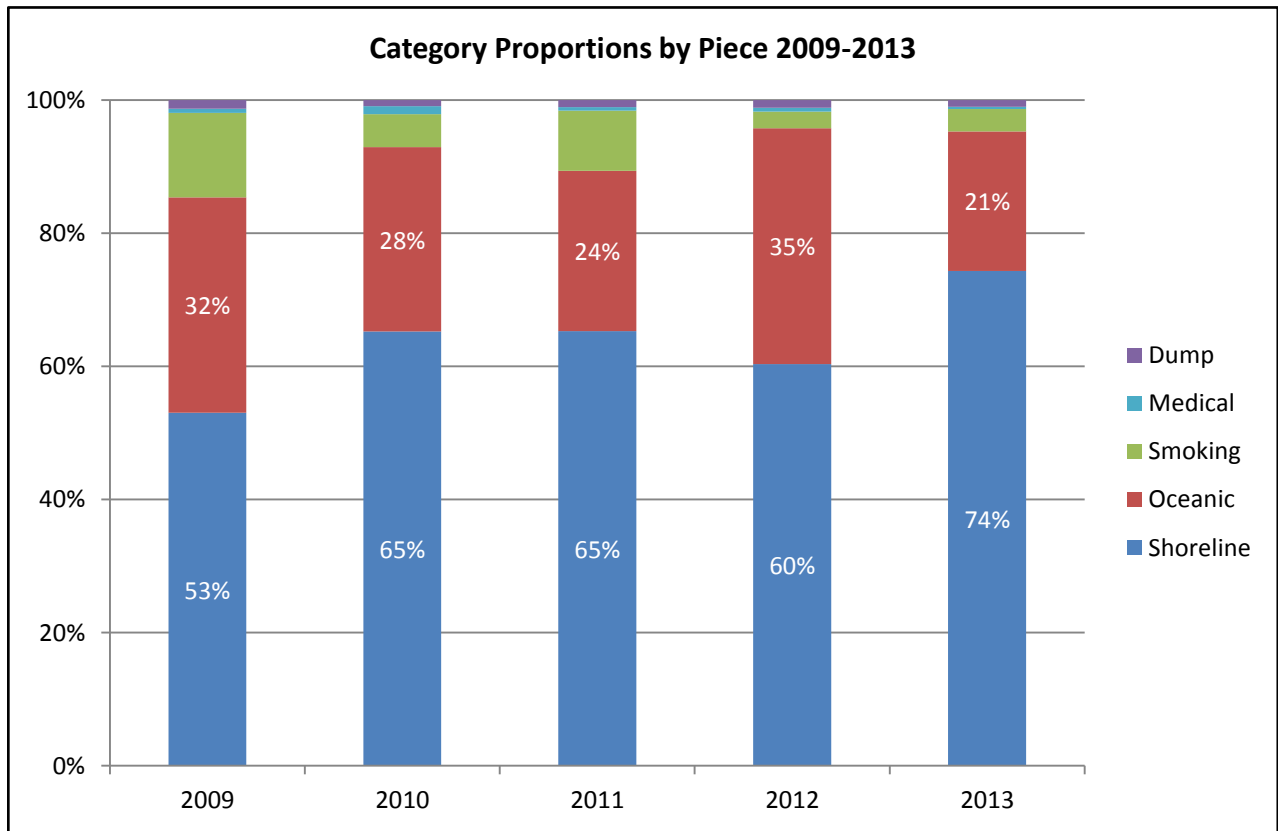


Figure 9 Debris categories by proportion by piece at all beaches from 2009 to 2013

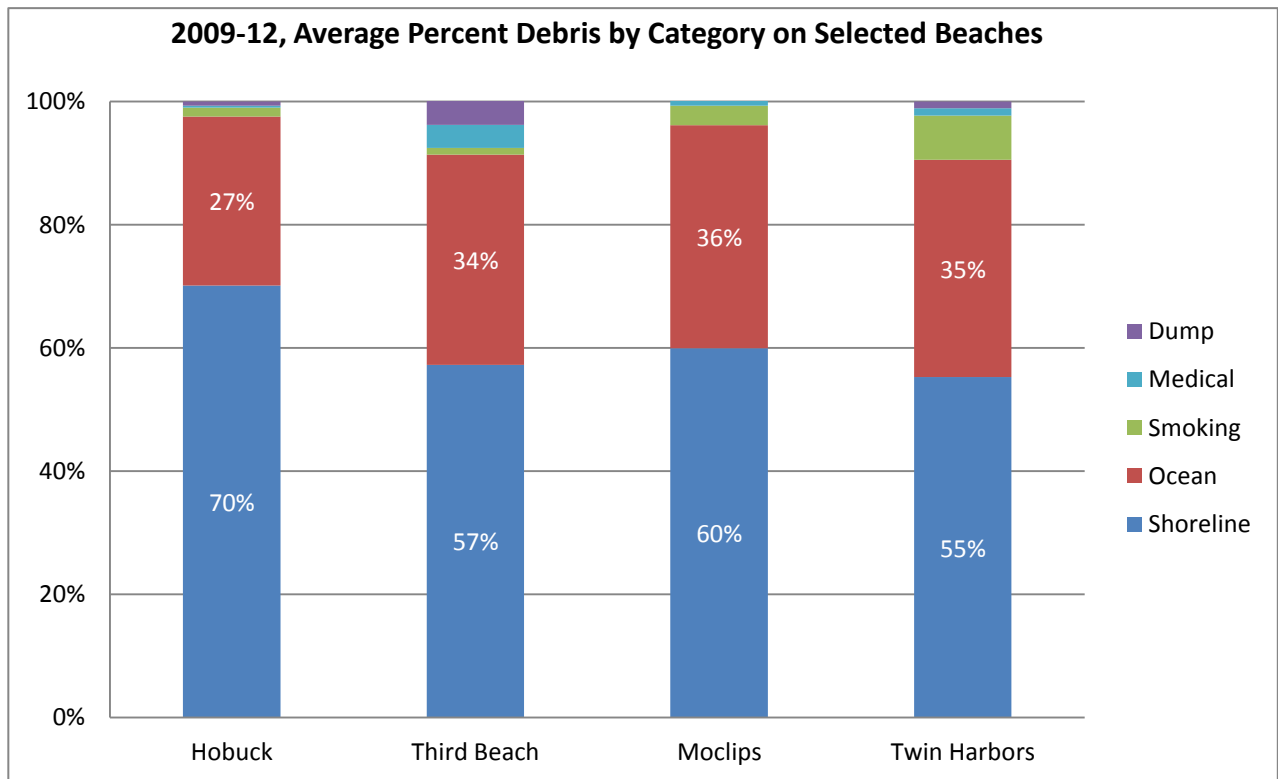


Figure 10 The average percent, by category, of marine debris from 2009 to 2012 on four representative beaches.

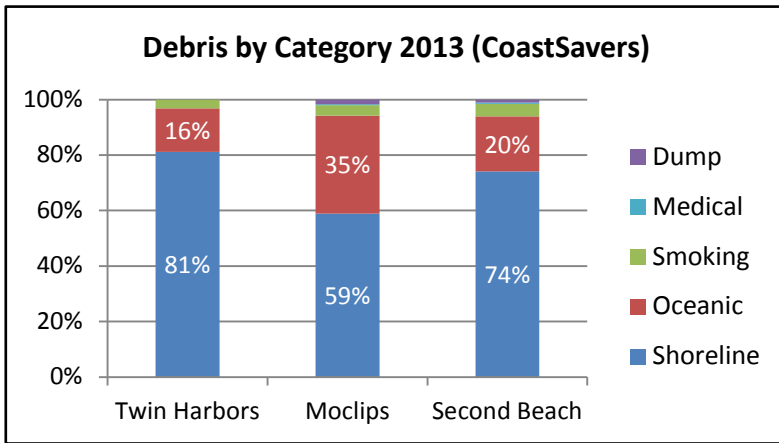


Figure 11 Marine debris by category in 2013 at beaches selected by WWU researchers

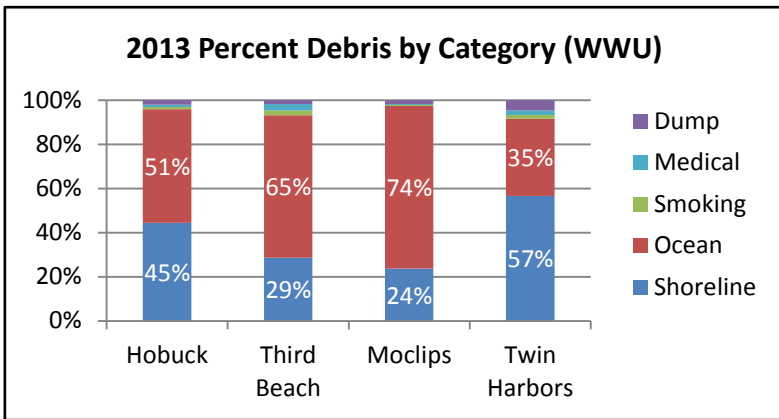


Figure 12 Marine debris by category in 2013 at beaches selected by WWU researchers

During the April 2013 cleanup, WWU volunteers were careful to keep all of their data during the cleanup separate from the CoastSavers volunteers' data. As a result, WWU researchers were able to test the accuracy of some of the CoastSavers Debris Data Card categories (i.e. volunteers estimated weight) using the actual weight data collected by WWU volunteers as a comparison. The separation of datasets also allowed WWU researchers to compare and contrast other variables of the WWU volunteer's data with the data collected by CoastSavers

volunteers, such as piece count.

The results of this analysis were surprising and fascinating. The CoastSavers volunteer's data, as seen in Figure 11, demonstrates a large shift from the historical data in the shoreline debris category. In contrast, the WWU researcher data shows a shift in the oceanic debris category rather than the shoreline debris category (Figure 12). Hobuck did not have any Debris Data Cards returned in the April 2013 cleanup, and therefore is not represented in Figure 11.

The WWU researchers found three out of four of the chosen beaches experienced a significant shift in the oceanic category's number of pieces collected. For example, the percentage of oceanic debris pieces at Hobuck increased from 27 to 51 percent of the total debris collected, Second Beach¹ increased from 34 to 65 percent, and Moclips increased from 36 to 74 percent. The fourth beach, Twin Harbors, did not experience the same shift.

To test whether the four selected beaches are outliers, WWU researchers then compiled the CoastSavers data for all beaches participating in the 2013 beach cleanup and calculated the proportions by debris category (Figure 9). Consistent with the CoastSavers data, the data showed a substantial shift in the shoreline debris category.

To understand the considerable discrepancy between CoastSavers and WWU researcher piece counts, the WWU researchers began considering debris that may have been underrepresented on CoastSavers data cards. During the April 2013 cleanup, WWU researchers and volunteers observed a high number of polystyrene pieces as they categorized debris returned by CoastSavers volunteers. This observation

¹ WWU volunteers were lost and went to Second Beach instead of Third beach. Second Beach and Third Beach are right next to each other, so the data was still analyzed. Second Beach does not have consistent longitudinal data of debris piece counts.

prompted further analysis. WWU volunteers were not certain which category to put polystyrene in, due to the fact that it currently does not fit into any of the existing CoastSavers categories. It was not discussed before the cleanup and therefore researchers used their best judgment choosing a category. Most WWU volunteers put it in the ocean category, but one group of volunteers categorized it in the dump category. In post-cleanup processing of the data, WWU researchers were able to use photos taken by the WWU volunteers to identify and count most of the pieces of polystyrene in the dump category, moving the number of pieces into the ocean category. No change in weight was made.

After examining the comments made on CoastSavers Debris Data Cards, it became evident that CoastSavers volunteers likely did not include polystyrene pieces in any category. This may account for the large shift in oceanic debris that WWU volunteers recorded, compared to the shift in the shoreline category in the CoastSavers data. While CoastSavers volunteers may have not counted polystyrene on their score cards, they were removing it from beaches and handing it over to WWU researchers who did fully count this debris type.



Figure 13 Polystyrene pieces mixed in with other debris in the oceanic category

Although polystyrene does not fit into a debris category, volunteers often noted it in the “Debris Items of Local Concern” category at the bottom of Section 5 of the CoastSavers Debris Data Card. To try and calculate whether there has been an increase of polystyrene since the 3.11 tsunami, WWU researchers calculated the percentage of the debris items of local concern comments mentioning polystyrene in any form (i.e. Styrofoam, foam, etc.) each year since 2009. The results are seen below, in Table 2 (See Appendix 2 for all comments).

Table 2 The number of comments mentioning polystyrene from 2009 to 2013 on the CoastSavers Debris Data Cards

	Number of comments	Comments mentioning polystyrene	% of total comments mentioning polystyrene
2009	38	9	24%
2010	55	16	29%
2011	47	12	26%
2012	29	12	41%
2013	44	22	50%

The percentage of comments before the 3.11 tsunami mentioning polystyrene remains fairly constant, fluctuating between 24% and 29%. After the 3.11 tsunami, the percentages of comments mentioning polystyrene pieces increase to 41% in 2012 and 50% in 2013. This suggests the possibility that there has been a significant increase in polystyrene since the 3.11 tsunami. Logically, this makes sense. For example, NOAA predicted polystyrene to be one of the fastest traveling types of debris due to its buoyancy and light weight. Therefore, it is possible polystyrene traveled across the Pacific Ocean the fastest, resulting in the large shift in 2012 is a result of the 3.11 tsunami, continuing to rise into 2013.

Unlike beverage bottles and other items with tracking numbers and foreign characters, it is impossible to determine the origins of most polystyrene pieces. Most polystyrene pieces had broken off larger pieces and lacked any indication of their original use. See photos below in Figure 14 for examples. Polystyrene is



Figure 14 Biological colonization on polystyrene pieces and other long-range debris at Twin Harbors beach

used for building docks, packing material and constructing houses. Although there was a noticeable amount of polystyrene collected in the April 2013 cleanup, there is not substantial evidence that it originated from the 3.11 tsunami. Rather, it is likely that some of it originated from local sources.

Analysis of Weight and Volume

Analyzing the weight of each category of debris illuminated some historical patterns. Shoreline, dump and oceanic debris make up a substantial portion of the total weight of debris collected at each beach. Oceanic debris is the heaviest category. Because items tend to be small and few, the debris making up the medical and smoking categories does not weigh a significant amount. In general, the smoking and medical categories are the smallest. This may be because beaches along the Washington coast does not have any large populations centers nearby, resulting in less smoking and medical debris.

When comparing category proportions by piece count, the dump category is insignificant (Figure 12). However, when comparing categories by weight, the dump category makes up a significant proportion of total debris (Figure 15). Although the dump category is only made up of a few pieces, a majority of the pieces are large and heavy, like car tires and waterlogged lumber.

The proportion of each categories volume of the total has not been studied in past years. Looking at Figure 16 it is evident that oceanic debris and shoreline debris are by far the largest and most prominent categories of debris in 2013. This is partly due to the fact that the types of items that make up this section are by nature much larger than other categories. For example, beverage bottles are a much larger volume than cigarette lighters.

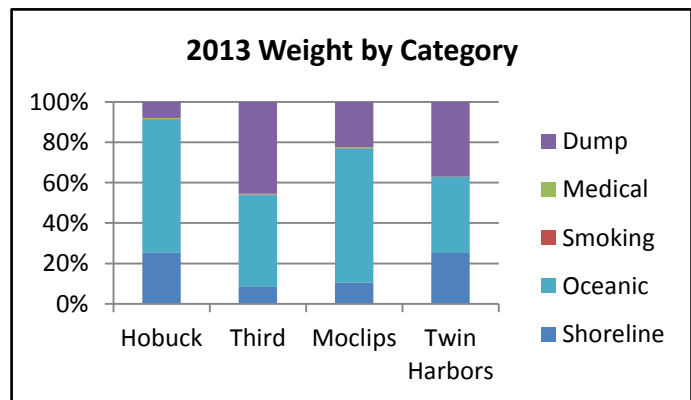


Figure 15 Weight distributions by category in 2013 at beaches selected by WWU researchers

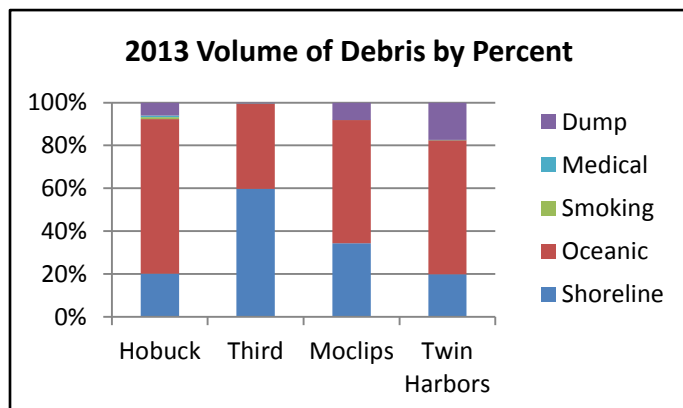


Figure 16 Volume distributions by category in 2013 at beaches selected by WWU researchers

Throughout out the three measurements of debris collected by CoastSavers volunteers – piece count, weight and volume – oceanic and shoreline debris categories consistently dominate.

Analysis of Data Card Accuracy

There are many notable differences between the data collected by CoastSavers volunteers and the data collected by WWU volunteers and researchers from the 2013 CoastSavers beach cleanup. For example, the number of pieces counted and recorded by CoastSavers volunteers is a substantially lower number than recorded by WWU volunteers. As stated above, WWU researchers sorted and counted all debris by category and counted each piece, keeping debris with a Debris Data Card and debris without one separated.

Table 3 Comparison of WWU volunteer debris counts to CoastSaver volunteer debris counts at Moclips Beach

	CoastSavers	WWU	Percent of WWU
Shoreline	101	436	23%
Smoking	0	8	0%
Medical	1	9	11%
Dumping	1	32	3%
Oceanic	12	1347	1%
Total	115	1832	6%

CoastSavers volunteers all filled out the Debris Data Cards to varying degrees of accuracy. WWU

researchers observed some volunteer groups meticulously going through every piece of trash and counting it, while other groups turned in their Debris Data Cards nearly blank or filled out with vague descriptions. For example, instead of using tick marks as the Debris Data Card instructs, many CoastSavers volunteers wrote notes like “lots” or “several” under certain types of debris, like ropes and plastic beverage

bottles.

At Moclips beach, WWU volunteers counted a total of 436 pieces in the shoreline category, 8 in smoking, 9 in medical, 32 in dumping and 1347 pieces in oceanic, as shown in Table 3. The categories total to 1832 pieces of debris collected and counted by WWU volunteers. The Debris Data Cards returned by CoastSavers volunteers state a total of 101 pieces in the shoreline category, zero in medical, one in dump, and twelve in ocean were collected. The CoastSavers volunteer data totals 115 pieces of debris collected compared to the 1832 pieces counted by WWU volunteers. In other words, at Moclips beach, only 6% of the total debris picked up by volunteers using CoastSavers Debris Data Cards was actually recorded on those data cards during the April 2013 cleanup. The vast different between the CoastSavers Oceanic category and the WWU Oceanic category could possibly be because WWU data includes polystyrene pieces, while CoastSavers data may not.

Discussion

The many inconsistencies cleaning the historical data and analyzing the 2013 data have led to more questions than answers. The shifts and changes in data documented above may be significant, or they may not. While analysis showed a noticeable shift between the proportion of pieces in each category between the historic data and the data collected in 2013 by WWU volunteers, several uncontrollable variables may be influencing this shift. The influence of lumber and volunteer mentality is discussed here; other uncontrollable variables may also exist.

Models predict that a large amount of debris from the 3.11 tsunami appearing along Pacific Northwest coastlines will be lumber, originating from collapsed houses and drift wood (Government of Japan, 2013). However, it is unlikely that all, or even a majority, of lumber debris is picked up by CoastSavers volunteers

during any April beach cleanup. Even when lumber is picked up, there is no category to count it on the CoastSavers Debris Data Card, meaning it is either ignored or lumped in with another category.

At some of the remote beaches along the coast, volunteers have to carry all the debris collected a large distance, sometimes a mile or more, to the dumpster where it is processed. Third Beach is a good example of this most lumber WWU volunteers observed was waterlogged and very heavy as a result. The size and weight of some lumber made it challenging for volunteers to transport it to the dumpster. Some volunteers dragged lumber to the dumpster just to show off the impressive weight and size to other volunteers. The few pieces of lumber strong volunteers cleaned up imply that much more lumber remained on the beach.



Figure 17 An example of long-range lumber at Moclips beach

In addition to lumber being large and heavy, it does not necessarily look like anthropogenic or tsunami debris. Unlike plastic and polystyrene, lumber blends in well with the coastline environment. Washington beaches are characteristically strewn with drift wood. Beach cleanup volunteers may not be as motivated to pick up lumber that looks like drift wood as opposed to shiny plastic covered in biological colonization.

It is highly probable that substantial lumber debris, both of local and tsunami origins, remains on the beach during cleanups. As such, the category of dump, into which lumber is sorted, may under represent actual dump debris on the coastline. Historic data in the dump category likely also does not represent actual debris levels. Similarly, April 2013 data in the dump category likely underrepresents, perhaps substantially so, the lumber on the beaches originating from the tsunami.

A secondary uncontrollable variable is the volunteers collecting debris. As WWU volunteers spoke with the citizen volunteers dropping off their beach debris, it became evident a large portion of the volunteers were people who had not planned on attending the beach cleanup event. Many of the volunteers were citizens on their routine walks along the beach who became aware was occurring and decided to participate.

The type of people participating in these cleanup events or the training provided for data collection may significantly affect the integrity of data collected. WWU volunteers spoke to beach cleanup volunteers returning from picking up debris and a couple common mentalities emerged.

Many volunteers expressed that they were not interested in filling out a Debris Data Card, simply wanting to pick up trash. There are no historical records about how many people picked up debris in addition to the ones that filled our Debris Data Cards. Historically, there may have been a substantial amount more debris collected than is documented.

Volunteers were also keen on keeping interesting debris personally. Of special interest was debris with foreign characters that looked as though it had travelled a long distance. Consequentially, debris from the 3.11 tsunami may not make it to the hands of researchers because citizens are keeping it as their own without reporting it to authorities.

The Data Debris Cards have different lines within each category for each category of debris (for example, plastic beverage bottles). In many cases, volunteers would document the first instance within a category of debris, but then not all cases afterward. For certain abundant items, like plastic beverage bottles, this means that considerably less than actually occur is being documented. As a result, the Debris Data Card is a

better representation of the spectrum and range of debris categories rather than the actual piece count of debris within each category.

The CoastSavers April cleanup occurring each year is just one of many beach cleanups that occur along the coast. Some cleanups are organized by established organizations such as the Surfrider Foundation. However, many more cleanups occur sporadically throughout the year by individuals or unofficial cleanups. As a result, the CoastSavers data may be skewed if other cleanup efforts took place recently. The un-organized cleanups happen with little geographic consistency, with a high variability along the coast. It may be argued that Washingtonians are embedded with an innate sense to “keep our beaches clean”, resulting in inconsistent data but considerably cleaner and more pristine beaches.

In addition to the un-organized cleanups occurring over the years, Washington coastlines have received an increase in media attention since the Japanese earthquake and the 3.11 tsunami which have prompted more people to head out to the beach in search of Japanese artifacts. While some people may report what they find, others do not.

Items found with Asian characters could still have local origins, too. Washington has many Asian grocery stores and other stores that carry Asian products. Therefore, assuming that an item with Korean characters on it is from Korea may not be accurate.

Because of the unavoidable inconsistencies in historic and 2013 data, concluding whether or not the tsunami debris has affected the weight of debris being picked up in the April beach cleanup remains somewhat speculative.

Implications and Future Work

The CoastSavers Debris Data Card is successful at measuring certain variables of marine debris, but not others. It is most successful at measuring the range of debris categories collected. It is unsuccessful at measuring the exact piece count within each category. Many times, volunteers documented the first cases of debris but then did not record every piece afterward. This was particularly common for larger categories, such as beverage bottles, because there were so many of them.

If CoastSavers is trying to gauge a well-rounded picture of the categories of marine debris coming off the beach, the current Debris Data Card is sufficient. However, if the resulting data is being used for further analysis, especially analysis of piece count or weight by debris category, then the current data collection strategy may not be sufficient. Several potential changes are proposed here:

One potential useful change to the Debris Data Card would be adding a category or subcategory for polystyrene. Establishing a system for measuring and documenting the amount of polystyrene coming off Washington beaches would eventually provide enough baseline data for comparison, allowing researchers to quantitatively analyze whether or not a shift has occurred after tsunami events.

Another type of marine debris that is not accurately being accounted for is debris that is too large or heavy for volunteers to carry off, such as waterlogged lumber. A way to document this type of debris would provide information about the marine debris that is not leaving the beach.

While adding these categories would be beneficial, if officials need accurate data about marine debris piece counts and other variables, WWU researchers recommend a different approach of data collection.

WWU researchers recommend drastically reducing the use of the Debris Data Card. Instead of having each volunteer group fill out and return the Debris Data Card, the first volunteer who arrived at the cleanup site in the morning would be provided a Debris Data Card to use. This volunteer would not pick up debris on the beach, but rather walk a set amount of distance while documenting each item of debris present or until the Debris Data Card is full. Heavy or large items that cannot be removed would also be documented.

After documenting all the debris within a predetermined distance along the beach, the volunteer would count their paces walking straight back to the volunteer station and record their height. This would allow researchers to estimate more accurately the distance of shoreline documented. This strategy provides a sample of each beach and accurate data about the proportions of debris collected.

If funds can be found, the research team plans to return to the sites in September 2013 for the 28th Annual International Coast Cleanup. Debris from Japan will have been blown further by westerlies in the Pacific, providing the team with another opportunity to explore how long-range debris on the Washington coast is changing. The team would use both the data characterization method used in April 2013, as well as the walk-the-beach method proposed here.

Returning to the coast and cataloging another cleanup worth of debris will allow the research team to compare the September data with the April data as well as historical data, providing more context for this issue. It will also better bring to light whether the change in debris proportions is due to the change in methods from CoastSavers volunteers to WWU volunteers or whether it is due to the 3.11 tsunami.

Works Cited

Carlton, J.T. (3 Feb, 2013). *Tsunami Floating Dock: Misawa 3*. JTMD-BF-8. Olympic National Park. Retrieved on 4/13/2013 from Oregon State blogs at <http://blogs.oregonstate.edu/floatingdock/>

Cole, M. (2013). Microplastic ingestion by zooplankton. *Environmental Science and Technology*.

Derraik, J. G. (2002). The pollution of the marine environment by plastic debris: a review. *Marine pollution bulletin*, 44(9), 842-852.

Government of Japan, Ministry of the Environment. (2013). *Estimation of trajectory of 3.11 tsunami debris by running simulation models*. Retrieved from website:
http://www.kantei.go.jp/jp/singi/kaiyou/hyouryuu_eng.html

Ministry of the Environment, Government of Japan. (2013). *A report on forecasts of tsunami debris location*. Retrieved on 4/13/2013 from Government of Japan website
<http://www.kantei.go.jp/jp/singi/kaiyou/hyouryuu/pdf/gaiyou.pdf>

National Oceanic and Atmospheric Administration. (2013). *When will the debris from the tsunami in Japan reach the U.S.?* Retrieved on 4/13/2013 from NOAA website
http://marinedebris.noaa.gov/tsunamidebris/debris_model.html

D.G. Shaw, R.H. Day. (1994). Colour- and form-dependent loss of plastic micro-debris from the North Pacific Ocean. *Marine Pollution Bulletin*, 28, 39–43.

Washington State Military Department, Emergency Management Division. (2012). *Marine debris response plan: September 2012*. Retrieved from website:
http://marinedebris.wa.gov/docs/responseplan_marinedebris.pdf

Appendix 1 2012 CoastSavers Debris Data Card



Debris Data Card

Year-round Collection

Section 1: Getting Started

Thank you for helping to clean up Washington’s Pacific Coast!

The data you collect while cleaning the beach is invaluable to our efforts; helping us educate public, business, and government officials about the scale and serious consequences of marine debris on our coast. This data will also be shared with the Ocean Conservancy to further their efforts to address marine debris on a global scale.

What to Do With This Information

As you and your team are cleaning the beach, please record the types and quantities of debris you remove. After the Cleanup, transfer your findings to our online debris database right away:

www.coastsavers.org/debrisdata

Section 2: Cleanup Site Information

1. What is the date of the cleanup? _____
2. Which beach are you cleaning up? _____
3. How many people are you reporting for? _____
4. Approximate distance cleaned (in miles): _____
5. Number of trash bags filled: _____
6. Total estimated weight collected (in pounds): _____
7. Estimated time spent cleaning up the beach (in hours): _____

Section 3: Contact Information (Each Individual Team Member):

1. Name: _____ Email _____ Address: _____
2. Name: _____ Email _____ Address: _____
3. Name: _____ Email Address: _____
4. Name: _____ Email Address: _____

Section 4: Entangled Animals

List all entangled animals found during the cleanup. For each animal found, record the following information: type of animal; status (alive/released or dead); type of debris it was entangled in (fishing line, fishing nets, balloon string/ribbon, crab/lobster/fish traps, plastic bags, rope, six-pack rings, wire, or other items.)

Type of Animal	Status (Alive/Released or Dead)	Type of Debris Entangled In

Section 5: Items Collected

1. What was the most peculiar item you collected? _____

NOTE: Please pick up ALL items that you find. Only record information for the items listed below. Keep a count of your items using tick marks and enter the item totals in the box:

Example: 12 Beverage cans: |||| |||| ||

2. Shoreline Recreational Activities.

	Bags (Paper): _____		Cups, Plates, Forks, Knives, Spoons: _____
	Bags (Plastic): _____		Food Wrappers/Containers: _____
	Balloons: _____		Pull Tabs: _____
	Beverage Bottles (Plastic): _____		6-Pack Holders: _____
	Glass Beverage Bottles: _____		Shotgun Shells/Wadding: _____
	Beverage Cans: _____		Straws, Stirrers: _____
	Caps, Lids: _____		Toys: _____
	Clothing, Shoes: _____		Fireworks: _____

3. Ocean & Waterway Activities.

	Bait Containers/Packaging: _____		Fishing Nets: _____
	Bleach/Cleaner Bottles: _____		Light Bulbs/Tubes: _____
	Buoys/Floats: _____		Oil/Lube Bottles: _____
	Crab/Lobster/Fish Traps: _____		Pallets: _____
	Crates: _____		Plastic Sheeting/Tarps: _____
	Fishing Line: _____		Rope: _____
	Fishing Lures/Light Sticks: _____		Strapping Bands: _____

4. Smoking-related Activities.

	Cigarettes/Cigarette Filters: _____

	Cigarette Lighters: _____
	Cigar Tips: _____
	Tobacco Packaging/Wrappers: _____

5. Dumping Activities.

	Appliances (refrigerators, washers, etc.): _____
	Batteries: _____
	Building Materials: _____
	Cars/Car Parts: _____
	55-Gal. Drums: _____
	Tires: _____

6. Medical/Personal Hygiene.

	Condoms: _____
	Diapers: _____
	Syringes: _____
	Tampons/Tampon Applicators: _____

7. Debris Items of Local Concern.

Identify and count 3 other items found that concern you:

	Yellow Poly Rope, 6-12 inch pieces

Appendix 2 "Debris of Local Concern"

Recorded on CoastSavers Debris Data Cards, 2009-2013

2009	2010	2011	2012	2013
firework pieces - 4	broken glass	Medical syringe - the park ranger disposed it.	Styrofoam	aerosol can
broken glass	old fence	Kite String	Styrofoam	broken fiberglass step with STYROFOAM
dead dog	pieces of styrofoam	styroform	styrofoam	STYROFOAM pieces
13 Fireworks plastic	Many, many broken bits of plastic	net balls that were left	Large pieces of white styrofoam	Cardboard
syringe	Gas Can	lots of small pieces of plastic, continually breaki	windex tin can	Huge white tarp 1/2 buried in front of Quin Casino
1 flourescent light blub		1" plastic pieces, mostly blue	Styrofoam	various size STYROFOAM
2 styrofoam blocks	Plastic bags of diapers	tires	chunks of styrofoam	STYROFOAM chunks and big floats
clumps of paper towel used as toilet paper		Styrofoam bits	styrafoam pieces	Much, much STYROFOAM of all size up to 1 cu ft
32 small hard plastic pieces	the usual pieces of yellow rope (less this year)	Nerdles	oil blob (small, but sticky)	big piece STYROFOAM
4 heavy plastic circular items, 12" diameter, we didnt know what they were	none other than above	Styraphom	pink paint ball	STYROFOAM chunks
fireworks debris	possible aluminum phosphide container (glass bottle however)	3 gal heavy plastic container - unsure of contents	propane tank	long 50 ft rope
Clear plastic firework parts 30	Gas bottle	fire extinguisher	small bits of plastic	STYROFOAM bits
6 inch pieces of nylon rope by the hundreds	barbecue	Styrofoam, various pieces	heavy wire/cable 6" to 12"	STYROFOAM
4' flourescent light bulb	partially buried nets	broken glass, near 'people use' areas	foam	Lots of STYROFOAM this year
2 Cargo Netting	Styrofoam pieces	Galvinized Metal	tire tread	foam chunks, raisin to thumb size
4 huge chunks of	gas can with fuel	styrofoam	gas cans	melted car part

styrofoam		chunks		
Styrofoam packing pieces – multitudes of them	hard keeping track of everything with the rain! Sorry	Styrofoam bits	Large styrofoam, garbage bag size or bigger	twine
9 pieces (VERY large to few very small) Styrofoam	Iron ploes	Motor Oil	Blue Rope 6"-12"	STYROFOAM
10 spent pastic firework parts	styrofoam-ubiquitous	large chunks of styrofoam	chunks and bits and pieces of styrofoam	random plastic
1 plastic bucket	pieces of styrofoam	of pieces of plastic, broken by waves	thick foam rubber	dog feces in bag
hubcap -	thumbnail-sized pieces plastic & foam	tent	Large pieces of hard yellow foam - insulation?	lots of STYROFOAM
condom	countless chunks of styrofoam	toilet paper in the parking lot	misc.plastic pieces	STYROFOAM
2 plastic bins	one 3gallon plastic jug	Bird	paint ball caps	large STYROFOAM chunks
board with rusty nails	pieces of styrofoam	carpet	broken glass bottles	20-gallon propane tank (full)
9 chunks styrofoam	Fiberglass shards scattered around Sand Point South	syringes were turned over to beach rep for special	plastic bags	Polystyrene everywhere (about half of our garbage)
boards with nails	Mainly the netting	styrofoam pieces	couch cushion	large STYROFOAM float
Countless bits of debris from fireworks	dead seal just north of Point of Arches (not entangled)	Pillow	"Biological liquid maritime toilet cleaner"	shaving cream can
3 Large Styrofoam Blocks	many shards of plastic- unidentifiable source	piece of a boat propeller	film canisters	lots of STYROFOAM pieces
TONS of small chunks of styrofoam and hard plastic	Large Styrofoam - 50% of what we collected was styrofoam pieces - most at least 6 inches square, some 1.5 ft square	rope	Small styrofoam pieces	bits of plastic
1 propane cylinder	fishing seine	heavy plastic cooler lid		HUGE amt hotel garbage on Quin Casino beachfront
20 small pieces of styrofoam	Pieces of styrofoam	large chunks of styrofoam		assorted plastic items
unidentified sytrofoam pieces				

	Chunks of plastic	Plastic, various pieces		black plastic building block
nails	large tarp	Fiber Glass		bits STYROFOAM
wire hangar fashioned into marshmallow roaster	all the little pieces of plastic	misc. hard plastic		filters
Telephone	Large plastic net bags	Coleman fuel canister		thumbnail size pieces of hard plastic
fish hooks, croc shoes (it was just a matter of time)-9	anti-freeze	Small Pieces of Plastic		refrigerator
3 Korean aquaculture spacers	partially buried tent	large molded piece of plastic		lots of small STYROFOAM
25 small pieces of plastic	Plastic pieces	confetti guns		toothbrush
	styrofoam	hot dog		pieces of STYROFOAM
	blankets!	paint can		Plastic pieces
	large styrofoam cooler	8" black plastic hose		deflated basketball
	one gutter 1.5 ft x 3inch diameter black plastic	pieces of styrofoam, all sizes		STYROFOAM pieces
	Rusted cube as big as a closet at Ericsons Bay Trail	Electrical Wiring, various pieces		
	many pieces of styrofoam-unidentifiable source	Easter eggs		
	Styrofoam was the type used under floating docks, NOT for food items.	Styrofoam		
	Boards with protruding nails	moderately sized styrofoam		
	front half of TV	Burned out drift wood		
	the garbage left by the clammers - lots at the waterline			
	Pieces of wood with nails			
	fish nets			
	5-gallon bucket			

	pieces styrofoam in numerous small sizes			
	So much styrofoam, breaking apart into little pellets			
	small tire (from a child's wagon?)			
	Styrofoam - hundreds of small pieces on beach			