Inventory of marine natural values in the East Part of Simpson Bay Lagoon

Effects of bridge-construction for Link 9 in relation to the current ecological functioning of the Lagoon

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EcoVision
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CONTENTS

1 HISTORIC CONTEXT AND CURRENT SITUATION

The Simpson Bay Lagoon is an inland lagoon on the island of St. Maarten whose Northern part is French territory whereas the Southern portion is part of the Kingdom of the Netherlands. The Lagoon, which is one of the largest inland bays in the Caribbean, is almost completely surrounded by land. The land bordering the Lagoon has experienced intense (coastal) development (**Figure 2**) to accommodate a local infrastructure to support the tourism industry, which is the main source of income of the island. 85% of all islanders are employed in this sector. Most development has occurred during the last 20 years and has largely progressed unplanned and uncontrolled. As a result the area currently suffers from infrastructural problems such as traffic jams, horizon pollution and waste water issues and a general and wide-spread destruction of the island's natural resources.

Over the last 2 decades the Lagoon itself has reduced 23% in size due to land reclamation associated with tourism-related infrastructural projects. The majority of these developments are currently not connected to any type of (central) sewage treatment facility and much of the effluent enters the Lagoon through the existing groundwater flow and terrestrial run-off (Lips & Van Slooten, 2009). The many yachts in the harbour exacerbate this phenomenon, again, due to the absence of a central sewage treatment facility and pollution resulting from boat maintenance and fuel spills. The Lagoon was hit by hurricane Luis in 1995 and many ships seeking shelter in the Lagoon were shipwrecked and never removed. Hence the Lagoon is currently littered by a large number of rusting shipwrecks above and below the Lagoon's surface. The removal of mangrove stands around the Lagoon and dredging activities have altered the sediment balance of the Lagoon with subsequent effects on benthic marine life. Removal of mangroves has resulted in an increased influx of fine sediments from nearby hill sides. Such sediments would normally be trapped in near shore mangrove-seagrass systems, but now enter the water unhindered. Sedimentation has increased accordingly, with negative effects on the Lagoon's marine life and shipping routes. Lastly, the Lagoon has seen immense overfishing and most of the once commercially harvested species (e.g., spiny lobsters, conch, fish > 30cm) are currently "ecologically extinct" meaning that their contribution to the wider ecosystem dynamic currently approaches zero due to their low abundance.

2 PROPOSED ACTIVITY

The St. Maarten Harbour Holding Company (SMHHC) is planning to construct a new bridge across Simpson Bay Lagoon between Airport Road and Union Road. The planned bridge (Link 9) is intended to improve the accessibility from and to St. Martin's airport area (**Figure 1**). The bridge will consist of one traffic lane in each direction where traffic can move at a maximum speed of 50 km/hour.

The preferred type of bridge is a bridge with a movable section through which yachts can pass. The bridge will be constructed several meters above the water surface of the Simpson Bay Lagoon by using 2 rows of foundation piles.

At present it is not exactly known which method will be used for the bridge's construction. It is likely however that floating construction equipment will be used.

In addition to the bridge's construction, SMHHC plans to reclaim 2 areas from the Lagoon:

An area that will be used to compensate Port de Plaisance for offering their land so the connecting road and roundabout can be built (shown in yellow in **Figure 1**).

An area to be used as a service area for SMHHC (environmental services including waste and sewage reception) (shown in blue in **Figure 1**).

3 DESCRIPTION OF MARINE AND ASSOCIATED SYSTEMS IN THE PROJECT AREA

3.1 Historic context

Oral accounts describe that the Lagoon once harboured dense seagrass stands (mainly *Thallassia testudinum*) and that mangroves bordered the Lagoon in many places until the development around Simpson Bay Lagoon started. These mangrove-systems are valuable assets as they provide so-called “nursery habitats” for many commercially interesting species (e.g., snapper, conch, lobster). Nursery habitats contain characteristics preferred by juveniles of these organisms. Removal of mangrove-seagrass systems simply results in the (near) disappearance of species whose juveniles depend on them. Anecdotal accounts from local fishermen suggest that pre-1970’s the Lagoon was able to sustain a small but productive fishery for fish, lobster and conch. Since then developments, logging of mangrove stands and dredging inside the Lagoon have resulted in serious damage to the natural ecosystems in the Lagoon. In combination with general overfishing by local fishermen, the marine fauna inside in the Lagoon now represents an extremely deprived version of its former bounty. While comparisons are difficult due to the lack of historic data, the Simpson Bay Lagoon situation is probably much worse compared to similar lagoonal systems elsewhere in the Caribbean. The present situation of Lac Bay on Bonaire probably illustrates best what Simpson Bay Lagoon might look like before developments began. In contrast to Simpson Bay Lagoon, Lac Bay has seen no development in its direct vicinity and is protected under various international agreements to protect its unique wildlife. The Bonaire example is simply mentioned here to provide some indication of the natural systems that could be present in Simpson Bay Lagoon at present day.

Once seagrass beds started disappearing from Simpson Bay Lagoon after the 1970-1980’s, space formerly occupied by these species was taken over by green algae with calcified skeletons similar to corals (mainly *Halimeda* and *Penicillus* species). These green algae species were still present in 1995 (Aidenvironment/EcoVision, 1995) and their calcified remains can still be found in present day sediments inside the Lagoon. At present, most of these species have disappeared as well and have been replaced by a fast growing seagrass (*Halophila* spp.) and algal species (*Hypnea* spp.). These three different plant communities indicate that the overall degradation of the Lagoon ecosystem increasingly favours more opportunistic and fast growing species capable of sustaining functional populations under an increasingly degrading environmental setting (Sandin et al. 2008, Vermeij et al. 2009). While plant communities still dominate the marine ecosystem at present, the aforementioned change towards more opportunistic species will finally result in a so-called microbialization of the Lagoon ecosystem (Dinsdale et al. 2008).

3.2 Expected microbialization of the Simpson Bay Lagoon

“Microbialization” means that opportunistic bacteria and phytoplankton will become the dominant groups of organisms inside the Lagoon. This trajectory of decline is often referred to as the “Slippery slope to slime” meaning that marine systems often shift to an ecosystem state dominated by unicellular organisms (i.e., bacteria, but also algal blooms). This shift has occurred in a wide variety of marine systems around the world and while restoration and/or recovery to the system’s original state has been attempted, no successes have been reported so far. According to GESAMP (2001), contamination of the coastal marine environment by sewage from coastal developments or boats leads to significant numbers of infectious diseases (e.g., diarrhoea, cholera, dysentery, typhoid, and hepatitis A) linked to bathing and swimming in marine waters and to the consumption of seafood. The overabundance of microorganisms in disturbed systems thus takes its toll. For example, Shuval (2003) estimated that the global economic loss caused by pathogenic microorganisms in marine ecosystems is about $12 billion per year. Likewise, increased microbial abundances disrupted traditional uses of natural systems in Greece, Italy and Spain which are estimated at $329 million annually (European Environment Agency, EEA 2005). Human exposures to toxins associated with algae blooms also impose significant risks and chronic influx of excess nutrients to marine systems can eventually cause such systems to turn into so-called “dead zones”, areas of anaerobic conditions at the sea bottom where life is no longer possible (UNEP/GPA2006). During severe weather conditions, increased groundwater flow or overflow of sewage systems results in temporal spikes of microbial densities in nearby coastal zones followed by sewage-related outbreaks of diseases (GEF et al 2001).

The first signs of such shift towards a microbe-dominated system are present in the Simpson Bay Lagoon. During our surveys in February 2010 various indications were observed that microbes are presently becoming very abundant inside the lagoon: (a) approximately 30% of the benthic surface surveyed is covered by a thick layer of bacteria (**Figure 3a**); (b) “marine snow”, i.e. colonies of bacteria living off particulate organic matter in water column (**Figure 3b**), is observed in the water column throughout the Lagoon; (c) release of gas (most likely CO_2 and CH_4) from the bottom in various areas of the Lagoon indicates unnaturally high abundance and productivity of bacteria in the Lagoon sediments (**Figure 3c**); and (d) the thick (> 0.80m), largely anoxic layer of silt on basically the entire Lagoon bottom (**Figure 3d**) creates the potential for release of toxic substances (e.g. H_2S).

3.3 Likelihood of microbialization scenario: Examples from the Caribbean

The hypothesized scenario for Simpson Bay Lagoon in the (near) future is not without precedent. Bays in the US Virgin Islands with high numbers of boats contain significantly higher concentrations of bacteria and algae known to cause serious threats to human health, fish kills and beach closures (DPNR/DEP & USDA/NRCS 1998). Similar changes in water quality have decimated coral populations in Barbados (Linton & Warner 2003). Reefs around Grenada & the Grenadines started degrading in the early 1980's and became overgrown with algae resulting from a combination of sewage and sedimentation caused by coastal development (Smith et al 2000). Efflux of non-treated wastewater in Cartagena Bay and Ciénaga de Tesca along the Caribbean Colombian coast caused mass fish mortalities associated with pathogenic bacteria and similar events have been confirmed in Barlovento Venezuela (UNEP 2002) and Islas del Rosario, Colombia (Garzón-Ferreira et al. 2000). Between 1991 and 1996, a pronounced nutrient spike resulted in a severe phytoplankton bloom followed by sudden oxygen depletion ("dead zone") resulting in near-total mortality of all marine life in Morrocoy National Park, Venezuela (Garzón-Ferreira et al 2000). In Mexico, tourism generates large quantities of wastewater and the management of this has become problematic. The wastewater is often discharged directly into lagoons and bays. According to a recent GIWA study (UNEP et al. 2006) the tourism industry has lost income and fisheries production has been reduced in Costa Rica and Chetumal Bay as a result of pollution. In short, microbialization of Caribbean marine systems is very much a reality and generally results in the loss of biological diversity, "dead zones" that kill marine organisms, threats to human health due to elevated numbers of pathogenic microorganisms (e.g. viruses, bacteria) and toxins created by algal blooms and as such: serious threats to tourism.

3.4 Marine life inside the Lagoon

The bottom inside the Lagoon is relatively shallow and lies at a depth of 2.5-3.5m in most of the Lagoon, but deeper (± 5m) in the shipping lanes. Locally, water flowing from the bottom into the water column was observed which is indicative of active groundwater flow by which nutrients and pollutants generally enter into Lagoon from land. Since a large fraction of the nutrients entering the Lagoon does so through the bottom and most marine organisms (especially plants) occur near the bottom, much of the nutrients are absorbed before they can be measured in the water column. The release of nutrients from the Lagoon's sediments likely contributes to the dense plant canopy covering most of the Lagoon's bottom.

The majority of the bottom in the surveyed area of the Simpson Bay Lagoon is covered by two small and fast growing seagrass species (*Halophila decipiens* and *H. johnsonii*; **Figure 4**). Both species occur on soft sediments in water up to 5m depth. Whereas the first species (*H. decipiens*) occurs throughout the Caribbean region, the latter (*H. Johnsonii*) is only reported from Florida (Littler & Littler 2000) making its presence inside the Simpson Bay Lagoon somewhat remarkable. Both species form dense mats between depths of 0.8m near shore and 5.0m inside the shipping channel that runs through the Lagoon. In areas used for anchoring and areas where boats have run aground, seagrass is no longer present, though rapid regrowth was often observed as indicated by bright green "runners" (also known as "stolons") growing from nearby seagrass beds into the damaged area. Turtlegrass (*Thalassia testudinum*), once a dominant seagrass species in the Lagoon was sparsely observed on the Eastern side of the Lagoon. Calcareous green algae (mainly *Halimeda* and *Penicillus* species) were observed throughout the surveyed area, but never in dense aggregations that dominated the benthic community of Simpson Bay Lagoon in the 1990's. In short, the Simpson Bay Lagoon is presently dominated by a marine plant community where two seagrass species prevail with certain algae being locally present, but never in great abundance. An exception are two fast growing red algae (*Laurencia* and *Hypnea* spp.) that epiphytically occurred on the seagrass throughout most of the Bay. The dark red color of these algae is indicative of high nutrient loading of the surrounding water (Vermeij et al. 2009).

Animals were hardly observed during the survey, except near shore (<0.60m). Inside the Lagoon various species of echinoderms (seastars, mainly *Oreaster* sp. and seacucumbers, mainly *Actinopygia* and *Holothuria* spp.) were observed, but all in low to very low abundances. Lobsters (*Panulirus* sp.) were observed once protective habitats (e.g., rocks) were present, though such habitats were once again extremely rare inside the Lagoon. Dense communities of blue crabs (*Callinectes* sp.) were observed in shallow sandy areas nearshore, although some individuals were observed roaming across the seagrass fields in the Lagoon itself.

Fish were rare inside the Lagoon. The most common fish species observed were those typical of a mangrove-seagrass associated fish community: juvenile barracuda

(*Sphyraena barracuda*), juvenile grunts (*Haemulon* spp.), juvenile parrotfish (*Sparisoma* and *Scarus* spp.) and mojarra's (*Gerres cinereus* and *Eucinostomus* spp.). The abundance of fishes and the abundance of various unidentified juvenile fishes increased in sea grass beds close to shore in areas where mangroves were also present, i.e. the area where the Eastern side of the planned bridge connects to the island. No hard corals (Scleractinia) were observed during the survey.

3.5 Nearshore and mangrove areas

The area where the Eastern side of the planned bridge connects to the island is characterized by one of the few remaining mangrove stands dominated by the "black mangrove" (*Avicennia germinans*) in the Simpson Bay Lagoon (**Figure 5**). Black mangroves stabilize the shoreline, provide buffers from storm surges, trap debris and detritus and provide feeding, breeding, and nursery grounds for a great variety of fish, shellfish, birds, and other wildlife. The uniqueness of this area was already noticed in 1995 (Aidenvironment/EcoVision, 1995). Dense mangrove stands grow from land into the Lagoon and seagrass communities of the once dominant seagrass species (*Thallassia testudinum*, but also *Syringodium filiforme*) are still present at this location. Fish abundance in this area is highest of all areas surveyed. In addition to numerous fish species, this area provides a habitat for various species that were otherwise rarely observed inside the lagoon: communities of blue crabs (*Callinectes* sp.) and upside down jellyfish (*Cassiopea* spp.). The presence of the latter is not surprising as larvae of this species use the substances released by decaying mangrove leaves in the water column as a cue for settlement and metamorphosis (Fleck & Fitt 1999). The area still seems to function as a "nursery habitat" for various reef fish species as evidenced by the high abundance of their juveniles. A great number of birds (a.o. snowy egrets, green herons and yellow warbler) were observed in the mangroves themselves. For a complete inventory of birds living in the mangrove habitats of the Simpson Bay Lagoon, see Birds of the Simpson Bay Lagoon (EPIC, 2008).

Combined, the features described above characterize this area as a relatively unique location within the wider Simpson Bay Lagoon area where similar habitats have already been destroyed by near shore development. Areas where relatively healthy stands of mangroves still exist at present are the Cole Bay area[1], the Cupecoy area, Little Key

[1] Recently part of these mangrove stands were removed, pers. comm. Mr. R. Thompson (EPIC).

and Mullet Pond. Combined, these areas cover less than 10% of the Simpson Bay Lagoon shores.

4 IMPACT OF THE PROPOSED ACTIVITY

4.1 General remarks

Reclamation, bottom modification and dredging will likely form a major component of the bridge construction programme whereas intertidal mud/sand flats, mangroves and other coastal ecosystems may also be impacted by the construction of the associated transportation network. Such development work in conjunction with pollution and sedimentation will negatively impact the survival of all organisms occurring in the affected area.

This report focuses on the anticipated effects of the bridge's *construction* and short term effects of the bridge's *presence* on the nearby marine environment. Long term effects of the bridge are being evaluated in separate documents.

When the current situation of the areas that fall within the bridge's footprint is considered, two habitat types can be distinguished that will be differently affected by the bridge's construction: (a) dense meadows dominated by fast growing seagrass species (*Halophila decipiens* and *H. Johnsonii*) covering most of the Lagoon bottom and (b) the nearshore mangrove-seagrass systems that occur near- and onshore in the Eastern part of the proposed construction area. Below, the implications of the planned bridge construction for each habitat will be discussed.

4.2 Impacts on seagrass beds

Bridges can restrict tidal flows and reduce the tidal prism, though accurate predictions in this matter are currently beyond the scope of this study. Altered hydrodynamic conditions can in turn lead to increased rates of siltation and deterioration in water quality, with consequent degradation of seagrass beds and other habitats around the obstruction (NSWG, Department of Water and Energy 2007).

Because both seagrass species that dominate the benthic plant communities in the Simpson Bay Lagoon are fast growing species, it is expected that these species will recover relatively fast from impacts associated with the bridge's construction and presence as long as the damage to the seagrass beds concerns relatively small areas so that affected areas can be recolonized from surrounding, unaffected seagrass stands. It is presently not possible to speculate whether hydrodynamic changes caused by the bridge's physical structure will affect these communities. Although negative impacts have been described for similar situations in the Florida Keys and Hong Kong

(NSWG, Department of Water and Energy 2007), we expect that flow speeds in the Simpson Bay Lagoon are too low to induce such impacts. In short, the expected negative impact of the bridge's physical presence will probably not result in irreversible damage to the already degraded benthic communities in the Simpson Bay Lagoon, though the severity of the net impact will depend on the methods used during the bridge's construction.

Although the seagrass species currently present are capable of surviving a certain sedimentation load, it is essential that construction does not cause an overload of sediments and loss of seagrass cover beyond the actual position of the foundation piles.

4.3 Impacts on nearshore mangrove-seagrass areas

In contrast to the above mentioned seagrass beds in the Lagoon, the near shore mangrove-seagrass systems represent a unique and valuable natural asset that has become extremely rare on St. Martin over the last three decades. The bridge is planned to connect to the Eastern side of the Lagoon exactly at a location where these systems are still present. Certain damage seems to be unavoidable and is probably outweighed by the bridge's economic / infrastructural importance, but such damage needs to be minimized and appropriately compensated. At present the planned works involve the reclamation of an area (**Figure 1,** blue area) to be used as an operational base during the bridge's construction phase and later as a semi-industrial area where SMHHC intends to treat sewage collected from yachts moored in the Lagoon and to conduct other activities aimed at improving the infrastructure and general condition of the Lagoon area. SMHHC has voiced their willingness to contribute to future improvement of the management of the Lagoon area and in their capacity as potential future caretakers of the Lagoon will logically contribute to strategies aimed at reversing the ongoing degradation and microbialization of the Simpson Bay Lagoon.

4.4 Impacts in the context of the current physical condition of Simpson Bay Lagoon

We want to stress that the consequences of this construction are marginal within the broader context of the Lagoon's overall "health" status (see: *Expected microbialization of the Simpson Bay Lagoon*). Using a common-sense approach, one would assume that all stakeholders on St. Martin want to solve the aforementioned problem given the island's ambition to become a tourism/ yachting hotspot in the Caribbean. Environmental assets (i.e. "healthy" mangroves and seagrass beds) as well as a well-functioning island infrastructure (i.e. the planned bridge) are both crucial to guarantee long-term interest from visiting/ returning tourists on which the local economy depends. The impact of the planned bridge thus needs to be considered in this wider context as well, as to effectively guarantee the basis for a healthy tourism economy on the long run in terms of natural and infrastructural assets.

5 RECOMMENDATIONS AND MITIGATING MEASURES

5.1 Reducing damage to mangroves east border

It is recommended to design and construct the bridge in such a way that damage to the mangrove stand on the eastern bank is avoided altogether, e.g. by heightening the bridge so it passes over the existing mangrove stands.

5.2 Increasing protection level of similar habitats

It is recommended that damage to the natural systems in the affected area be compensated by increasing the protection level of similar habitats that are still present in the Lagoon: the Cole Bay area, Little Key, the Cupecoy area and Mullet Pond (**Figure 6**). It is highly recommended that such areas be given “full protection” meaning that their survival is guaranteed through legal protection in combination with active management and/or restoration.

In addition, a portion of the east bank of the Lagoon near Port de Plaisance which was covered with sediments from dredging in the past can be used as a nature development area. The area is suitable for mangrove restoration, evidenced by the high number of successfully recruiting mangroves. The area possesses typical characteristics of mangrove areas i.e. shallow water, reduced water flow and reduced wave action. It must be stressed however, that it may take decades before this area will have a conservation value similar to the mangrove stand that will be removed.

5.3 Restoration of seagrass/mangroves

Restoration of areas in which seagrass / mangrove systems once thrived seems to be one remedy to compensate for declines in seagrass beds associated with the bridge’s construction, but this is an inherently complicated process and has not yet been demonstrated to consistently prevent net habitat loss (Fonseca, 1989; Fonseca et al., 1994). Moreover, unless seagrasses are established over reasonably large areas, sediment movement may lead to an unsuccessful restoration. It is often difficult to find a site to fulfil the biological and physical requirements for persistence of restored seagrasses and mangroves.

Restoration should be regarded as a last resort for compensation. Keeping this in mind only one opportunity for seagrass / mangrove restoration can presently be appointed:

the site to be reclaimed from Simpson Bay Lagoon for Port de Plaisance (yellow part in **Figure 1**). The conditions at this site can be made favourable to seagrass and mangrove resettlement. To guarantee successful resettlement, clear restrictions on the use of this area need to be negotiated.

5.4 Relocation of planned service area

The area to be used as an operational base during the bridge's construction phase (blue in **Figure 1**) should not be constructed at the currently planned location (i.e., in the Eastern part of the planned construction area) as this would destroy unique and rare mangrove / seagrass systems that have become extremely rare on St. Maarten. Moreover, the currently planned location does not seem to fully comply with SMHHC's plans to collect / treat sewage as such activities would require boat access and the water in this area is too shallow to be used for boat traffic. Additionally, a semi-industrial area does not seem to fit within the relatively unspoiled nature on this side of the Lagoon and could reduce the visual appeal to island visitors that will cross the bridge in the future.

An area with the required characteristics can be found elsewhere where the same activity would result in less negative impacts to the environment. The area located Northeastern of the airstrip (**Figure 7**) is recommended as an alternative location where the same activity would have significantly less impact on the marine environment.

5.5 Silt screens at construction site

It is recommended that silt screens are used at the construction sites in the Lagoon to prevent heavy sedimentation and prevent loss of seagrass cover.

5.6 Management of Lagoon as a whole

Again, all measures mentioned above will be fruitless on the longterm as will be St. Maarten's attempts to increase its appeal to boaters and tourists if the overall degradation of the Lagoon ecosystems is not reversed. A wide variety of problems, not all solvable by one of the island's stakeholders, have caused the Simpson Bay Lagoon to deteriorate to the point where acute, irreversible and total microbialization of the system is to be expected. Such change will come with undesired consequences for the island's natural resources as well as for those that intend to use the Lagoon for e.g. boating or recreational activities (see: *Expected microbialization of the Simpson Bay Lagoon*). All stakeholders that are directly or indirectly concerned with the management of the Lagoon (e.g., SMHHC, local government agencies, conservationists and wildlife managers) should get together and start working on a management plan for the Lagoon to curb the doom scenario outlined above. There is no question that *in principle* all such parties are better off when the Lagoon's health improves whether that's for future conservation or tourism motivated purposes.

Future joint-management of the Lagoon should hence be one of St. Martin's top priorities and should focus on land and ocean-based sewage pollution which is regulated in many different frameworks ranging from regional legislation, international non-binding and binding agreements, action plans and national legislation and regulations (UNEP 2005). The most important regional legal framework is the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention). The Convention became operational in 1986 and is a legally binding, regional multilateral environmental agreement for the protection and development of the Wider Caribbean Region. The "Protocol Concerning Pollution from Land-Based Sources and Activities" (LBS Protocol) of the Cartagena Convention sets forward general obligations and a legal framework for regional co-operation, provides a list of priority source categories, activities and associated pollutants of concern and promotes the establishment of pollution standards and schedules for implementation. Annex III relates directly to domestic wastewater and establishes specific regional effluent limitations, as well as a time table for the implementation of wastewater treatment.

6 CONCLUSION

Over the last decades Simpson Bay Lagoon has changed dramatically. Historically covered by turtle- and manatee seagrass the Lagoon bottom is now dominated by dense meadows of the fast growing seagrass species (*Halophila decipiens* and *H. Johnsonii*). This finding together with recent water quality measurements confirm that a significant eutrophication process is taking place in the Lagoon. The construction of the bridge is not expected to generate irreversible damage to the seafloor when silt screens are used during the bridge's construction. On the other hand it must be stressed that the nearshore mangrove-seagrass system that occurs in the Eastern part of the proposed project area is one of the last remaining and valuable mangrove / seagrass systems of St. Maarten. Damage to this area should be minimized, and preferably avoided altogether, by:

Minimizing the number of mangroves to be cleared at the east border, e.g. designing a bridge that passes over the mangrove stands;

Relocation of the planned service area;

Compensation for the losses associated with the bridge's construction by increasing the protection level of similar habitats elsewhere in the Lagoon.

The quality of the Lagoon as a habitat for marine species as well as a source for tourism can only be improved by taking action on the scale of the Lagoon as a whole, i.e. by introducing a coherent management plan in which eutrophication and habitat loss are adequately addressed and guidelines are developed for future construction projects around and inside the Lagoon.

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8 FIGURES

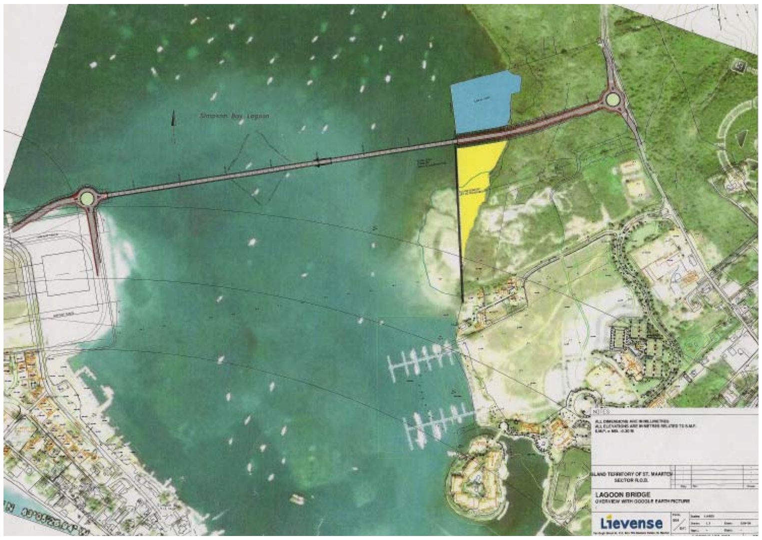

Figure 1. Overview of proposed activities (bridge and areas to reclaim)

Figure 4. Simpson Bay Lagoon
(a) in 1970
(b) in 2005

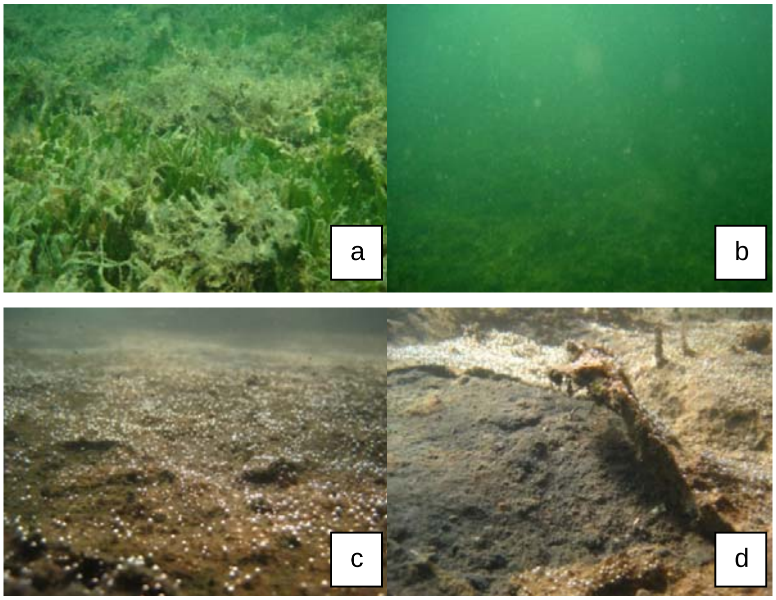

Figure 3. (a) Seagrass covered by thick layer of bacteria

(b) marine snow (colony of bacteria in the watercolumn)

(c) gas release from the bottom (probably CO_2 or CH_4)

(d) tar-like anoxic soil

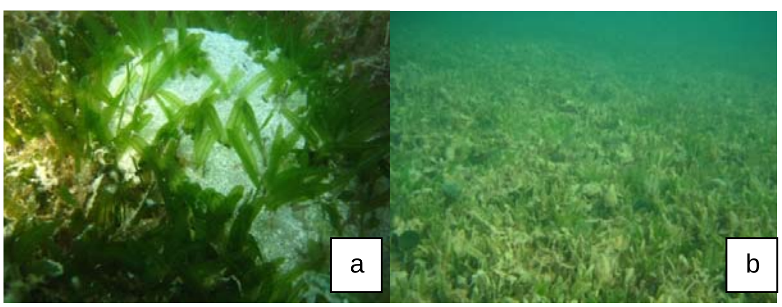

Figure 4. (a) *Halophila* detail

(b) *Halophila* bed

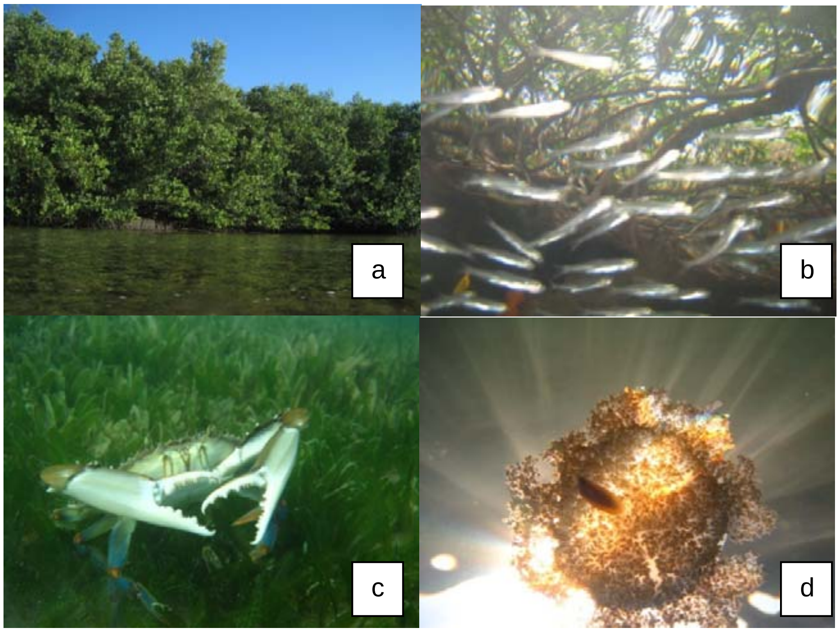

Figure 5. Mangrove area Eastern part of Lagoon

(a) Mangrove trees *Avicennia germinans*

(b) Juvenile fish close to mangroves

(c) Swimming crab *Callinectes* sp.

(d) Upside down jellyfish *Cassiopea* spp.

Figure 6. Valuable areas to be protected

Figure 7. The blue and yellow areas on the east side are located within areas (green frames) of ecological and historical values. The blue area on the west side is recommended as alternative location for development.

9 ADDITIONAL INFORMATION

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) is a programme that provides guidance for sustainable development of oceans and seas and their resources. Read more at http://www.gpa.unep.org/ .

Agenda 21 is a programme run by the United Nations (UN) related to sustainable development. Read more at http://en.wikipedia.org/wiki/Agenda_21 and http://www.un.org/esa/sustdev/documents/agenda21/index.htm

The Johannesburg Plan of Implementation, agreed at the World Summit on Sustainable Development affirmed UN commitment to 'full implementation' of Agenda 21, alongside achievement of the Millennium Development Goals and other international agreements. Read more at http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POIToc.htm , http://www.un.org/events/wssd/ , and http://en.wikipedia.org/wiki/Agenda_21

The United Nations Programme of Action on the Sustainable Development of Small Island Developing States, referred to as the Barbados Program of Action (BPOA), is a policy document that both addresses the economic, environmental, and social developmental vulnerabilities facing islands and outlines a strategy that seeks to mitigate those vulnerabilities. Read more at http://www.sidsnet.org/ , http://en.wikipedia.org/wiki/Barbados_Programme_of_Action and http://www.unep.ch/regionalseas/partners/sids.htm .

The Mauritius Strategy (International Meeting for the 10-year Review of the Barbados Programme of Action). Read more at http://www.sidsnet.org/MIM.html .

The Millennium Development Goals (MDGs) are eight goals to be achieved by 2015 that respond to the world's main development challenges. Read more at http://www.un.org/millenniumgoals/ .