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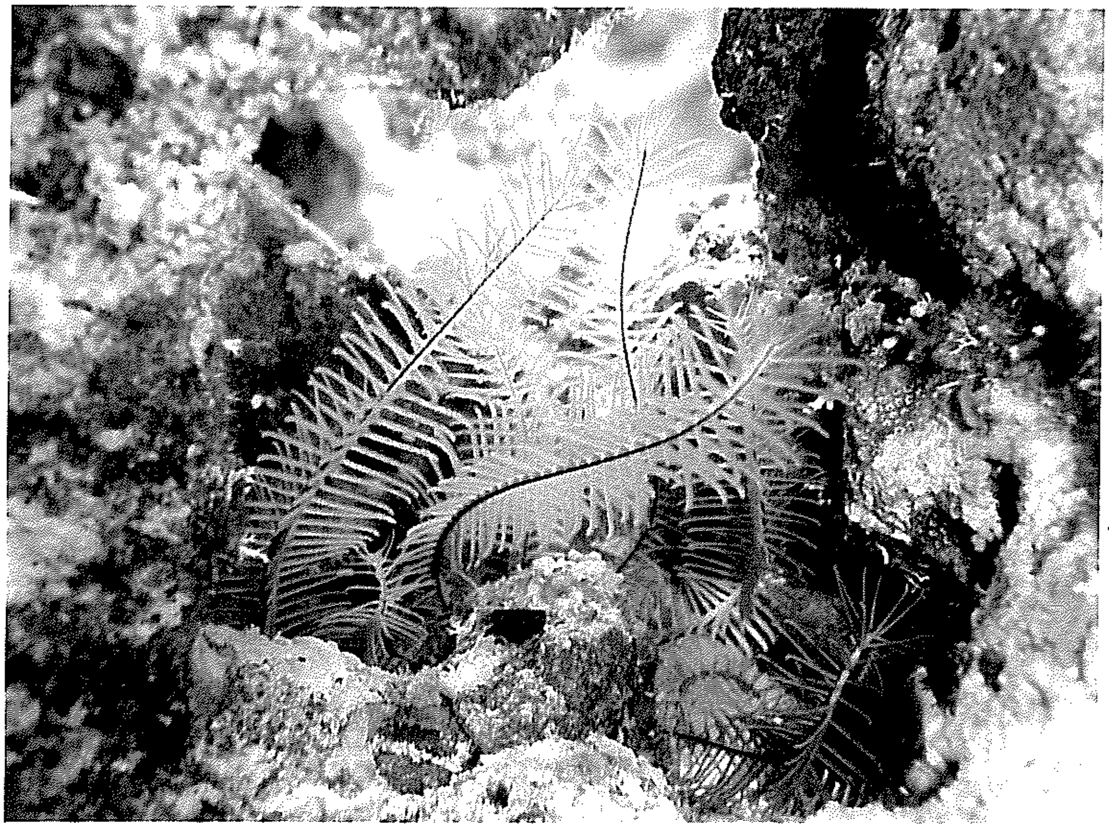

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MARINE ANTHROPOGENIC DEBRIS SURVEYS ON HANNA BAY AND EAST BEACHES, SAN SALVADOR ISLAND, BAHAMAS, 1998-2004

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ABSTRACT

Measurements of marine debris accumulation were carried out on the same sections of Hanna Bay Beach in January 1998, 2000, and 2004, and June 2004 and a section of East Beach in January 2002. Debris was collected along 50-m beach transects. Individual pieces were sorted by material category and weighed. The width of transects varied from 3 to 10 m depending on the width of the backshore debris distribution zone. Hard plastic was always the dominant material present followed by glass, polystyrene foam, and metal. Large pieces of wood and fishing gear were present in the debris but were not measured or counted in the comparisons.

The average · kg/m^2 of debris was calculated for each survey using a combined weight of hard plastic, glass, polystyrene foam, and metal. The average kilograms of combined materials/meter of beach (kg/m) was also calculated, as well as a value for just hard plastic. We found the average kg/m measurement to be the best statistic for comparative purposes. The range from our surveys for total marine debris was 0.19 to 0.72 kg/m. These values fall within the range of 0.034 to 1.11 kg/m determined in 2002-2004 surveys conducted in various places by the Ocean Conservancy Coastal Cleanup program and the South Carolina Sea Grant program. Our hard plastic value range was 0.14 to 0.43 kg/m. Given that hard plastic typically is the dominant material found in most surveys, this statistic alone may be the best for comparative analyses.

Hurricane Isabel passed close to San Salvador in September 2003 and removed much of the marine debris from the island's windward-coast beaches. Our Hanna Bay Beach surveys of January 2004 and June 2004 permitted determination of rates of marine debris accumulation over four- and five-month periods of "normal" weather conditions. The total marine debris deposition rates for the two periods were 0.078 and 0.082 kg/m/month, and hard plastic rates were 0.048 and 0.045 kg/m/month.

Observations in January 2005 following Hurricane Frances indicated that much marine debris ends up in the dunes following storms. Storms also rework marine debris by erosion of dune areas. The ultimate fate of hard plastic debris is of some concern and is unknown. We did not find micro plastic debris (< 2 cm) in a preliminary survey of beach samples. This study provides baseline data and rates for the accumulation of marine debris on San Salvador's windward beaches, and for comparison with similar studies in other areas. The scope and gravity of the marine debris problem worldwide warrant continuation of such studies on San Salvador Island and elsewhere in the Bahamas.

INTRODUCTION

"Trashed – Across the Pacific Ocean, plastics, plastics, everywhere" is the title of a recent and provocative article by Charles Moore (2003) on the increasing occurrence of floating marine debris on the world's oceans. Moore reports that the problem is particularly acute on the ocean's subtropical gyres. These represent twenty-five percent of the Earth's surface area

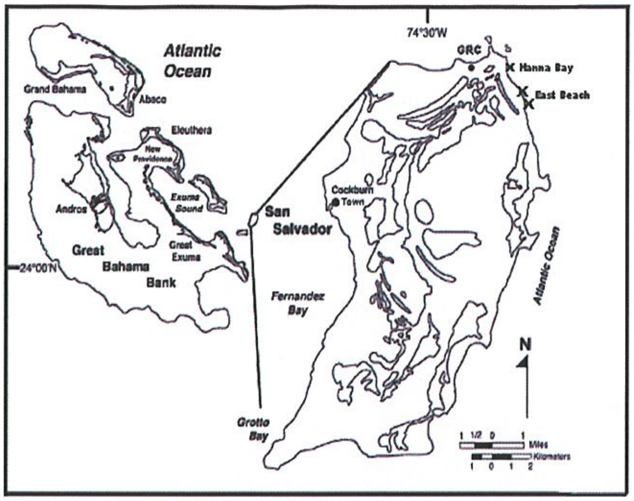

Figure 1. Index map for San Salvador and the location of debris surveys at Hanna Bay Beach and East Beach on the northeast coast of the island.

and which, today, are modern accumulators of floating plastic debris. Where does the marine debris end up? What is the ultimate fate of plastics and what are the effects on the marine ecosystem and beyond? These are big and important questions. One thing we do know is that considerable quantities of marine debris ultimately wash up on the coastlines of the world, be they populated or remote.

The beaches of San Salvador Island, which are lightly developed to undeveloped, are a case in point and the subject of this report. Even the most casual observer visiting the east coast beaches of San Salvador will notice, and commonly be shocked by, the large quantities of anthropogenic debris on these beaches. This debris is of marine origin with no significant contribution from the island's communities.

In an interesting preliminary study of marine debris on the beaches of Blanket Sound on Andros Island, Brown and Spotswood (1998) discuss, at some length, the problem of marine debris on Bahamian beaches and the potential negative effects. The general observations and findings of the Andros study in terms of types and composition of debris materials are similar to what we report in this study.

San Salvador Island lies atop an isolated carbonate platform about 620 km ESE of Miami, Florida, at the eastern edge of the Bahama Archipelago (Figure 1). The windward eastern coast of the island faces the open western North Atlantic Ocean and receives the full wind and wave effects of the prevailing easterly trade winds. Offshore, the Antilles Current, part of the North Atlantic circulation gyre, sweeps northwestward along the eastern margin of San Salvador. The currents of the gyre transport floating marine debris toward San Salvador in waters that pass the Lesser Antilles Islands, Puerto Rico, Hispaniola, and much more distant points.

A preliminary survey of marine debris on San Salvador's beaches conducted in 1996 (Alter et al., 1999) identified the beaches of the northeastern corner of the island as the locations with the greatest accumulations of debris. Hanna Bay Beach and East Beach (Figure 1), the survey sites of this study, are within the reach of coast most heavily impacted by marine debris. The photographs in Figure 2 illustrate the general characteristics of the beach at Hanna Bay. East Beach has similar characteristics and appearance, although it is generally wider. See Brill et al. (1993) for a more complete discussion of East Beach, which is representative of the sediment dynamics operative on San Salvador's east coast beaches.

The initial goal of our surveys was to gather data to establish a baseline description of the types and amounts of debris accumulating on San Salvador's windward beaches as an indicator of the magnitude of the marine debris problem on outermost Bahamian islands. A second goal was to design a protocol for the rapid quantitative assessment of marine debris on a section of a beach such that an increase or decrease in deposition of debris might be recognized over a period of time. Surveys to accomplish these goals were carried out in January 1998, 2000, and 2002.

On September 16, 2003, Hurricane Isabel passed by the island and cleaned San Salvador's windward beaches of debris (pers. comm. with GRC staff members). This provided the opportunity for a January 2004 survey at Hanna Bay Beach to collect and measure debris

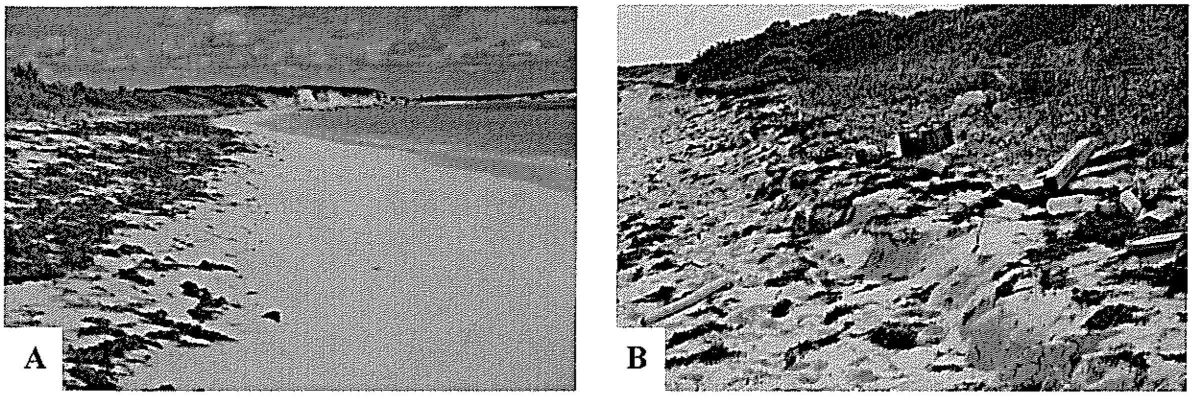

Figure 2. A) Survey areas at Hanna Bay Beach with Site 2 in the foreground and Site 1 farther down the beach (north) adjacent to the Hanna Bay cliffs. B) Marine debris at Site 1; on the windward coast of San Salvador, storms tend to move even large items of debris across the narrow beaches and into the proto-dune and primary dune areas as shown here.

deposited over a four-month interval of deposition under normal weather conditions. A repeat survey was made at Hanna Bay Beach in June 2004 after a further five months of debris deposition. This survey yielded data for comparison of the rate of debris deposition at a single site within the same year.

METHODS

Our primary soource for establishing a protocol for the marine debris surveys of this study was the NOAA Marine Debris Survey Manual (Ribic et al., 1992, Chapters 1 and 4). To facilitate comparison of the data collected for this study with past and future studies, we followed the guidelines of the NOAA Manual in our surveys to the fullest extent possible, while making minor modifications to accommodate our logistical limitations and to fit the particular conditions presented by the San Salvador beach study areas.

Two schemes of classification of marine debris are outlined in the NOAA Manual (Table 3, p. 8). One is based on classifying the material composition of debris items, e.g. hard plastic, foam plastic, glass, wood, rubber, metal, cloth, paper, etc. The other classifies the functional use of each item of debris, e.g. fishing gear, domestic use, industrial use, medical use, etc.

In our surveys, we classified all mega-debris items (>2-3 cm in size) encountered along and within the area of our transect lines. We did not find significant amounts of rubber, cloth, or paper. Large pieces of wood and fishing gear deeply buried in the sand could not be removed and were not evaluated and included in our tabulations. Likewise, we found determination of functional use to be either obvious or obscure, so we did not use this mode of classification in any systematic way.

In all studies, debris pieces larger than 2-3 cm (mega-litter) were collected and sorted into four material categories: hard plastic, polystyrene foam, glass, and metal. Smaller fishing gear items and synthetic rubber-type shoes composed of hard plastic or polystyrene foam were added to the appropriate material category.

The material categories of identification of marine debris items of this study are:

1 *Hard plastic*, including the following polymers:
  •Polypropylene: PP (e.g. bottle caps, battery cases, outdoor carpeting, rope or line, fishing net, etc.).

•Polyvinyl chloride: PVC (e.g. light sticks, pens, "bubble" package wrap, plumbing pipe, garden hoses, etc.).
•Low density polyethylene: LDPE (e.g. plastic bags, toys, electrical insulation, etc.).
•High-density polyethylene: HDPE (e.g. milk and water jugs, cups, etc.).
•Polyethylene terephthalate: PETE (e.g. liquor and soft drink bottles, audio/video tape, fleece clothing, etc.).
•Nylon 6.6 (polyamide): (e.g. carpet fibers, fishing line, home furnishings, clothing, etc.).

2 *Polystyrene foam*: PS - was counted separately in our surveys since its low weight (and low density) due to trapped air content does not truly reflect the quantity of foam trash on the beaches (e.g. buoys, fishing floats, packing materials, etc.).
3 *Glass*: (e.g. bottles, light bulbs, etc.).
4 *Metal*: (e.g. aluminum soda cans, copper piping, brass fittings, etc.).

The transects for the surveys of this study were all taken in the beach backshore zone and were 50 m in length. Transect widths varied from 3 to 10 m, depending on the pattern of distribution of marine debris at the particular transect site. Dates, locations, and sites on location of the surveys are given in Table 1.

Since many of the debris items were fragmented, the classification of marine debris in our surveys was by material and weight, not by number of items or item utility. The debris in each category was weighed and compared among the sites of each survey. The amount of marine debris relative to beach surface was calculated in two ways, by average kg/m^2 and by average kg/m.

		Site 1: (high debris deposition)	Site 2: (low debris deposition)	Site 3: (high debris deposition)
Jan. 1998	Hanna Bay Beach	50 x 10 m	50 x 10 m	n/a
Jan. 2000	Hanna Bay Beach	n/a	3 x (50 x 3 m)	n/a
Jan. 2002	East Beach	n/a	n/a	50 x 3 m
Jan. 2004	Hanna Bay Beach	50 x 8 m	50 x 8 m	n/a
June 2004	Hanna Bay Beach	50 x3 m	50 x 3 m	n/a

Table 1. Dates, locations and sites of the marine debris surveys of this report. "High debris deposition" indicates surveys with a high volume of marine debris and "low debris deposition" refers to surveys with low volumes of debris.

RESULTS

The marine debris items accumulating in the survey areas on Hanna Bay Beach and East Beach could be sorted reliably into our four cate gories of material. Plastic items of various material compositions dominated the debris both in total numbers of items (not reported) and by weight, followed by glass, polystyrene foam,and metal (Table 2 and Figure 3). Only small numbers of items of miscellaneous materials were found, and these were not weighed.

As stated earlier, identification of debris items into categories of functional use proved problematic so this was not done systematically. However, we can say that the great majority of the marine debris items encountered in our surveys appear to be from shipboard trash, with lesser amounts being parts of fishing gear or ships and boats. Furthermore, most debris items had lost identifying labels due to exposure to the elements or were fragmented, so we did not make a rigorous assessment of countries of origin, but our casual observations indicated a wide spectrum of manufacturing production points, from Europe to North and South America, the Caribbean region, and Asia.

The measurements of total quantity of marine debris by weight collected from the different surveys varied considerably, with the greatest quantity of material collected during

	Hard Plastic (kg)	Poly Foam (kg)	Glass (kg)	Metal (kg)	Total (kg)
Jan-98	42.9	8.20	15.9	4.80	71.8
Jan-00	21.4	0.14	6.3	0.62	27.9
Jan-02	10.9	3.60	16.8	0.45	31.8
Jan-04	19.2	4.50	6.4	0.47	30.6
Jun-04	18.2	9.00	9.5	4.20	40.9

Table 2. Quantities by weight of the four material categories of marine debris collected in the survey areas. All measurements in kilograms. The January 2002 survey was on East Beach. All other surveys were on Hanna Bay Beach, with Site 1 and Site 2 measurements combined.

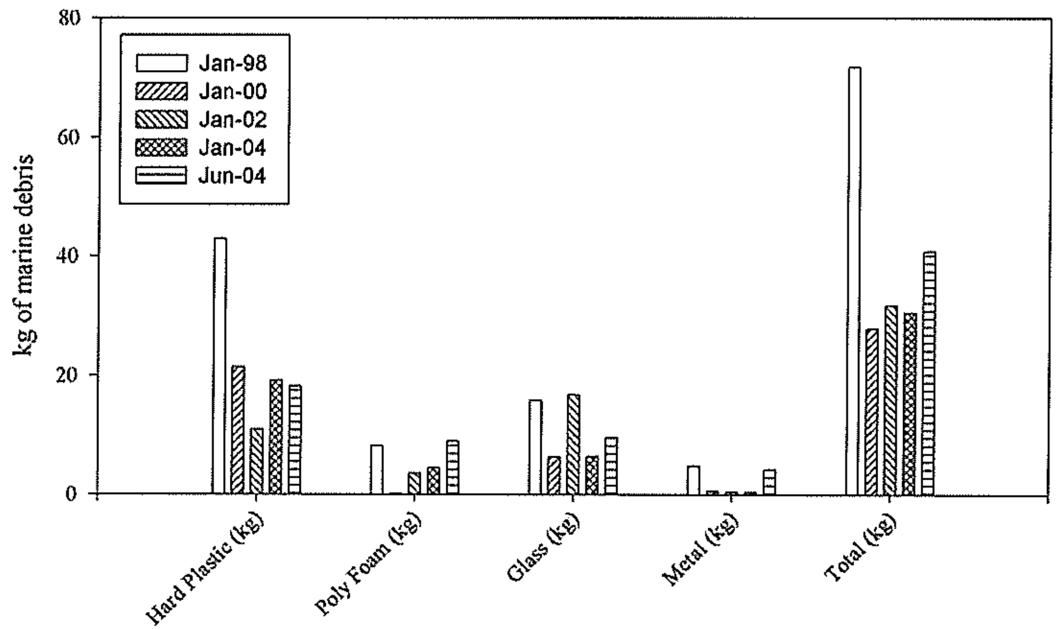

Figure 3. Composite histogram to compare the quantities by weight of the marine debris categories among surveys. Total kilogram weights for the material categories are given at right.

Surveys	Total Area of Beach Sampled - m^2	Hard Plastic kg/m^2	Poly Foam kg/m^2	Glass kg/m^2	Metal kg/m^2	Total kg/m^2
Jan. 1998 Hanna Bay	1000	0.043	0.0082	0.016	0.0048	0.072
Jan. 2000 Hanna Bay	450	0.048	0.00031	0.014	0.0014	0.048
Jan. 2002 East Beach	150	0.073	0.024	0.11	0.0030	0.21
Jan. 2004 Hanna Bay	800	0.023	0.0056	0.0080	0.00059	0.038
June 2004 Hanna Bay	300	0.061	0.030	0.032	0.014	0.14
		Range: 0.023 – 0.073 kg/m^2	Range: 0.00031 – 0.030 kg/m^2	Range: 0.0080 – 0.11 kg/m^2	Range: 0.00059 – 0.014 kg/m^2	Range: 0.038 – 0.21 kg/m^2

Table 3. Tabulation of the four material categories of marine debris in the survey areas by kg/m^2.

	Length of Beach Sampled - m	Hard Plastic kg/m	Poly Foam kg/m	Glass kg/m	Metals kg/m	Total kg/m
Jan. 1998-Hanna Bay (Site1, high deposition + Site 2, low deposition)	50+50	0.43	0.082	0.16	0.048	0.72
Jan. 2000-Hanna Bay (Site 2, low deposition)	150	0.14	0.00093	0.042	0.0041	0.19
Jan. 2002-East Beach (area of high deposition)	50	0.22	0.072	0.24	0.009	0.64
Jan. 2004-Hanna Bay (Site 1, high deposition + Site 2, low deposition)	50 +50	0.19	0.045	0.064	0.0047	0.31
June 2004-Hanna Bay (Site 1, high deposition + Site 2, low deposition)	50+50	0.18	0.090	0.095	0.042	0.41
		Range: 0.14 – 0.43 kg/m	Range: 0.00093 – 0.090 kg/m	Range: 0.042 – 0.24 kg/m	Range: 0.0041 – 0.048 kg/m	Range: 0.19 – 0.72 kg/m

Table 4. Tabulation of the four material categories of marine debris in the survey areas by kg/m.

our first survey in January 1998 (Table 2). This survey also represented our largest area of collection (see Table 3), so Table 2 does not present a valid comparison of total quantity of material from survey year to survey year. Rather, the more meaningful comparisons to be made from Table 2 and Figure 3 regard the types of materials accumulating at the survey sites from year to year. Here we see that hard plastic is the dominant material by weight followed by glass, poly foam, and metal. The exception was the January 2002 survey at East Beach where glass was the largest material category.

In terms of distribution of debris, we observed that different areas of a given beach clearly had zones of high volume deposition and zones of lower deposition. For instance, the northern section of Hanna Bay Beach close to the cliffs (our Site 1, see Figure 2) is an area of high volume deposition whereas the more open central section of this beach (Site 2) has a lower volume of deposition. High and low volume depositional areas also were noted along East Beach, where we surveyed only the high deposition area. These differences undoubtedly result from the variable effects of waves and currents on any given beach. Zones of high volume deposition typically reflect prevailing wave refraction and longshore current patterns that over time, tend to concentrate floating debris on a given section of beach with time.

Table 3 presents a better comparative measure for the debris collections of our surveys because it eliminates area of survey variability. Here we compare total weight of debris per m^2 for each survey area and kg/m^2 for the categories of debris for each area. Our measured range of debris in kg/m^2 was 0.038 kg/m^2 in January 2004 (post Hurricane Isabel) at Hanna Bay Beach to 0.21 kg/m^2 at East Beach (high deposition area) in January 2002. For categories of material, the same pattern holds as reported earlier, with hard plastic being the dominant material in kg/m^2 for all surveys except at East Beach.

The variability in width of our transect surveys resulted solely from the pattern of debris distribution in the given survey area, regardless of whether the debris had a wide zone or narrow zone of distribution on the beach berm. In either case, all of the debris was collected, categorized, and weighed. Table 4 presents our tabulations in kilograms per meter of beach transect. In many ways, we think this is the simplest and most meaningful measurement to make for surveys of this type. This is the standard of most previous studies and

	Surveyed Coastline in km	Total Weight of Marine Debris in kg	Marine Debris in kg/m
Virgin Islands 2002	37.1	12,025	0.325
British Virgin Islands 2003	11.0	2,011	0.183
Puerto Rico 2002	85.3	94,633	1.11
Florida Coastline			
2002	3,885	269,935	0.065
2003	2,691	283,495	0.106
South Carolina Coastline			
Sept. 21, 2002	246	14,064	0.057
Sept. 20, 2003*	250	12,781	0.051
Sept. 18, 2004	270	9,263	0.034
Bahamas 2003**	50	7,030	0.141
For all surveys above	n/a	n/a	0.034 – 1.11
Bahamas – this study	n/a	n/a	0.19 – 0.72

*This South Carolina survey made four days after Hurricane Isabel. **This survey elsewhere in the Bahamas, not on San Salvador.
http:/www.scseagrant.org/education
http:/www.coastalcleanup.org/conservation.cfm (both sites accessed March 2005)

Table 5. Comparative marine debris data from surveys of the Ocean Conservancy Coastal Cleanup Program 2002-04, the South Carolina Sea Grant Program (both Anonymous, 2004), and this study.

permits ready comparisons with those studies. Table 4 shows a total debris materials range of 0.19 to 0.72 kg/m of beach for all of our surveys. The high value is from the January 1998 Hanna Bay Beach survey of both sites whereas the low value occurred at the low deposition site of Hanna Bay Beach in 2000. Hard plastic again is the dominant material using the kg/m measure (range 0.14 to 0.43 kg/m) with glass second except for the January 2002 East Beach survey where glass slightly exceeds hard plastic in kg/m. Glass bottles are commonly found unbroken on the carbonate sand beaches of the Bahamas, as opposed to fragmented on siliciclastic sand beaches in other areas of the world.

DISCUSSION AND CONCLUSIONS

Table 5 presents results obtained by Ocean Conservancy Coastal Cleanup surveys and South Carolina Sea Grant surveys conducted in 2002-04 along the coastlines of the Virgin Islands, Puerto Rico, The Bahamas, Florida, and South Carolina. These surveys showed a total marine debris range of 0.034 to 1.11 kg/m, with the lowest value from one of the South Carolina surveys and the highest value from Puerto Rico. The marine debris kg/m values for Hanna Bay Beach and East Beach (Table 4; range = 0.19 to 0.72 kg/m) fall within this range.

In the 1996 survey of five San Salvador beaches by Alter et al. (1999), East Beach, the only truly windward beach of that study, was found to be the beach most heavily impacted by marine debris. We agree with the conclusion that San Salvador's windward beaches are the most heavily impacted. Our East Beach survey of January 2002 showed a marine debris/linear meter value of 0.64 kg/m, even higher than the 0.455 kg/m value reported by Alter et al. (1999).

As with the previous studies in the

Bahamas by Brown and Spotswood (1998, their Figure 1) and by Alter et al., (1999, their Figure 5), we found hard plastic to be dominant marine debris material with glass the second most abundant component. Our hard plastic showed a range of 0.14 to 0.43 kg/m.

The variation in the hard plastic range in kg/m is much less than for the other categories of marine debris, suggesting that monitoring only hard plastic on San Salvador beaches and elsewhere could act as a reliable proxy for monitoring marine debris.

Based on our Hanna Bay Beach surveys of January and June 2004, we think we can say something meaningful about the rate of marine debris accumulation on San Salvador's windward coast. The amounts of marine debris collected during the January and June 2004 surveys were 0.31 kg/m and 0.41 kg/m respectively. These depositions occurred under "normal" weather conditions during the four month interval from September 2003, the time of Hurricane Isabel when the beach was swept clean of debris, to January 2004, and the subsequent five month "normal" interval from January 2004 to June 2004. These data indicate a rate of total debris deposition of 0.078 kg/m/month and 0.082 kg/m/month, offering an initial assessment of the baseline rate of deposition for Hanna Bay Beach.

The hard plastic debris collected during the same surveys was 0.19 kg/m and 0.18 kg/m giving a hard plastic deposition rate of 0.048 kg/m/month and 0.045 kg/m/month. Likewise, these rates provide a reference for future studies to evaluate any increase or decrease in marine debris deposition over a period of time at Hanna Bay Beach and as a comparison rate for studies elsewhere.

We think that one very important and unanswered question is what ultimately happens to plastic and polystyrene foam debris? We conducted a preliminary study to find hard plastic fragments smaller than 2-3 cm at Hanna Bay Beach. Sand was removed from four sections (30 cm by 30 cm and 2 cm deep) along a transect normal to the beach from the high tide line to the landward edge of the backshore. The sand samples were passed through a set of sieves, sizes 10-230, and each sieve fraction was treated with hydrochloric acid to compeletly dissolve the carbonate sand. No residue of plastics or other anthropogenic debris was found. This suggests that micro-marine debris (<2 cm) is not being washed ashore and that the small quantities of plastic debris (2-3 cm) found in our surveys must be formed by in situ ultra violet degradation of larger plastic fragments. The fate of these fragments as they further degrade remains unanswered. Are they blown into the dunes and buried or are they blown even farther afield?

On September 2, 2004, Hurricane Frances made a direct hit on San Salvador, and erosion was severe along the entire windward coast of the island (Parnell et al., 2004). In January 2005, Al Curran visited Hanna Bay Beach and East Beach and observed extensive and severe erosion of the primary dune line at both sites. It also was obvious that much marine debris had been washed well into the dunes by the storm waves. Furthermore, plastic and glass debris items were commonly found protruding from the dune erosion scarps. These observations suggest that the ultimate fate of much marine debris along the San Salvador windward coast is burial within the dunes. Recycling of debris materials is also part of the story, as many "Portuguese" glass fishing net floats were found in the days following Hurricane Frances. Presumably these glass floats along with other debris items had been exhumed from the eroding dune during the storm.

In many respects, our surveys of marine debris accumulation at Hanna Bay Beach and East Beach remain preliminary. However, following the lead of previous studies, we think we have perfected a viable and efficient methodology for marine debris surveys on Bahamian beaches. Furthermore, we have established baselines for the categories and amounts of marine debris accumulating on San Salvador's windward coast beaches and we have presented initial data on the rates of marine debris accumulation. Many further interesting questions remain to be answered, and we hope to be able to address these in future marine debris surveys.

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REFERENCES

Alter, R.C., Shaklee, R.V., and Buckler, W.R. 1999, Beach litter survey on San Salvador Island: Bahamas Journal of Science, v. 5, p. 23-28.

Anonymous, 2004, Ocean Conservancy Coastal Cleanup Study: http:/www.coastalclean-up.org/conservation.cfm and http:/www-.scseagrant.org/education.

Brill, A.L., Curran, H.A., and Fox, W.T., 1993, Long-term, seasonal, and event-driven sediment movement on East Beach, San Salvador Island, Bahamas, *in* White, B., ed., Proceedings of the 6th Symposium on the Geology of the Bahamas: San Salvador, Bahamian Field Station, p. 23-34.

Brown, L., and Spotswood, J., 1998, If life's a beach, we'd better be born wearing shoes: Bahamas Naturalist, v. 9, no. 1, p. 8-12.

Moore, C., 2003, Trashed – Across the Pacific Ocean, plastics, plastics, everywhere: Natural History, November, p. 46-51.

Parnell, D.B., Brommer, D., Dixon, P.G., Brown, M.E., and Gamble, D.W., 2004, A survey of Hurricane Frances damage on San Salvador: Bahamas Journal of Science, v. 11, p. 2-6.

Ribic, C.A., Dixon,T.R., and Vining, I., 1992, Marine Debris Survey Manual: NOAA Technical Report NMFS 108, U.S. Department of Commerce, 92 p.