Ocean Waste in the Gulf of Honduras:

Where it goes and what to do about it

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Executive Summary

Waste management is a serious global and regional issue and multiple entities have attempted to characterize the problem and identify solutions. We have confined our review to investigating the potential sources of waste in the part of the Western Caribbean that stretches from Corozal (Belize) to La Ceiba (Honduras) including the Gulf of Honduras (hereafter 'the Gulf of Honduras') that could be affecting the coast of Belize and its atolls. We hope results from this review will be used to identify potential solutions for NGOs and/or governments to employ to address the massive human health and ecological problems that solid waste causes. We reviewed national census data from Belize, Guatemala and Honduras; analyzed reports from the Pan-American Health Organization (PAHO), the World Health Organization (WHO), the World Bank, and the Inter-American Development Bank (IADB); and incorporated information from interviews with local people in the study area, including local government representatives and fishermen.

This review has identified the following factors influencing waste in the study area:

- The production, use, transportation, and disposal of waste are directly proportional to population size, urban development, industrial and commercial activities and tourism. It is estimated that 12.4 million people live near the coasts and in the watersheds that flow into the Gulf of Honduras and that each person produces between 0.5-1 kg of solid waste daily.

- In general, most plastic litter (*e.g.*, bottles, shopping bags, containers) is generated close to populated areas. Land-based sources such as poorly managed domestic solid waste, riverine transport, industrial and recreational use of coastal areas, and tourism facilities in Belize, Guatemala and Honduras all contribute to waste in coastal areas.

- A shortage of infrastructure throughout the region (*e.g.,* technically managed landfills, reliable systems for collection) means that a substantial proportion of the daily waste that is generated is not collected or contained. Municipal solid waste service in the region exists almost exclusively in urban areas and collects only about half of the domestic waste produced. Where there are no official collection services (especially in semi-rural areas), collection is occasionally done informally and waste is dumped in clandestine dumps. A substantial amount of the waste is burned, buried or deposited in rivers, creeks, lakes and the sea.

- A substantial portion of the population in the region lives in rural areas, where solid waste collection either does not occur regularly, or does not occur at all. In these areas in particular, solid waste is often found on roadsides, in gullies, creeks, swamps and on open or abandoned land.

- The water circulation pattern in the study area is dominated by cyclonic, counterclockwise rotating circulation gyres in a north-south direction flowing from the coast of Belize towards Guatemala and Honduras. Given those prevailing currents, it is at least as likely that, rather than originating in Guatemala and/or Honduras and being transported by the ocean currents to Belize, the bulk of the waste seen along the coastline and atolls in Belize originates in Belize.

Introduction

Marine litter often creates large, widespread, pervasive and persistent negative effects on marine and coastal ecosystems, with serious effects on aquatic biota at both the local and the global level. This review is not exhaustive but rather focuses primarily on these issues:

- What are the main sources of solid waste, particularly plastic bottles, bags and other municipal solid waste affecting the coastal areas of the Gulf of Honduras, principally in Belize?

- What is the influence of marine currents and climate conditions on the trans-boundary migration of solid waste in the Gulf of Honduras? Could the waste in Belize be coming from Guatemala and/or Honduras?

- What steps might be taken to begin to address this problem?

This review is based on the analysis of secondary information sources (research documents, publications, news articles) and consultations with public interest organizations affiliated with the Environmental Law Alliance Worldwide (ELAW) in the region. ELAW partners interviewed local authorities, community members and fishermen about the problems related to solid waste management in the area (especially plastics) to learn their perspectives about what already is being done by local authorities and citizen's groups, and to identify what needs to be done to address these problems.

Figure 1: Solid waste on the Guatemalan coast. Source: Prensa Libre, 5 November 2009.

Ocean waste, a global problem

Drifting ocean waste is a global problem with long-lasting and serious impacts on human health and living marine resources (See Appendix I). Several attempts have been made to identify the sources of ocean waste at particular locations and to highlight solutions. In 2009, scientists from South Africa, the United States and the Netherlands collaborated on a study monitoring the abundance and spatial distribution of ocean waste through beach surveys of stranded plastics and other litter, at-sea sampling of ocean waste, and studies of seabirds and other marine organisms that accumulate plastics in their stomachs (Ryan *et al.* 2009). These scientists offered the following premises and reached the following conclusions:

> "Plastics dominate marine debris…. The proportion of plastic articles among litter increases with distance from source areas because they transport more easily than do more dense materials such as glass or metal and because they last longer than other low-density materials such as paper. Most plastics are less dense than water, but some are more dense (e.g. polyamide, polyterephthalate, polyvinyl chloride). Floating plastic debris has become a global problem because it is carried across ocean basins, contaminating even the most remote islands ….. "Plastics in the marine environment derive from two main sources: rubbish dumped from ships at sea and land-based sources such as runoff from rivers, waste water systems, wind-blown litter and recreational litter left on beaches …." [Emphasis added]

In 2010, scientists with the Woods Hole Oceanographic Institution in Massachusetts and the International Pacific Research Center in Hawaii collaborated on a study of how plastic waste varies over time on the surface of the western North Atlantic Ocean, and in the Caribbean Sea, over a period of 22 years (from 1986 to 2008) (Law *et al.* 2010). These scientists offered the following opinion about the sources of plastic ocean waste.

> "Although no direct estimates of plastic input to the ocean exist, the increase in global production of plastic materials [fivefold increase from 1976 to 2008] together with the increase in discarded plastic in U.S. municipal solid waste (MSW) [fourfold increase from 1980 to 2008] suggest that the land-based source of plastic into the ocean increased during the study period. Ocean-based sources may have decreased in response to international regulations prohibiting dumping of plastic at sea …. Given the measured steady plastic concentration in the western North Atlantic, loss terms must exist to offset the presumed increase in plastic input to the ocean." [Emphasis added].

Finally, in 2011, researchers with the United Nations Environment Program (UNEP) published a far reaching report about plastic debris in the ocean (Kershaw 2011). These researchers concluded:

> "Land-based sources include poorly managed landfills, riverine transport, untreated sewage and storm water discharges, industrial and manufacturing facilities with inadequate controls, wind-blown debris, recreational use of coastal areas, and tourist activities (Barnes *et al.* 2009). These sources are thought to dominate the overall supply of marine debris, but there are important regional variations. For example, shipping and

fisheries are significant contributors in the East Asian Seas region and the southern North Sea (UNEP/COBSEA 2009 ….). In general, more litter is found closer to population centers, including a greater proportion of consumer plastic items such as bottles, shopping bags and personal hygiene products (Ocean Conservancy 2010).

"Ship- and platform-based sources of plastic litter in the ocean include fishing and recreational vessels, cruise liners, merchant shipping, oil and gas platforms, and aquaculture facilities (Figure 2). There are large regional differences in the relative importance of these potential sources ….. Discharges of plastic and other litter from ships and offshore structures are addressed under international law, but implementation and enforcement are often inadequate ….."

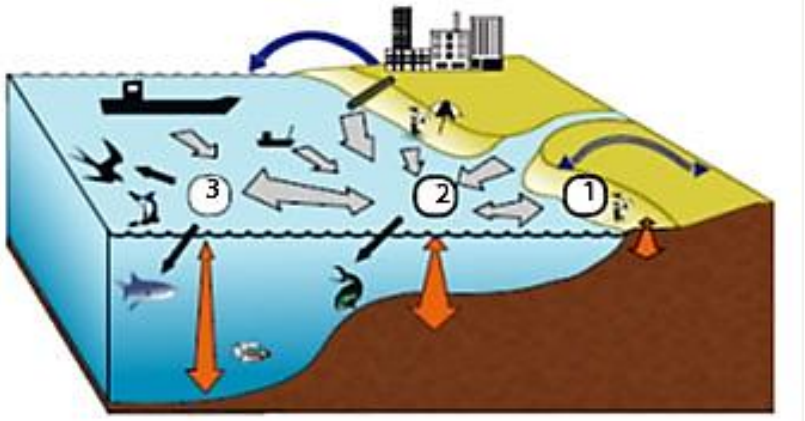


Figure 2. "Main sources and movement pathway for plastics in the marine environment. Most plastic accumulates on beaches (1); in coastal waters and their sediments (2); and in the open ocean (3). The dark blue arrow depicts wind-blown litter, grey arrows waterborne litter; orange arrows vertical movement through the water column, including burial in sediments; and black arrows ingestion by marine organisms." Source: Adapted from Ryan *et al.* (2009).

This UNEP report also provided insights into the relative contribution of individual types of ocean waste to the overall burden of these waste in the world's oceans.

Table 1: Most Common Debris Items. Source: Ocean Conservancy 2010.

Rank	Debris Item	Number
1	Cigarette/Cigarette filter	2,189,252
2	Bags (plastic)	1,126,774
3	Food wrappers / containers	943,233
4	Caps, lids	912,246
5	Plastic bottles	883,737
6	Cups, plates, forks, knives, spoons	512,517
7	Glass bottles	459,531
8	Beverage cans	457,631
9	Straws, stirrers	412,940
10	Paper bags	331,476
Top 10 debris items		8,229,332

The UNEP report offered the following conclusions, which can inform choices about how to reduce the burden of ocean waste in the Gulf of Honduras.

"Solutions need to be part of comprehensive programs to improve waste management generally: that is, waste collection and disposal infrastructure, waste management practices, and enforcement. Such programs could include improved design and application of single-use plastics, increased consumer awareness and behavioral changes, improved recycling and re-use, and the introduction of economic instruments to reduce littering and promote secondary uses of plastic debris …. Innovative technologies in the recycling sector present possibilities to recycle a greater proportion of waste and should be encouraged. Part of the answer may lie in the application of the concept of extended producer responsibility, according to which USA a producer's responsibility for a product is extended to the post-consumer stage of the product's life cycle ….."

The Study Area

This analysis examines the coastal areas of the Western Caribbean region shared by Belize, Guatemala and Honduras and including the Gulf of Honduras (Figure 3).

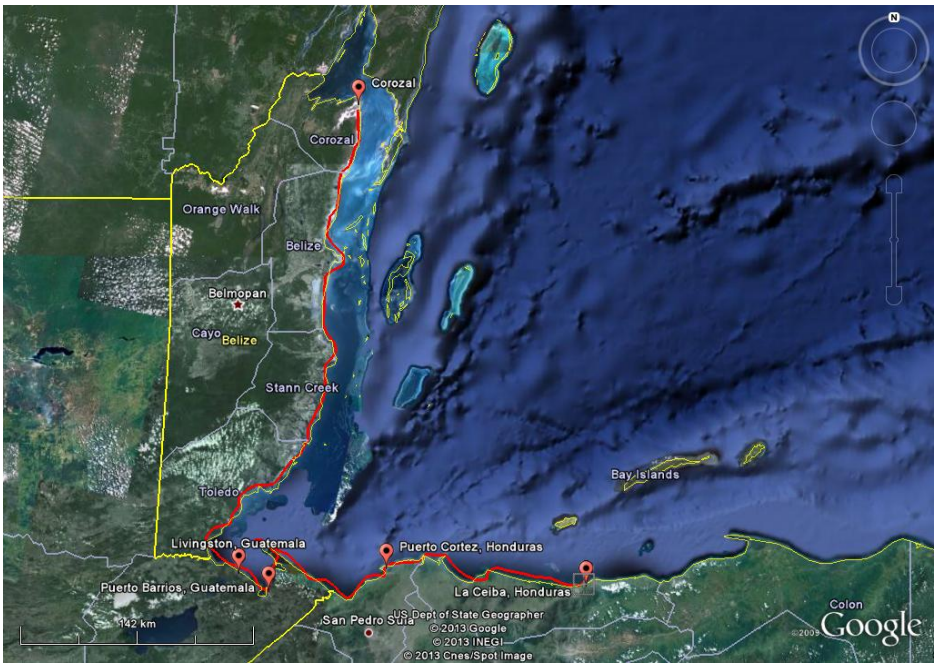


Figure 3. Study Area (highlighted in red) Source: Google Earth Pro 2013.

Background

Population

Approximately 12.4 million people live near the coasts and in the watersheds that flow into the Gulf of Honduras. This number constitutes 70% of the population of Belize, Guatemala and Honduras. Of this number, 2 million people live in urban areas: Guatemala City, in Guatemala, and San Pedro Sula in Honduras. Small groups of culturally diverse populations reside along the Gulf's coasts, including a half a million people who are predominantly Garifuna, Mestizo and Creole. Coastal communities directly affect coastal and marine ecosystems, contributing an average of 0.5 – 1 kg of daily waste per person, of which 50% could potentially reach water bodies and areas with no proper disposal (Lopez & Padilla 2007, Abt Associates, 2003).

Rivers, ocean currents and their influence on the presence of solid waste in the coastal areas of the Gulf of Honduras

Rivers

As in most developing countries, the health of rivers and their contribution to coastal pollution is closely related to the capacity of the communities and local governments to adequately manage solid waste. A report from the Pan American Health Organization (PAHO 1997/98:101) states that "in Latin America and the Caribbean, there are no adequate and sufficient installations to manage hazardous and municipal solid waste since wastes are disposed of in uncontrolled landfills, municipal dumps, ravines… *rivers, lakes and beaches"*. This report mentions that rivers, lakes, swamps, lagoons and coastal areas are final disposal sites for hazardous and municipal solid waste, causing serious environmental effects such as the contamination of drinking water supplies, and eutrophication processes, which promote algae growth that results in diminishing resources available for human consumption, recreation, aquatic fauna and the deterioration of landscape. (PAHO 1997/98:110).

The discharge of rivers is an important source of plastics and municipal waste in the study area. This is especially relevant considering that sixteen rivers discharge their waters in this area with an approximate rate of 1,232 m^3/second. Table 2 has a list of the major rivers discharging in the Gulf of Honduras.

Table 2. Major Rivers Discharging in the Gulf of Honduras.

River Name	Country	Length (km)	Mean Discharge (m^3/sec)
Sittee River	Belize		32
Stan Creek River	Belize		40
Swasey Branch	Belize		27
Monkey River	Belize		63
Rio Grande	Belize		26
Moho River	Belize		37
Sarstoon	Belize (Black Creek)/Guatemala (San Pedro)	42	160*
Rio Dulce	Guatemala	42	300*
Motagua	Guatemala	487	530*
San Francisco	Guatemala		
Piteros	Guatemala		
Ulua	Honduras	358	690* (1,400**)
Chamelecon	Honduras	256	370 (400**)

* Heyman and Kjerfve, 1999
* * Comisión Ejecutiva Valle de Sula, 2002
Source: Abt Associates, 2003:6.

Guatemala and Honduras have the largest rivers but Belize has more rivers. The mean water discharges of rivers in Belize are 10 to 20 times smaller than those in Guatemala and Honduras. However, their distribution and number could be contributing to the presence of solid waste in the coastal areas. Figure 4 shows the river systems, coral reefs and land elevation above sea level in the Mesoamerican Region.

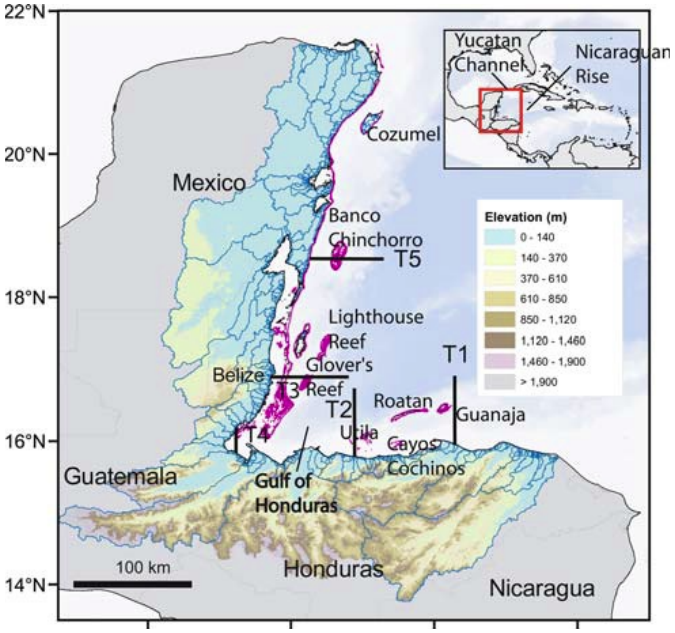


Figure 4: River systems, coral reefs and land elevation in the Mesoamerican Region. Land elevation is shown in color, rivers in blue, and reefs in magenta. Source: Cherubin 2007.

Ocean Currents

Water circulation in the study area is generally characterized by two features: 1) an offshore gyre that rotates counterclockwise, and 2) nearshore currents that flow north-to-south (Fig. 5).

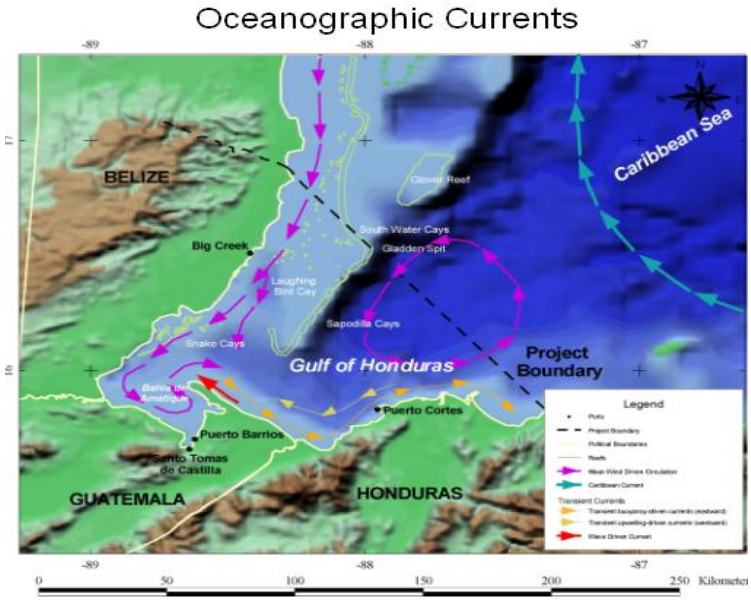


Figure 5. Dominant water circulation patterns in the Gulf of Honduras. Source: Mesoamerican and Caribbean Sea Hydrographic Commission

Additional localized dynamics interact with these regional characteristics to impact the transportation of waste. Appendix 2 illustrates circulation patterns in Bahía de Amatique, where population centers in Puerto Barrios and Livingston, Guatemala generate substantial waste and have inadequate disposal infrastructure.

At the local level, however, the currents are considerably more variable, as they are influenced by wind, season, and local bathymetric features. For example, researchers studying the currents on an annual basis around Glover's Reef in Belize have found that they change multiple times within the year (Table 3).

Surface Water Current Direction Adjacent to Glover's Reef Adapted from Stoddart, 1962		
Month	**Current Direction**	
January	North or south	Dependent on wind direction
February	North	
March	North	
April	South	
May	South	
June	North	
July	North	
August	North	
September	North	
October	North	
November	North or south	Dependent on wind direction
December	North or south	Dependent on wind direction

The variability in these currents makes it difficult to assign definitive external sources for the trash that arrives along the coasts and reefs of the study area. The most conservative approach, therefore, is to assume that the majority of coastal marine waste is generated locally.

Table 3. Monthly current directions near Glover's Reef, Belize. Source: Wildtracks/Wildlife Conservation Society 2007

Solid waste generation in the coastal areas of Belize, Guatemala and Honduras

To understand the social-environmental conditions that influence the generation of solid waste in the Gulf on Honduras, it is necessary to understand not only the physical characteristics of the area, but also the population distribution in the region.

BELIZE

The Pan American Health Organization (PAHO) estimates that the daily municipal waste generation in urban areas of Belize is 1.32 kg/person.

The PAHO (2003) also states:

> "All landfill sites in Belize, except that of Belmopan, are operating with inadequate resources, supervision and financial support. Sites deteriorate because of lack of equipment for the operation of landfills and cover material is not used in most cases. Most of these sites can best be described as controlled landfills.
>
> In addition to the existing landfills, there are many illegal open dumps and places where garbage is used for the filling of yards. Illegal roadside dumps, dumping in rivers,

dumping in sensitive areas, occur mostly in rural areas, outside existing villages and smaller communities." [Emphasis added]

Belize has a larger rural population than urban. The urban/rural ratio in 2000 indicated that 52% of the population lives in rural areas (without access to municipal waste collection services) and 48% live in towns and cities. In small municipalities along the coast of Belize, solid waste management via private contracts and community-based management strategies are just beginning (ibid: 8, 22).

Solid waste in rural areas is often dumped at designated, but sometimes illicit, local dumps. Illicit rural dumps include roadsides, gullies, creeks, swamps and open or abandoned land. Certain sectors of the country have designated local sites for the disposal of waste, but with no waste collection services. Wherever waste collection services exist, they are handled by small micro-operators who are paid by residents or by local village councils. Disposal services are carried out by the use of pick-up trucks, and are transported to local sites. Many sites currently pose a nuisance to residents and visitors, resulting in odor and poor aesthetics. This is viewed negatively, particularly in areas such as Placencia Village, which is a tourism destination (ibid).

Three out of the six districts of Belize are located along the coast of the Gulf of Honduras (Belize, Stan Creek and Toledo), four districts (Corozal, Belize, Stan Creek and Toledo) have coasts on the Caribbean Sea. These coastal districts concentrate 61.3% of the total population, of which 154,800 inhabitants (47% of the total population) live on the coasts of the Gulf of Honduras. Detailed waste quantity and composition studies have not been undertaken in Belize but ABT Associates (2003:29) reports:

> "The estimated daily municipal waste generation rate is 0.93 kg/capita, which means that the urban areas yearly generate a total of almost 45,000 tons of waste. The waste collected in all cities and towns around the country is currently disposed in open dumps (Picture 2). These facilities lack technical and environmental controls and operate without adequate equipment or sufficient cover material. The largest disposal site, located at the edge of Belize City, handles more than 60 tons/day, which are disposed in an unsuitable mangrove area. On the offshore islands, the inadequacy of the waste disposal practices is especially worrisome due to the environmental vulnerability of the islands, their proximity to coral reefs and their importance to the eco-tourism market. Fires are common at most sites and leachate escapes to the immediate surroundings, which in many cases are watercourses or the sea. Human scavenging is common at all sites and experience with formal recycling methods, waste reduction, and composting is very limited.
>
> "The main funding for solid waste management comes from municipal revenues, mainly in the form of property taxes, supplemented by Central Government subsidies. With the exception of Placencia, Ladyville, Belmopan and San Pedro, where households pay for waste collection (monthly rates ranging from US$ 3 to US$ 6), all other towns and Belize City provide residential waste collection services free of charge. Large commercial establishments are typically charged a separate amount by private collectors for waste removal services. It is generally agreed that the municipal funds being allocated to these operations are insufficient to provide an environmentally sound waste disposal service. None of the ports in the Gulf of Honduras has adequate installations for the reception of solid waste. Belize City Port, Big Creek, Puerto Barrios and Puerto Santo Tomás de

Castilla do not receive waste from ships. In Puerto Cortés, Honduras, this service is given by the municipality"

Figure 6. Wastes in Punta Gorda in Southern Belize (near the Maya Mountain Marine Corridor. Source: Wagnitz, 2009.

The Statistical Institute of Belize has the following information from the 2010 Population and Housing Census about municipal waste in Belize:

Table 4. Total municipal waste disposal in Belize.

Garbage disposal	Counts	%
Prepare it for municipal collection	26,434	50%
Public dump	4,415	8.5
Dump in own yard	2,335	4.5
Burn it	17,098	32.92
Bury it	887	1.71
Throw in river/creek/pond/sea	**247**	**0.48**
Other	427	0.82
Do not know/ not stated	102	0.2

Source: Statistical Institute of Belize. 2010 Population and Housing Census.

The Statistical Institute of Belize does not provide a definition of what 'prepare for municipal collection' means, but the information in Table 3 indicates that roughly half of the domestic waste produced is not collected by the municipal services and that from 0.5 – 1% (see Table 4) of the wastes are thrown in rivers/creeks/ponds and sea in Belize.

Summary of Waste Generation Analysis in Belize

ABT's estimate of municipal waste volume in Belize (45,000 tons/day) and Wagnitz' (2007) analysis of the composition of domestic waste, which states that roughly 5-10% of this waste is

plastics (dense and film), taken together suggest that between 2,250 to 4,500 tons of plastics waste may be produced in the urban areas of Belize daily. Considering the limited institutional and technical capacity of the municipal authorities to adequately collect and manage domestic waste, it is reasonable to estimate that more than half of this waste -- which could contaminate freshwater resources and coastal areas -- is not collected. In addition, given that between 0.48 and 1% of waste is thrown into rivers/creeks/ponds and the sea in Belize, it is reasonable to infer that some 11 to 21.6 tons of waste could be thrown in surface water sources each day. It would be valuable to explore in more detail the institutional and legal issues affecting the solid waste in Belize.

GUATEMALA

Izabal is the second largest department (state) of Guatemala, covering an area of 14,545 sq. kilometers. Izabal has five municipalities as well as small villages or rural areas spread along the coastline (Figure 7). Puerto Barrios (pop. 106,000) and Livingston (pop. 65,929) in the Amatique Bay are two relevant areas for this analysis because of their location and population. Only the urban areas of Izabal have a waste collection system (UNEP 2003).

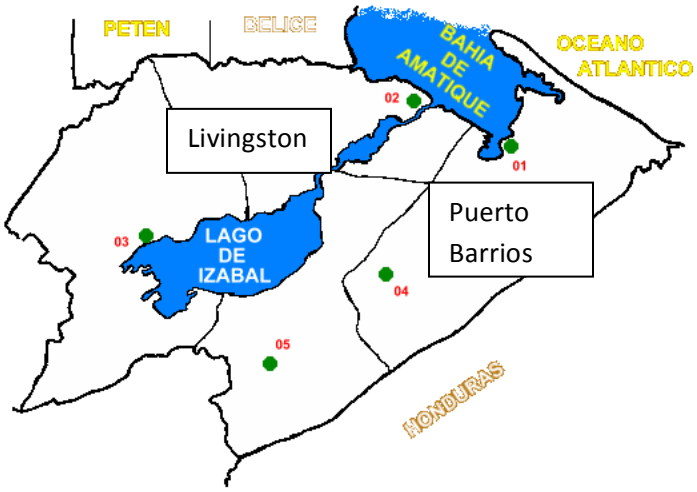


Figure 7. Izabal, Guatemala. Source: http://www.zonu.com/fullsize/2009-09-17-4990/Mapa-del-departamento-de-Izabal.html

Puerto Barrios

Puerto Barrios is located approximately 300 km east of Guatemala City on the coast of the Amatique Bay in the Atlantic Ocean. Puerto Barrios is one of the most populated areas of Izabal, home to approximately 60% of the population. Puerto Barrios does not have a sanitary landfill or a waste treatment facility. Numerous dumping grounds affect environmental quality and water sources (Consejo Municipal de Desarrollo del Municipo de Puerto Barrios 2011).

Livingston

Eighteen percent of homes and businesses from Livingston pay for the collection of domestic waste. The remaining 82% burn their waste on roadsides. According to the Development Plan of Livingston 2010, the municipality does not have a policy for the management of solid waste. Moreover, other activities such as livestock and agriculture (e.g. sugar cane, bananas) are a substantial source of hazardous waste such as fertilizers, pesticides and organic matter. In addition, coastal areas receive waste from boats such as plastic containers, lubricants and oil spills (Consejo Municipal de Desarrollo del Municipo de Livingston 2010:43).

The municipality is aware of the need to improve sanitation and waste management as shown in Livingston's Development Plan 2010. This plan has outlined an ambitious set of objectives to address these and other urgent needs such as land management, health, education, public safety and economic development.

Izabal

Waste management and sanitation are a serious problem in Izabal, especially in the urban areas of Puerto Barrios, Santo Tomás de Castilla and Livingston, due to the lack of adequate collection, transportation and disposal sites. A report by UNEP (2005) states that ships operating in Amatique Bay do not have adequate storage to hold the waste generated on-board, therefore waste waters are discharged unlawfully in the ports and nearby offshore areas. It is likely that some of the discharges from boats and other tourist ships occur near corals and in the ports with tourist and fishing terminals.

HONDURAS

Honduras has five departments on the coast of the Atlantic: Cortés, Atlántida, Colón, Gracias a Dios and the Bay Islands. This analysis will focus on the areas of Cortés, Atlántida and the Bay Islands since they are relatively closer to Belize and may have more influence on the migration of plastics and other solid waste to the coasts of Belize. Areas of particular interest include Omoa (pop. 30,000), Puerto Cortes (pop. 200,000) and La Ceiba (pop. 180,512). A report by the Pan-American Health Organization (PAHO) estimates that the average person living in urban areas in Honduras generates 0.65 kg/day. The authors were unable to locate recent data about the amount of municipal waste and plastics specifically produced in Omoa and Puerto Cortes. However extrapolating from the average urban rate and the population, it is reasonable to roughly estimate waste generation in those two states: Omoa 19.5 tons/day, and Puerto Cortes 195 tons/day. Lopez & Padilla (2007) estimated that La Ceiba produces 150 tons/day of domestic waste, 80% of which comes from urban dwellers. An estimated 29% of the waste produced in Honduras is not biodegradable (plastics, aluminum, hospital waste, electronic waste, and others). Moreover, Lopez & Padilla estimated that 12% of the domestic waste in Tegucigalpa is plastics (ibid:15-17).

As in most areas of Central America, only urban areas in Honduras have access to municipal waste collection services. Between 76 and 90% of large urban areas in Honduras have some municipal waste collection services while less than 40% of small urban areas have those services. Moreover, the municipal collection services do not collect 100% of the waste

produced. It is estimated that only 28% of the domestic waste produced is collected and only 3.69% of the total domestic waste in the largest urban areas of Honduras makes its way to a sanitary or controlled landfill (PAHO: 65, Lopez & Padilla 2007). The vast majority of municipalities in Honduras do not have sanitary landfills but Puerto Cortez and La Ceiba have sanitary landfills (Lopez & Padilla 2007).

Honduras does not have a national standard and policy for the management and final disposal of solid waste, nor to address the environmental and health impacts caused by the contamination produced by municipal waste. The Census of 2001 in Honduras showed that 52% of homes in Honduras burn or bury their waste; 9% leave the waste on the streets, lakes or rivers and only 2% pay someone (besides the municipal service) to get rid of the waste – commercial or industrial (National Institute of Statistics of Honduras, Census 2001, cited by Lopez & Padilla 2007). There is no data available about the possibility that plastics and other wastes are recycled informally in Puerto Cortes, La Ceiba or the Bay Islands. As a reference, 28% of plastics in Tegucigalpa's dump are recycled (Figure 8).

Figure 8. Recovery of materials at Tegucigalpa dump in 2006. Source: Lopez & Padilla 2007

Conclusions

1. Domestic waste management and final disposal in Belize, Guatemala and Honduras is a critical problem that needs to be addressed urgently because it poses a risk to public health and the environment. The PAHO (2003) assessment of the problem in the region concludes that this situation is due to institutional weakness, lack of leadership in regulatory agencies, and inadequate information and service coverage.

2. The estimated amount of municipal waste in Belize is 45,000 tons/day and roughly 5-10% (weight) of that waste is plastic. Therefore, between 2,250 to 4,500 tons of plastic waste is produced each day in Belize. More than half of the total municipal solid waste in Belize is not technically managed or deposited in sanitary landfills; it is burned, buried or thrown in rivers, creeks and the sea (see Tables 4 and 5).

3. The water circulation pattern in the study area is dominated by cyclonic, counterclockwise rotating circulation gyres in a north-south direction flowing from the coast of Belize to Guatemala and Honduras. Although some trans-boundary transport of solid waste may be occurring, a more likely scenario is that local sources contribute a greater portion of the overall burden.

4. From the UNEP (2011) report: "Tackling the plastic waste issue will demand political commitment, investment and an integrated approach at all levels of society, in order to

prevent litter from reaching the ocean from sea and land-based sources and to move towards a cleaner ocean, reducing the many pressures and impacts on biodiversity and, at the same time, greatly reducing related social and economic costs."

Recommendations

- Encourage local solutions: Municipal governments are struggling to provide the infrastructure and collection services necessary for proper waste collection and management. NGOs can look for neighborhoods or municipalities where there is citizen concern or demand for improvement and help identify and assess positive experiences addressing solid wastes management at the local level.

- Invest in educating the next generation: It can take decades to alter cultural attitudes. Reaching children through school programs about waste responsibility, ocean stewardship, public health, and marine biology will help change behavior.

- Research economics of recycling: NGOs can develop arguments for where and how recycling can save municipalities and citizens money.

- Pressure the municipalities to increase efforts: Tourism and public health costs from poor waste management can be quantitatively measured, often in economic terms. NGOs can collect these data to present to officials to pressure change at the political level.

- Promote collaborative efforts and information exchange and collaboration among municipalities, tourist operators, citizen groups and NGOs to formulate creative and alternative ways to find sustainable solutions.

- Develop a citizen science project to identify sources: Work with the Glover's Reef research staff to inventory and track garbage as a pilot project. Conduct a drift card study[1] to assess currents and identify geographic sources for waste arriving along the coast of Belize and its reefs.

[1] Drift cards are small floating plastic cards that are used to determine local current conditions where oceanographic models are inaccurate or have not yet been developed. Cards are dropped in along the shore, upriver, or out in the ocean, and carry identification and contact information. Card drop location, date, time, and water conditions are recorded. When citizens retrieve the cards, they are instructed on them to contact the study leaders and to provide the same information. From these data, it is possible to assess how quickly and where surface currents are travelling. The cards serve as good proxy for floating debris transport and are a standard marine ecology research tool. A drift card study has the added benefit of engaging communities in solving the garbage source "mystery" and educating citizens about the importance of waste responsibility.

References

Abt Associates Inc. / Woods Hole Group. 2003. *Gulf of Honduras. Preliminary Transboundary Diagnostic Analysis. Final Draft.* Global Environmental Facility – Inter-American Development Bank.

Acurio, G. *et al*. 1997. *Diagnosis of Municipal Solid Waste Management in Latin America and the Caribbean.* Pan American Health Organization (PAHO) and the Inter-American Development Bank. Retrieved from http://www.bvsde.paho.org/acrobat/diagnos.pdf

Ballance, A., P. Ryan, and J. K. Turpie. 2000. How much is a clean beach worth? The impact of litter on beach users in the Cape Peninsula, South Africa. South African Journal of Science 96: 210-213.

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (July 27, 2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364,* 1526, 1985-1998.

Burke, L. and J. Maidens. 2004. Reefs at Risk in the Caribbean. Contributing authors: M. Spalding, P. Kramer, E. Green, S. Greenhalgh, H. Nobles & J. Kool. (available online only at www.wri.org/biodiv/pubs_description.cfm?PubID=3944).

Chérubin LM, Kuchinke C, Paris C.B.2008. Ocean circulation and terrestrial runoff dynamics in the Mesoamerican Region from spectral optimization of SeaWiFS data and high resolution simulation. *Coral Reefs,* 27:503-519

Comisión Ejecutiva Valle de Sula. 2002. Plan de Desarrollo Estratégico: Cuenca del Ulúa y Chamelecón Honduras. Informe Final Volumen 1.

Consejo Municipal de Desarrollo del Municipo de Livingston. 2010. "Plan de Desarrollo Livingston."

Consejo Municipal de Desarrollo del Municipo de Puerto Barrios. 2011. "Plan de Desarrollo Puerto Barrios."

Heyman, W.D. & B. Kjerfve. 2000. The Gulf of Honduras. In *Coastal Marine Ecosystems of Latin America.* U. Seeliger & B. Kjerfve, *eds*. Heidelberg: Springer-Verlag. Retrieved from http://marinegeog.tamu.edu/data/pdf/heyman_2000_TheGulfOfHonduras_part1.pdf

Kershaw, P., S. Katsuhiko, S. Lee, J. Samseth and D. Woodring. 2011. Plastic debris in the ocean. Retrieved from http://www.unep.org/yearbook/2011/pdfs/plastic_debris_in_the_ocean.pdf

Laist, D. W. 1996. Marine debris entanglement and ghost fishing: A cryptic and significant type of bycatch? pp. 33-39. In: Solving bycatch: Considerations for today and tomorrow: Proceedings of the Solving Bycatch Workshop, Sept. 25-27, 1995, Seattle, WA. Alaska Sea Grant College Program report no. 96-03. Fairbanks, AK: Alaska Sea Grant. 322 pp.

Law, K. L., S. Morét-Ferguson, N. A. Maximenko, G. Proskurowski, E. E. Peacock, J. Hafner, and C. M. Reddy. 2010. "Plastic Accumulation in the North Atlantic Subtropical Gyre." *Science* 329, no. 5996: 1185–1188.

Lopez, R. & Padilla, A. 2007. Presentation *Manejo de Residuos Sólidos en Honduras.* Retrieved from http://www.epa.gov/lmop/documents/pdfs/conf/central-america/MRSHonduras.pdf

Marine Affairs Research and Education. 2011. Marine Debris and MPA: Managing the Impacts of Litter on Marine Ecosystems. MPA News. Vol 13 (3):1-4.

Meso American and Caribbean Sea Hydrographic Commission. http://www.iho-machc.org/

National Academy of Sciences (NAS). 2009. Tackling Marine Debris in the 21st Century. National Research Council, Committee on the Effectiveness of International and National Measures to Prevent and Reduce Marine Debris and Its Impacts, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAA). 2013. Retrived from http://marinedebris.noaa.gov/marinedebris101/impacts.html Visited 24 January 2013.

Ocean Conservancy. 2010. Trash Travels. From our hands to the sea, around the globe and through time. Retrieved from http://act.oceanconservancy.org/images/2010ICCReportRelease_pressPhotos/2010_ICC_Report.pdf

Organization for Economic Cooperation and Development (OECD). 2006. Fact Sheet: Extended Producer Responsibility. Retrieved from: http://www.oecd.org/search/Result/0,3400,en_2649_201185_1_1_1_1_1,00.html

Pan-American Health Organization (PAHO). 1997/98. Diagnosis of Municipal Solid Waste Management in Latin America and the Caribbean.

Pan-American Health Organization (PAHO) and the World Health Organization (WHO). 2003. Regional Evaluation Municipal Solid Waste Management Services. Country Analytical Report Belize / Evaluation 2003.

Pan-American Health Organization (PAHO) and the World Health Organization (WHO). 2005. "Report on the Regional Evaluation of Municipal Solid Waste Management Services in Latin America and the Caribbean." Area of Sustainable Development and Environmental Health, PAHO, Washington, DC.

Roman, J. 2009. Basura inunda la provincial. Prensa Libre. 3 November 2009. Retrieved from http://www.prensalibre.com/noticias/Basura-inunda-provincia_0_147587457.html

Ryan, P. G. 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526).

Sheavvly Consultants. 2006. *Marine Litter in the Wider Caribbean.* UNEP CAR/RCU.

Statistical Institute of Belize. 2010 Population and Housing Census. Retrieved from http://www.statisticsbelize.org.bz/

United Nations Environment Program (UNEP). 2005. Marine Litter, an analytical overview. United Nations Environment Program. Nairobi, Kenya. 48 pp. Retrieved from www.unep.org/regionalseas/marinelitter/publications/docs/anl-oview.pdf

United Nations Environment Program (UNEP) & the Coordinating Body on the Seas of East Asia (COBSEA). 2009a. Marine and Coastal Assessment. Retrieved from http://www.un.org/Depts/los/global_reporting/china_presentations/Presentation6.pdf

United Nations Environment Program (UNEP). 2009b. UNEP's Global Initiative on Marine Litter. United Nations Environment Programme. Retrieved from http://www.unep.org/regionalseas/marinelitter/publications/docs/Marinelitter_Flyer2009.pdf

Wagnitz, P. 2009. Punta Gorda Municipal Waste Report. Toledo Institute for Development and Environment (TIDE). Retrieved from http://www.tidebelize.org/documents/SW-ReportBelize2009PhilippWagnitz.pdf

Wildtracks / Wildlife Conservation Society. 2007. Management Plan Glover's Reef Marine Reserve World Heritage Site 2008 – 2013. 167 pp.

Yañez-Arancibia, A., D. Zárate Lomelí, and A. Terán Cuevas. 1995. EPOMEX. Evaluation of the Coastal and Marine Resources of the Atlantic Coast of Guatemala. CEP Technical Report No. 34. UNEP Caribbean Environment Programme, Kingston, Jamaica. 64 pp. Retrieved from http://www.cep.unep.org/pubs/Techreports/tr34en/content.html

Appendices

Appendix 1

Reasons for Concern: Impacts of Marine Debris on Living Marine Resources

Eight million pieces of marine debris enter the ocean every day (UNEP 2005). Solid waste in the coastal marine environment has both direct and indirect impacts on many nearshore species. Sessile and slow-moving species, including corals, sponges, anemones, sea stars, sea grasses, mangroves, and macroalgae are likely to be trapped, suffocated, or damaged by floating or sinking debris. Mobile species, including sea turtles, sea birds, marine mammals, fishes, crustaceans, mollusks, jellyfish, and ctenophores, are also likely to be physically damaged or entangled by marine debris. Additionally these animals are likely to ingest harmful debris in their search for food.

The U.S. National Oceanic and Atmospheric Administration (NOAA 2013) recognizes 10 broad impacts from marine debris: Wildlife Entanglement, Ingestion, Habitat Damage, Vessel Damage/Navigational Hazard, Alien Species Transport, Ghostfishing, Economic Impact, Human Health and Safety Risk, and Aesthetics. Here we outline each of these impacts in turn.

Wildlife Entanglement

Collage of various species caught by marine debris. Clockwise from upper left: photos courtesy of FAO, NOAA, www.origomu.com, Neil Mattocks, and redditmirror.cc.

The most visible impact of marine debris is species entrapment or entanglement. Fishing gear, ropes, plastic soda can rings, tires—these items become weapons of mass destruction when launched into the fragile marine ecosystem. Reliable data on mortality rates are difficult to obtain but there is no shortage of examples from a wide spectrum of species. Entanglement can suffocate or constrict animals, prevent them from being able to eat or defend themselves against predators, swim freely, clean themselves, mate, or raise their young. In long-lived species with low survivorship, such as sea turtles, the loss of a relatively small number of individuals can jeopardize entire populations. In sessile species especially, such as corals, there is little hope of removing the debris naturally.

Ingestion

Any species actively searching for food in the marine environment can ingest objects that mimic food. Sea turtles are known to ingest plastic bags that resemble their jellyfish prey, and birds consume cigarette butts, bottle tops, and plastic pellets. Whales can inadvertently consume substantial amounts of trash in their search for food. There are at least 250 species that have been reported as being entangled or having ingested marine debris (Laist 1996). When animals ingest marine debris, it can be immediately toxic, or it can tear or block their digestive track, preventing them from eating further and getting the nutrition they need to survive.

Sperm whale stranded in California with nearly 450 pounds of marine debris in its stomach. Photo and information courtesy of Chris Whittier and the Marine Mammal Center, 2008.

In addition to macro pieces of debris floating around the ocean, more recent research is revealing that persistent organic pollutants—including PCBs from manufacturing, DDT and DDE from agricultural runoff, and dioxins from incinerators and some paper products—as well as heavy metals such as mercury, are readily binding to the particles of plastic in the ocean, being ingested, and causing endocrine disruption and developmental and immune system problems with many species. According to NOAA (2013), "Plastic debris accumulates pollutants such as PCBs (polychlorinated biphenyls) up to 100,000 to 1,000,000 times the levels found in seawater." Many of these substances further bioaccumulate (their concentrations increase exponentially as they travel up the food chain), meaning the final concentrations consumed by humans or other species have the potential to be acutely toxic.

Habitat Damage

Debris causes deleterious impacts to coral reefs, sea grass beds, and mangroves, by actively destroying them, by smothering the habitat, and/or by preventing access to it by other species. Coral reefs remain viable and healthy when they are grazed by parrotfish and other species; if they are covered in debris, algae are more likely to grow and take over the reef, eventually killing it. Debris that is ensnared in sea grass beds can dislodge or tear the delicate blades, resulting in the loss of that habitat as a nursery for juvenile fish, crab, and snail species.

Vessel Damage/Navigational Hazard

Any subsurface debris can pose a serious navigational risk to boats, from the largest ships to the smallest artisanal and marine protected area patrol boats. Ropes and nets can tangle around propellers or clog intakes, and vessels can run over stationary or heavy metal debris that has settled below the surface.

Alien Species Transport

Many fouling marine organisms, such as barnacles, mussels, tunicates or sponges, will settle on any hard substratum they encounter in the ocean. Once settled, they will persist on the drifting debris as long as conditions remain similar enough to their native habitat. Debris that travels thousands of kilometers can arrive with a myriad of living, attached species that then thrive and establish new populations in novel habitats. But the distances do not have to be great; species endemic to one region can cause serious harm in nearby habitats, depending on the health of the marine communities and the life histories of the particular species involved.

Ghostfishing

Fishing gear—nets, lines or traps—left at sea often continue to "fish," but the species ensnared are never collected and the gear is never recovered. Some of these passive fishing devices can be responsible for the death of thousands of individual organisms, from marine mammals to crabs. In Guadeloupe alone, researchers estimate that 20,000—or 50 percent—of the traps set each year are lost (mostly in hurricanes) (Burke & Maidens 2004).

Economic Impact

Data are scarce on precise monetary figures but debris can slow down the shipping industry if vessels are damaged. The tourism industry can be affected in geographic areas that depend on beach or reef access. One study conducted on the Cape Peninsula in South Africa suggested that lowering the aesthetics at a particular beach could result in as much as a 52% drop in tourism revenue (Ballance *et al.* 2000). Finally, if debris is harming fished species, fishermen may see a negative economic impact from marine debris.

Human Health and Safety Risk

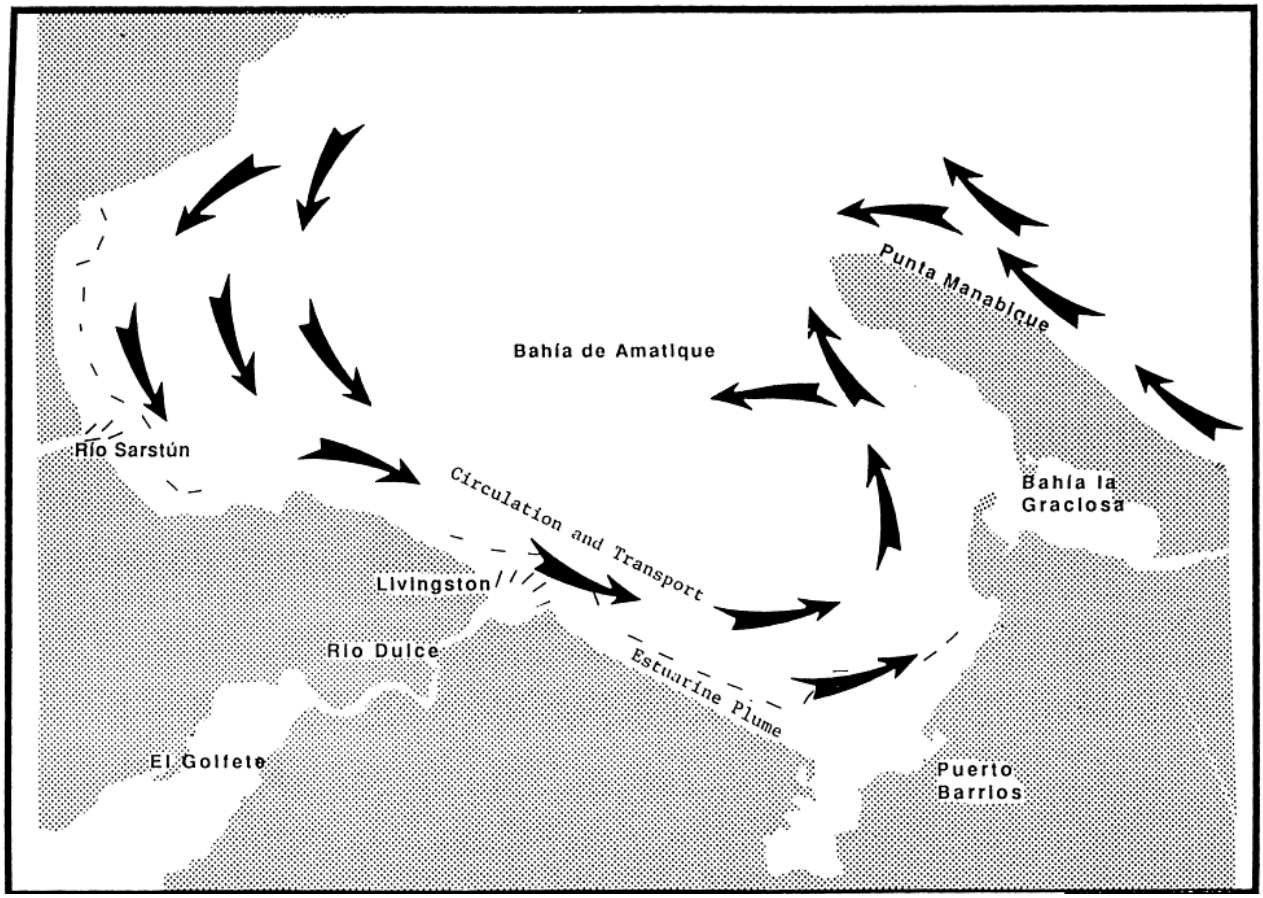
The visible debris can include medical waste, such as needles and items that may contain pathogens (*e.g*,. diapers, tampons, condoms). In addition to being unsanitary, some debris can be sharp and rusty or contaminated.

Aesthetics

Tourists and residents are likely to avoid areas that appear trashed and dirty. It is important to engage everyone in cleaning and protecting campaigns, as individuals are less likely to trash a pristine habitat as they are one that is filled with debris.

Appendix 2

Local oceanographic currents within Amatique Bay, Belize and Guatemala



Source: Yañez-Arancibia *et al.* 1995.

Appendix 3

Ecosystems of the study area

The Abt Associates Inc. / Woods Hole Group. 2003 report provides detailed information about the ecosystems and species in the study area. What follows is a brief summary of the data contained in that report.

The terrestrial and marine ecosystems of the Gulf of Honduras include mangroves/coastal forests, estuaries, coastal lagoons, coastal embayments, inner cays, mid lagoon cays, barrier reefs, beaches and the open ocean. These ecosystems are home to a vast diversity of terrestrial and marine species, including tapir, manatee, jaguar, marine turtles, manatees, shrimp, mollusks, fish and numerous species of reptiles, amphibians and birds.

This area also has unique vegetation: at least four different types of mangrove forests are distributed from the Sarstoon River to Livingstone, Livingstone to Punta Palma, Rio Dulce to El Golfete River, Puerto Barrios and Punta de Manabique. The mangroves of the Sarstoon-Temash and the Port Honduras-Payne's Creek systems form the largest mangrove stand on the coasts of Guatemala and Belize. This area serves as critical habitat for the majority of marine species within and beyond the gulf.

Another plant species that is critical to this area is the seagrass[2] which forms vast undersea meadows. The presence and distribution of these species are a result of environmental processes that determine water transparency, shallowness and availability of sandy bottoms. The seagrass habitat is critical to fishery production, food supply for certain threatened species, and for coastal stabilization.

Finally, the Gulf of Honduras contains part of the Mesoamerican Barrier Reef System (MBRS), which extends 250 km and covers 22,800 km^2 as an assemblage of lagoon patch reefs, fringing reefs and offshore atolls. The Belize Barrier Reef Reserve, within the MBRS, was added to the list of World Heritage Sites in Danger in 2009. Corals in the area have been affected by bleaching and suffer high mortality levels due to water pollution and elevated seawater temperatures in the Caribbean.

[2] *Thalassia testudinum* (turtle grass) and in a lesser degree other species such as *Halodule wrightii* and *Syringodium filiform* and *Vallisneria Americana*