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Coastal Capital: Jamaica

Coral Reefs, Beach Erosion and Impacts to Tourism in Jamaica

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Project Partners

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Glossary

Access value. The value of compensating tourists if they were to experience a total loss of the beach and coral reef recreational services at their destination.

Beach nourishment. The placement of sand on the beach, which offers protection by reducing the wave energy near-shore and creating sacrificial beach to be eroded during a storm.

Breakwaters. Structures constructed on coasts to reduce the intensity of wave action in inshore waters to reduce beach erosion.

Consumer surplus (also consumer welfare). The difference between the maximum price a consumer is willing to pay and the actual market price they do pay.

Contingent valuation approach. Economic valuation technique that asks individuals for their preferences by conducting surveys that construct a hypothetical.

Coral cover. A measure of the proportion of the reef surface covered by live, hard coral cover.

Coralline. Originating from offshore coral reefs, including calcareous algae and other calcareous-producing organisms.

Ecosystem services. The tangible benefits provided by ecosystems that sustain and fulfill human life.

Elasticity of demand. The percent drop in demand associated with a percent increase in price.

Fringing reef. A reef that follows the coastline, tracing the shore tens or hundreds of meters from the coast.

Marine protected area. Any area of the intertidal or subtidal terrain—together with its overlying water and associated flora, fauna, historical, and cultural features—that has been reserved by law or other effective means to protect part or all of the enclosed environment (*IUCN World Conservation Union*).

One-year storm event. Refers to the largest storm that occurs at a specific location during a typical year.

Patch reef. A reef outcrop, typically part of a lagoon or embayment.

Payment for ecosystem services (PES). Offering incentives in exchange for an ecological service.

Real gross domestic product. A measure of the value of an economy's output, adjusted for inflation.

Rugosity. Refers to the "roughness" or three dimensional-complexity of the ocean floor, and thus its frictional quality.

Stated choice approach. An economic valuation method that utilizes surveys to ask individuals to state their preferences for an environmental good or service, according to a hypothetical situation.

Stopover. A visitor staying at least 24 hours in the country.

Value. The quality of a thing according to which it is thought of as being more or less desirable, useful, estimable, or important.

Willingness to pay (WTP). The maximum amount an individual is willing to pay to receive a good or avoid something undesirable.

Executive Summary

Coral reefs provide a diverse array of goods and services to the people and economy of Jamaica. They buffer coastlines from storms; slow erosion; provide habitat for commercial, artisanal, and sport fisheries; attract local and international tourists to the coast; and are a source of cultural and spiritual significance to many people. However, their value is often not reflected in policy and development decisions. A lack of information and knowledge of the extent and value of the benefits provided by reefs hinders effective decision-making in support of reef conservation and contributes to the continued degradation of Jamaica's reefs from widespread overfishing, coastal development, and pollution.[2] Jamaica's white coralline beaches represent an important draw and the primary focus of most international tourists, and thus provide a critically important contribution to Jamaica's economy. To help illuminate the importance of reefs, this study assesses the economic value of the contribution of reefs to erosion control and the economic benefits derived from beach tourism. The *Coastal Capital: Jamaica* project also examines two other "ecosystem services" that coral reefs provide to Jamaica: coral reef-associated fisheries, and the role of coral reefs in reducing coastal flooding during storms. Working papers on these topics can be found at *www.wri.org/coastal-capital*.

This study focused on the three main beach tourist destinations in Jamaica—Negril, Montego Bay, and Ocho Rios—which are all impacted by coral reef degradation and associated beach erosion (Map ES-1). An average current beach erosion rate of 0.3 m/yr was used for each of these beaches. We applied a model developed by Sheppard et al. (2007) to each of the three sites, to estimate how the further loss of live reef structure and the subsequent erosion of the reef substrate over 10 years would lead to increased wave heights and thus increased beach erosion.[3] We found that increased coral degradation would lead to significant increases in beach erosion in all three sites over 10 years—more than 50 percent for Montego Bay, 70 percent for Ocho Rios, and more than 100 percent for Negril compared to the current rate.

Map ES-1. Jamaica's reefs are at risk from overfishing, coastal development, watershed-based pollution, and marine-based pollution

Source: Burke et al. 2011.

Using the increased erosion rates as inputs, we then determined the loss in consumer welfare associated with a decline in beach quality due to erosion at each site. A study by Edwards (2009), which looked at visitors' willingness to pay for environmental quality, was used as the basis to determine the welfare loss per meter loss of beach width.[4]

We estimate that at the end of 10 years, current erosion rates at the beaches in Negril, Montego Bay, and Ocho Rios will cause a US$19 million annual loss in value. If reefs degrade further, we estimate that the additional beach erosion will increase this loss to US$33 million that year. This represents an additional US$13.5 million—a 70 percent increase in the annual loss of value if the reef degrades further. This loss of value is projected to have knock-on impacts by reducing tourist visitation between 9,000 and 18,000 stopover visitors per year, costing an estimated US$9 million to US$19 million per year to the Jamaican tourism industry and US$11 million to US$23 million per year to the entire Jamaican economy.

Jamaican coastal tourism is highly dependent on the quality of the natural environment. With improved coastal and fisheries management, the ecosystem services provided by Jamaica's coral reefs and beaches could recover—and thus their value to coastal tourism and other services and benefits to the Jamaican economy would increase. More revenue from ecosystem services associated with coral reefs would in turn correspond to an increase in the economic feasibility of protecting and restoring beaches affected by erosion.

The continued contribution of coastal tourism to Jamaica's economy rests on the ability of key stakeholders to better protect the coral reefs and coastal ecosystems the industry is so critically dependent upon. The estimates produced in this study are meant to inform decision-making, while also encouraging new opportunities to finance reef and coastal conservation measures. We offer several strategies to utilize our results in ways that will promote reef conservation, including:

- *Build national political will for greater reef conservation.* History demonstrates that conserving ecosystems begins with widespread awareness of the benefits they provide and the political will to act. In order to leverage these results, it is important to publicize and disseminate the key findings of this paper to the Jamaican government, citizens, conservation groups, industry, and development agencies.

- *Strengthen environmental policy*. Policies that address the main drivers of coral reef degradation (overfishing, coastal development, and pollution) over short-term measures such as beach nourishment must be developed. This includes strengthening existing policy opportunities, such as the draft National Fisheries Policy, with language that makes the economic case for more holistic conservation measures. Current laws—such as the Tourism Enhancement Fund, the Natural Resources Conservation Act, and the Beach Control Act—must also be examined to assess how well existing institutional mechanisms, norms, and regulations address local threats to coral reefs.

- *Create new opportunities for long-term conservation funding.* By quantifying the economic losses likely to occur due to degradation of reefs, it is possible to tap public and private funding for coastal management, gain access to new markets, initiate payments for ecosystem services, and charge polluters for damages. Key stakeholders must invest in solutions to protect and restore the beaches and coral reefs that support Jamaican tourism over the long term.

The Coastal Capital Project

This study is part of the World Resources Institute's (WRI) *Coastal Capital* project. The project was launched in 2005 and aims to provide decision-makers in the Caribbean with information and tools that link the health of coastal ecosystems with the attainment of economic and social goals. WRI and its local partners have conducted economic valuation studies of coral reefs and mangroves at national and subnational levels in five countries: Trinidad and Tobago, St. Lucia, Belize, the Dominican Republic, and Jamaica. We are using the results to identify and build support for policies that help to ensure healthy coastal ecosystems and sustainable economies.

Products from *Coastal Capital: Jamaica,* in addition to this paper, include a working paper on coral-reef associated fisheries; a working paper by the University of the West Indies, Mona GeoInformatics Institute, on coastal inundation; an 8-page summary of results for decision-makers; and a literature review and summary of 14 previous coral reef valuation studies from Jamaica. These products, along with additional information about WRI's *Coastal Capital* series, are available online at *http://www.wri.org/coastal-capital*.

Introduction: Jamaica's Coastal Capital

Coral reefs provide a diverse array of goods and services to the people and economy of Jamaica. They buffer coastlines from storms; slow erosion; provide habitat for commercial, artisanal, and sport fisheries; attract local and international tourists; and are a source of cultural and spiritual significance to many people. However, the full value of these reefs and coastal ecosystems—and the goods and services they provide—is often not reflected in policy and development decisions. A lack of information and knowledge of the extent and value of the benefits provided by reefs hinders effective decision-making about investments, conservation efforts, and management.

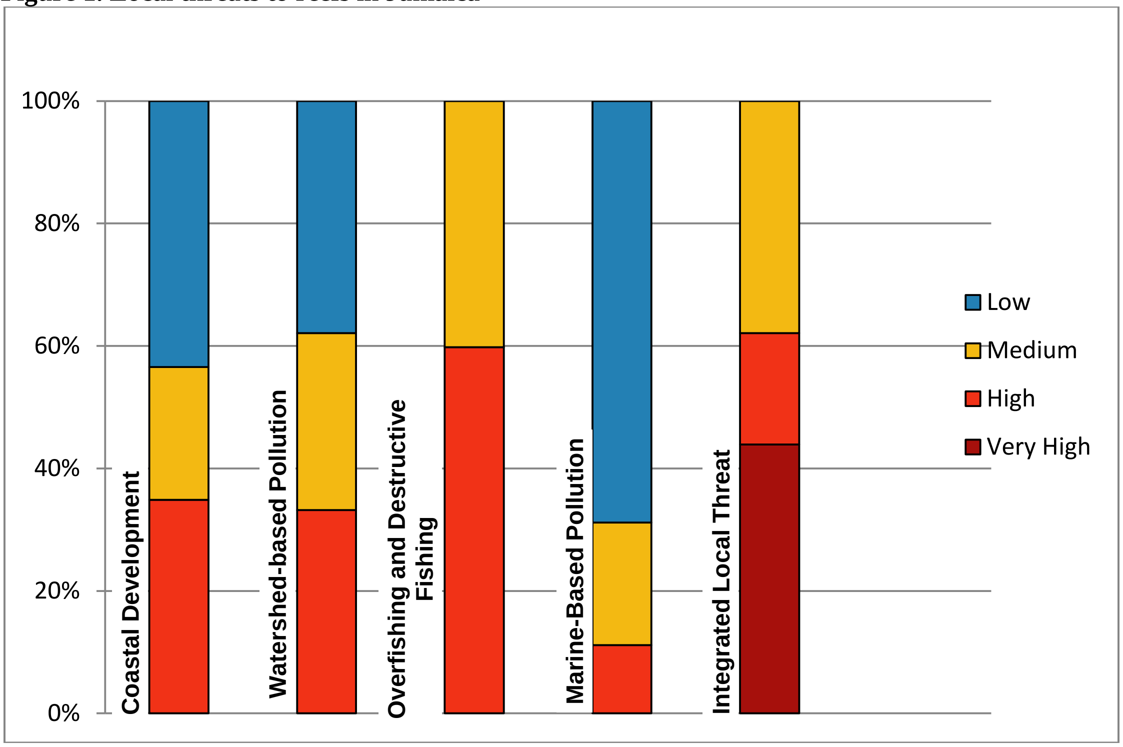
Jamaica is a mountainous archipelagic state surrounded by a narrow discontinuous coastal plain. The mainland island extends 234 km in length and 82 km in width, encompassing a land area of 11,000 square kilometers, making it the third largest island in the Caribbean Sea. Its 1,022 km coastline has many coralline beaches, as well as rivers and wide marshy flats, providing a diverse coastal environment.[5, 6]

Jamaica's reefs are some of the most diverse in the Atlantic and also among the best studied in the world, with data available since the 1950s.[7] Its fringing reefs are broadly distributed along a narrow 1–2 km shelf on the northern coastline and also, although to a lesser degree, on the broader 20 km wide southern shelf.[8] Additionally, reefs and corals can be found on its two largest offshore banks, Pedro Cays, 80 km to the south, and the Morant Cays, 50 km to the southwest. Jamaican reefs face several serious human pressures. Overfishing, the most prevalent human pressure, threatens all of Jamaica's reefs. Watershed-based pollution and coastal development threaten nearly 60 percent of the country's reefs, while marine-based pollution threatens over 30 percent of reefs (Map 1 and Figure 1).[2]

Map 1. Jamaica's reefs are at risk from overfishing, coastal development, watershed-based pollution, and marine-based pollution

Source: Burke et al. 2011.

Figure 1. Local threats to reefs in Jamaica



Source: Burke et al. 2011.

Note: This figure summarizes current threats to Jamaica's reefs. Individual local threats are categorized as low, medium, high, and very high. These threats are integrated to reflect cumulative stress on reefs. The fifth column, integrated local threats, reflects the four local threats (bars 1-4) combined.[9]

A combination of human-induced and natural stresses have contributed to the decline of Jamaica's reefs.[2] Limited employment opportunities, a large informal economy, densely populated coastal zones, and easy access to the narrow shelf areas have led to overfishing in nearshore areas. In addition, natural disturbances from hurricanes, coral bleaching prompted by warming seas, and diseases have contributed to considerable coral mortality. In 1983–84, *Diadema antillarum*, the Caribbean long-spined sea urchin, experienced one of the most devastating mortalities ever recorded in a marine animal.[10] Long-spined sea urchins play a critical ecological role by grazing on algae, clearing areas of hard substrate so new corals can settle. Healthy populations of long-spined sea urchins are particularly important after mass bleaching events when corals are more susceptible to algal overgrowth.[11] The dramatic decline in *Diadema* abundance, combined with persistent overfishing of herbivorous fish, caused a dramatic shift on Jamaica's reefs from coral cover to algal cover by the 1990s. To make matters worse, significant coral bleaching took place in Jamaica during 1987, 1989, and 1990, with widespread and severe bleaching occurring in 1998.[12] The combination of stresses from hurricanes, bleaching, disease and human pressures have all contributed to the overall decline in coral reef ecosystem health. As a result, all of Jamaica's coral reefs are considered threatened, with over 60 percent in the high or very high categories (Figure 1).[2]

More recently, there have been some hopeful signs, including rising numbers of sea urchins and the discovery of several sites with relatively high coral cover and increasing numbers of coral recruits.[8] Jamaican coral reefs have recovered from a 5 percent mean coral cover in the early 1990s to an average coral cover of 15 percent in 2008.[13] This improvement is likely due to the recovery of long-spined sea urchin populations and resilience in the system.[13, 14] Coral cover remains variable across Jamaica, with the percent of live coral cover ranging from 2 to 38 in a 2008 survey, and half of sites supporting less than 10 percent live coral cover.[8,15] However, in general, Jamaica's reefs remain degraded, as many human-induced and natural stresses persist.[13] Furthermore, the projected increase in sea level and the intensity of hurricanes from climate change is expected to further exaggerate the impact of degrading reef structure.[2, 16]

These human pressures and other stresses and threats have led to the widespread degradation of Jamaica's coral reefs.[2, 7] To reverse the degradation of Jamaica's reefs, it will be essential to curb these threats. Economic valuation—which assigns a monetary value to the goods and services provided by ecosystems—gives policy makers an important tool with which to set priorities and improve decision-making around natural resources. By highlighting the long-term economic benefits derived from effective management of reefs, we make the case that reef conservation efforts are investments in "coastal capital" that have real economic benefits.

Reefs provide an important source of white sand for beaches and also dissipate wave energy to reduce erosion and lower inundation and wave damage during storms. This analysis emphasizes the contribution of reefs to beach erosion control and the economic benefits derived from beach tourism, as white sand beaches represent an important draw and the primary focus of most international tourists to Jamaica. The paper focuses on Negril, Montego Bay, and Ocho Rios—the three main beach tourist destinations in Jamaica. These beautiful white sand beaches are threatened by erosion in many places along the coast. We chose Long Bay in Negril as the primary case study, as beach dynamics are best documented and understood there and considerable data were available.

The analysis proceeds in two parts, where we quantify (1) the relationship between coral reef degradation and beach erosion in Jamaica; and (2) the relationship between beach erosion and potential losses of tourism revenue in Jamaica.

This analysis will demonstrate how continued coral reef degradation will result in economic losses for Jamaica's travel and tourism industry, which is forecast to account for nearly 24 percent of Jamaica's gross domestic product in 2011.[17] Our results make a compelling case for greater investment in reef protection and conservation in Jamaica, including managing coastal development, reducing watershed-based pollution and sedimentation, and promoting sustainable fishing practices.

Box 1. *Economic Valuation of Coral Reefs*

Economic valuation is a tool that can aid decision-making by quantifying ecosystem services, such as those provided by coral reefs, in monetary terms. In traditional markets, ecosystem services are often overlooked or unaccounted for, an omission that regularly leads to decisions favoring short-term economic gains at the expense of long-term benefits. Economic valuation provides more complete information on the economic consequences of decisions that lead to degradation and loss of natural resources, as well as the short- and long-term costs and benefits of environmental protection.

Many studies have quantified the value of one or more ecosystem services provided by coral reefs. These studies vary widely in terms of spatial scale (from global to local), method used, and type of value estimated. Of the many ecosystem services provided by coral reefs, reef-related fisheries, tourism, and shoreline protection are among the most widely studied because their prices are traceable in markets and are thus relatively easy to calculate. Although cultural, aesthetic, and future benefits associated with reefs are also significant, they have largely been absent in valuation studies due to a lack of information from existing or comparable markets.

Ultimately, the goal of economic valuation is to influence decisions that will promote sustainable management of reefs. By quantifying the economic benefits or losses likely to occur due to degradation of reefs, it is possible to tap public and private funding for coastal management, gain access to new markets, initiate payments for ecosystem services, and charge polluters for damages.

Challenges and Limitations

Despite the usefulness of economic valuation, there are still many challenges to its practical application. This is evidenced by the wide variation in the quality and consistency of existing economic valuation studies. Economic valuation can produce only a partial estimate of total ecosystem value, as humankind's limited technical, economic, and ecological knowledge prevents us from ever truly identifying, calculating, and ranking all of an ecosystem's values. Ultimately, valuation results should be used as part of a larger decision-making "toolbox" rather than being relied upon in a vacuum. In particular, valuation studies need to take into account the local context—both social and biological—and be undertaken with an eye toward the bigger picture. For example, what are the implications of under- or overestimating a given ecosystem service? Who will be the winners and losers if an ecosystem service is gained or lost? It is critically important when undertaking economic valuation to engage local stakeholders, document all data and assumptions, and carefully explain the uses and limitations of the research. Despite these challenges, economic valuation provides a powerful tool to target key decision-makers, while making the economic case for greater investment in conservation efforts.

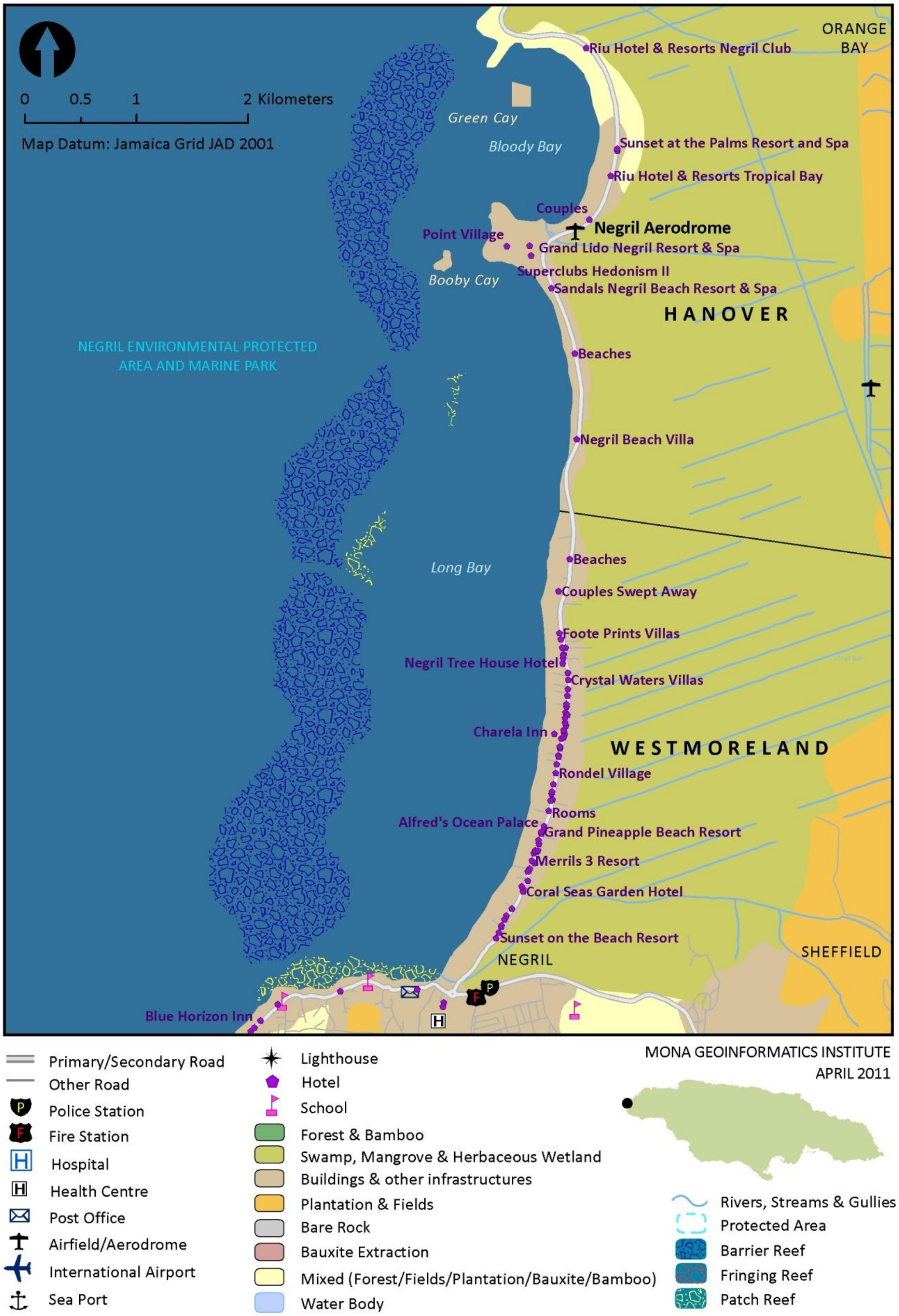
1. Coral Reefs and Beaches in Jamaica

Beaches, in their natural state, are in dynamic equilibrium between the sources that supply sand and the forces that erode it.[18] The remains of corals provide an important source of sand, and are deposited along beaches by wind, waves, and currents. Living corals, and remains of corals, also contribute to the three-dimensional complexity and bottom friction of the ocean floor, which is an important factor in the dissipation of wave energy.[3] Coral reefs can reduce wave energy by more than 75 percent.[19] By reducing the energy of incoming waves, coral reefs help to control beach erosion. If living coral no longer covers the ocean floor, the substrate of old coral skeletons that make up a reef becomes exposed to waves and erode. This increases the depth of the water, leading to an increase in wave energy. The ability of coral reefs to control beach erosion thus becomes impaired and beaches lose sand.[18]

Beach Erosion in Long Bay, Negril

Negril Beach, located on Jamaica's west coast and shared by both Hanover and Westmoreland parishes, has two carbonate beaches known as Long Bay and Bloody Bay that stretch a total of 9.1 km.[20] Long Bay, the focus of this case analysis, has a total length of 7 km and an average width of 15 m, with beach width ranging from as low as 1 m to as wide as 43 m in the central section.[21] In general, the beach is shallow with a mild slope average of 10 percent. Large all-inclusive resorts are, for the most part, found on the northern end of Long Bay, while smaller restaurants and hotels occupy the southern section of the bay. There is a 500 m long patch reef located 1.4 km offshore in front of the widest section of beach on Long Bay, and a fringing reef situated 2–3 km offshore on the outer shelf of the reef with a water depth of 20 to 50 meters.[20, 22, 23] Negril's reefs averaged 15 percent coral cover in 2007.[8] Please see Appendix 1 for a reef profile for Negril.

Map 2. Negril infrastructure and reef map



Current Rates of Beach Erosion in Negril

Negril's beach is extremely dynamic, as beach width in some sections has been recorded to fluctuate more than 30 m in a single year.[20] A study by Smith-Warner reports a 40 m loss of beach in certain areas over the past 40 years, or an average rate of beach erosion of 1 m per year during that period.[20] The University of the West Indies' Marine Geology Unit (MGU) found a net average beach loss of 8.4 m for Long Bay from 1971 to 2008, or 0.23 m per year.[21] Although these averages vary, both studies conclude that overall the beach width has been diminishing in recent decades. This beach loss has not occurred gradually over time, but rather sporadically through periods of accretion, recession, and relative stability, and losses have most notably followed hurricanes and big storm events.[20, 21]

Negril's beach is, for the most part, a natural beach and has had few engineering interventions. There have been some steps taken to conserve Negril's reefs, most notably in 1998 with the establishment of the 16,000 ha Negril Marine Park. The park includes almost all of Negril, stretching from the high water mark on shore to 3.2 km out to sea. The park incorporates coral reef, sea grass, and mangrove habitat and is zoned to provide for mixed uses.[24]

Modeling the Impact of Reef Degradation on Beach Erosion

We applied two models to explore the implications of further coral reef degradation and the resulting changes to wave height, wave energy, and impact on beach erosion. The first, simpler model, developed by Sheppard et al. (2007), predicts how the loss of live reef structure and the subsequent erosion of the reef substrate increase beach erosion through increased wave heights.[3,25,18] The second model, MIKE 21, is a hydrodynamic model, which can be run in both two- and three- dimensional modes and models how corals attenuate wave height for a variety of storm conditions.[26] We applied the Sheppard model for all three sites, but we only had data required to apply MIKE 21 for Negril.

Sheppard Model Application and Results

The aim of the analysis was to understand how future degradation and death of coral reefs in Long Bay, Negril, and the subsequent erosion of the dead coral colony would affect beach erosion through increased wave height. The modeled scenario involved the loss of friction from live, standing coral cover, followed by the erosion of the coral substrate. Within the Sheppard model, the frictional coefficient was reduced from .14 to .10, which corresponds to a shift between two categories of live coral cover in Sheppard et al. from 10–25 percent live coral cover to 75–100 percent smooth coral rock.[3] In addition, a 6 mm per year erosion rate of the coral rock was used to evaluate the effects of erosion of the reef substrate over 10 years, subsequent to the loss of friction from the live, standing coral. The increase in beach erosion is calculated using a base erosion rate for Negril of .3 m/yr, which is fairly conservative, in light of the .23 m/yr estimate from MGU and the 1 m/yr estimate from Smith-Warner. We examine this increase in beach erosion due to loss of reef rugosity[a] and height relative to this base (current) erosion rate.

Application of the Sheppard model for Negril suggests wave height could increase by 30 percent due to the initial loss of rugosity from live standing coral and up to 36 percent by year 10 due to the additional erosion of the reef. These increases in wave height from 30 to 36 percent would result in roughly a doubling (118 percent) of the rate of beach erosion relative to current conditions (3.0 m beach loss by year 10). Under the status quo, the beach erodes about three meters over a 10-year period. Under this scenario of enhanced coral degradation and reef erosion, the beach erodes at about 6.2 meters over the 10

[a] Rugosity refers to the "roughness" or 3-D complexity of the ocean floor, and thus its frictional quality.

year period. Please see Table 1 for a summary of the modeling results and Appendix 2 for the full results, data sources, and input values used in the application of the Sheppard model for Negril.

Table 1. Sheppard model results for Long Bay, Negril

Model Scenario	Inshore Wave Height (m)	% increase in inshore wave height	% increase in erosion rate relative to current	Beach loss (using a base erosion rate .3 m/yr)
Current 15% live coral cover (baseline)	.159	0 (current)	0 (current)	.30
No live coral cover (bottom friction is reduced)	.207	30	94	
Year 1 of erosion	.208	31	96	.59
Year 10 of erosion	.217	36	118	.65
Total loss of beach width after 10 years (average for Long Bay, in m)				
If reef degrades and erodes				**6.2**
Base scenario – Reef unchanged, current erosion rate of 0.3 m / yr continues				**3.0**

MIKE 21 Application and Results

The MIKE 21 model was applied in both two- and three-dimensional modes for Negril to examine how coastal inundation is likely to change if the reefs in Long Bay degrade further.[b] Using the outputs of that modeling effort, a specific storm scenario was examined that most closely matches the scenario evaluated above using the Sheppard model. The scenario uses the "1-year storm event"[c] for Negril and a 1 meter loss of reef height (the water level above the reef increases from 1 m to 2 m). The estimated model output of change in inshore wave heights from the MIKE 21 model was used to compare to the equivalent output from the Sheppard model. In both cases, the percent change in wave height was used to estimate the likely change in beach erosion.

Table 2 presents a summary for a 1-year storm event in Negril of the effect of a 1 m loss of reef height during a 1 year storm event. MIKE 21 results suggest that the inshore wave height would increase by 43 percent (from .40 to .57 m height), which translates to more than doubling the rate of beach erosion. Figure 2 shows estimated wave height for the 1-year storm event using the MIKE 21 model. Note the diminished wave height is most pronounced behind the location of the larger shallow reef in Long Bay. The diminished wave height noted along the remaining shoreline is most likely a result of the protection afforded by the offshore fringing reef.

[b] This was part of a separate project component mapping the influence of reef degradation on coastal inundation. See *http://www.wri.org/coastal-capital.*

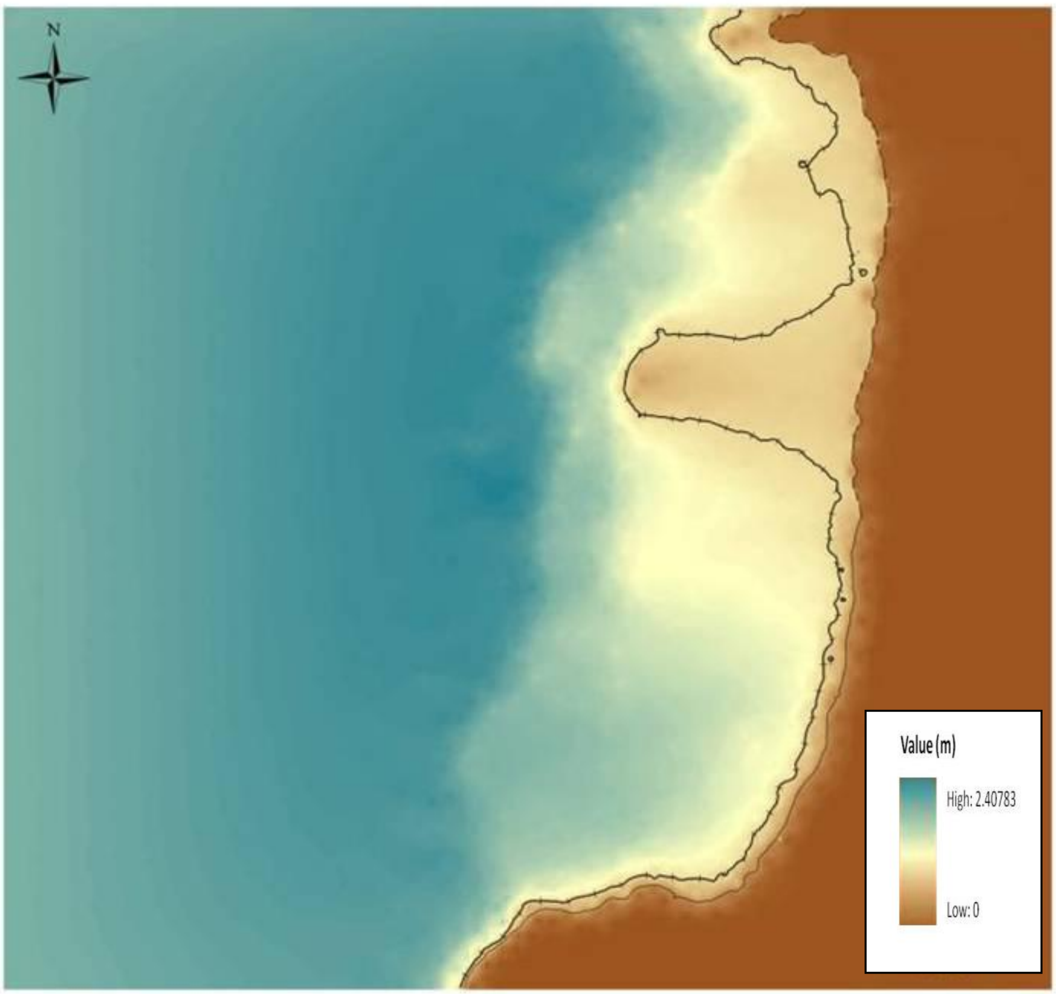
[c] A 1-year storm event refers to the largest storm that occurs at a specific location during a typical year.

Table 2. MIKE 21 results for a 1-year storm event in Long Bay, Negril

Model Scenario	Inshore Wave Height (m)	% increase in inshore wave height	% increase in erosion rate relative to current	Beach loss (base rate of erosion rate .30 m/yr)
1-year storm event (reef 1 meter below the surface)	.40	-	-	.30
1-year storm event (reef 2 meters below the surface)	.57	43	142	.73

Note: The model assumes that coral loss will cause a 1 m drop in the average reef depth.

Figure 2. Spatial variation in the significant wave height for the 1-year storm event at Long Bay, Negril



Note: the shoreline is identified by the solid black line and the contour for the 1 m wave height is shown as the hatched line, which highlights the location of the patch reef.

Comparison: MIKE 21 and Sheppard Model Results for Negril

We found that the 10-year scenario in the Sheppard model is similar to the results of a 1 m loss of reef height in the MIKE 21 model. Although the Sheppard and MIKE 21 applications project somewhat different wave heights for present conditions, they project fairly similar changes in wave height as the reef degrades. The results of the Sheppard model showed a 36 percent increase in wave height, compared to a 43 percent increase in wave height (with the erosion of the reef 1 m to a 2 m depth below the water level) from MIKE 21. Both models predicted that beach erosion would more than double.

Beach Erosion in Montego Bay and Ocho Rios

The Montego Bay and Ocho Rios beaches are located on Jamaica's northwestern coast. Montego Bay, the capital of St. James parish, is Jamaica's second largest city and a magnet for tourists, drawing over 80 percent of Jamaica's visitors through the Sir Donald Sangster International Airport.[27] Ocho Rios, located in the St. Ann parish, represents another important tourist destination, drawing nearly 65 percent of all Jamaican cruise ship visitors to its port each year. Both Montego Bay and Ocho Rios have had significant engineering interventions to stabilize and nourish beaches, particularly in comparison to Long Bay, Negril.[28]

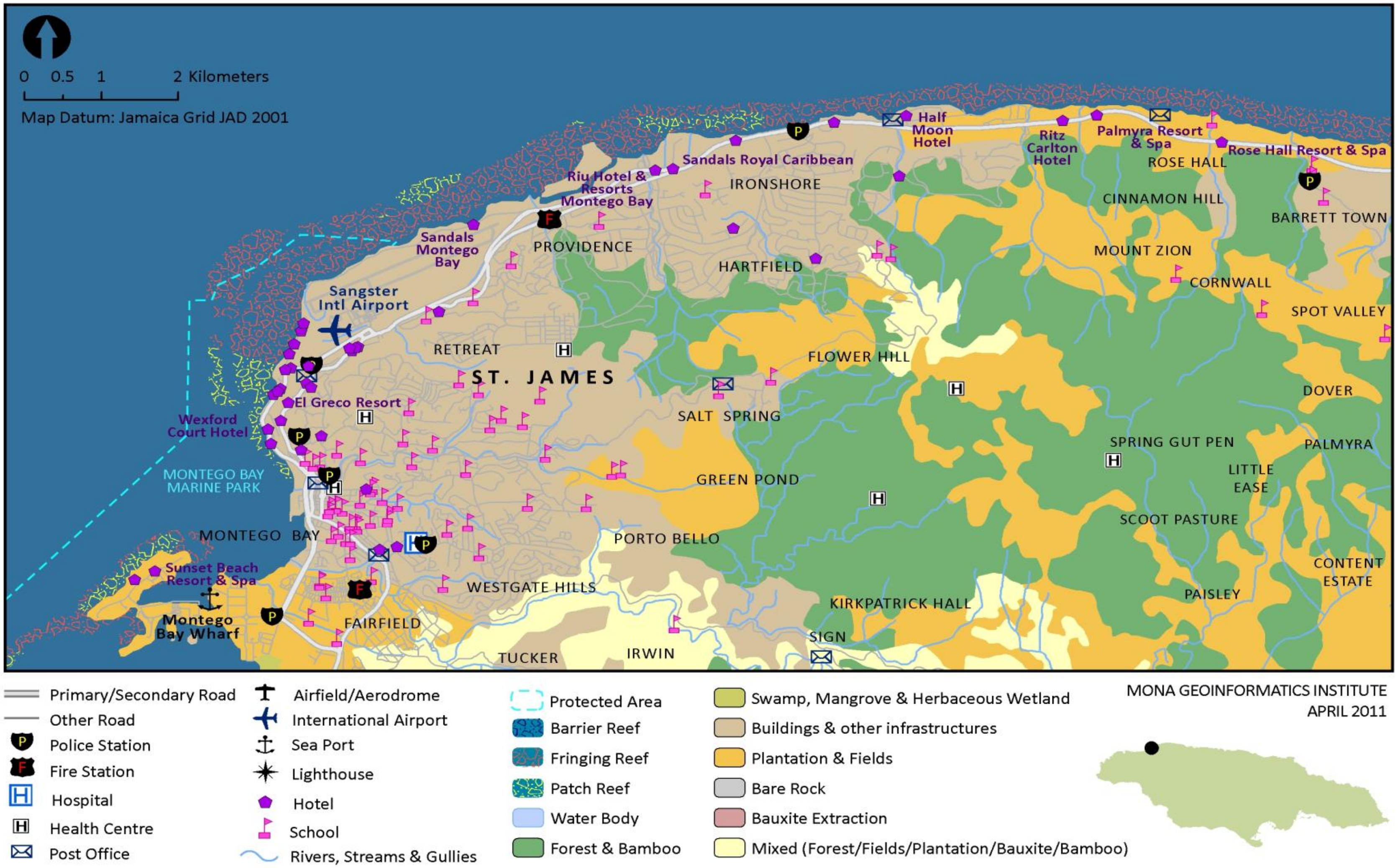
Beaches and Resorts Impacted by Reef Degradation

Montego Bay's most prominent beaches form discontinuous patches of white sand that are separated by limestone ledges and extend from Sangster Airport south toward the city. Walter Fletcher and Cornwall Beach are the only public beaches, while numerous resorts, hotels, restaurants, and bars dot Montego Bay's coastline. Thirteen small pocket beaches that stretch east along the St. James coast approximately 8 km from the airport were also included in the analysis due to their proximity to Montego Bay and their importance as tourism beaches.

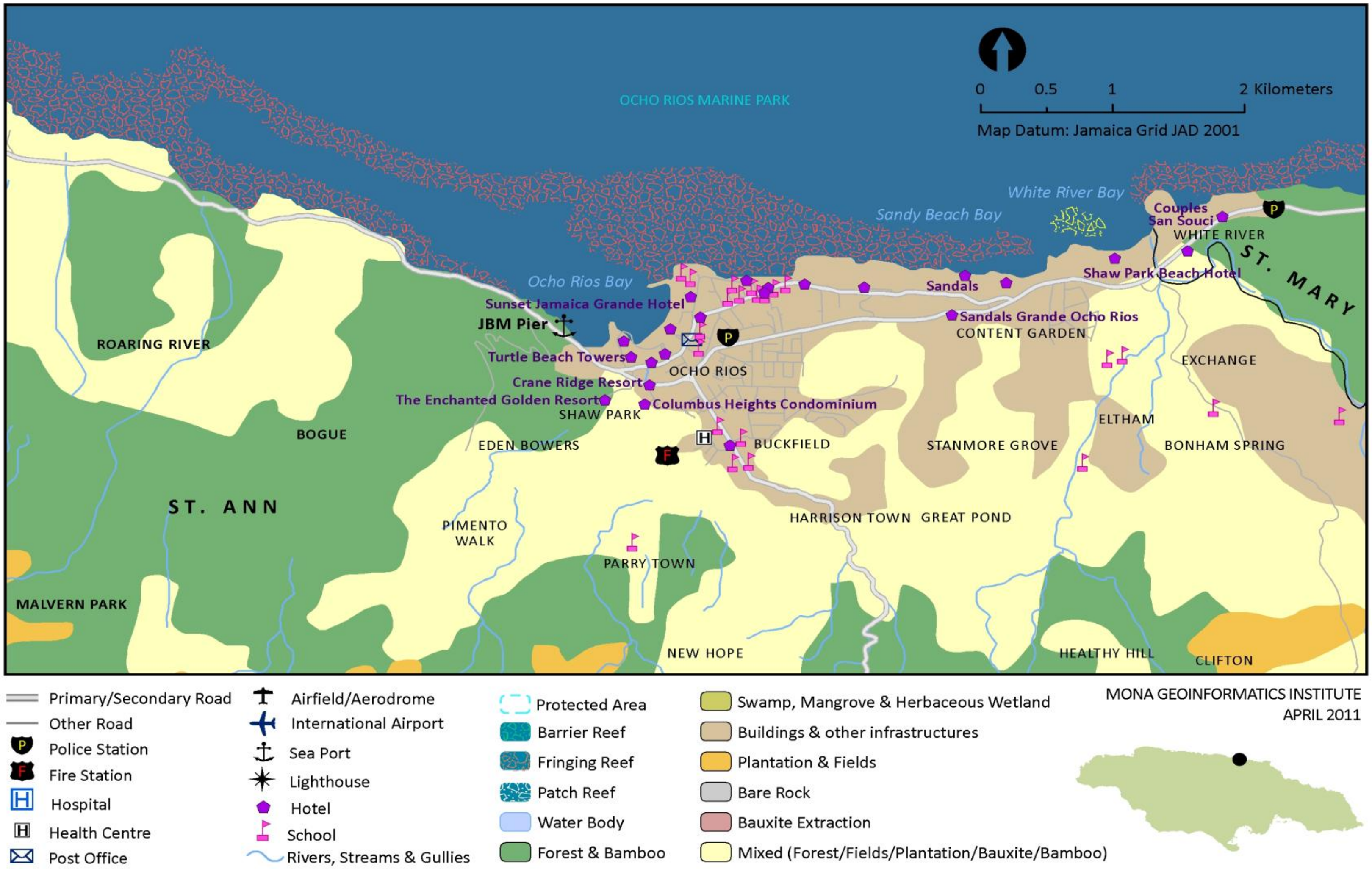
Montego Bay's coastline below Sangster Airport is buffered by a patch reef located 500 m offshore, which contains approximately 4,300 ha of coral reef substrate (see Map 3).[22, 23, 29] South of Doctor's Cave, the reef transitions to a fringing reef.[22] As of 2000, several sites had a 7 percent average live coral cover.[7] There are a number of threats confronting these reefs, including poor waste disposal, habitat clearance for hotel development, overfishing, hurricanes, and bleaching events. Additionally, physical damage caused by boat anchors and careless divers has also impacted reef health.[29] The Montego Bay Marine Park, which encompasses 1,530 ha and includes Dead End, Cornwall, Doctor's Cave, Walter Fletcher, and Dump Up beaches, extends from the Sangster Airport all the way south to the Great River. The Montego Bay Marine Park manages for the mixed use of the coastline, but confronts a number of challenges, including a lack of sufficient funding and conflict among user groups.[27, 29]

The center of activity in the town of Ocho Rios is the Ocho Rios Bay Beach, a sandy and relatively wide 0.6 km long patch of white sand surrounded by hotels, resorts, restaurants, bars, and an active cruise ship port (see Map 4). Ocho Rios also has a fringing reef that lies 1,000 m offshore.[22, 23] In 2000, a survey showed a site in Ocho Rios with only 2 percent coral cover.[7] The reefs in Ocho Rios face similar challenges as those of Montego Bay, but are also subject to heavier boat traffic, particularly from cruise ships.[27] Beach width also has been rapidly shrinking due to new hotel developments coupled with land encroachment, as highlighted by the large loss of beach that resulted from the construction of the massive Sunset Jamaica Grande Resort.[27] The Ocho Rios Marine Park, which is bordered by 13.5 km of shoreline, was delineated to protect Ocho Rios' coral reefs, but is considered a "paper park." [2, 30, 31]

Map 3. Montego Bay infrastructure and reef map



Map 4. Ocho Rios infrastructure and reef map



Results of Modeling (Sheppard) of Reef Degradation on Beach Erosion in Montego Bay and Ocho Rios

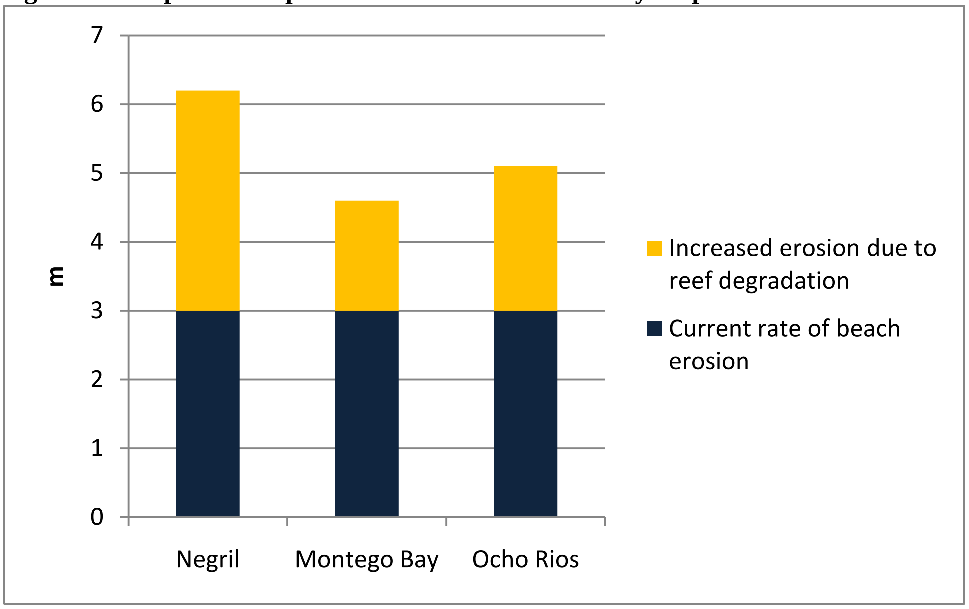
Using a similar scenario as Negril, the loss of all live coral cover (and associated friction) followed by 10 years of erosion of reef substrate was applied to Montego Bay and Ocho Rios. The starting condition is slightly different due to lower coral cover in Montego Bay and Ocho Rios compared to Negril. A base erosion rate of 0.3 m/yr also was used for Montego Bay and Ocho Rios. The application of this model scenario for Ocho Rios produced a 26 percent increase in wave height and a 77 percent increase in beach erosion, resulting in a 5.1 m loss of beach width over 10 years or a 2.1 m loss above the base scenario. In comparison, the loss of reef in Montego Bay is slightly less influential, resulting in a 21 percent increase in wave height and a 60 percent increase in erosion. This increase in erosion is anticipated to result in a 4.6 m loss of beach over 10 years, compared to a 3 m loss of beach if the reef remains in its current condition. As seen in Table 3, the greatest influence of reef loss on the subsequent erosion of beach is in Long Bay, Negril, followed by Ocho Rios. See Appendix 2 for more detailed results, data sources, and input values used in the application of the model in Montego Bay and Ocho Rios.

Table 3. Comparison of results for erosion over 10 years for Negril, Montego Bay, and Ocho Rios

Location	Inshore Wave Height (m)			Beach Erosion Rate (m)			Beach Loss over 10-Year Period (m)		
	Current Reef	*Degraded Reef*	*% Increase*	*Current Reef*	*Degraded Reef*	*% Increase*	*Current Reef*	*Degraded Reef*	*% Increase*
Negril	0.159	0.217	36	0.3	0.65	118	3	6.2	107
Montego Bay	0.344	0.415	21	0.3	0.48	60	3	4.6	53
Ocho Rios	0.219	0.276	26	0.3	0.53	77	3	5.1	70

Note: Inshore wave height and annual beach erosion rate are for year 10, while beach loss over 10-year period is for years 1–10.

Figure 3. Comparison of predicted beach loss over a 10-year period



Considerations and Limitations on Modeling Beach Erosion for Negril, Montego Bay, and Ocho Rios

Our analysis of future beach erosion rates combines information from multiple sources in a complex, multi-stage analysis. We applied the Sheppard model for all three sites, but we only had data required to apply MIKE 21 for Negril. We found local information for several variables within the Sheppard model—such as beach slope and erosion rates—in Negril (0.3 m/yr). Where local input values were not available, we averaged values from the Caribbean—such as for offshore wave height, offshore wave period, and reef erosion rates. Additionally, for Montego Bay and Ocho Rios, where erosion estimates were not available, we assumed a similar erosion rate as Negril. We also used the "ruler tool" of Google™ Earth 5.0 to determine variables such as average beach width for Montego Bay and Ocho Rios. We derived reef height from reef profiles provided by the Mona GeoInformatics Institute (MGI). The scenarios we explored focused on coral death, degradation, followed by erosion of the reef substrate. However, current trends in live coral cover and reef health are not clearly established and thus this scenario represents only a possible scenario of unmitigated threats and degradation, resulting in the death of all corals.

Our estimate of a beach erosion rate is based on a change from the current base erosion rate. There is uncertainty in this rate due to the difficulty in tracking shoreline modifications due to changes in vegetation from development and coastal infrastructure (breakwaters, groynes, etc). The fairly large disparity in estimates for current erosion rates between Marine Geology Unit (0.23 m/yr) and Smith-Warner (1 m/yr) further highlights this uncertainty. Additionally, the most significant increase in wave height occurs with the loss of rugosity, but it is not fully understood how long it takes to lose or what stage of degradation the reefs in Negril, Montego Bay, and Ocho Rios have already reached.

It is clear, however, that Jamaica's beaches are eroding and that further degradation of Jamaica's coral reefs would probably result in accelerated rates of erosion. Below, we examine the potential negative effects of increased beach erosion rates on Jamaica's tourism economy.

2. Economic Contributions of Reefs and Beaches to Tourism in Jamaica

Economic Importance of Tourism

The travel and tourism sector plays a critical role in the Jamaican economy alongside remittances and the bauxite/alumina industry. Travel and tourism is the largest contributor to Jamaica's gross domestic product (GDP), and is projected to directly contribute over US$1 billion or 7.4 percent of the country's GDP in 2011.[17] The total contribution, including its wider economic impacts, is forecast to contribute nearly US$4 billion or 24 percent of the GDP in that same year.[17] The industry also is expected to directly employ over 7 percent of the workforce in 2011, while the wider tourism economy, including supporting industries (such as food, infrastructure, communications) is expected to account for nearly 23 percent of employment.[17] Jamaica has the fourth largest tourism economy in the Caribbean. Visitor spending in 2011 is expected to generate roughly US$2 billion in foreign exchange for the country.[17] In 2009, Jamaica drew 1.8 million stopover visitors and an additional 900,000 cruise tourists.[32]

Jamaica is facing a number of economic challenges, including high unemployment, a 12.6 percent inflation rate in 2010, and a large foreign debt.[6] The global downturn has put additional pressure on the economy, reducing its real GDP growth to -1.1 percent in 2010.[33] The state of the economy puts additional pressure on elected officials to encourage foreign investment, hotel, and cruise-related development in the short term. Unfortunately, without careful planning, many of these projects degrade or threaten the longer-term health of the coastal ecosystems upon which much of the country's tourism depends.

Below, we establish the importance of the coralline beaches at Negril, Montego Bay, and Ocho Rios to Jamaica's appeal as a tourism destination, using existing surveys of visitors and analysis of tourism data, and by placing a dollar value on the loss or degradation of beaches in the country.

Dependence of Tourism on Reefs and Beaches

A key challenge in estimating the contribution of coral reefs to the larger tourism economy is identifying the percentage of visitation or visitor spending attributed to the presence of coral reefs. In addition to visiting beaches and reefs, many people also travel inland to visit Jamaica's beautiful waterfalls, wetlands, and mountains; others come primarily to experience the culture, music, or history of the country. Since this analysis is limited to secondary data sources, estimating the contribution of reefs and beaches to Jamaican tourism is particularly challenging. For this analysis, we examined tourism data and visitor surveys to produce a rough estimate of the importance of beaches to tourists. These estimates could be improved by follow-up surveys on the ground—a possibility for future research.

According to the Jamaica Tourist Board (JTB),[d] the vast majority of tourist days are spent in one of the three major beach destinations in the country. Montego Bay, Ocho Rios, and Negril account for roughly 72 percent of total overnight (non-cruise) visitors, and 93 percent of total "bed-nights" (i.e. nights spent in hotels in the country) recorded by the JTB from 2006 to 2009 (Table 4). The ports of Montego Bay and Ocho Rios also account for nearly 92 percent of cruise ship arrivals.[32] Furthermore, these three destinations provide an important source of jobs, employing nearly 87 percent of the staff from the accommodation sector in 2009.[32] If only the accommodation numbers are considered, beaches and coastal tourism strongly dominate the time spent by tourists in the country. However, these figures inflate

[d] The JTB, a component of the Ministry of Tourism, is the lead organization responsible for promoting and marketing Jamaica as a lead tourism destination.

the role of coastal tourism somewhat, in part because although most people stay on the beach, many take day trips to the interior where accommodation is scarcer.

Table 4. Average number and percent of total tourists visiting the three largest coastal tourism destinations in Jamaica over the past 5 years (2006–09)

Destination	Avg. # of overnight visitors / year	% of total visitors	Avg. # of bed nights / year	% of total bed nights	Avg. # of cruise visitors/year
Negril	360,927	21	2,119,240	28	0
Montego Bay	466,075	27	2,379,106	31	399,883
Ocho Rios	425,026	24	2,510,664	33	726,779
Coastal Destination Total	**1,252,028**	**72**	**7,009,009**	**92**	**1,132,778**

Source: Jamaica Tourism Board, 2006, 2009. [32, 34]

We also examined information on the role of beaches in attracting tourists to the country. For instance, it would be ideal to know how many tourists would choose to go elsewhere if the beaches were severely degraded. There are some partial answers to this question. A 2006 JTB visitor survey asked tourists to rate features of their trip by level of interest (very, somewhat, or not very interested) and found 78.5 percent of visitors to be "very interested" in beaches, which was the top choice by a wide margin (see Appendix 3).[35]

Taking another approach, Edwards (2009) conducted a "stated preference"[e] survey of visitors to the island to estimate the recreational value visitors place on the presence of beaches and nearshore coastal waters.[4] [36] Using a contingent choice modeling approach[f], Edwards estimated that the average access (recreational) value for an overall coral reef and beach was US$128 per visitor. This amount represents the value of compensating tourists if they were to experience a total loss of the beach and coral reef recreational services at their destination. It can also be expressed as the tourist's willingness to pay (WTP)[g] to avoid the decline. It is also possible to disaggregate the attributes of a coastal vacation in order to focus on the value the beach adds to visitors' enjoyment; this will be discussed in further detail in the next section. Using the survey results and tourism data, we estimated that between 70 and 80 percent of tourists care strongly about the presence of beaches in their visits to Jamaica. It should also be noted that like the tourist board study, Edwards' survey respondents also indicated that beach and beach-related activities played a key role in deciding to take their vacation in Jamaica.

[e] A stated preference approach is an economic valuation method that utilizes surveys to ask individuals to evince their desire for an environmental good or service according to a hypothetical situation.

[f] A contingent valuation approach asks individuals for their preferences by conducting surveys that construct a hypothetical market where individuals must state their willingness to pay for an asset or their willingness to receive payment to give something up.

[g] Willingness to Pay (WTP) is defined as the maximum amount an individual is willing to pay to receive a good or avoid something undesirable.

In the study mentioned above, Edwards examined the loss of consumer surplus[h] stemming from changes in the quality of beaches and other elements of the coastal environment in Jamaica.[4] The study placed a dollar value on the loss of consumer surplus associated with a loss of environmental quality. A randomly sampled set of visitors to Jamaica was given a survey that included different coastal management scenarios and associated levels of environmental quality. The survey then identified the respondent's willingness to pay (WTP) to achieve or maintain that level of quality. An example of a hypothetical scenario and survey question is shown below in Figure 4. For a full description of the methods and results used in the study, see Appendix 4.

Figure 4. Example of a WTP question included in a stated choice survey (US$)

Suppose you were planning to take a trip to Jamaica and one of the previously mentioned management options were already implemented. Suppose also that each option would vary by the cost of the tourism surcharge as well as environmental quality.

First, assume you were faced with one of the following three options

	Low Management	***Basic Management***	***Advanced Management***
Per person-Tourism Surcharge	$10	$40	$80
Beach Quality	Fair	Good	Good
Water Clarity	Fair	Good	Excellent
Coral Reef	Fair	Fair	Good
Fish	Fair	Fair	Good

…which of the options (if any) would you prefer?

Source: Edwards (2009).

Putting a Dollar Value on Beach Loss

Overview of Methodology for Determining Welfare Loss of Beach Erosion

Edwards' original study question focuses on visitors' WTP for overall coastal environmental quality, but it is possible to isolate the loss of value (consumer surplus) associated with a loss of quality for any of the attributes (i.e., beach quality, water quality, coral reef quality, fish size and abundance) using econometric simulation techniques (see Appendix 5). Consistent with other surveys of Jamaican tourists, respondents exhibited the highest willingness to pay for preservation of beach quality; the average tourist was not interested in paying higher fees for better fish or reef quality alone.

For the purposes of this study, we were interested in the value that tourists place on beach quality alone. Edwards' survey defines beach quality by the width of the beach and the quality of the sand.[37] In order to translate Edwards' results into a useable format for this analysis, the authors needed to define quantitative

[h] Consumer surplus (used interchangeably with consumer welfare) is defined as the difference between the maximum price a consumer is willing to pay and the actual market price they do pay. For example, if a tourist pays $30 to go on a snorkeling trip, but would have been willing to pay $50, there is a $20 consumer surplus, which represents the benefit the tourist got for free.

bounds for the qualitative descriptions of beach quality included in the survey. These beach width estimates are provided in Table 5 below.

Table 5. Quantitative beach width ranges associated with each quality level in Edwards (2009)

Beach quality	Associated beach width
Poor	0–15 ft/ 0–5m
Fair	16–30 ft/ 5.1–10m
Good	31–60ft/ 10.1–20m
Excellent	61–100ft/ 20.1–30m

The changes in value as a result of these changes in quality can be modeled using the estimated parameters from the contingent choice data. The movement from good to fair (or good to poor) beach quality can therefore be represented by a change in economic value (consumer surplus) to visitors. This information on the loss in value due to beach degradation can be useful to the tourism industry over the long term, given their concerns regarding current rates of beach loss, as well as visitor demand and pricing.

Loss in Consumer Surplus Associated with a Beach Loss

Table 6 shows the results of simulating the changes in value for a change in beach quality. All other attributes except beach quality were kept constant, thus these results represent consumer welfare changes for the beach attribute only. The results below show that if current beach width at an average of 15 meters ("good quality") were to decline by 12 m to a 3 meter width or less ("poor"), this would be equivalent to a loss in value of US$95 per person. If this figure is divided by the average number of days spent per visitor as per Edwards' study (7 nights), then this would be a per-person loss of approximately US$14 per person per day. A less dramatic decline from good to fair would represent a loss in value of US$51 per person per visit. The consumer surplus associated with preventing a total loss of the recreational services of the beach is estimated at US$105 per person.

To get a sense of what this result means, one can compare the figure of US$105 to the total access value associated with combined beach and reef ecosystem services of US$128, as discussed in the previous section. As noted above, access value represents the amount of compensation that would be necessary if a tourist visited Jamaica and (because of some disaster such as a hurricane or environmental accident) the tourist had no access to the beaches and coral reefs. Based on the estimated access value for the beach attribute, one can see that the recreational value of beach is a significant component of the overall access value.[38]

Table 6. Results of simulating the welfare changes for a change in the beach attribute for beach quality

Beach Quality Change	Economic Value* per Person (US$)
Good to Poor (15m loss)	-$95
Good to Fair (10m loss)	-$51
Fair to Poor (5m loss)	-$44
Maintain at Good Quality (Access value of the beach alone)	$105

*Negative sign represents a loss in value or consumer surplus.

Table 7 below presents the consumer welfare loss of the simulation model, showing a decline in attribute quality per meter of beach loss. Per-meter loss was calculated based on the beach quality thresholds, as a means to capture instances where beach loss did not result in a threshold being crossed, although this was still significant. Due to the qualitative aspect of the model, these assumptions of per-meter loss in consumer welfare are best estimates based on professional judgment. The table reflects the annual loss of consumer welfare for the tenth year of the degradation scenario. More details on the model simulation are provided in Appendix 4.

Current erosion at beaches is estimated to have grown to over US$19 million in loss of consumer surplus in the tenth year of the scenario. Additional erosion caused by further reef degradation is estimated to increase this loss to US$33 million by year 10. This represents an additional US$13.5 million loss of consumer welfare if the reef degrades further—an annual increase of 70 percent from the base scenario. As seen in Table 7, the deterioration of reef has the greatest impact on consumer welfare in Long Bay, Negril, which would lose an additional US$5.3 million from the baseline scenario. Next, Ocho Rios would lose US$11.1 million in year 10 if its reef degrades, compared to US$6.5 million if the reef remains unchanged. This represents an additional US$4.6 million. Finally, Montego Bay is estimated to lose an additional US$3.6 million if its reef degrades further (increasing from US$7.1 to US$10.7 million).

Figure 5. Annual welfare loss (US$ millions): status quo vs. reef degradation scenario for Negril, Montego Bay, and Ocho Rios

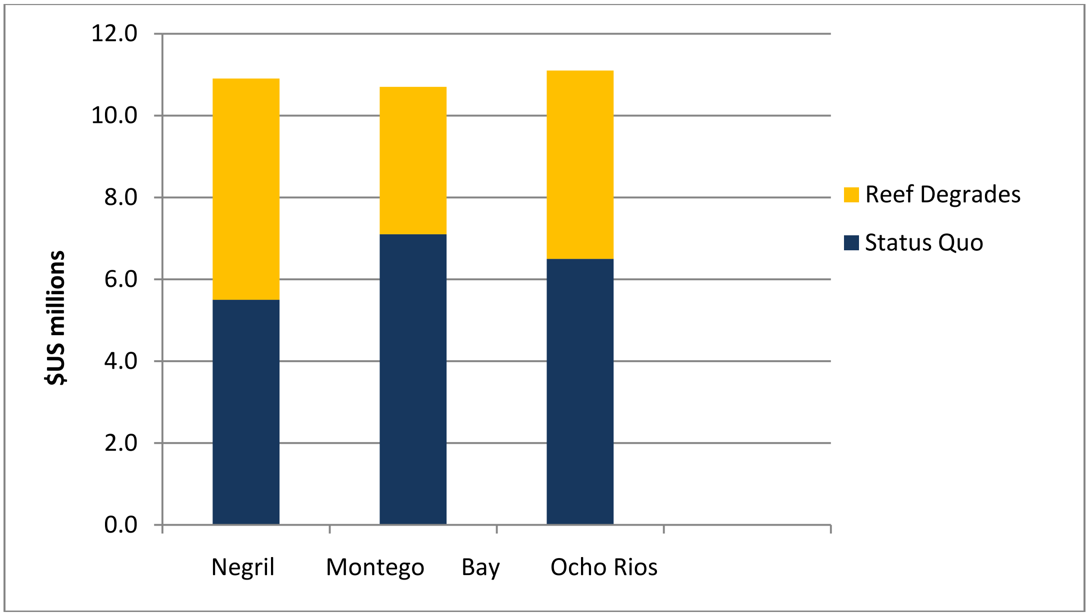


Table 7. Annual loss in consumer satisfaction (US$) at beaches due to coral reef degradation (after 10 years of erosion)

Location	Current quality rating	Future rating if reef remains unchanged	Loss in value due to current rates of beach erosion($US)	Future rating if reef erodes further	Loss in value if the beach erodes faster due to reef degradation ($US)	Difference due to further reef degradation ($US)
Negril	Good (14.6 m)	Good (11.6 m)	$5.5 million	Fair (8.7 m)	$10.9 million	$5.3 million
Montego Bay	Good (18.6 m)	Good (15.6 m)	$7.0 million	Good (14.1 m)	$10.7 million	$3.6 million
Ocho Rios	Excellent (25 m)	Excellent (22 m)	$6. 5 million	Good (19.9 m)	$11.1 million	$4.6 million
Total:			**$19.2 million**		**$32.7 million**	**$13.5 million**

Note: The welfare loss was calculated using a per meter value of $5.11 per visitor, coupled with the average number of overnight visitors a year for each site: Negril (360,927); Montego Bay (466,075); and Ocho Rios (425,026). Figures may not total correctly due to rounding.

Loss of Consumer Surplus and Resulting Economic Impacts

Beach degradation and the resultant decline in consumer welfare could reduce demand for Jamaica's tourism product, leading tourists to consider substitute destinations. Measuring this loss in demand requires the identification of the elasticity of demand[i] for Jamaican tourists—the percent drop in tourism associated with a 1 percent increase in price. While a study has not been identified that measures the elasticity of demand specifically for Jamaican tourists, the impact can be roughly estimated based on research from other Caribbean locations and more general tourist studies.

It is important to note, in reference to calculations made using price elasticity of demand, we have assumed that a loss in consumer surplus is equivalent to an identical increase in the price of the vacation, and used this assumption to predict changes in demand for tourism to Jamaica. The price elasticity of demand may have some aspects of beach quality included, but there may be other dominating market factors, such as air fare, food, and beverage costs. As a result, demand based on beach quality is different from demand based on price, and changes in beach quality could then have a different effect on tourists' decisions than a rise in prices. In other words, prices could go up quite a bit without having a large impact on demand, but should the attribute degrade, demand would then be substantially impacted. Accordingly, there may be some effect on demand from a loss in consumer surplus, but not necessarily a direct correlation.

In a survey of studies on demand for international tourism, Crouch finds the average price elasticity of demand to be between -0.6 and -0.8. Eilat and Einav's 2004 study supports this range, finding an average elasticity of -0.7 for a sampling of eleven countries. [39] [40] For the Caribbean region, Tsounta[41] finds that price competition is an important factor for tourists choosing destinations, and that competitiveness is of "paramount importance in attracting tourism flows." Estimates of overall price elasticity of demand for the Caribbean tend to be in line with the low end of the studies mentioned above: Craigwell and Worrell [42] found a price elasticity of demand to be -0.71 for fifteen Caribbean nations (including Jamaica), and Gawande et al.,[43] using changes in real exchange rates for the Caribbean area as a whole, estimate it to be between -0.41 and -0.48. In looking only at demand for Aruban vacations from U.S. tourists, Croes and Vanegas[44] estimate long-run price elasticity of demand to be -0.22. As a whole, these studies provide reasonable guidance that a percentage point increase in price (or, identically, decline in tourist welfare) for Jamaica can be expected to reduce tourism by between one-quarter and one-half of a percent.[45]

This analysis finds an average per visitor loss in consumer welfare due to beach erosion associated with coral degradation. In the case of Jamaica, coral degradation could result in loss of consumer welfare from beach erosion averaging US$26.10 per vacation. According to the JTB (2009), there were 1.83 million stopover tourists, and a total stopover expenditure of US$1.85 billion, or US$1,009 per person. We assumed a conservative average airfare estimate of US$300, bringing the total vacation cost to US$1,300 per person. The loss of consumer welfare represents an effective price increase for the vacation as a whole of 2.0 percent.[32] The quality of the vacation experience will thus decrease as a result of beach loss, while the actual price of the vacation remains unchanged.

Using the estimated elasticity figures of one-quarter and one-half of a percent, this leads to a decline in tourism of 0.5 percent to 1.0 percent, representing a loss of between 9,200 and 18,400 stopover visitors per year, costing the tourism industry between US$9 million and US$19 million. The loss to Jamaica as a whole is amplified as the effects ripple through the economy. While income multipliers tend to be

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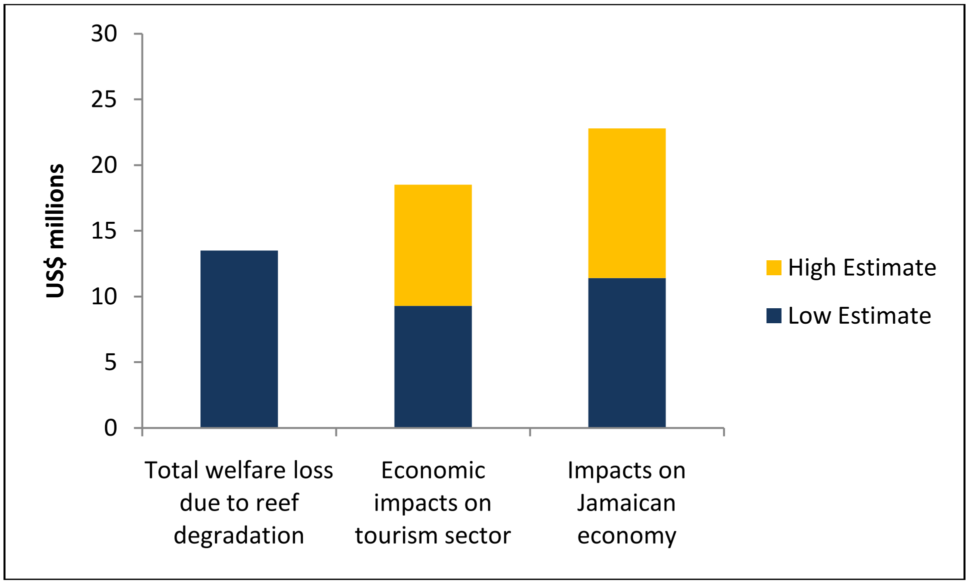
[i] Price elasticity of demand (PED)-the percent drop in demand associated with a percent increase in price. A good or service is considered relatively inelastic when PED is less than 1. Thus a change in price has relatively little effect on the quantity of a good demanded.

relatively low for small-island economies like Jamaica, they are still positive, with each stopover tourist dollar generating an estimated additional US$ 0.23 cents for the rest of the economy.[46] The final loss to the Jamaican economy from decreased tourism due to degraded beaches could thus range from US$11 million to as high as US$23 million, depending on the extent of erosion and the associated loss of tourism.[47]

Figure 6. Losses from beach erosion due to further reef degradation (annual losses during the tenth year of erosion)



Considerations for the Design of Follow-up Studies on the Economic Impacts of Reef Degradation and Beach Erosion

For the stated choice study, there were some limitations with respect to the study design. In particular, the qualitative nature of the attributes used (poor, fair, good, and excellent) limited somewhat the direct estimation of discrete marginal changes in value for each unit of change in quality (for example per meter loss in beach width). However, we were able to make some reasonable assumptions about loss of welfare with incremental reductions in beach quality. Future studies should aim for a larger sample size, use fewer attribute levels, and also quantitatively define the attributes. That is, instead of using qualitative attributes the respondent should face quantitative attributes, such as beach width (10 m, 20 m, 50 m), varying percentage of live coral cover (10 percent, 40 percent, 50 percent), and actual numbers of fish seen per snorkel tour. The use of photographs or other audiovisual aids could also be considered for similar studies. This paper emphasizes the contribution of coral reefs to international tourism, but it is also important to note that they also support local tourism. Additional research in the area is needed to gain a more complete understanding of the contribution of coral reefs to the larger tourism industry. Furthermore, this analysis relies on best available information and expert judgment, as recent data (i.e. elasticity and multiplier figures) for Jamaica are not readily available.

Conclusions and Recommendations

This study models a link between reef degradation, wave energy, and beach erosion to assess the economic impacts of beach erosion on tourism and the Jamaican economy. Loss of live coral and subsequent erosion of reefs protecting major tourist beaches would significantly increase the rate of beach erosion and result in an increased loss of consumer satisfaction amounting to US$13.5 million in the tenth year of our scenario. This represents direct revenue losses of US$9 million to US$19 million per year to the tourism industry and an annual loss of US$11 million to as high as US$23 million to the entire Jamaican economy.

This study combines physical oceanography and coastal modeling with natural resource economics and presents a scenario of the potential loss of ecosystem services and the corresponding loss in economic benefits to Jamaica. This biophysical-economic approach is innovative and based on the valuation of ecosystem services and the tangible benefits they provide to society. An analysis is presented that incorporates reductions in tourists' economic welfare as a result of decline in beach quality (width). This reduced potential consumer surplus would have the likely result of reducing rates of tourist visitation to the island of Jamaica, which in turn would result in the loss of crucial revenue for the tourism industry and jobs for many Jamaicans.

Jamaican coastal tourism is dependent on the health of Jamaica's coral reefs and is further enhanced by the culture and history of the people of Jamaica.[48] Jamaica's coral reefs have suffered significant mortality in recent decades as a result of many factors, including overfishing, pollution, and coastal development. However, with adequate coastal and fisheries management it is highly likely that Jamaica's reefs could recover critically important and valuable ecosystem services that have positive impacts on beaches. The recovery of these services would likely increase their economic contribution to Jamaica's tourism industry. This rise in value would, in turn, correspond to a reduction in coastal protection costs and an increase in the value of coastal tourism.

Overfishing, coastal development, and runoff from the land are all major threats to the country's reef ecosystems.[2] A number of well-intended but insufficient actions have already been taken to mitigate these threats and their effects, including the passage of legislation, the creation of several marine protected areas ("paper parks"), and beach engineering. However, enforcement of laws protecting coastal ecosystems (and including inside MPAs) has been weak thus far, due to in large part to a lack of financial support for these activities. Furthermore, individual hotels are spending a lot of money on beach engineering solutions such as beach nourishment and the construction of near-shore breakwaters. A study by Smith-Warner estimated that beach nourishment efforts over 20 years in Negril would cost US$5.0–$7.5 million, and an additional US$12.8–$16.0 million if breakwaters were also constructed.[20] These engineering solutions are expensive and—since they fail to address the root causes of beach erosion—will need to be repeated in the future. Furthermore, beach engineering solutions may cause additional environmental impacts, including the destruction of habitat, increased sedimentation, and the alteration of hydrological processes.

The economic risks to the Jamaican tourism industry are large, as beach erosion due to reef degradation will reduce visitor demand and the costs from beach engineering solutions will likely increase in the future. According to the World Economic Forum's Travel & Tourism Competitiveness 2011 rankings, Jamaica now ranks 65th out of 139 countries (down from 60th in 1990).[49] The report also highlights sub-indices of uncompetitive performance by Jamaica, including ranking 110th for natural resources and 116th for environmental sustainability.[49] Jamaica's inability to protect its coral reefs and prevent beach erosion will continue to put it at a competitive disadvantage.

The importance of coastal tourism's continued contribution and potential future benefits to Jamaica's economy rests upon the ability of key stakeholders to protect coral reefs, focusing on managing coastal development, reducing watershed-based pollution and sedimentation, and promoting sustainable fishing (see Box 1). It is beyond the scope of this project to provide an exhaustive set of recommendations, as this would require a more detailed examination of the institutional, legal, political, and economic factors that drive conservation success and failure in Jamaica. Rather, we offer strategies to utilize our results in ways that will promote reef conservation, including:

- *Build national political will for greater reef conservation*. History demonstrates that conserving ecosystems begins with widespread awareness of the benefits they provide and the political will to act. In order to leverage these results, it is important to publicize and disseminate the key findings of this paper to the Jamaican government, citizens, conservation groups, industry, and development agencies.

- *Strengthen environmental policy*. Policies that address the main drivers of coral reef degradation (overfishing, coastal development and pollution) over short-term measures such as beach nourishment must be developed. This includes strengthening existing policy opportunities, such as the draft National Fisheries Policy, with language that makes the economic case for more holistic conservation measures. Current laws—such as the Tourism Enhancement Fund, the Natural Resources Conservation Act, and the Beach Control Act—must also be examined to assess how well existing institutional mechanisms, norms, and regulations address local threats to coral reefs.

- *Create new opportunities for long-term conservation funding*. By quantifying the economic losses likely to occur due to degradation of reefs, it is possible to tap public and private funding for coastal management, gain access to new markets, initiate payments for ecosystem services, and charge polluters for damages. There are numerous examples of economic analyses successfully informing policy. For example, in the United States, the states of Hawaii and Florida adopted legislation setting amounts for monetary penalties per square meter of damaged coral reef, based on calculations from valuation studies. The Belize government used an economic valuation study of its coral reefs as the premise to sue for damages after the container ship Westerhaven ran aground on its reef in January 2009, resulting in the Belizean Supreme Court ruling that the ship's owners must pay the government US$6 million in damages. The Bonaire National Marine Park, one of the world's few self-financed marine parks, used economic valuation to determine appropriate user fees. Finally, a hydropower company in Costa Rica, Emergia Global, makes payments to a forest protection fund that pays landowners to restore tree cover, reducing river siltation.[50] To encourage new opportunities, such as those listed above, it is critical that key stakeholders who use or impact reefs and beaches are targeted. Important stakeholders include nonprofit conservation groups, hotels, tourism operators, academic institutions such as the University of the West Indies, and the government of Jamaica, as well as Caribbean regional decision-makers and governments. Key stakeholders must invest in solutions to protect and restore the beaches and coral reefs that support Jamaican tourism over the long term.

The results of this analysis are clear. Reefs provide Jamaica's economy real economic benefits in their role as buffers against beach erosion and as a foundation for the continued prosperity and vitality of the tourism industry. Continued degradation of Jamaica's reefs could result in destructive beach erosion valued at tens of millions of dollars. Many other critically important and economically valuable ecosystem services that reefs provide could also be lost, including tourism, shoreline protection, and habitat for fisheries, resulting in losses of jobs, revenue, and increased erosion and property damage during storms. The extent and severity of threats to reefs in Jamaica, in combination with the critically important ecosystem services they provide, point to an urgent need for action. Jamaica's reefs can recover, but this will require effective management and protection. In order to promote reef protection, it is crucial that development plans take full account of the economic value of reef-based ecosystem services, environmental policy be strengthened, and new opportunities for long-term conservation funding be secured by tapping key stakeholders with direct interests in the goods and services that reefs provide.

Box 2. *Summary of Key Findings on Recommendations for Improving Ecosystem Management of Coral Reefs*

In 2010, the United Nations Environment Programme (UNEP) collaborated with the Planning Institute of Jamaica to investigate the role of ecosystems in reducing human vulnerability to natural disasters.[1] The project brought together Jamaican stakeholders from the national to community levels to discuss improved ecosystem management for reducing human vulnerability. The study recommends the following actions:

Manage coastal development wisely:

- *Improve wastewater management*. Improved management of waste and runoff from the hotel and construction industries would improve coastal water quality, benefiting both coral reefs and fish.
- *Protect mangroves*. Mangroves serve as important fish habitats, and also act as buffers, preventing agricultural runoff from reaching coral reefs. The government should seek to protect remaining mangroves from clearance for beach and coastal development, particularly in sensitive areas.
- *Improve land-use planning and zoning.* Reassessment of the government's current setback regulations would establish a more adequate buffer zone between beaches and coastal infrastructure, protecting both coastal ecosystems and beachside hotels.

Reduce watershed-based sedimentation and pollution:

- *Promote improved agricultural techniques*. Improved soil conservation (using terracing) and reduced use of chemicals would reduce flows of sediment and pollutants to coastal waters.
- *Retain and restore vegetation*. Reforestation—using local species—would help reduce erosion, especially on steep slopes and in riparian areas.

Promote Sustainable Fishing:

- *Manage fisheries.* Develop fisheries management plans that define specific restrictions and regulations, and increase the legal authority of officials to enforce fines.
- *Utilize Marine Protected Areas*. Develop long-term funding for integrated management efforts, including the expansion of protected area networks and fish sanctuaries.
- *Reduce excessive fishing*. Provide for alternative livelihoods of artisanal fishers and remove perverse fishing subsidies.

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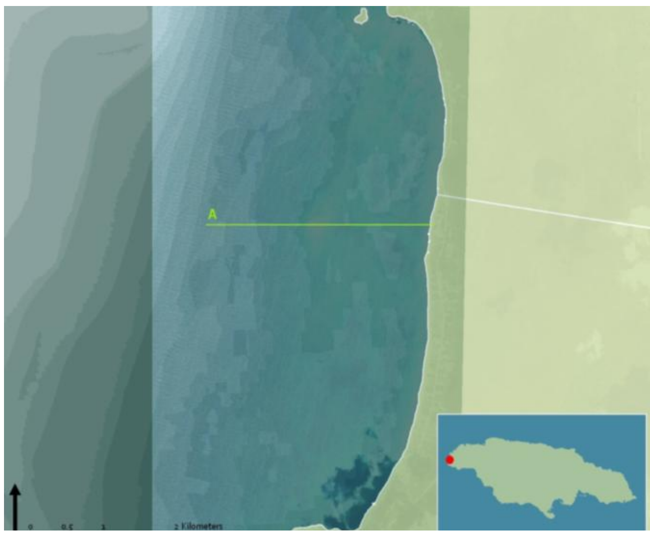
Appendix 1. Reef Profiles for Negril, Montego Bay, and Ocho Rios from the University of the West Indies, Mona GeoInformatics Institute (MGI)

Negril

Figure 1. Reef Profile for Long Bay, Negril (based on a 3000 m transect)



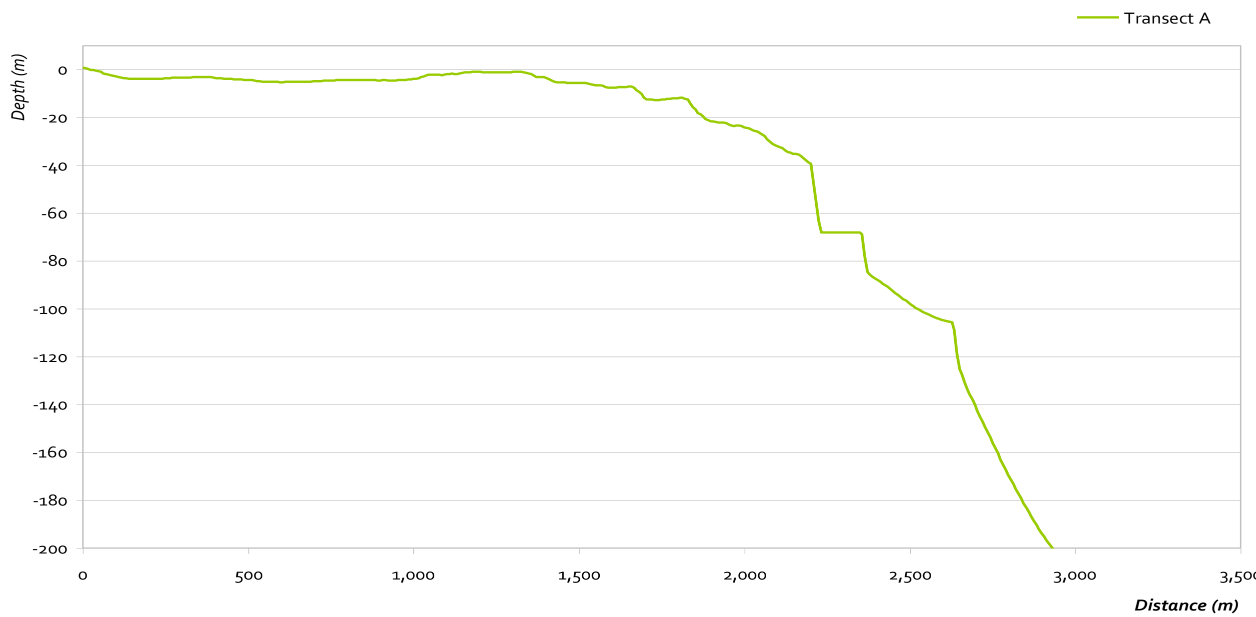
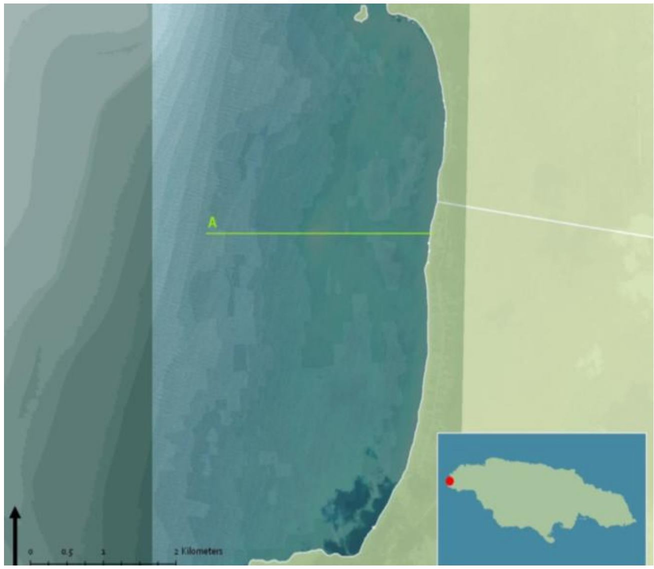
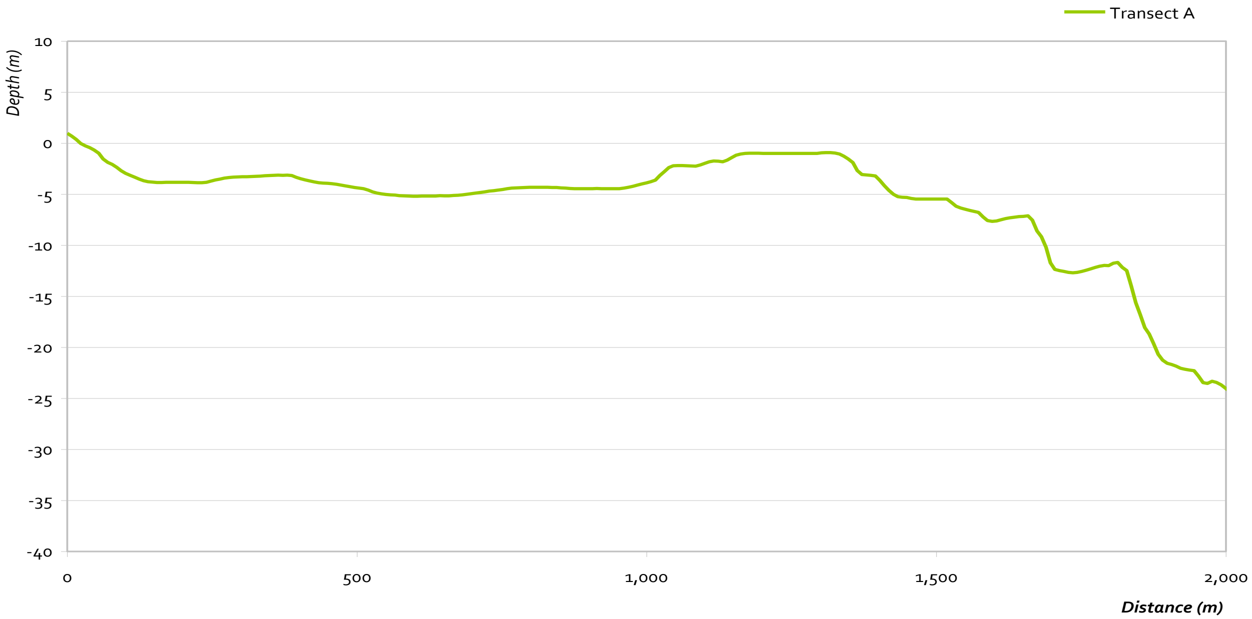


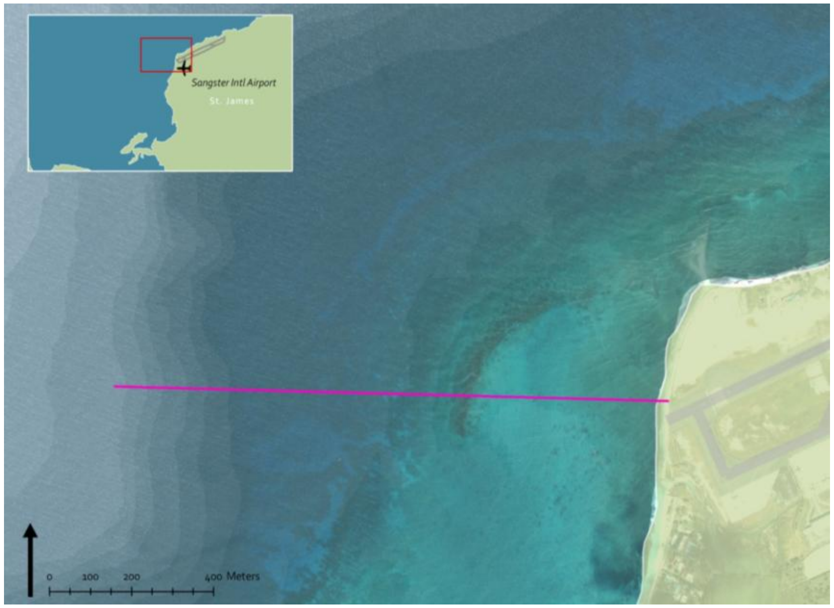
Figure 2. Reef Profile for Long Bay, Negril (based on a 2000 m transect)





Montego Bay

Figure 3. Reef Profile for Montego Bay (based on a 1,500 m transect)



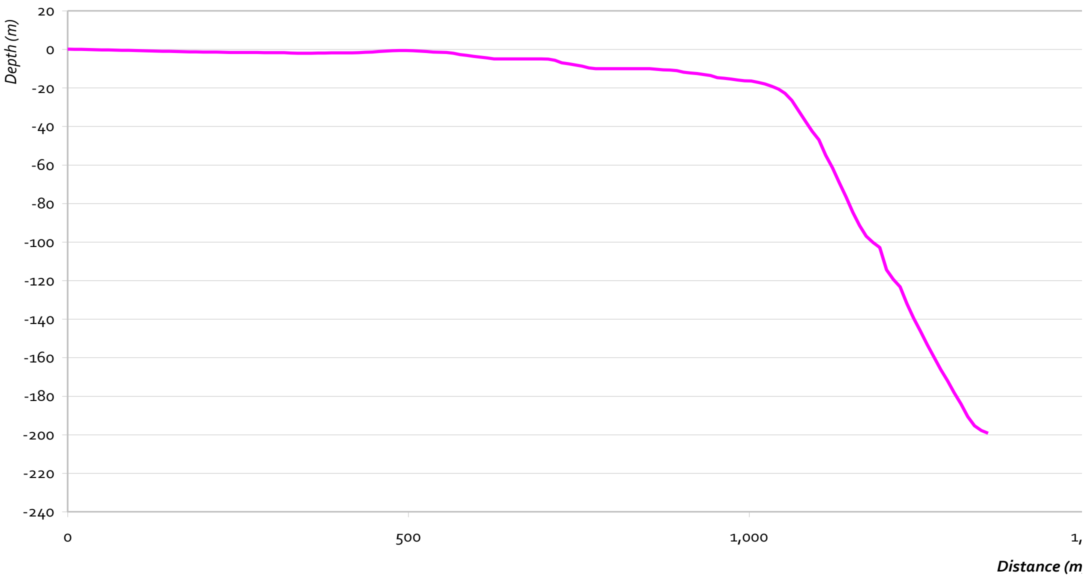
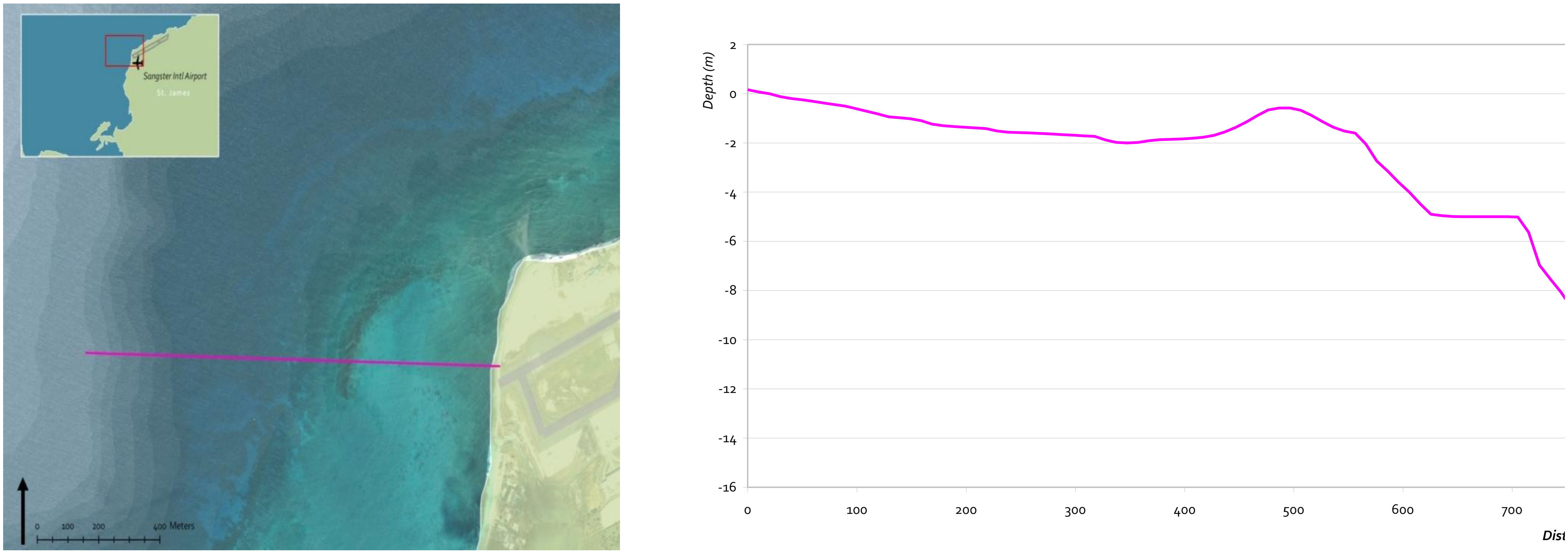
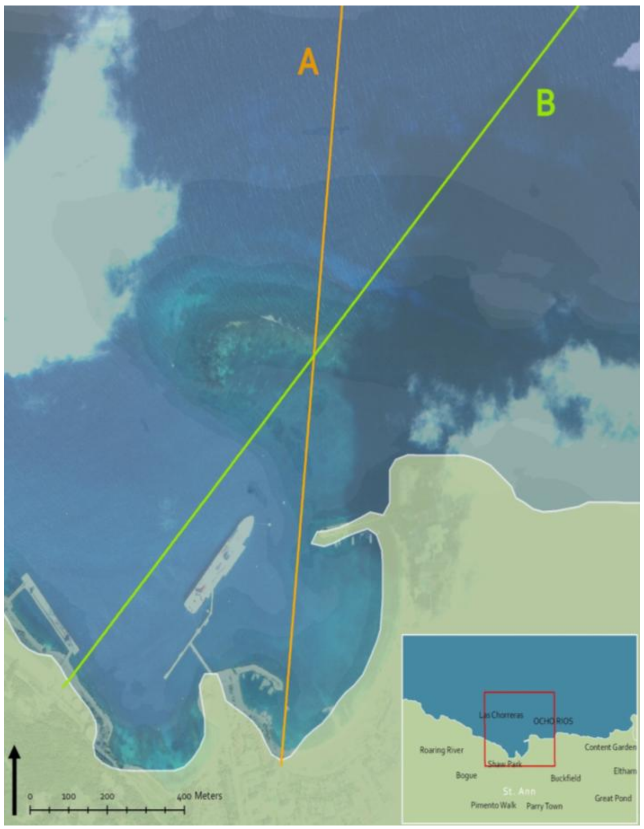


Figure 4. Reef Profile for Montego Bay (based on an 800 m transect)



Ocho Rios

Figure 5. Reef Profile for Ocho Rios (based on a 2000 m transect)



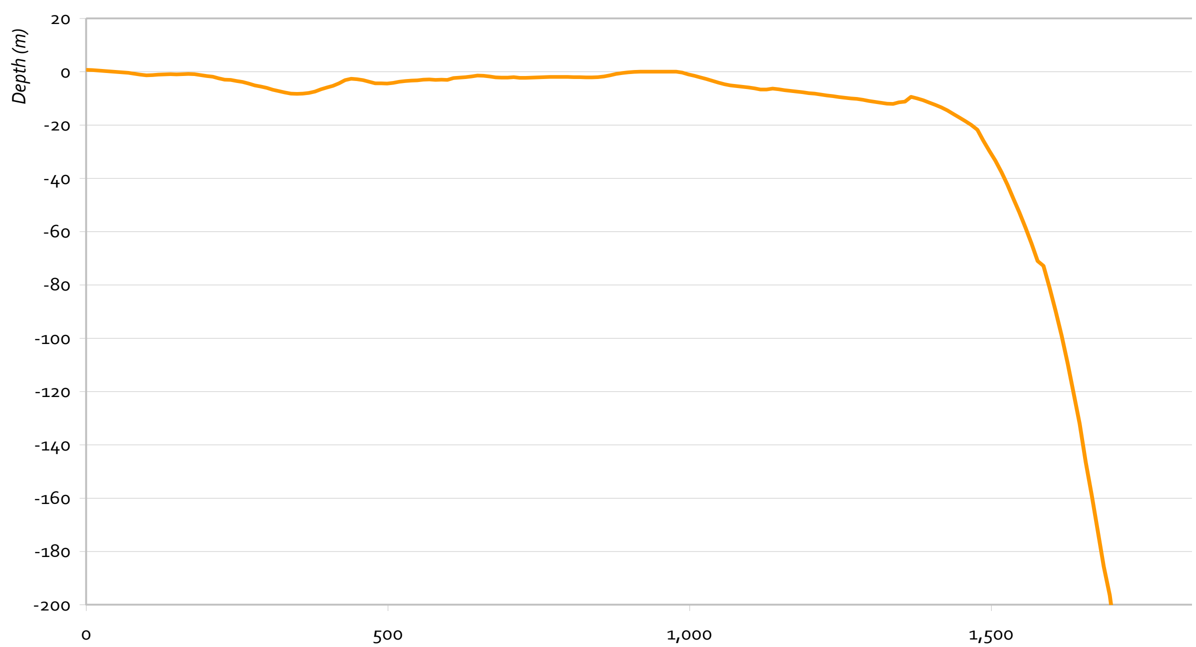
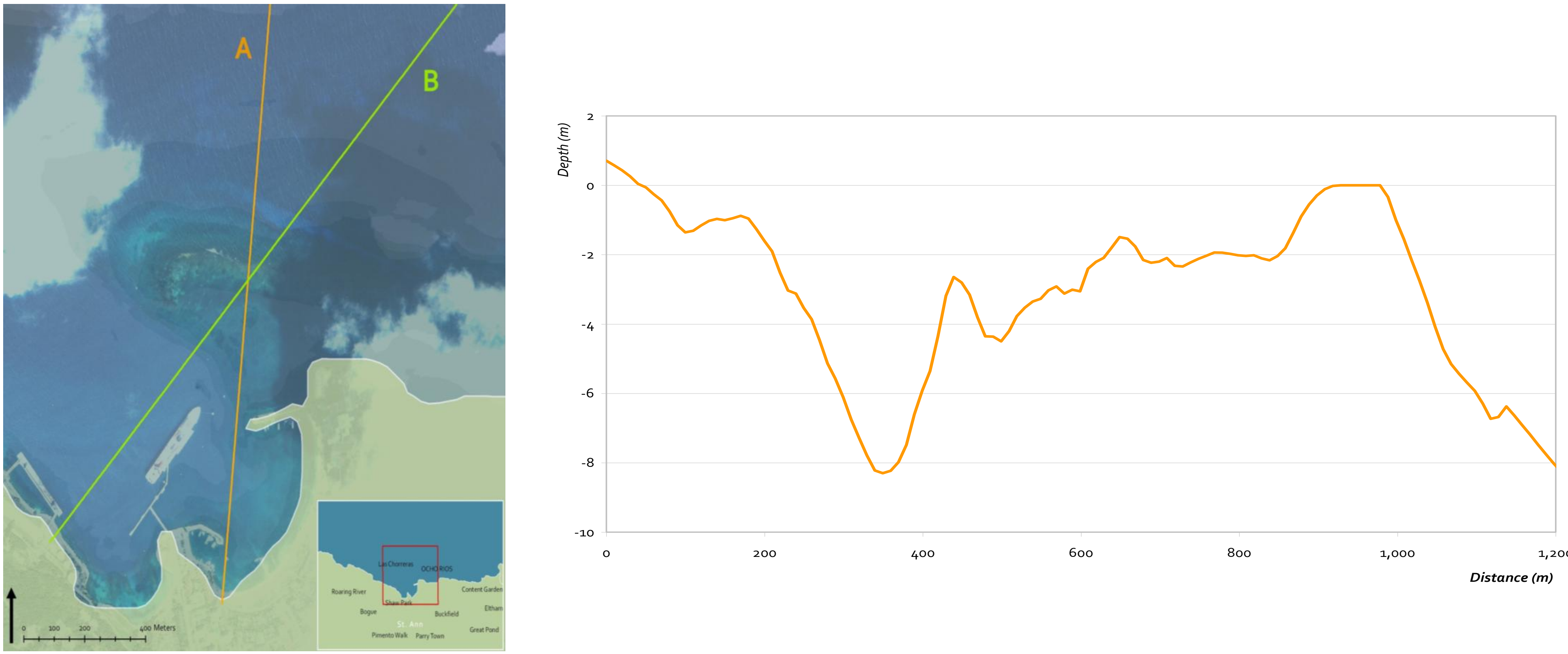
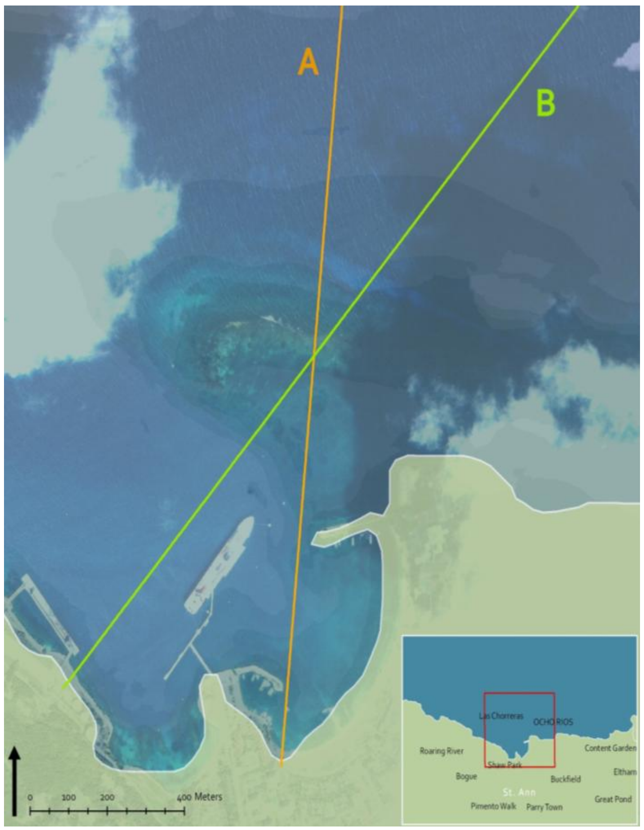


Figure 6. Reef Profile for Ocho Rios (based on a 1,200 m transect (transect A))




A
B
0
100
200
400 Meters
Las Chorreras
OCHO RIOS
Roaring River
Shaw Park
Content Garden
Bogue
Buckfield
Eltham
St. Ann
Great Pond
Pimento Walk
Parry Town

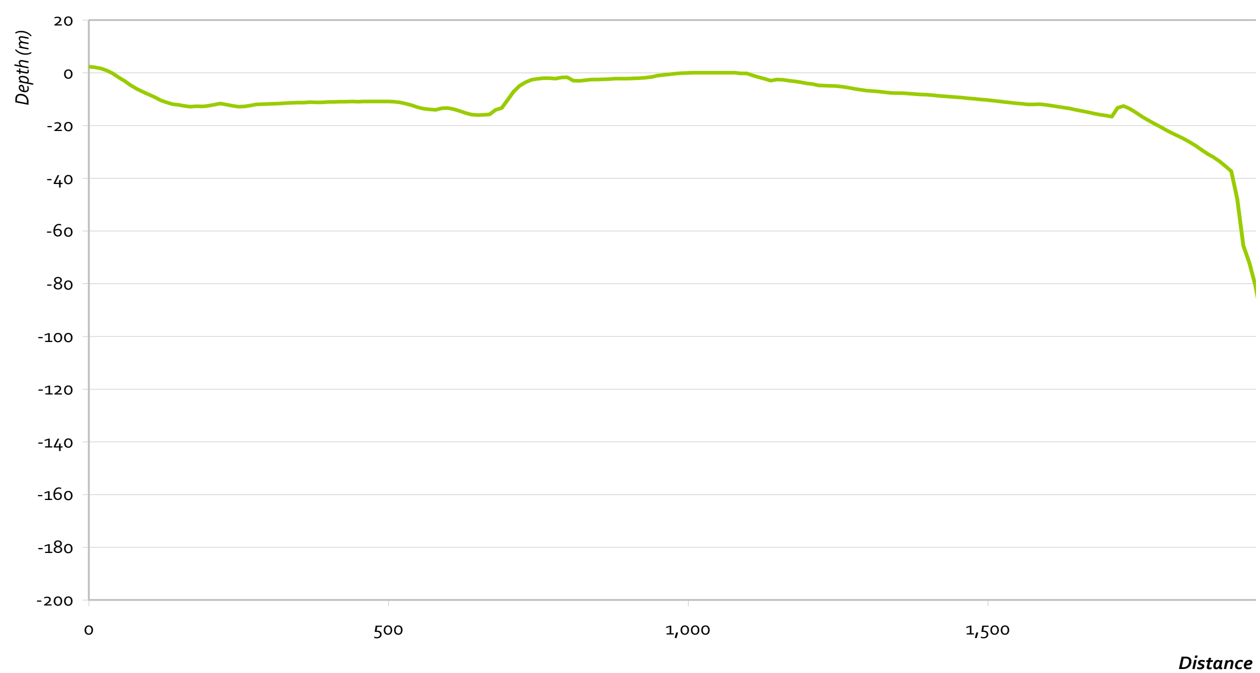
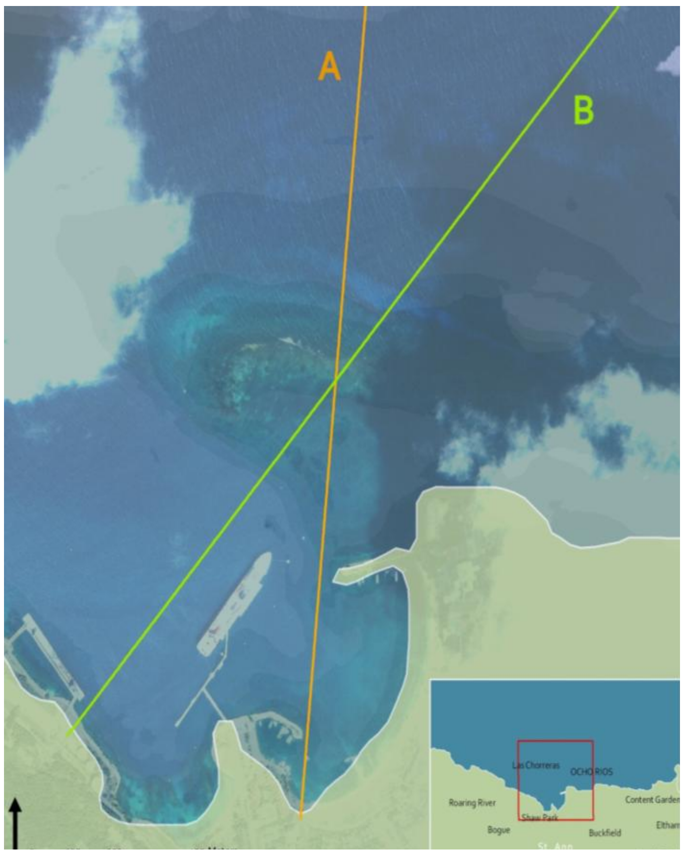
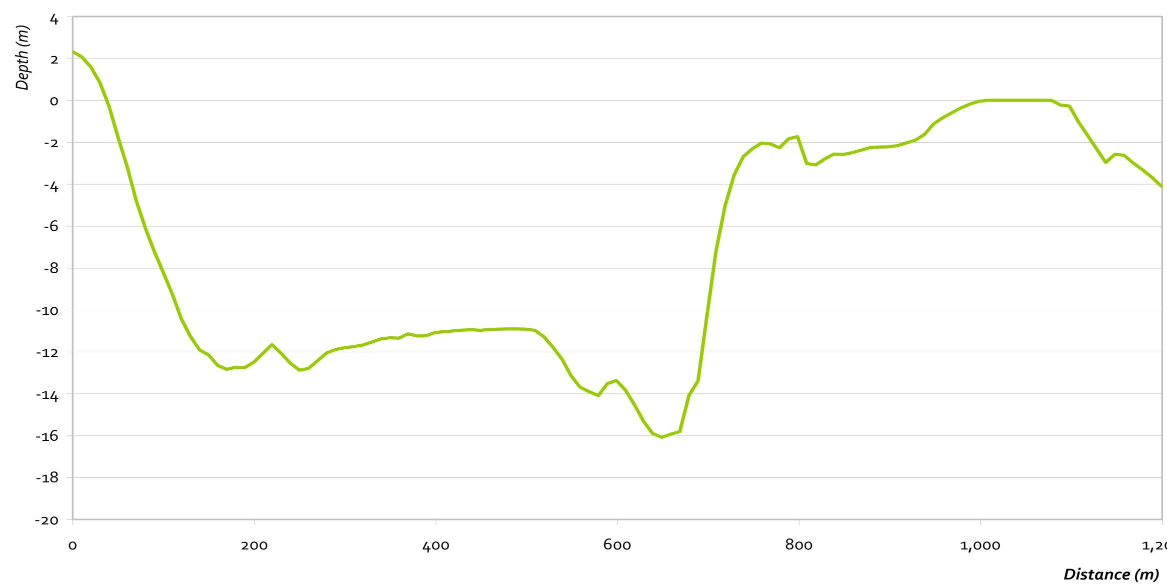

Depth (m)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
0
500
1,000
1,500
Distance

Figure 8. Reef Profile for Ocho Rios (based on a 1,200 m transect (transect B))





Appendix 2. Summary of Results, Data Sources, and Input Values used in the Application of the Sheppard Model in Negril, Montego Bay, and Ocho Rios

The Excel spreadsheet model requires information for the following parameters (see Sheppard et al. 2005 for details):

1) slope of the edge of the reef where the waves break (reef face);
2) depth of the reef edge (he/ha);
3) average depth of the reef (multiple points) (hr);
4) average width of the reef from the edge to the beach (W);
5) slope of the beach;
6) root mean square (RMS) of offshore wave height (Hoff);
7) mean offshore wave period (T); and
8) the coefficient of bottom friction of the reef flat (Fw).

Diagram of reef structure used in model

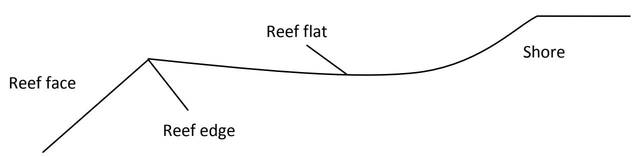


Table 1. Summary of results of Sheppard Model: Negril, Montego Bay, and Ocho Rios

Inputs	Long Bay_Negril	Montego Bay	Ocho Rios	Comments:
Kp (reef profile)	.60	.67	.67	The angle of the slope of the reef face is used to look up the Kp value in the Sheppard chart (2005). This was determined using MGI reef profiles. An angle of the slope of 30° was used for Negril and 20° for Ocho Rios and Montego Bay.
Tangent of the angle of the reef (tan alpha reef)	.36	.58	.58	This is the tangent of angle of the reef slope.
H_{off} (RMS of offshore wave height)	1.2	1.2	1.2	Root Mean Square (RMS) estimates of significant wave height (the mean of the highest 1/3 of waves) for the Caribbean were found in Calverley et al. (2001). Significant wave height (SWH) was converted to RMS wave height by using the equation SWH = 1.4•RMS (Gourlay 1997). An offshore wave height of 1.7 was used.
T (offshore wave period seconds)	5.2	5.2	5.2	RMS estimates of significant offshore wave period was used from Calverley et al. (2001).
hr (reef flat depth in m)	2	2	2	This was determined using MGI reef profiles.
he/ha (depth of reef edge/avg reef rim depth in m)	7	.5	0	This was determined using MGI reef profiles.
nr (initial wave setup)	.2	.2	.2	This variable was extracted from Wielgus et al.(2010), based on the authors' application of the Sheppard model to the Dominican Republic.
nw (meterological surge)	0	0	0	From Wielgus et al.(2010)
Tangent of the angle of the beach slope	.11	.11	.11	For Negril, this was determined using a 6° beach slope, taking beach slope data from MGU (2008).
W (distance reef is offshore in m)	1400	500	1000	This was determined using MGI reef profiles.
dx (increment wave height decay calculation)	10	10	10	From Wielgus et al.(2010)
Percent of live coral cover	15%	7-10%	7-10%	Comes from 2007 Reef Check assessment in NEPA (2008) and from expert judgment through MGU/MGI.
Fw (frictional coefficient)	.14	.13	.13	The average percent of coral cover is used to look up the Fw value in the Sheppard chart.

Table 2. Model results predicting the impact of reef degradation (indicated by increasing wave height over the reef) on beach erosion for Long Bay, Negril (assumes a dead reef erodes 0.3 m/yr)

Long Bay, Negril	**Wave height (m)** H_o is the initial wave height with the reef intact, and H is the wave height for each period after all corals die	**% increase in wave height**	**% increase in erosion relative to current** $\left[\left(\frac{H}{H_o}\right)^{2.5} - 1\right] * 100$	**Beach loss (in meters)** **(This erosion rate includes the current (base) erosion rate of 0.3 m/yr)**
Current (live coral cover = 15%)	H_o =.159	-	-	-
No live coral (bottom friction is reduced)	H=.207	30.19	94.00	-
Year 1 (erosion of the reef substrate begins)	H=.208	30.82	95.73	0.59
Year 2	H=.209	31.45	98.09	0.59
Year 3	H=.210	32.08	100.47	0.60
Year 4	H=.211	32.70	102.87	0.61
Year 5	H=.212	33.33	105.28	0.62
Year 6	H=.213	33.96	107.71	0.62
Year 7	H=.214	34.59	110.16	0.63
Year 8	H=.215	35.22	112.62	0.64
Year 9	H=.216	35.85	115.10	0.65
Year 10	H=.217	36.48	117.60	0.65
Sum				**6.20**

Table 3. Model results predicting the impact of reef degradation (indicated by increasing wave height over the reef) on beach erosion for Montego Bay (assumes a dead reef erodes 0.3 m/yr)

Montego Bay	**Wave height (m)** H_o is the initial wave height with the reef intact, and H is the wave height for each period after all corals die	**% increase in wave height**	**% increase in erosion relative to current** $\left[\left(\frac{H}{H_o}\right)^{2.5} - 1\right]*100$	**Beach loss (in meters)** **(This erosion rate includes the current (base) erosion rate of 0.3 m/yr)**
Current (live coral cover = 15%)	H_o =.344	-	-	-
No live coral (bottom friction is reduced)	H=.398	15.7	44.0	-
Year 1 (erosion of the reef substrate begins)	H=.400	16.3	45.8	.44
Year 2	H=.401	16.6	46.7	.44
Year 3	H=.403	17.1	48.5	.45
Year 4	H=.405	17.7	50.4	.45
Year 5	H=.406	18.0	51.3	.45
Year 6	H=.408	18.6	53.2	.46
Year 7	H=.410	19.2	55.1	.47
Year 8	H=.411	19.5	56.0	.47
Year 9	H=.413	20.1	57.9	.47
Year 10	H=.415	20.6	59.8	.48
Sum				**4.6**

Table 4. Model results predicting the impact of reef degradation (indicated by increasing wave height over the reef) on beach erosion for Ocho Rios (assumes a dead reef erodes 0.3 m/yr)

Ocho Rios	**Wave height (m)** H_o is the initial wave height with the reef intact, and H is the wave height for each period after all corals die	**% increase in wave height**	**% increase in erosion relative to current** $\left[\left(\frac{H}{H_o}\right)^{2.5} - 1\right] * 100$	**Beach loss (in meters)** **(This erosion rate includes the current (base) erosion rate of 0.3 ,m/yr)**
Current (live coral cover = 15%)	H_o =.219	-	-	-
No live coral (bottom friction is reduced)	H=.264	20.5	59.5	-
Year 1 (erosion of the reef substrate begins)	H=.265	21.0	61.1	0.48
Year 2	H=.266	21.5	62.6	0.49
Year 3	H=.267	21.9	64.1	0.49
Year 4	H=.268	22.4	65.7	0.50
Year 5	H=.270	23.3	68.8	0.51
Year 6	H=.271	23.7	70.3	0.51
Year 7	H=.272	24.2	71.9	0.52
Year 8	H=.273	24.7	73.5	0.52
Year 9	H=.275	25.6	76.7	0.53
Year 10	H=.276	26.0	78.3	0.53
Sum				**5.1**

Appendix 3. Visitor Interest Survey 2007 (JTB 2006)

	Jan–Mar 2007*	Apr–Dec 2007*	Average for 2007		
	very interested	very interested	very interested	somewhat interested	not very interested
	%	%	%	%	%
How interested were you in visiting nature areas	35	38	36.5	33.5	29.5
How interested were you in guided tours	23	28	25.5	35.5	39
How interested were you in shopping	29	30	29.5	37.5	34
How interested were you in dining out	49	47	48	31	21.5
How interested were you in beaches	81	76	78.5	13.5	8.5
How interested were you in water sports	39	41	40	33	27
How interested were you in nightlife activities	34	33	33.5	37.5	30
How interested were you in other activities	54	44	49	17	34

Note: The yellow highlight represents the value used in our estimate to determine what percent of tourists care strongly about the presence of beaches in their visits to Jamaica. For brevity, only the 6th month breakdown of results was shown for "very interested." For a breakdown of all categories by 6-month period, see JTB 2008a.

Appendix 4. Choice Experiments and Simulation of Consumer Welfare

Use of Choice Experiment Approaches in Ecosystem Services Valuation

Choice modeling (CM) techniques include choice experiments (CE), contingent ranking, contingent rating, and paired comparisons. Choice experiments are based on the theory that individuals derive their *utility* (well being or satisfaction) from the combination of characteristics that make up a given good (including environmental goods and services), not only from the consumption of the good itself. Survey response data from CM techniques can provide information to researchers for estimating components of respondents' *utility* and the economic values they hold for those components.

Choice models predict how individuals would react in a particular situation. Unlike a poll or a survey, the tool allows predictions to be made over a very large number of scenarios. Choice modeling is highly regarded as a reliable, general purpose tool for making probabilistic predictions about human decision-making behavior. In addition, choice modeling is regarded as the most suitable method for estimating consumers' willingness to pay for quality improvements in multiple dimensions (multiple attributes). In general, it is assumed that individuals maximize their *utility*, meaning that, when presented with two options with differing characteristics or "attributes," they will choose the option that will yield the highest level of satisfaction given certain constraints such as income, leisure time, etc. If a good (such as an environmental restoration program) can be described in terms of its attributes (such as acres of marsh restored in a restoration program, or number of corals re-planted in a reef restoration program), then changing those levels (such as restoring 5 vs. 10 acres of marsh) will result in a different "good" being produced.

Choice experiments tend to focus on the value of changes in the individual attributes and are therefore particularly useful in the context of policy analysis because they allow for the identification of the following:

- Attributes that are significant determinants of the values for non-market goods
- Implied ranking of these attributes
- Value of simultaneously changing more than one attribute
- Economic value of a resource, good, or service.

Results from stated choice experiments can be used to guide policy and inform the best use of the public's resources for managing and restoring natural resources.

There are five general design stages for choice experiments as outlined by Bateman et al. (2002). The table below describes these stages.

Stage	Description
1. Selection of attributes	The good being evaluated in the choice scenario must be described by a number of characteristics, or “attributes.”
2. Assignment of levels	Each attribute must be assigned a range of levels. Levels should be realistic and relate to respondents’ preferences.
3. Experimental design	Statistical design theory is used to generate a number of alternatives to be presented to respondents.
4. Construction of choice sets	Alternatives are paired to create choice sets.
5. Measuring preferences	A method is chosen to collect the appropriate data, and the survey is conducted.

Adapted from: Bateman et al., 2002, p. 259.

Appendix 5. Welfare Simulation

(Edwards, 2009)

Simulations for possible scenarios of changes in beach attribute quality were conducted based on the parameter estimated derived from the following econometric model.

Where utility U_i = U_B, U_L, or U_A (basic, low and advanced management) and U_N (no trip) = 0. β_1 is the coefficient on the environmental surcharge (fee), while β_2 through to β_5 are coefficients that correspond to the different levels of attribute quality for each alternative. ε_i represents the error terms of the four options.

The quality attributes for the status quo remained the same while for the policy scenarios, the beach quality attributes were made to decline by various levels (from good to fair or good to poor), while all other attributes were held at the status quo. The surcharge (fee) remained fixed at $10 for all scenarios.

<u>Welfare Calculation</u>

The simulations are based on the aforementioned qualitative ratings of attribute quality (*i.e.* 0 = poor, 1 = fair, 2 = good, 3= excellent). This requires the simulation of a mean compensating variation, which refers to the amount of additional money an individual would need to reach his/her initial utility (feeling of well being) for, in this example, a decline in attribute quality, which takes the following form:

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The beta’s are the same as the previous equation. The first term in brackets describes the given change in environmental quality (future scenario). In our simulation all other attributes are held to the status quo, while the beach attribute is changed. The second term describes the status quo (i.e. good beach and good water clarity and fair reef and fish).

It should be noted in the equation above, that the status quo ratings for the attributes are beach = 2, water = 2, reef = 1, and fish =1. The model was estimated using LIMDEP© econometric software.

Potential levels of quality change in Jamaican coastal ecosystems (from Edwards, 2009)

Attribute	**Levels of environmental quality**			
	Poor	**Fair**	**Good**	**Excellent**

Beach	Eroded, poor sand quality	Some erosion, slightly improved sand quality	No erosion, with mainly white sand	Wide, with very white sand
Water	Poor underwater visibility (cloudy)	Variable visibility, sometime cloudy	Good underwater visibility (clear)	Crystal clear underwater visibility
Coral Reef	90% of corals dead, other marine life absent	15% live coral (85% dead) other marine life (eg lobster) rarely seen	40% live coral, other marine life seen sometimes	75% live corals, other marine life seen (lobsters, octopi)
Fish	Only few small fish seen	Moderate number of small fish live on reefs	Moderate number of small and few large fish	Many large and small fish seen on reefs

Simulated welfare estimates for the four scenarios of quality change($/per person) (Edwards 2009:167)

Scenario (Quality Change)	**Welfare Change**
Beach and Water: God to Poor	-$116.67
Beach: Good to Fair	-$35.00
Water: Good to Fair	-$35.36
Beach and water: Good to Fair	-$66.74
Beach: Good to Excellent	$37.85
Water: Good to Excellent	$38.29
Beach and Water: Good to Excellent	$78.33

Note: For a more detailed summary of how Edwards' (2009) research was conceived and conducted, please refer to Case Study #2 in the *Coastal Capital Literature Review: Economic Valuation of Coastal and Marine Resources in Jamaica*, which is available online at <http://www.wri.org/coastal-capital>.

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