Ecosystem Service and Natural Resource Valuation Assessment

Princess Hotel and Resorts Hanover Jamaica

Prepared By:

ECONEXUS Consulting Group

Jan 2020

Disclaimer

Econexus Consulting Group has exercised reasonable skill, care and diligence to assess the information acquired during the preparation of this report, but makes no guarantees or warranties as to the accuracy or completeness of information provided by third parties. The information contained in this report is based upon, and limited by, the circumstances and conditions acknowledged herein, and upon information available at the time of its preparation. The information provided by others is believed to be accurate but cannot be guaranteed.

Econexus Consulting Group does not accept any responsibility for the use of this report for any purpose other than that stated herein, and does not accept responsibility to any third party for the use in whole or in part of the contents of this report. Any alternative use, including that by a third party, or any reliance on, or decisions based on this document, are the responsibility of the alternative user or third party.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The site has three key ecosystems (corals, seagrasses and mangroves) that on the one hand provide the conditions for private (eco) tourism investment because of the recreational ecosystem services associated with them. However, the proposed development footprint will have significant and, in some cases, irreversible impacts on all of these ecosystems. At present the most significant impacts will impact the pristine tertiary mangrove forest. Using a social cost of carbon (SCC) of $48 T-1 C the value of annual sequestration for the Cove Site is **US$1,111,680** per annum. The annual cost of emitted carbon for the 4.128 Ha lost mangrove portion of is US$76,483 per annum. There are significant negative economic impacts from permanently removing virgin mangrove forest (including the cost of emitted Carbon Dioxide) that will be passed on to the Jamaican public and wider global community. Although most of the natural resource values present at the site are public (non-market) goods this site is in fact privately owned. The compensation of the environmental losses and costs to society must be negotiated between the developer and the government regulatory agency. This can be approached in various ways and this this report outlines some suggestions for how this could be achieved.

Impacts to sea grasses and corals are also expected to negatively affect the non-market values for their respective ecosystem services. The expected lost value of seagrass due to permanent removal of 1.07 Ha of seagrass is estimated to be **US$25,924 per annum**.

Using previous analyses, the reefs in Negril are providing an annual economic value of **US$45,984,128**. While a portion of this value is attributed to the Cove site, it is not possible to derive an area-based value for the site because this valuation context from with this number was used from the benefit transfer (Edwards 2009) was not based on area based valuation. Another potential benefit transfer approach could be to use the project's proposed maximum per person occupancy rate and multiply this number by **US$128**. This could be a simple alternative approach that could be linked to this particular site. The consumer surplus or non-market value is expected to decrease with lost in environmental health of the existing reef including due to direct impacts from construction activities. The coral reefs in Negril are expected to lose economic value by **US$10.9 Million per year**.

There other un-estimated losses expected from honey bee harvesting, recreational bird shooting, subsistence fishing among others. It is also important to note that the economic estimates provided above (carbon value, non market values, productivity) were derived using slightly different approaches. In this types of studies there is a temptation to sum different types of values to get a grand "TEV" total. This is however theoretically inconsistent with good economic practice. It is more beneficial to present economic estimates, where feasible, for each type of ecosystem and associated services to allow the reader to see that various types of benefits can flow from a particular site. However since some of these economic estimates are based on a variety of approaches including avoided costs, market values, non market valuation to name a few, there is a risk of double counting values and some may be embedded within others. To give an example presenting economic information on the avoided cost of carbon pollution by maintaining mangroves is different from a willingness to pay for preserving mangrove study. Both provide valid and useful economic information, but one is a cost and the other is a benefit. Summing these two numbers if they were generated for a study would be wrong. This is why this report does not provide summed values but presents different types of values that inform the cost benefit and mitigation approaches that might be required for this development.

Losses could be offset using an appropriate mitigation approaches. One plausible approach that might work to achieve a no net loss of ecosystem functions and services of the in the wetlands at the Cove development could be via the establishment of a Wetlands Mitigation Bank. Notwithstanding, the proviso for consideration for this approach, is that mitigation for should only be considered for approval only after the developer has provided practical modifications to reduce or eliminate adverse impacts that would be caused be the proposed development.

The potential economic benefits are contingent upon successful implementation of the full suite of proposed restoration activities and should in turn mitigate the lost ecosystem services (and values) from ecological impacts to corals, seagrass and mangroves. Using an Ecosystem Services framework in this manner supports improved decision-making for coastal development and planning. Identifying and quantifying of the types of benefits that flow from natural systems and how these can be offset with restoration activities will lead to better outcomes for all stakeholders.

1.0 INTRODUCTION

The purpose of this document is to provide an Ecosystem Service and Natural Resource Valuation Assessment (ESV and NRV) of the proposed Princess Hotel development at Industry Cove, Hanover. A natural resource assessment is a useful component that should be included as part of an Environmental Impact Assessment (EIA). The identification of in situ ecosystem services and where feasible assigning monetary values to them provides additional information that can be used to guide the examination of project alternatives. An NRV also improves the cost benefit analytical component of any major infrastructure development because it identifies ecosystem (including monetary) benefits that are often not accounted for in the decision-making process.

Recognizing that coastal tourism infrastructure projects have the potential to contribute to national economic development, at the same time, it is important to note that human pressures on ecosystems such as wetlands, mangrove forests, seagrass beds and coral reefs reduce their effectiveness in providing important social and economic benefits in their current undeveloped states. The environmental degradation of mangroves is likely to result in impacts such as the loss of natural breakers of wave and wind energy, reduction in commercial and non-commercial fisheries (essential for livelihoods and food security), reduction of natural water filters, biodiversity loss, and loss of the ability to sequester atmospheric carbon. Combined these losses reduce Jamaica's climate change resilience and exacerbates for the ability to implement adaptation, mitigation and disaster risk management strategies.

Specifically, data that shows the economic and social benefits of protecting coastal communities from natural hazards (tropical storms, coastal inundation, and shoreline erosion) and related fisheries and tourism benefits should be included in the cost benefit calculations used to decide the scope and extent of these type of irreversible coastal development projects.

The primary purpose of this analysis is to provide an estimation of natural resource values of the key ecosystems present at this site in their current (in situ) state. The estimated values are expected to provide the client and the regulatory agency (NEPA) with information that can be used to guide decisions about the cost of the proposed environmental footprint of the development and inform the types of alternatives and options for mitigation activities.

2.0 BACKGROUND

A detailed site description was provided in the main EIA (Chapter 6). The site is predominantly wetland vegetation (primarily mature Mangrove trees, 10-15m high), with shrub in disturbed areas surrounded by a mixture of residential and commercial activities along the main road. The tree heights and diameters indicated that this was a mature and established forest, achieved over a very long period of time. The report also found that the site currently has a high level of biological diversity. Over 100 species of plants were identified of which four are endemic and two of which are only identified from the Negril area. Avifaunal assessments determined that the site is an important roosting and foraging area for a number of local and migrant bird species.

Based on proposed development as described in the EIA, the three key ecosystems that are expected to be most impacted are coral reefs, sea grasses and mangroves.
Description of the impacts include;

1) Corals – It is expected approximately 165 coral heads will be impacted, of this number 60 are slated for relocation.
2) Seagrass beds – Approximately 10,676.81 m^2 of seagrass located within the entire project footprint will be impacted.
3) Mangroves – Are expected to be most significantly and irreversibly impacted from this proposed development. As indicated in the EIA, the proposed development is expected to result in the loss of 4.128 hectares of the most functional and mature mangrove forest (central and northern sections), as well as mangrove areas less robust (southwestern red mangrove forest). These areas include parking and industrial areas, roads, drains and the boardwalk.

The use of the Ecosystem Service or Natural Resource Valuation approach in this case is important because of the need to identify the natural capital components of this site that may not be captured regular market prices (and costs). The identification and where possible quantification of these values provides additional information that can be used to make better trade off decisions regarding coastal developments such as the Cove site.

However, the application of natural resource valuation approaches as part of an EIA process is not without its limitations. The typical timeline for conducting an EIA within the context of an application processing period does not often allow for natural resource valuations techniques that require longer periods of time for the collection of primary data. Some ecosystem services are best valued using a technique that require the collection of primary data, for example using stated preference surveys (contingent valuation or choice experiments). These approaches take much longer and are typically very costly to implement. Additionally, there are times when the scale, scope and size of the projects and likely ecosystems impacted do not lend themselves to expensive primary data collection. In other words, it does not make sense to conduct an extensive NRV for a relatively small site/ecosystem because the valuation context will not be appropriate. This is a consideration for regulatory agencies as many of these key ecosystems (coral reefs, sea grasses, mangroves, large terrestrial forests) should rather be estimated at a national (or regional level) by academic or an external (unbiased) entity that would provide economic estimates that could then be used to provide smaller per unit area measures of value for regulatory purposes. This is however beyond the scope of this study.

Finally, natural resource valuation studies are often aimed at assessing economic values that represent the public good characteristics of natural systems. Willingness to pay measures are typically used to estimate ecosystem goods and services that benefit not only a select few but wider society. In the context of coastal tourism development, these sites are often located on private lands, or public lands leased to private entities. Natural resource valuation estimates may indeed signal the value over and beyond the formal market, however unless there is legislative framework to compensate private owners to leave these ecosystems intact this is unlikely to happen. Therefore, development of these natural resources may lead to the environmental costs being borne by the public.

3.0 METHODOLOGICAL OVERVIEW

Ecosystem services are the contributions that a biological community and its habitat provide to the day-to-day lives of human beings or society. Some ecosystem services are not easily exchanged in markets. These public goods (clean air, forests, bee pollination) may provide significant value to society but because they cannot be traded in traditional markets and require "nonmarket" valuation methods to estimate their economic worth. Examples of these goods include biodiversity, unique creatures and places such as whales or culturally significant sites, wildlife viewing, or snorkeling on a coral reef. Some of these goods do not have easily observable monetary values and determining which method to use to value them require careful assessment of the type of services being provided and their relative worth.

Estimating the public ecosystem services associated with the potential area to be impacted can be done following these steps: 1) The geographic/spatial, ecological and economic scope of the study site is identified; 2) The existing characteristics of the ecosystem (mangroves) and potential changes in the flow and value of ecosystem services based changes or pressures; 3) Existing data is used to estimate average economic values (including $ per unit area) for ecosystem service streams that are identified.

The objective of this analysis is to provide a framework to explore the potential trade-off between; the alternative development options including proposed mitigation and restoration action as suggested in the EIA. It is hoped that this information will inform the trade-off decision making process between key ecosystems, namely mangrove forests, seagrass beds and coral reefs associated with the proposed hotel development area at Cove, Hanover.

The methods used in this analysis highlights the monetary value that the development area contributes to the community through mitigation and other services as well as the replacement cost for the ecosystem. This method has been employed as a means of enabling stakeholders to see the real value of natural resources.

To achieve this, this report will identify the main streams of ecosystem services at the proposed site. The feasible this analysis will correlate these ecosystem functions and services with monetary values that can be used to guide trade off decisions. Some of the ecosystem services of mangroves seagrasses and coral reefs include;

- Surface water detention; (mangroves)
- Nutrient transformation; (mangroves, seagrass)
- Sediment and other particulate retention; (mangroves, seagrass, coral reefs)
- Coastal storm surge detention; (mangroves, seagrass, coral reefs)
- Shoreline stabilization; (mangroves, seagrass, coral reefs)
- Provision of fish and other shellfish habitat; (mangroves, seagrass, coral reefs)
- Provision of waterfowl and other water-bird habitat; (mangroves, seagrass)
- Provision of other wildlife habitat; (mangroves, seagrass, coral reefs)
- Conservation of biodiversity; (mangroves, seagrass, coral reefs)
- Carbon sequestration (mangroves, seagrass)

Where feasible, for a select few of these ecosystem services economic estimates will be derived using desk research and value transfer approaches. For example, estimates of the value of carbon sequestration from mangroves the role they and coral reefs play in protecting the coastline will be the likely candidates for economic estimation. This desktop analysis will rely on a literature review of relevant studies applicable to the project context. This includes economic and ecosystem service information. An examination of the relevant ecosystem services and economic valuation literature will be the basis for developing the methods to be applied to the ecosystem services of interest. This will include but not be limited to approaches such as benefit transfer methods, social cost of carbon, market-based approaches among others, when necessary.

Millennium Ecosystem Services Framework

In identifying the ecosystem services provided by natural environments, a common practice is to adopt the broad definition of the Millennium Ecosystem Assessment (MEA

2005) that ‘‘ecosystem services are the benefits people obtain from ecosystems.’’ Broken down into the main categories, Supporting, Regulating, Provisioning and Cultural/Recreational Ecosystem Services.

A broader interpretation of ecosystem services equates ecosystem services with benefits. This analysis will include both intermediate and final services as benefits. The rationale being that supporting services, in economic terms, are akin to the infrastructure that provides the necessary conditions under which inputs can be usefully combined to provide intermediate and final goods and services of value to society (Polasky and Segerson, 2009; TEEB 2010). In other words, ‘‘ecosystem services are the direct or indirect contributions that ecosystems make to the well-being of human populations’’. There are a number of different ways in which humans benefit from, or value, ecosystem goods and services. The first distinction is between the ‘‘use values’’ as opposed to ‘‘nonuse values’’ arising from these goods and services. Typically, use values involve some human ‘‘interaction’’ with the environment, whereas nonuse values do not. Direct-use values refer to both consumptive and non-consumptive uses that involve some form of direct physical interaction with environmental goods and services, such as recreational activities, resource harvesting, drinking clean water, breathing unpolluted air for example (Barbier et al 2011).

The fundamental challenge of valuing ecosystem services rests in providing an explicit description supported by accurate assessments of the links between the structure and functions of natural systems, the benefits (i.e., goods and services) derived by humanity, and their subsequent values. Assigning economic attributes is usually easiest with information that allows for the quantification of coastal communities' dependence of resources for example fuel wood, timber, raw materials, honey, crabs and shellfish (i.e. provisioning ecosystem services).

The economic values associated with coastal ecosystem goods and services can be categorized into distinct components of the total economic value according to the type of use. Direct use values are derived from the uses made of a wetland's resources and services, for example wood for energy or building, water for irrigation and the natural environment for recreation.

This analysis will include but not be limited to approaches such as benefit transfer methods, social cost of carbon, among others, when necessary. The benefit transfer method is used in this analysis to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. The basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Benefit transfer is often used when it is too expensive and/or there is too little time available to conduct an original valuation study, yet some measure of benefits is needed. It is important to note that benefit transfers can only be as accurate as the initial study (or studies).

3.1 Benefit and Value Transfer

The economic valuation methodologies that is proposed for this study include a combination of approaches that highlight different values based on the specific ecosystem services being examined. The analysis will look at carbon sequestration services, role of mangroves in preventing social disruption to adjacent communities and possible role of mangroves as nursery habitat for commercially important fishery species. Benefit transfer or value transfer is a commonly-applied technique that involves adapting research found in the available literature and conducted for one purpose, to another purpose, to address the policy questions at hand. It should be noted that any benefit transfer application should take into consideration the possible differences across sites (geographies, countries) with respect to environmental quality as well as institutional frameworks governing environmental management and protection. Benefit transfer application s therefore rely on desktop analysis and where feasible model simulation for sensitivity analyses.

The benefit transfer method will be used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. For example, values for natural resources such as coral reef, seagrass, mangroves and fisheries may be estimated by applying measures of fishing values from a study conducted in another area.

Thus, the basic goal of benefit transfer is to estimate benefits for one context by adapting an estimate of benefits from some other context. Benefit transfer is often used when it is too expensive and/or there is too little time available to conduct an original valuation study, yet some measure of benefits is needed. It is important to note that benefit transfers can only be as accurate as the initial study (or studies). Likely monetary valuation estimates will be provided for the following ecosystem services.

3.2 Damage Cost Avoided Approaches

The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services. This approach will be applied to the analysis of the economic benefits of these ecosystems by providing protecting lives, livelihoods and property as well as eliminating excess Carbon dioxide from the atmosphere.

3.2.1 Economic Value of Carbon

This approach will involve as highlighted above a review of the relevant literature on economic valuation of carbon sequestration services. This will include specific focus on tropical coastal wetlands, including mangroves. One of the approaches that will be used to estimate values will be calculating the economic benefits of removing carbon from the atmosphere by mangroves and assigning a value based on the social cost of carbon (SCC) or another suitable metric.

3.3 Market Based Approaches

This approach uses available data the economic contribution of key ecosystem services to observable market-based activity, including fisheries, fuel wood, honey and other non-destructive economic activities. Market-based approaches can be applied to provisioning services as well as regulating services particularly when they can be easily observed or traded in the market. It should be noted that even where market transactions occur, the prices do not necessarily reflect the value of the particular good or service being provided by the key ecosystem services of interest (mangroves, seagrasses and coral reefs) and in fact may be underreporting the full value.

4.0 ECONOMIC VALUES OF KEY ECOSYSTEM SERVICES

The sections below describe ecosystem service flows for coral reefs, seagrasses and mangroves. Where feasible, estimates of economic value as well as avoided costs (benefits of keeping in place) are provided.

4.1 Natural Resource Values of Seagrass Beds

There have been only a few studies that provide dollar estimates of the value of seagrass ecosystems. A main reason for this is that seagrass itself does not have much direct market value. Therefore, economic assessments of their worth rely on indirect values derived from the services these systems provide. Since some of these services result in social benefit, traditional market methods may be insufficient for deducing actual economic value. There have been very few studies done on the non-use value of seagrass ecosystems. Reviews that we have found on ecosystem valuations of coastal ecosystems contain little data on non-use valuation (Dewsbury et al 2016).

The replacement model is one of the more common valuation methods of seagrass ecosystems. This approach is common in calculating costs incurred by vessels that inadvertently or otherwise run aground or inflict damage onto seagrass beds. The productivity method is the only method which actually links seagrass ecosystem structure and function to an ecosystem service that has market value. Some studies report location-specific values of seagrass beds based on catch-per-unit-efforts (CPUE), by extrapolating yearly estimates multiplied by the market price of the fish species in question (McArthur and Boland, 2006). MacArthur and Boland (2006) used this approach to estimate the overall contribution of seagrass habitats to the economy in Australia to be US$103.74 million dollars per year.

Some studies have used hedonic pricing (a valuation technique that estimates a good based on its contributing characteristics) to estimate the value of coastal properties with or without erosion (Pompe and Rinehart, 1995). The effect of seagrasses on reducing erosion of the coastline can be a contributing estimator toward the total value of the coastline area.

Until very recently, the role of seagrass ecosystems in carbon sequestration was not documented on a global scale. In the wake of concerns over the climate change effects resulting from increased carbon dioxide emissions, multiple stakeholders are seeking ways to reduce the global carbon footprint. These reductions can occur by reducing emissions, as well as increasing the number of sinks available. These estimates purport that globally, seagrasses can possibly store up to 19.9 Billion MT per year of organic carbon in their meadows. The economic implications of these calculations are made more apparent by the reality that many of these meadows are disappearing at a substantial rate. The loss of these meadows means that the resulting carbon release increases the atmospheric carbon pool.

The absence of models that appropriately connect the ecological to the economic systems have resulted in valuations that are based on proxy variables that may unintentionally grossly undervalue seagrass beds. The Sea Grass Ecosystems Valuation (SEV) model proposed by Dewsbury et al (2016) provides a conceptual framework that allows for the use of both ecological and economic models.

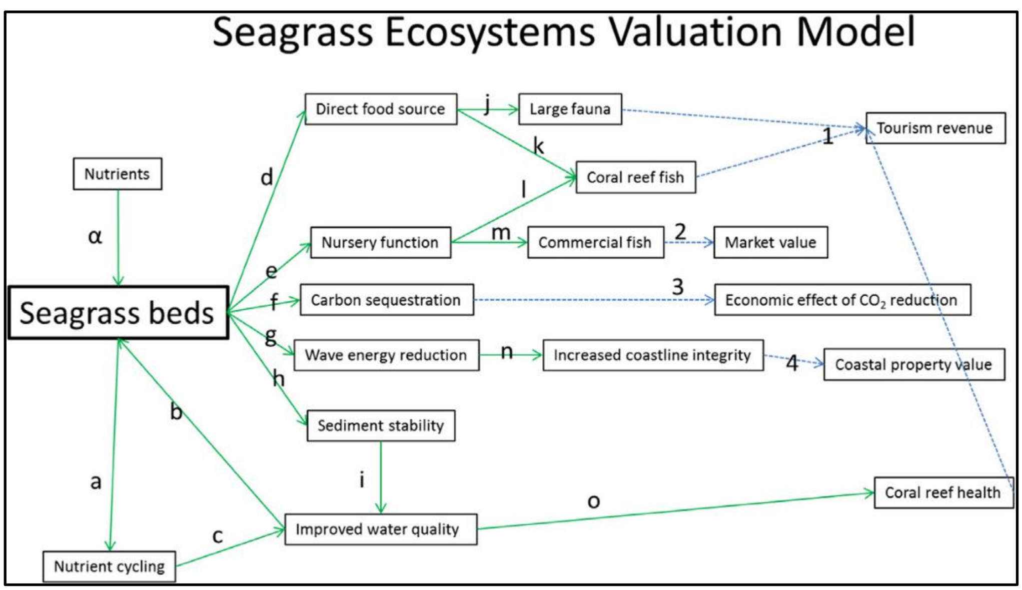

Figure 2 Conceptual diagram for seagrass ecosystem value (adapted from Dewsbury et al 2016). Green arrows represent ecological function, blue arrows represent economic contribution.

Table 3
Published seagrass ecosystem economic valuations.

Value	MEA service	Ecology studies	Economic valuation studies	Valuation method	Value
Use (direct)					
Mulch	Fiber	Orquin et al. 1999, Orquin et al. (2001)			
Insulation	Fiber	Wyllie-Echeverria and Cox (1999)			
Embroidery	Ornamental resources	Huong et al. (2003)			
Provisioning			Dirhamsyah (2007)	Market price; Travel cost	US2,287/ha/yr
			Kuriandewa et al. (2003)		US80,226/ha/yr
Use (indirect)					
Nursery	Food/Recreation	Heck et al. (2003)	Anderson (1989)	Productivity method (commercial fisheries)	US1.8million/yr
			Watson et al. 1993, Kirsch et al. (2002)	Productivity method (prawn commercial value)	US1150/ha/yr
			NOAA 1997, Gacia et al. (1999)	Replacement	US28,000–684,000/ha
			Vithayaveroj (2003), Madsen et al. (2001)	Productivity method	US203,200/yr
			McArthur and Boland (2006)	Productivity method (fish commercial value)	US103.74 million/yr
			Paulsen (2007)	CVM	US960,000/yr
			Samonte-Tan et al. 2007, Sunamara (1977)	Productivity	US 204/ha/yr
			Unsworth et al. (2010)	Market price	US78/ha/yr
			Guerrey et al. 2012, Spurgeon (1992)	Productivity method (multiple services)	US4585/ha
			Vassallo et al. (2013)	Market cost	US2.3 M/ha/yr
Tourism	Recreation	Daby (2003)			
Carbon sequestration	Primary Production	McLeod et al. 2012, Mcleod et al. (2011), Fourqurean et al. (2012), Greiner et al. (2013)	Pendleton et al. (2012), Lavery et al. (2013)	Carbon storage calculation	US394/ha/yr
Wave attenuation	Erosion regulation	Fonseca and Calahan (1992)			
Sediment stabilization	Erosion regulation	Terrados and Duarte (2000)	Guerrey et al. 2012, Spurgeon (1992)	Productivity method (multiple services)	US4585/ha
Nutrient cycling	Nutrient cycling	Short (1987)	Costanza et al. (1997)	WTP	US19,004/ha/yr
			Brenner et al. 2004, Marshall et al. (2000)	Meta-analysis	US24,228/ha/yr
			Engeman et al. (2008), Fourqurean et al. (2012)	Transfer method (original WTP, King, 1998)	US140,752.23/ha
			Han et al. 2008, Haynes et al., (2007)	CVM, Benefits-transfer, WTP	US100,640/ha
			Guerrey et al. 2012, Spurgeon (1992)	Productivity method (multiple services)	US4585/ha
Non-Use					
Existence			Vithayaveroj, (2003)	WTP	US10.43 million/yr
Wellbeing			Cullen-Unsworth et al., (2014)	Case study analysis	Location-specific range of positive externalities

Figure 1. Range of estimated seagrass values (Adapted from Dewsbury et al 2016).

The figure above shows a range of per hectare economic values for seagrasses based on a variety of services and metrics. Depending on the type of ecosystem service and policy context annual per Ha values range from as low as US$78/ha/yr to $100Million/ha/yr. However, for the context of this site carbon sequestration, tourism and sediment stabilization values are probably the most appropriate to compare. These values range from approximately US$394/ha/yr for carbon storage to $960,000/ha/yr that represents consumer surplus or willingness to pay (pure non market value).
For the purposes of this analysis we can use a value from the table Brenner et al 2004 that generates a per hectare value based on a meta analysis. The per hectare, per annum value for seagrasses was shown to be $US24,228. If we apply this value for the proposed site, where 10,676.81m^2 (or 1.07 Ha) of seagrass are expected to be negatively impacted (lost) through development activities we can provide an estimate of the annual lost value from removing this area of seagrass. The estimated lost value would be equal to **US$25,924 per annum**.
However as the figure above suggests there are other benefits that will be lost (carbon, erosion, fish nursery) that may comprise different levels of value. Each of these value streams while valid should not be summed to give a "grand total" because of the potential issues around double counting and the fact that different types of valuation approaches are based on different policy and theoretical constructs.

So while this approximately one type of (lost) value, there are other ecosystem benefit streams that will also be lost. Thus, developers and regulatory agencies can keep these factors in mind as part of the overall cost benefit analytical framework used to weigh alternative development option.

4.2 Natural Resource Values of Coral Reefs

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.

Edwards 2009 conducted a non-market valuation survey of the recreational value of coral reefs and their associated ecosystems (seagrass beds and beaches). Using a contingent choice approach an annual value of US$217 Million was estimated. The study was based on the value of the coral reefs located on the northern coast of Jamaica in other words those reefs that directly and indirectly support the coastal tourism product. Using Edwards (2009) per person value estimate of $128, Negril's beaches and reefs have a current economic value of **USD 45,984,128**. Economic value here represents the "worth" of a beach and coral reef vacation to the average visitor. It does not represent costs and expenditures associated with the tourism industry. This value represents the amount over and above what each person has already spent on their beach related vacation.

Economic value for the reef system at the proposed Cove site is captured within the aggregated estimate for Negril highlighted above. It is not possible to estimate value based on a portion of this total value as the policy context for the valuation studies do not lend itself to that. However it can be demonstrated by previous empirical studies that reefs in and around Negril provided economic above and beyond what can be revealed in the market. Any deterioration of environmental quality and function will serve to reduce this overall economic value.

Another study that examined the value of coastal protection services of coral reefs demonstrated that as a result of coral reef decline and expected beach degradation, would cause a loss in economic value. Table 1 below presents the consumer welfare loss of the simulation model, showing a decline in attribute quality per meter of beach loss.

Based on the model simulations conducted (Kushner et al) the loss in economic value due to erosion at three north coast beaches is estimated at US$19 million. Additional erosion caused by further reef degradation is estimated to increase this loss to US$33 million after 10 years. This represents an additional US$13.5 million loss of consumer welfare if the reef degrades further.

Table 1 Annual loss in consumer surplus due to coral and beach degradation.

Location	*Annual Welfare loss for status quo ($US Million)*	*Annual Welfare loss if reef erodes ($US Million)*	*Difference Due to Reef Degradation ($US Million)*
Negril	$5.5	$10.9	$5.3
Montego Bay	$7.1	$10.7	$3.6
Ocho Rios	$6.5	$11.1	$4.6
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. (Adapted from Kushner et al 2011)

The purpose of referencing the two studies above is to demonstrate that there are significant values associated with coral reef and beach ecosystem services. This is particularly so for the near shore coral reef ecosystems of Jamaica's north coast. Maintaining or rehabilitating these ecosystems is equivalent to investing in the coastal "bio-infrastructure" that supports the tourism industry. Although not easily "traded in the market place" it is important to consider these values when making development decisions including trade-offs.

4.3 Natural Resource Values of Mangroves

Non-use values of mangroves are unrelated to any direct, indirect or future use, but rather reflect the economic value that can be attached to the mere existence of a wetland (Pearce and Turner 1990). In addition to market and non-market valuation approaches other portions of value such as the value per tonne of carbon sequestered and stored. The empirical studies conducted on wetland valuation vary widely in their use of valuation techniques, the actual products and services being valued, and the type and geographical location of the wetlands being considered. This analysis will be restricted to an assessment of the regulating services of coastal protection and carbon sequestration with a discussion of additional ecosystem services.

The Brander *et al* (2006) study showed that the most significant ecosystem service associated with coastal wetlands is biodiversity. The study estimated biodiversity services of wetlands at US$17,000 per hectare per annum (Ha-1 yr-1). Other valuable services were water quality, recreational fishing, flood protections and amenity values. It is important to note however that directly transferring the values from one study to a particular study site must be done with caution. The Brander *et al* study used a global data set and accounts for some geographic and socio-economic differences. The study shows highest values for wetlands in Europe and lowest for South America, (where Jamaica was grouped). Thus, the value per hectare reported must be understood within this context. Notwithstanding, there is clear evidence that the coastal wetlands of Jamaica provide services that annually contribute value.

The other key approach is to use the relevant literature on economic valuation of carbon sequestration services to provide an estimate for the Cove study site. In particular, the approach that is used is the calculation of the economic benefits of removing carbon from the atmosphere by the mangroves at the study site by assigning a value based on the social cost of carbon (SCC). The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services.

On average, mangroves contain three to four times the mass of carbon typically found in boreal, temperate, or upland tropical forests (Donato *et al* 2011, Jardine et al 2014). Much of this carbon storage, however, is at risk of being lost, because mangroves are among the most threatened and rapidly vanishing ecosystems globally, with habitat loss rates similar or greater to those in tropical forests (FAO 2016),

Market-based mechanisms such as carbon off-sets used to credit mangrove conservation for associated emissions reductions are potential options for addressing conservation needs while providing sustainable financing. Carbon credit schemes are typically modelled on the REDD (reduced emissions from deforestation and degradation) programs designed to protect tropical forests. The purpose of these programs is to provide market incentives to reduce emissions from deforestation usually by encouraging developing countries to reduce deforestation in return for compensation from developed countries committed to emission reductions (Angelsen 2008, Kindermann *et al* 2008).

4.3.1 Estimating Mangrove Carbon Stocks

Designing and evaluating market mechanisms for mangrove conservation requires several spatially explicit scientific inputs, including information on the mangrove area susceptible to deforestation, carbon in mangrove biomass and soils, annual carbon sequestration, the emissions profiles of mangroves converted to other uses, and the opportunity cost of protecting mangroves (Siikamäki *et al* 2013, FAO 2016). Estimation of sequestered carbon is an important first step in this process.

Mangrove carbon storage varies substantially over space; therefore, the benefits from mangrove conservation depend critically on the location of the mangroves conserved. Unlike other tropical forests, for which the bulk of carbon storage is in biomass, mangrove carbon is primarily stored in the soil. The data show that mangroves in North and Central America contain some of the most carbon-rich soils whereas mangroves in East Asia are among the most carbon-poor soils (Jardine et al 2014). Soils in South East Asia, where approximately 32.8% of the world's mangroves are located, have considerably greater carbon content than mangroves soils in East Asia but substantially less carbon content than mangrove soils in North and Central America (Jardine et al, 2014). This study estimated global mangrove carbon averages of 369 ± 6.8 Mg C ha^{-1} (in the top meter of soil). One Megagram (Mg) is equivalent to a Metric Ton. Regional differences suggest that Jamaican mangroves are likely to have a higher content than the global average.

The UN Framework Convention on Climate Change – UNFCC has a list of land use (LU) types including; Forest Land (FL), Cropland (CL), Grassland (GL), Wetland (WL), Settlements (SL) and Other Land (OL). This analysis focuses on the carbon sequestration capacity at the study site which is estimated to have an area of 9.29 hectares. For the purpose of this analysis, the suggested Global Tier 1 estimates for blue carbon stocks are used to calculate values for sequestered carbon. The global average for mangroves of 386 $MgCHa^{-1}$ assuming a carbon-rich soil depth of 1 meter is applied to this analysis for Cove (Donato et al 2011, Pendelton et al 2012, Hoyt et al 2014. Table 1 below shows comparisons of carbon stock between mangroves, tidal salt marsh and seagrass beds.

Table 2 Global mean and range of values of soil organic carbon stocks (1m depth) for tropical coastal ecosystems and CO2 equivalents

Ecosystem	Carbon Stock Mg/Ha	Range Mg/Ha	CO_2M equiv/Ha
Mangrove	386	55 – 1376	1415
Tidal salt marsh	255	16 – 623	935
Seagrass	108	10 – 829	396

Adapted from Hoyt et al 2014

In order to convert the sequestered carbon (per hectare) to some relative economic value social cost of carbon is used as the main metric.

4.3.2 Social Cost of Carbon

The social cost of carbon (SCC) may be interpreted as how much we should be willing to pay to reduce carbon dioxide emissions, or as the tax that we should impose on such emissions. The SCC is a concept that reflects the marginal external costs of emissions: it represents the monetized damage caused by each additional unit of carbon dioxide, or the carbon equivalent of another greenhouse gas, emitted into the atmosphere (Kotchen 2017). In more technical terms, the social cost of carbon is defined as the incremental impact of emitting an additional ton of carbon dioxide, or the benefit of slightly reducing emissions. The social cost of carbon is the Pigou tax (Pigou 1920), that is, the amount GHG emissions should be taxed in order to maximize welfare (Nordhaus 2014; Tol 2018).

4.3.3 Discount and Pure Rate of Time Preference

Some of the controversy concerning the social cost of carbon arises from the complexity of its computation. Golosov et al. (2014) show that the social cost of carbon can be written as a function of total economic output, the pure rate of time preference, elasticity of damage with regard to the atmospheric concentration of carbon dioxide, and the rate of decay of carbon dioxide in the atmosphere. In economics, comparing impacts over time requires a discount rate. This rate determines the weight placed on impacts occurring at different times. For this analysis we will also present some estimates that take rate of time preference (discount rate) into consideration. Since the social cost of carbon (SCC) is the marginal cost of emitting one extra tonne (World Bank, 2019).

An amount of CO_2 pollution is measured by the weight (mass) of the pollution. Sometimes this is measured directly as the weight of the carbon dioxide molecules. This is called a tonne of carbon dioxide and is abbreviated "tCO_2". Alternatively, the pollution's weight can be measured by adding up only the weight of the carbon atoms in the pollution, ignoring the oxygen atoms. This is called a tonne of carbon and is abbreviated "tC". Estimates of the dollar cost of carbon dioxide pollution is given per tonne, either carbon, $X/tC, or carbon dioxide, $X/$tCO_2$. One tC is equivalent to 3.67 (44/12) tCO_2. The uncertainty about the social cost of carbon is fairly wide too and grows over time (Tol 2012). A component of this discount rate, the rate of pure time preference, measures the weight to attach to future levels of well-being solely because they are enjoyed later in time. The discount rate is critical when dealing with long time periods as with climate change. The higher the discount rate, the lower the concern for the future and the lower the social cost of carbon: As the uncertainty grows as we look further into the future, a lower discount rate implies a loss of confidence. A review of additional recent literature in this area found a wide range of estimates of the value of carbon stored, typically presented as a value per metric ton of carbon ($/tC). For the purposes of this report a median value of $48/tC is the SCC price estimated for Latin America and the Caribbean region (Kotchen et al 2014). This analysis also uses three pure rate of time preferences (0%, 1% and 3%) to estimate price per metric tonne of carbon emissions (Tol 2018).

Table 3 Annual Carbon sequestration Mangrove values

	Existing Mangrove Area	Mangrove Area to be Removed
Area (Ha)	**60 (Rough Estimate)**	**4.128**
Tonnes C Sequestered	23,160	1,593
Tonnes of CO_2 equivalent	84,920	5,843
Estimated Price T^{-1} C (Social Cost of Carbon)		
$48 (Latin America)	**$1,111,680**	**$76,483**
Discount Rates		
0% ($220)	$5,095,200.00	$350,550
1% ($93)	$2,153,880.00	$148,1867
3% ($28)	$648,480.00	$44,615

Using a social cost of carbon (SCC) of $48 T-1 C the value of annual sequestration for the Cove site is US$1,111,680 per annum. The annual cost of emitted carbon for removing 4.128 Ha is US$76,483 per annum.

4.3.5 Avoided Damages: Value of Mangrove Protection

At present, coastal flooding from storms in Jamaica is estimated to result in US$136.4 million in damages every year, in the presence of mangroves. If these mangroves were lost, the expected damages from flooding would increase to $169 million annually. Thus, mangrove forests in Jamaica provide over US$32.7 million in annual flood reduction benefits to built-capital (more than US$2,500 per hectare per year).

Historically, climate events in Jamaica have caused considerable damage to transport infrastructure. The costliest disasters in the country were due to floods and storms (USAID 2018). While the mangroves at this site are further away from direct contact with coastal infrastructure (namely the main road) they are currently providing coastal protection ecosystem services at the site.

4.3.6 Economic Contribution of Mangroves to Nearshore Fisheries

Mangrove fisheries benefits are typically derived from two key ecological mechanisms. The first, is the high level of primary productivity from the mangrove trees and from other producers in the mangrove environment that supports secondary consumers. This high level of primary productivity forms the basis of food chains that support a range of commercially important species. The second is the physical structure (habitat) that they provide, creating attachment points for species that need a hard substrate to grow on, as well as shelter from predation and a benign physical environment. These two mechanisms combine to make mangroves particularly effective as nursery grounds for juveniles of species that later move offshore or to adjacent habitats such as coral reefs (Hutchinson et al 2014).

In addition to nursery services, mangroves also support commercial harvest of fin and shellfish species these include mullets, crabs, oysters and other estuarine species. While some species use mangroves only at certain life history stages, for example snapper may live in the mangrove as juveniles before moving to coral reefs as adults, other species live outside the mangrove but enter it at high tide to feed. This highlights the potential importance of habitat linkages in enhancing fish productivity, while also making it challenging to isolate the role of mangroves in supporting fisheries in such mixed habitat systems.

Estimating the economic value of mangrove-associated fisheries is challenging, particularly at regional or global scales (Hutchinson et al 2014). Estimation of the proportional contribution to commercial (or subsistence) fish harvest is typically very data limited. The additional challenge these estimates is the underlying complexity and variability of the types of fisheries. Several studies are limited to individual target species or specific fishing methods and as a result capture only a part of the total fisheries value. Estimates for the economic contribution of mangrove habitat support to offshore fisheries can also vary spatially given differences between quality of the habitat at the seaward edge or ‘‘fringe’’ of the mangrove forests as compared to further inland (Aburto-Oropeza et al 2008).

Mangroves are important as breeding and nursery areas for fish and prawns that form the basis of major fisheries (Bann, 1997; Sasekumar et al., 1992). Annual commercial fish harvests from mangroves have been valued at from US$6,200 per km^2 in the United States to US$60 000 per km^2 in Indonesia (Bann, 1997). Other studies have produced estimates with ranges between 5-25 per cent contribution of mangrove to offshore fishery (Spurgeon, 2002). Another study estimated a 31.7 % contribution of the local fishery landings the mangrove (Aburto-Oropreza, 2008), an equivalent of $15,000 dollars per acre. While another study on the contribution of Malaysian mangroves to nursery areas, coastal food chains and fisheries show that net fisheries contribution from 1 ha of mangrove forest amounted to US$846 yr^{-1} (Chong, 2007).

The primary method utilized in for this component is a value transfer approach based on relevant global and Caribbean literature. The value transfer approach relies on linking the area of mangrove to its potential contribution to nearshore fisheries. These value transfers are based on studies that utilized a production function-based approach to derive estimates of fisheries value from mangroves. It is also dependent on objective measures of biophysical parameters that can then be tracked to corresponding changes in marketed output of the product. In this case, fish and seafood products.

There are some common factors that influence production and fishery value in all mangroves. These can be demonstrated in the figure below (adapted from Hutchinson et al 2014) which describes a conceptual model of the drivers of mangrove fishery catch and value. The conceptual diagram below is based on the assumption that environmental drivers determine the potential fishable biomass that might be present in natural conditions. This means that there can be human impacts to fish stocks based on degradation of mangroves. These impacts may however be mitigated by conservation and fishery management.

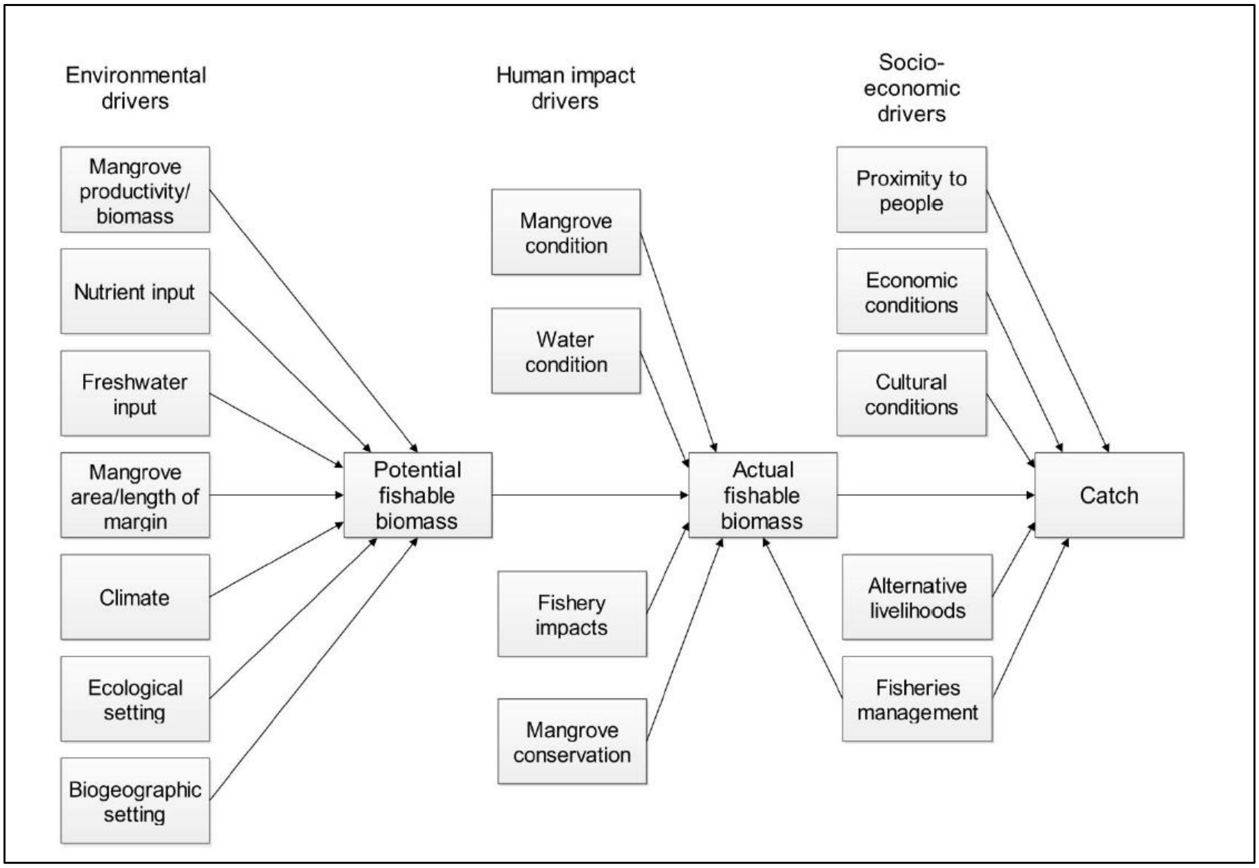

Figure 3 Conceptual Model of the drivers of mangrove fisher catch and value (from Hutchinson et al 2014)

The estimates of fisheries values linked to mangrove area are based on a review of related literature and subsequent benefit (value) transfer. There are studies with broad range estimates of mangrove-associated fisheries economic values often in excess of US$1000 per hectare per year. Based on a comparison of a variety of studies that included a range of mangrove types and fisheries, the global median value of US $77/ha/yr for (fin) fish, and US $213/ha/yr for mixed species fisheries (Hutchinson et al 2014) was used for this analysis. These median values are within the context of a wide variation value. For example, for mixed-species fisheries, the values ranged from

$17.50 to $3,412 ha/yr. These median values are used as the value transfer estimates for the Jamaican mangrove sites.

Table 4 Estimated annual economic contribution of mangrove to small-scale mixed fisheries

Per Ha Value	Cove	Removed Mangrove
	60 Ha	**4.128 Ha**
	$ Per Ha Per Annum	
Fin Fish (US$77/J$10,010)	US$4,620 (J$600,600)	$318 (J$41,321)
Mixed Fisheries ($213/J$27,690)	US$12,780 (J$1,661,400)	$879 (J$114,304)

These estimates show that the economic contribution from these sites are relatively modest in comparison to other systems. However, these are relatively small areas and limited their ability to contribute more significantly to fishers' incomes. As indicated previously, these figures are based on median global estimates with wide ranges. These extrapolations, especially when expressed as simple averages, are therefore highly uncertain. Such global extrapolations also miss the spatial variability in mangrove-associated fishery values due to both local ecological factors, and a host of social, cultural and economic influences.

The main EIA document provided information on fishers based on results from community questionnaires administered at fishing beaches within a 5 Km radius from the site (Section 7.1.3). Some of the species harvested by these fisheries utilize or are dependent on corals seagrasses and mangroves key habitats. Hotel construction and alterations to these habitats may in turn negatively impact the already modest weekly earnings of these key stakeholders.

4.4 Economic benefits of Honey Bees

Mangroves attract honeybees and facilitate apiculture activities for people living along the coastal zones (Siddiqi, l997). Mangroves apiculture activities accounts for about 90% of honey production among the mangrove communities in India (Krishnamurthy, l990). While in Bangladesh, an estimated 185 tons of honey and 44.4 tons of wax are harvested each year in the western part of the mangrove forest (Siddiqi, I997). Beekeeping is also a very benign way of obtaining a harvest from natural forests. Beekeeping is practiced by a variety of different techniques that can be selected and adapted depending upon the situation of resource-poor community members who depend on mangrove forests.

In Tanzania, the black mangrove *Avicennia germinans* is also known as the honey mangrove. It has small white flowers that produce abundant nectar. There is little research on the relationship between bees and mangrove, however from observation of the type of pollen, nectar and scent, it appears that mangrove species are dependent upon bee pollination, and mangrove provides excellent forage for bees and significant honey crops (Ibrahim, 2016). In Florida the main species for pollen and nectar production are the black mangrove *Avicennia germinans*, buttonbush (*Conocarpus erectus*), and white mangrove (*Laguncularia racemosa*) (Stanford, 1983). As part of their regular husbandry techniques, beekeepers in Florida migrate their hives between the citrus growing areas in central Florida and the mangrove areas, with the mangrove honey season extending from mid-May to early August. Average honey production from the mangrove is 35-40 kilogram per colony (Hamilton and Snedaker, 1984).

Beekeeping provides one of the few sustainable ways to use mangroves and if done without harming the bees, it has no overall negative impact. Implementing beekeeping extension as part of local social development efforts can be used not only as a mechanism for providing alternative livelihoods but also as a way to protect the mangrove vegetation from deforestation. The promotion of honey bees has been cited as an integral part of the national strategy for the protection of Guyana's mangrove forests though the Guyana Mangrove Restoration Project (GMRP) implemented by the Ministry of Agriculture (http://www.mangrovesgy.org/home/). In addition to European honeybees, mangroves are also home to other pollinators (insect and animal) and serve as a natural reservoir for pollination services that provides an ecosystem service benefit to the agricultural sector (Edwards 2019).

It is notable that the majority of the mangroves at the proposed Cove site are comprised on black mangroves. The EIA report also identified a number of honey boxes at the site and it can be assumed therefore that this is an economic activity that is currently occurring at the site. Based on data from the EIA it was understood that the approximately 7 boxes found at the site are owned by one individual. Through personal communication it was gleaned that each hive produces about a bucket and a half of honey which is approximately $40,000 JMD. For given season it was estimated that one box produces about 2 to 3 buckets. This individual is likely to be unable to continue this type of activity one this site has been developed. In addition to direct provisioning ecosystem services of honey the pollination services of bees are widely understood to be of immense value to natural and agricultural systems but putting a figure on this value is difficult.

4.5 Social and Cultural Importance of Bird Shooting

There is an intrinsic value to persons above and beyond any costs (time, petrol, accommodation, food) to engage in bird hunting. This non-market benefit is provided in addition to more direct economic benefits to persons who play supporting roles (bird boys, cooks and other guides). Even those bird shooting is a seasonal activity, it does provide a short-term influx of funds for lower income individuals. The proposed development is expected to eliminate this recreational activity and resulting in lost ecosystem services.

5.0 OPPORTUNITIES FOR MITIGATION

The proposed site currently has a level of high natural capital that will be significantly impacted based on the proposed development. Given that the site is privately owned, if the developer and NEPA decide to proceed, then aggressive mitigation activities will have to be pursued in order to offset the lost natural resource values and increased costs to the Jamaican public (increased risk of coastal damage, cost of Carbon Dioxide added to the atmosphere and other losses). To offset these damages, we outlined a set of possible ways to approach mitigation of these negative environmental and economic impacts.

It is worth mentioning that for mangroves to continue providing the services as described above, it may require active restoration in the face of man-made threats to existing forests. This may also be true for the Cove site. Interventions that are designed to produce a no net loss of ecological character and functions of a wetland areas such as restoration of mangroves could enhance or increase economic value by increasing the level and amount of ecosystem services (more fisheries, better coastal protection, more carbon sequestration) (World Bank 2004). In other words when mangroves are conserved, enhanced or restored, it should lead to an increase in the value of existing ecosystem goods and services or the value of other economic activities that depend on ecosystem conditions.

5.1 Wetlands Mitigation Banking

With any large scale development activity that may have deleterious impacts to wetland areas it is often challenging to provide adequate compensatory mitigation by way of replacement of the lost wetland onsite or in close proximity to the development. In such cases, other ecologically sensitive methods such as Wetland Mitigation Banking, can provide developers and government regulatory agencies with a viable alternative that will also ensure that there is a robust and ecologically sound compensation for the impacted wetland areas. Notwithstanding, the proviso for consideration for this approach, is that mitigation for should only be considered for approval only after the developer has provided practical modifications to reduce or eliminate adverse impacts that would be caused be the proposed development.

The idea of a wetlands mitigation bank is a unique approach for the environmental stewardship of wetland areas in Jamaica. The concept of a bank, however, is not new to the island and a similar approach was also recommended in the Highway 2000 project which impacted wetland communities along the Portmore Causeway. The EIA for that project "recommended that discussions be held with NEPA, the regulatory agency, regarding the establishment of a wetlands mitigation bank in Jamaica. This would require the evaluation of potential sites, the determination of the most suitable site and the expertise to seed and manage the area, as determined by NEPA. The establishment of a wetlands mitigation bank would not only serve the purpose of re-establishing mangroves removed as a result of the Highway 2000 project, but also have the long-term impact of providing an ecological viable area to facilitate future proposed developments in implementing the mitigation measure of mangrove replacement, as required.[1]"

A mitigation bank is a third party mechanism, recognized by a regulatory agency, in which allows one party to purchase "credits" from a mitigation bank to be used to compensate for expected adverse impacts to wetland and coastal resources usually within the same watershed area (service area) as the bank. Once mitigation credits have been purchased by a permittee, the mitigation bank then assumes all legal responsibility for satisfying the mitigation requirements of the permit (i.e., implementation, performance, and long-term management of the compensatory mitigation project approved under the and subsequent mitigation plans). Mitigation banking can therefore provide a cost-effective way of reducing delays in permitting as they provide upfront mitigation for future adverse impacts while also ensuring that vita natural areas are preserved for future generations.

[1] nepa.gov.jm/eias/highway2000/.../Final%20EIA%20Report.doc

Mitigation is only recognized if there is restoration, enhancement, creation, or preservation of wetlands, coastal resources. Table (xx) provides a definition of the types of mitigation acceptable for mitigation banking.

Table 5 Mitigation Banking Definitions[2]

Mitigation Bank	A mitigation bank provides means a system in which the creation, enhancement, restoration, or preservation of wetlands is recognized by a regulatory agency as generating compensation credits allowing the future development of other wetland sites.
Onsite Mitigation	means creating, enhancing, or restoring adjacent wetlands in an amount sufficient to mitigate for the specific development project needing regulatory approval but not producing "surplus" compensation credits available for use in mitigating other activities.
Compensation Credit	means the unit of wetland value that is recognized as the basis for comparing the destroyed wetland to the banked wetland offered in compensation. Credits are expressed in units such as acres, habitat units, or numbers.
Creation	Creating wetlands means to alter terrestrial environments or shallow aquatic environments to produce wetlands.
Restoration	Restoring wetlands means to return wetland values and functions to a former wetland or degraded wetland where human

[2] Adapted from Wetland Mitigation Banking Study Institute for Water Resources- Water Resource Support Center, US Army Corp of Engineers WR Report 94-WMB-6, prepared by Environmental Law Institute

	or natural activities have diminished or destroyed such values and functions.
Enhancement	Enhancing wetlands means to alter an existing wetland to add, or increase, particular wetland values and functions to levels not present under previous natural conditions, or to slow the natural impairment of existing values and functions.
Preservation	Preserving wetlands means to provide legal protection to natural wetlands that would otherwise be lost to lawful activities.

5.1.1 Determination of Available Credit for Mitigation Banking

There are several methodologies to determine and value the credits available in a mitigation bank. These methods are all designed to provide a reasonable approximation of the replacement required to compensate for the impacts to the values and functions of the wetlands or coastal systems lost. The evaluation of credits serves to define the working units for each credit available in the bank, for example the working units for one bank may be acreage while another may use units based on ecological values for example, habitat units. The second benefit of a credit evaluation process is to determine the replacement ratio of mitigation that will be required, for example based on the assessment of a mangrove stand it may be determined that the required mitigation ratio may be 10:1, that is one unit of impact will require 10 units of mitigation.

The determination of the available credits and by extension the value of these credits are usually determined by qualitative or quantitative methods, that can be simple or complex depending on the expertise available. The approaches for credit evaluation are varied and includes methods based on easily observed characteristics such as acres of wetlands, valuation based on assessment of ecological characteristics (e.g., wetland services, wildlife habitat, wetland functions etc.). Other approaches to valuation include best professional judgment, economic valuation or a combination of al the approaches mentioned above.

5.1.2 Compensatory Ratios

Once the working units of the bank has been established it is still necessary to determine the ratio of compensation required for the permitted wetland loss. Compensatory ratios take into account the following factors: 1) the different levels of functional lift associated with different types of mitigation, 2) the time required for the mitigation site to reach maturity or target condition, 3) the risk of the mitigation not achieving functional replacement, and 4) an appropriate consideration of the loss of function over time. In recognition of the levels of complexity and diversity of wetland habitats the ratio required for compensation is often linked to the quality of wetlands at the mitigation bank.

One example of the compensatory ratio mechanism is the “Ratio Method” that is utilized by the US Army Corp of Engineers in their mitigation banking process. The ratio method is often utilized in project where information required to conduct other qualitative methods are not available. The ratio method uses the following base ratios:

Table 6 Ratio method use for mitigation banking[3]

Type of Mitigation	Value of Impacted Wetland		
	Low	Medium	High
Restoration	1:2	1:3	1:4
Enhancement	1:3	1:5	1:9
Preservation	1:7	1:12	1:23

3 https://www.sam.usace.army.mil/Portals/46/docs/regulatory/docs/Mitigation/Ratio%20Method%20page.pdf

The approach in applying the ratio method is to determine the percentage of the proposed mitigation bank available for each mitigation type (restoration, enhancement and preservation) is available and what portion of the bank consists of non-wetlands. The type of mitigation credit available is calculated using the following formula:

Value of Impacted Wetland = BR (base ratio) x AA

Where AA = Affected area; and BR represent the base ratio for each mitigation type.

5.1.3 Opportunities for a Mitigation Bank at Cove

A plausible approach to achieve a no net loss of ecosystem functions and services of the in the wetlands at the Cove development could be through the establishment of a Wetlands Mitigation Bank. As mentioned above the determination of mitigation credits available in a bank can be complex however it is sometimes advantageous that use simple methods that are easy to understand by both the permittee and the regulatory agency and does not require complex or specialized skill sets. An example of this approach is the use of acreage, the ease of this approach is that one acre of wetland is equivalent to one unit of credit. The EIA indicates that Princess Hotels and Resorts Limited has acquired approximately 73 hectares (180 acres) of land in Green Island, Hanover and is desirous of constructing a 2037-room eco-resort on approximately 34 hectares (≈ 84 acres) of it. Approximately 96 acres is eligible or the creation of a wetlands mitigation banking. A breakout of the potential for each mitigation type available is outlined in Table 7 below

Table 7 Breakout of potential mitigation types

Mitigation Action	Affected Area (acres)	Percent of Total Area
Preservation	87.4	91
Restoration	6.68	6.9
Enhancement	2	2.07

Non-wetland	0.25	0.002

Table 8: Calculation of compensatory ratios for the Cove Development

Type of Mitigation	Area Affected (AA)	Value of Impacted Wetland = BR (base ratio) x AA		
		Low BRxAA	Med BRxAA	High BRxAA
Restoration	0.069	1:2 = 1: 0.14	1:3 = 1: 0.21	1:4 = 1:0.28
Enhancement	0.02	1:3 = 1: 0.6	1:5 = 1: 0.1	1:9 = 1: 0.18
Preservation	0.91	1:7 = 1: 6.37	1:12 = 1: 10.92	1:23 = 1: 20.93
Non-wetland*	0.002	N/A	N/A	N/A
Total		1: 7.11	1: 11.23	1: 21.39

For the case study for a potential wetlands mitigation bank at the Cove site Compensatory Ratio are:

Low Quality Wetlands: 1 :7; Medium Quality Wetlands: 1:11 and High Quality Wetlands: 1:21

Therefore, within the watershed area serviced by the Cove Wetlands Mitigation Bank the 2 acres of medium quality wetland impact would require 22 acres of credit from the Cove bank to offset those wetland losses.

Price of wetland Credits

The price of wetland credits is normally established by the bank and it takes into account the total economic cost to plan, implement, monitor the mitigation bank and maintain the performance standards established by the regulatory agency for the life of the bank.

For example, the unit cost per credit for the Bear Point Mitigation Bank, a mangrove/estuarine area in Florida ranges between USD$160, 000 and USD$240, 0000[4].

[4] https://mitigationbankinginc.com/pricing/

6.0 CONCLUSIONS

The site has three key ecosystems (corals, seagrasses and mangroves) that on the one hand provide the conditions for private (eco) tourism investment because of the recreational ecosystem services associated with them. However, the proposed development footprint will have significant and, in some cases, irreversible impacts on all of these ecosystems. At present the most significant impacts will impact the pristine tertiary mangrove forest. However negative impacts or permanently removing virgin mangrove forest (including the cost of emitted Carbon Dioxide) will be passed on to the Jamaican public and wider global community. However, the fact still remains that while most of the natural resource values present at the site lie within public (non-market) goods this site is in fact privately owned. The compensation of environmental losses and costs must be negotiated between the developer and the government regulatory agency. This can be approached in various ways and this report outlines some suggestions for how this could be achieved.

Using an ecosystem service conceptual framework, it was shown that most of the benefits accrue from the mangroves at this site via regulating services (carbon sequestration and shoreline protection), provisioning services (i.e. fisheries and, for mangroves, timber, honey and fuel wood). This report presented a suite of potential ecosystem service values associated with the Cove site. It presents some comparative ecosystem service values for the Northern Jamaican coastal areas as well as outlines a potential approach for calculating the value of carbon storage and sequestration for mangrove. It should be stated that no primary empirical research such as a non-market valuation survey was conducted for this study site. Given the relatively small size of the site this approach (a stated preference survey) would not have been appropriate. The project site is relatively small hence the calculated benefits may be comparatively modest in comparison to large areas (for example Cockpit Country, Portland Bight, Negril Beach). It is also not advisable to attempt to calculate per unit monetary values for some of these coastal ecosystems not all ecosystems are created equal and economic values are often linked to different contexts (demand, supply, quality and extent/area etc.). Instead of per unit dollar values for (corals or seagrasses) the alternative approach for examining these trade-offs should be to consider: 1) the existing suite of ecosystem service flows, 2) how they will be affected given the proposed construction activities and 3) how these flows will be restored and mitigated given ecological restoration.

This report demonstrates an approach for improving the trade-offs decision making process. The proposed construction works will alter the ecosystems at the site will in turn impact the flow of ecosystem services. It is therefore incumbent on the developer to ensure that there is no net decrease in economic or ecosystem service value in addition to mitigating any reduced capacity of the ecosystem(s) to continue providing the related ecosystem services (recreation, food, biodiversity, carbon sequestration, flood and nutrient regulation etc.). The proposed mitigation activities must address the potential disturbances to the nearshore areas such as coral reefs and seagrass beds that could lead to deleterious fisheries impacts and coastal sediment dynamics (erosion).

Based on the above-mentioned in order for the trade-offs to be meaningful, the developers should consider an appropriate level of net-loss to restoration ratio that includes an additional buffer for the biological and physical uncertainties that occur with construction and restoration. For example, for seagrass restoration or replacement with mangroves the areas should be 25-30% larger than that originally removed. Similar considerations should be given to the other restoration/coral relocation activities, taking into consideration professional best judgements and knowledge.

The proposed suite of restoration activities, if successfully implemented, should mitigate some of the lost ecosystem services (and values) of seagrass removal and benthic relocation. Given more time and resources this assessment could have been better calibrated with more accurate biophysical output production models (e.g. fish biomass per unit area, length of shoreline protected) for a discrete study area. Thus, allowing for bioeconomic modelling that appropriate monetary estimates (e.g. dollars per kg of food fish, cost savings from beach re-nourishment). However, applications such as these are expensive and not easily reproduced. In lieu of this the ecosystem service flows, relative benefits and costs due to loss, mitigating activities and expected results should be included as part of the decision-making process. Using an Ecosystem Services framework in this manner supports improved decision-making for coastal development and planning. Identifying and quantifying of the types of benefits that flow from natural systems and how these can be offset with restoration activities will lead to better outcomes for all stakeholders.

REFERENCES

Angelsen, A. (2008) Moving ahead with REDD: issues, options and implications. Center for International Forestry Research, Bangor, Indonesia

Ault, J. S., R. Humston, M. F. Larkin, E. Perusquia, N. A. Farmer, J. Luo, N. Zurcher, S. G. Smith, L. R. Barbieri, and J. M. Posada. 2010. Population Dynamics and Resource Ecology of Atlantic Tarpon and Bonefish. Pages 217–258 Biology and Management of the World Tarpon and Bonefish Fisheries.

Bann, C., 1997. An Economic Analysis of Alternative Mangrove Management Strategies in Koh Kong Province, Cambodia. Research Report, Economy and Environment Program for South East Asia, Singapore.

Barbier, E. B. 2008. Ecosystems as natural assets. Foundations and Trends in Microeconomics 4:611–681.

Barbier et al 2011 The value of estuarine and coastal ecosystem services. Ecological Monographs, 81(2), 2011, pp. 169–193

Beck M.W. and G-M Lange (Editors) (2016). Wealth Accounting and the Valuation of Ecosystem Services Partnership (WAVES); Managing coasts with natural solutions: guidelines for measuring and valuing the coastal protection services of mangroves and coral reefs. Washington, D.C., World Bank Group

Brander, L., R. Florax, and J. Vermaat (2006). The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature. Environmental & Resource Economics 33: 223–250

Donato D C, Kauffman J B, Murdiyarso D, Kurnianto S, Stidham M and Kanninen M (2011). Mangroves among the most carbon-rich forests in the tropics Nat. Geosci. 4: 293–7

Edwards, P.E.T. 2009. Measuring the Recreational Value of Changes in Coral Reef Ecosystem Quality in Jamaica: The Application of Two Stated Preference Methods. Doctor of Philosophy in Marine Studies thesis, University of Delaware.

Edwards, Peter E.T. "Valuation of Selected Ecosystem Service Co-Benefits Beyond Coastal Protection". Technical Report. World Bank, 2019.

FAO 2016. Mangrove carbon estimator and monitoring guide Jeremy S. Broadhead, Jacob J. Bukoski and Nikolai Beresnev. FAO, and IUCN, Bangkok

Golosov, M., J. Hassler, P. Krusell, and A. Tsyvinski. 2014. Optimal taxes on fossil fuel in general equilibrium. Econometrica 82(1):41–88.

Himes-Cornell A, Grose SO and Pendleton L (2018) Mangrove Ecosystem Service Values and Methodological Approaches to Valuation: Where Do We Stand? Front. Mar. Sci. 5:376.

Hoyt, S., J. Howard, K Isensee, E. Pidgeon and M. Telszewski (Eds) (2014). Coastal Blue Carbon methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows. The Blue Carbon Initiative, UNEP, UNESCO, CI

Hutchison, J; Spalding, M, and zu Ermgassen, P. (2014). The Role of Mangroves in Fisheries Enhancement. The Nature Conservancy and Wetlands International. 54 pages

Jamaica Gleaner (2018) Opinion Editorial by John Allgrove "Engineers Angle: Asphalt vs Concrete Roads, Cost Care and Convenience". http://jamaica-gleaner.com/article/news/20180513/engineers-angle-asphalt-vs-concrete-roads-cost-care-and-convenience

Jardine, S. L. and J. V. Siikamäki 2014. A global predictive model of carbon in mangrove soils Environmental Research Letters. 9 104013

Kimirei, I. A., I. Nagelkerken, Y. D. Mgaya, and C. M. Huijbers. 2013. The Mangrove Nursery Paradigm Revisited: Otolith Stable Isotopes Support Nursery-to-Reef Movements by Indo-Pacific Fishes. PLoS ONE 8(6):e66320.

Kindermann, G., Obersteiner M., Sohngen B. et al. (2008) Global cost estimates of reducing carbon emissions through avoided deforestation. PNAS 105, 10302– 10307

Kotchen M. J. 2017. Which Social Cost of Carbon? A Theoretical Perspective. JAERE, Volume 5, Number 3 http://dx.doi.org/10.1086/697241

Kushner, Benjamin, P Edwards, L Burke, and E Cooper. 2011. "Coastal Capital: Jamaica." Coral Reefs, Beach Erosion and Impacts to Tourism in Jamaica. Working Paper. Washington, DC: World Resources Institute.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

MICAF 2011. Special Fishery conservation areas (SFCS) http://moa.gov.jm/Fisheries/fish_sanctuary.php

MICAF 2017. (Ministry of Industry Commerce and Fisheries) Special Fishery Conservation Areas. Summary Document. Prepared by J Squire http://www.micaf.gov.jm/sites/default/files/Special_Fisheries_Conservation_areas.pdf

National Environment and Planning Agency (NEPA) (2011) State of the Environment Report 2010. National Environment and Planning Agency, Kingston, Jamaica ISBN 978-976-610-912-7

NEPA 2013 State of the Environment Report 2013. National Environment and Planning Agency, Kingston, Jamaica ISBN 978-976-654-007-4

Nordhaus, William (2014). Estimates of the social cost of carbon: Concepts and results from the DICE-2013R model and alternative approaches. Journal of the Association of Environmental and Resource Economists 1:273–312.

Pendleton L, Donato D C, Murray B C, Crooks S, Jenkins W A, Sifleet S, Craft C, Fourqurean J W, Kauffman J B and Marbà N (2012) Estimating global 'blue carbon' emissions from conversion and degradation of vegetated coastal ecosystems. PloS One http://dx.doi.org/10.1371/journal.pone.0043542

Pearce D.W. and Turner R. K. (1990) The Economics of Natural Resources and the Environment. New York: Harvester Wheatsheaf, 378 pages

Pigou, A. C. (1920). The Economics of Welfare. London: MacMillan and Co.

Polasky, S., and K. Segerson. (2009). Integrating ecology and economics in the study of ecosystem services: some lessons learned. Annual Review of Resource Economics 1:409– 434.

Ruitenbeek, H. J. (1992). Mangrove Management: An Economic Analysis of Management Options with a Focus on Bintuni Bay, Irian Jaya. for the Environmental Management Development in Indonesia Project (EMDI)

Siikamäki, Juha, James N. Sanchirico, Sunny Jardine, David McLaughlin & Daniel Morris (2013) Blue Carbon: Coastal Ecosystems, Their Carbon Storage, and Potential for Reducing Emissions, Environment: Science and Policy for Sustainable Development, 55:6, 14-29, DOI: 10.1080/00139157.2013.843981

Spurgeon, J. 2002. Socio-economic Assessment and Economic Valuation of Egypt's Mangroves. Cairo: FAO

Suthawan, S. (1999). Economic valuation of mangroves and the roles of local communities in the conservation of natural resources: Case study of Surat Thani, South of Thailand. EEPSEA (Economy and Environment Program for Southeast Asia) Research Report.

TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. Prepared by: Pavan Sukhdev, Heidi Wittmer, Christoph Schröter-Schlaack, Carsten Nesshöver, Joshua Bishop, Patrick ten Brink, Haripriya Gundimeda, Pushpam Kumar and Ben Simmons.

Tol, R. S. J. (2018) The Economic Impacts of Climate Change. Review of Environmental Economics and Policy, volume 12, issue 1, Winter 2018, pp. 4–25

Tol, R. S. J. (2012) On the Uncertainty About the Total Economic Impact of Climate Change. Environ Resource Econ. DOI 10.1007/s10640-012-9549-3

UNEP –WCMC (2006) In the front line. Shoreline protection and other ecosystem services from mangroves and coral reefs. UNEP-WCMC Biodiversity Series 24 by Wells, S., Ravilious, C., Corcoran, E.

UNEP (2011) Economic Analysis of Mangrove Forests: A case study in Gazi Bay, Kenya, UNEP, iii+42 pp.

USAID (2018) Vulnerability Assessment of Jamaica's Transport Sector. March 201 Prepared by Chemonics International Inc. for United States Agency for International Development. Washington DC

Venter, O. W.F. Laurance, T. Iwamura T, K. A. Wilson, R.A. Fuller and H.P. Possingham (2009) Harnessing carbon payments to protect biodiversity. Science 326, (5958):1368.

World Bank (2004) Assessing the Economic Value of Ecosystem Conservation. Environment Department Paper No. 101. Authors; Stefano Pagiola, Konrad von Ritter, Joshua Bishop in collaboration with TNC and IUCN.

World Bank (2008). World Development Report 2009: Reshaping Economic Geography. Washington, DC.

World Bank. 2019. “Forces of Nature: Assessment and Economic Valuation of Coastal Protection Services Provided by Mangroves in Jamaica