The GraceKennedy Foundation Lecture 2019

Clean Kingston Harbour: Pipe Dream or Pot of Gold?

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GraceKennedy Foundation

Published in April 2019
by the GraceKennedy Foundation
73 Harbour Street, Kingston
Jamaica, West Indies
Telephone: (876) 922-3440-9 • Ext. 3540/1

ISBN 978-976-8041-41-8 (eBook)

Printed in Jamaica by
The Phoenix Printery Limited

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GraceKennedy Foundation

The GraceKennedy Foundation (GKF) was established in 1982, in celebration of the company's 60th anniversary. The Foundation provides assistance in three areas: education, the environment, and health and well-being. This is accomplished primarily through the provision of grants, tertiary scholarships, diaspora activities, the funding of two Professorial Chairs at The University of the West Indies, and the Annual Lecture Series.

This year's lecture is closely aligned with GraceKennedy's commitment to environmental stewardship. GKF spearheaded discussions with public and private entities aimed at developing a long term, sustainable solution to reduce the pollution entering the Kingston Harbour. The "Clean Harbour Initiative" is the motivation behind the topic of this year's lecture.

The holder of the James Moss-Solomon Snr. Chair in Environmental Management, Professor Mona Webber, has made critical contributions to research, innovation, teaching and outreach for the enhancement of the Kingston Harbour. Much of her work focusses on the rehabilitation and protection of various aspects of the coastal and marine environment, including the island's mangrove stock. These initiatives are all aimed at increasing the island's resilience to natural disasters and the impacts of climate change.

In observation of International Coastal Cleanup Day, held on September 15, 2018, the GKF coordinated a large-scale clean-up of Buccaneer and Gun Boat beaches located on the Palisadoes strip. The effort, led by Foundation Chairman, Dr. Fred Kennedy, saw the involvement of over 250 volunteers comprised of: GraceKennedy employees, members of Campion College's Green Generation Club, the St. George's College Environmental Club and the Kingston Church of Christ Teen Ministry; students and parents from Hopefield Prep and the staff of the Mona GeoInformatics Institute. In just two hours, the team collected more than 4,500 lbs of garbage and plastic.

Our recycling programme continues to engage the interest and dedication of GraceKennedy staff. In 2018, the 11 subsidiary companies involved in the programme collected over 13,870 lbs of plastic. Since 2014, over 61,800 lbs of plastic have been collected among the subsidiaries. Nine educational institutions at the secondary and tertiary levels have also been trained in environmental stewardship and are coordinating recycling initiatives at their respective schools. For the past two years, the Foundation has partnered with the Youth Environmental Advocacy Programme (YEAP) under the Ministry of Economic Growth and Job Creation, to help increase environmental education in secondary schools across the island. The Foundation provides funding for the YEAP Bursary Programme to students who are outstanding environmental ambassadors. GKF was also the title sponsor for the Youth Climate Action Expo held on March 16, 2019.

Since 1989, the GraceKennedy Foundation has used its lecture series to engage the Jamaican public, both locally and in the diaspora, to promote discussion and debate on relevant topics affecting Jamaican society. For those who cannot be physically present, the lecture is streamed live on GraceKennedy's YouTube channel. In addition, copies of the lecture book are distributed to schools and public libraries across the island, and the e-book is available free of cost at www.gracekennedy.com in the hope that the lecture's reach will extend beyond those present at its delivery.

We are confident that the lecture will become an invaluable resource for all who seek a deeper understanding of significant national issues. The Foundation, as always, welcomes and looks forward to your comments.

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The GraceKennedy Foundation Lecture 2019

Clean Kingston Harbour: Pipe Dream or Pot of Gold?

We have the fortune of having not one, but three eminently qualified Jamaicans to present the 2019 GraceKennedy Annual Lecture: Professor Mona Kay Webber, Dr. Wayne St. Aubyn Henry, and Mr. Tijani Christian.

In this lecture, they take us on a frightening journey to show us the extreme degradation of one of our greatest natural resources, the Kingston Harbour. We come to appreciate its former state of glory, to understand the scientific, economic and social causes of its rapid deterioration, and to picture a future of its potential as a gem of the Caribbean and the world.

❋

Professor Mona Webber, our first contributor, is no stranger to the Foundation. In 2016, Professor Webber was appointed the GraceKennedy, James S. Moss-Solomon, Snr. Chair in Environmental Management at The University of West Indies.

As Professor of Marine Biology and Director of the Centre for Marine Sciences, Department of Life Sciences, The UWI, she has raised close to US$2M for her field research projects, which include mangrove forest assessment and rehabilitation, seagrass assessments and water quality/microplastics in the Kingston Harbour. She has a distinguished academic career with over thirty years' experience in research and teaching in the field of marine biology. She has conducted numerous training workshops, published extensively in academic journals, and is a member of many professional organizations. She has a BSc, MPhil and PhD from The UWI in Marine Zoology and Botany.

She presents a scientific approach to the causes, symptoms and solutions to the environmental hazards we face. By

showing us the magnitude of the problem, we are horrified by the enormity and complexity of the issues. Yet, like Dr. Henry and Mr. Christian, she emboldens us to action by showing the steps by which we can reverse the damage.

Last year, I was fortunate to have been invited by Professor Webber on a boat tour of Refuge Cay where she and her team are conducting research. I received first-hand a full description of the Kingston Harbour. I learnt of the passion for her work, and her deep sense of commitment to the protection of the environment. The progress that she and her team have made in the restoration of mangroves is astounding.

The layman's eye does not see what she sees. We know the harbour for its geographical and aesthetic appeal, its international air and sea transportation, for its research institutions, communities of fishers, and recreational facilities. We would not readily perceive the richness and variety of organisms and ecosystems, the 1,150 species of marine life harboured by the seagrass meadows and 318 hectares of mangrove forest. Neither would we realize the severity of the problem, the direct threats posed by decades of misuse. The ecosystems of the harbour have not been able to sustain the onslaught of urban development. Professor Webber's detailed descriptions, diagrams and results of scientific studies shock us into realizing the devastating effects of this impact. We wonder if sustainable development is even possible, if we will be able to meet the needs of today's society without compromising future generations.

The Kingston Harbour is being consumed. The endless flow of debris that streams into the harbour, exacerbated by rapid increases in industrial activity, are degrading the quality of sea life in unprecedented ways. Professor Webber gives results of environmental studies that show high levels of faecal bacteria and pesticides caused by raw sewage and industrial waste. The main culprit is the gully system. She uses sophisticated digital

analyses of “waste-scapes” prepared by Mona Geoinformatics Institute to show the extent of storm-water run-off from a network of 19 gullies that feed the Kingston Harbour. This increase in solid waste has now mushroomed into a constant rain of plastic and other debris that threatens the aesthetics, commercial activity and biodiversity of the entire harbour ecosystem.

Just as we believe all may be lost, Professor Webber gives us hope. She describes the Soapberry Treatment Plant Solution that treats sewage effluent; her own project to remove garbage pile-ups from Refuge Cay and restore the death areas of mangrove forest; the Government ban on single-use plastics, straws and Styrofoam, and the proposed GraceKennedy Foundation Clean Harbour Initiative.

We are pleased to have Professor Mona Webber as part of our GraceKennedy team that is developing an initiative to clean up Kingston Harbour. Our goal is to restore it to its former glory. This will be evidenced by improvement in the quality of marine life, with increases in levels of biodiversity and the rejuvenation of mangrove forests. The private sector has within its capacity the tools and resources to be a catalyst for change, to develop a successful mobilization strategy. But we do not do this alone. The blueprints already exist for the Redevelopment of downtown Kingston and Port Royal as outlined by the Urban Development Corporation. The role of the GraceKennedy Foundation will be to facilitate and launch a joint public/private partnership for bringing stakeholders together with a focus on the improvement of the storm water and waste management system for the Kingston area. These are the responsibility of government but we will work with them, with multilaterals and the private sector to tap into resources necessary to capitalize a central fund of US$100M. We will work with policy makers and government agencies to design a strategic implementation plan to save our harbour.

❋

Dr. Wayne St. Aubyn Henry, our second contributor, is the Director General of the Planning Institute of Jamaica (PIOJ). This government agency leads policy formation on economic, social and environmental issues to achieve sustainable development for the people of Jamaica. Dr. Henry brings to the discourse vast experience and expertise in the fields of finance and economics. He has served as Vice-President of Scotiabank Group Jamaica, Chief Technical Advisor in the Ministry of Finance, World Bank Representative in Jamaica, and Lecturer in Economics at The University of the West Indies. He has degrees in Agriculture and Development Economics, Finance and Economics and Management.

Dr. Henry analyzes the economic value of the Kingston Harbour and moves us to want of action for its full restoration. We come to understand not only its actual value but also the tremendous potential should a concerted effort be made to rehabilitate it.

He explains the concept of natural resource valuation, a system by which policy makers can make informed decisions about sustainable management of natural resources.

Dr. Henry thinks like an entrepreneur who assesses the economic and social benefits of the harbour to the country and the world. The Kingston Harbour is an asset of immense value: the size and importance of the shipping ports, the role it plays in research and education, the vibrant fishing industry which has 3000 registered fishers at beaches around the harbour. Yet, he is not remiss in revealing the potential hazards that this development has on the environment: the degree of waste, sewage and oil residues. We have misused our national treasure.

He impresses upon us aspects of marine life that we take for granted: the functional benefits that the Kingston Harbour produces in terms of storm protection and the

climate modification functions of mangroves and wetlands. We recognize the moral obligation we have to protect these ecosystems, to fortify the resilience of Kingston to natural disasters, and to safeguard the livelihood of all those who depend on the coastal economy.

In order to achieve Vision 2030, we must restore the Kingston Harbour. He challenges us to embark on a journey for the sustainable development of the marine environment, to recognize the potential of the blue economy.

He, too, calls for a concerted effort by both government and private sector to do the clean-up. With it will come prosperity, a vibrant economy and the revitalization of downtown Kingston. It is the responsibility of every Jamaican.

❈

Tijani Christian, our third contributor, was elected Chair of the Commonwealth Youth Council (CYC) in 2018, the first Caribbean national to fill this post. In this capacity, he liaises with the Duke of Sussex, Prince Harry, to advance the role young people play in the development of Commonwealth nations. He represents more than a billion youth from 53 member states. He has served in many other leadership roles including Special Advisor to the National Youth Council of Jamaica, President of UWI Students Today, Alumni Tomorrow (UWISTAT), Vice Chancellor's Ambassador Corps and member of the CARICOM Single Market and Economy (CSME) Bureau. A graduate of The UWI, Mona, his areas of expertise include democratic governance, community development, and strategic leadership among youth.

Tijani Christian offers us a social perspective on the topic of the Clean Kingston Harbour. He suggests that the solution to the problems we face of marine life pollution depends partly on the seaside communities, their activities and responses to environmental and economic factors. Years of misuse beckon for its full restoration, and the answer lies in the development of human capital.

All efforts by both government and private sector will be futile if we do not tap into human capital, defined as "a stock of skills that the labour force possesses" (Goldin, 2015). This represents an aggregate of the training and skills of a country's population, the standards and quality of which are indicators of a nation's progress. Without developing this resource, we cannot achieve nation-status as defined in Vision 2030, when Jamaica will become "the place of choice to live, work, raise families and do business".

The questions he raises jolt us into realizing that people are not fully aware of the present dangers. Have people who live in and around the Kingston Harbour been raised to understand the pressing issues? Has investment in development of human capital made any significant behavioural changes in people's attitudes to the environment? These are haunting questions considering the blatant signs of the degradation of marine life.

He outlines examples of the severity of the problem. These include the practice of illegal and harmful waste disposal; the constant flow of refuse from the gullies that feed the harbour; pollution caused from the oil refinery and from the shipping industry; plastics that have damaged the mangroves; and industrial waste caused from agriculture. All these endanger the life of the ecosystems of the harbour.

In discussing remedies, he poses a convincing argument for the need for consequences. Law enforcement is necessary. He strongly endorses the role that the rule of law plays in the protection of the environment. NEPA, which is the main government regulatory agency, could do more to enforce laws. He advocates for better communication, for inclusion of civics and environmental management in the school curriculum to increase people's awareness. Tijani is passionate about the need for a crusade, better coordination and increased dialogue between the enforcing agencies and the communities affected by the deteriorating conditions of the harbour.

He shows us that funding agencies and commissions over the years have arrived at the same conclusion: public outreach, education and training are the ways to mitigate the ills plaguing the Kingston Harbour. He lauds the government's most recent measures to ban single-use plastics and Styrofoam and their recognition that sustainable development is inextricably linked to the health of the oceans.

Tijani Christian exhorts us to action. He shows us that the power for positive change lies within the individual to take responsibility to be informed and to act, so that we each can play our own part in ending the pollution crisis. It is also a collective effort; companies and industries, private and public sector alike, must band together to save our harbour, nature's precious gem.

We thank our three contributors to the 2019 GraceKennedy Foundation Lecture, "Clean Kingston Harbour: Pipe Dream or Pot of Gold": Professor Mona Webber, Dr. Wayne Henry, and Mr. Tijani Christian. Their scholarship and passion serve to advance public debate on determining ways in which Jamaica can protect the natural environment. The presenters paint a picture of the enormity of the problem which, on the one hand, makes us think that the harbour's restoration is indeed a pipe dream. Yet, we come away with the conviction that we possess the will and the capacity to reverse the damage we have caused. Their presentations compel us to garner the support of both the private and public sectors to assume the moral responsibility and civic duty to restore the Kingston Harbour to its former glory.

Fred W. Kennedy
Chair, GraceKennedy Foundation
April 2019

Mona Webber

Wayne Henry

Tijani Christian

The Lecture

Clean Kingston Harbour: Pipe Dream or Pot of Gold?

Overview

A natural harbour is a body of water that is sheltered by natural barriers. The barriers act as breakwaters that reduce the intensity of waves inside the harbour. To this end, a natural harbour is generally characterized by calmer waters and depths that allow for the safe anchorage and movement of maritime transportation. Kingston Harbour is the seventh deepest natural harbour in the world and the ecological, economic and social value of this mere 51 km^2 coastal feature is tremendous!

Kingston Harbour is home to numerous species living in association with its varied habitats. It supports the island's main port (Port of Kingston), a leading regional transshipment port serving the Caribbean and Central America. Many people depend directly and indirectly on the Kingston Harbour and its resources for their survival and economic well-being.

Owing to its vista, the waterfront remains an important component of the harbour, attracting in excess of 300,000 local and international visitors during the annual Fireworks on the Waterfront hosted by the Urban Development Corporation. Victoria Crafts Market and the redeveloped Victoria Pier are also popular with locals and visitors alike. Although swimming is no longer recommended in the harbour, pleasure boating and sailing remain important recreational activities.

The sheltered nature of the Kingston Harbour, due to the tombolo joining Port Royal to main land, makes it an important disaster mitigation resource for the Kingston Metropolitan Area. The tombolo acts as a breakwater, mitigating the force of intense wave action from the Caribbean Sea.

Over the past few decades, water quality in the harbour has deteriorated significantly from human activities through **point and non-point source** pollution. Discharges from

Point and Non-Point sources – a point-source of pollution refers to material coming from a single (identifiable) point, such as a sewage treatment plant outfall. Non-point sources (by contrast) refer to pollution from (many) diffuse sources and may include land runoff associated with rainfall, atmospheric fall-out, seepage, and so on. These are usually difficult to identify and quantify.

ships, along with industrial waste from surrounding industries, drain into the harbour through many different channels. Pollutants from fertilizers and pesticides used in farming enter the harbour and a substantial amount of domestic waste from residences in the densely populated Kingston Metropolitan Area and sewage from improper treatment practices contribute considerably to the pollution of the harbour. Moreover, improper solid waste disposal practices continue to proliferate as is evidenced by the volume of litter (mostly plastics) found on the harbour's shores.

The most visible effect of pollution in the harbour is eutrophication which, among other things, gives rise to algal blooms, oxygen depletion, increased sedimentation and decline in biodiversity. Moreover, the weathering of the plastic waste creates another form of pollution (microplastics) that threatens the food chain.

In addition to the high level of pollution, over the years, Kingston Harbour has also been impacted by the removal of several hundred acres of mangrove swamps along Hunts Bay and the Kingston waterfront. These mangrove swamps were removed to make way for industrial and residential development, as well as the expansion of the Port of Kingston. The removal of mangroves has negatively impacted the regulating and provisioning ecosystem services as well as the overall environmental health of the harbour. This is because mangroves play an important role in the removal of nutrients (reducing eutrophication), reducing sedimentation and

significant carbon sequestration (the capturing and storing of carbon). A number of marine species and birds also rely on these ecosystems for habitat roosting and nesting, and they provide a nursery for juvenile fish. The mangroves that remain are further threatened by solid waste.

The complexity of the issues affecting the Kingston Harbour gives rise to the need for a multi-faceted and concerted approach to any harbour restoration initiative. Efforts have been made in the past to reduce the volume of untreated sewage entering the harbour through the development of the Soapberry Wastewater Treatment Plant in St. Catherine. However, the desired result has been limited by the impact of the large proportion of households (44.6 percent) in the Kingston Metropolitan Area which remain unconnected to the central sewage system (*Jamaica Survey of Living Conditions*, 2015). Previous interventions to reduce marine litter are expected to be bolstered by the ban on some single-use plastics imposed in January 2019, an initiative that should result in marked improvement in the volume of solid waste that enters the sea. The Kingston Harbour Institutional Strengthening Project of 2006 was intended to lay the foundation for the integrated approach needed to improve environmental management of the harbour.

Nevertheless, the harbour remains polluted and requires more targeted initiatives aimed at addressing not only pollution that arises within and around it but also non-point source pollution, such as run-off from farms and urban development. Mitigation against the negative effects of eutrophication requires a reduction of nutrient inputs, most of which enter the harbour from the drainage network of 19 gullies and two rivers (Rio Cobre and Duhaney River), the latter entering via Hunts Bay. There is also the need for a comprehensive valuation of our coastal ecosystems to fully understand the benefits these ecosystems provide and to make more informed decisions regarding the sustainability and vitality of these systems.

Although many activities are carried out in the harbour in its present deteriorating state, there is evidence to suggest that a clean, rehabilitated harbour would significantly enhance and increase the benefits to the country.

This lecture will explore bringing back the former glory of the Kingston Harbour, as it was in the 1950s and 1960s, and its contribution to food production and food security, and will emphasize ways of sustainably capitalizing on this natural resource as a means of generating growth. The role of industries – electrical, cement, oil refining, and others – operating in and around the harbour will be emphasized within the context of partnering with these firms to preserve this unique natural resource in order to safeguard their own sustainability, competitiveness and profitability.

It is clear that the pollution problem in Kingston Harbour has a detrimental effect on the reputation of Kingston and Jamaica, and carries economic as well as environmental impacts. The lecture will also explore the notion of **natural capital** within the context of advancing our country's blue economy – a new economic frontier – which provides us with a unique opportunity to rediscover ways to contribute to a sustainable pathway for our development – one which is inclusive and ensures prosperity for all in a sustainable manner. The current (and future) direct and indirect uses of the Kingston Harbour are major contributors to Jamaica's blue economy.

Natural capital – the world's stocks of natural assets which include geology, soil, air, water and all living things. It is from this natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible.

The importance of placing economic values on the many indirect use values of the harbour that are critical for enhancing

our resilience to natural disasters, especially in the face of a changing climate, will be outlined in the lecture.

The use of economic instruments for environmental management and the economic benefits of so doing in the pursuit of both natural capital and green economy goals will be emphasized. The importance of the ecosystems – seagrasses and mangroves – and their functions to reducing damage and loss of natural disasters will be highlighted, bearing in mind that whilst mortality from natural disasters is decreasing, the economic losses of disasters are increasing, and some of the increasing negative impacts are directly correlated with the deteriorating state of these ecosystems.

The way forward emphasizes the need for public outreach, education and training; some of the many ways to improve and tap into the human capital of the citizens living in and around Kingston Harbour. These measures are not only feasible but practical, as each steward plays an active role in conserving the environment through investing in his or her own behavioural change. The ripple effect of tapping into the human capital of the Kingston Harbour communities would extend beyond sustainable economic development to improving livelihoods benefits to citizens in a vibrant downtown Kingston.

The lecture concludes by showing that as we make efforts to achieve developed country status within the context of Vision 2030 Jamaica, a concerted effort is required from government, the private sector and citizens to clean up Kingston Harbour. A vibrant economy supported along the entire harbour shoreline could, in the long run, reduce crime and violence; improve the prospects for businesses; and enhance the natural beauty, thus contributing to the overall impact of attracting more locals and tourists to the nation's capital and importantly, assist us in propelling sustainable prosperity in Jamaica.

Chapter 1

Kingston Harbour and Its Natural Environment

Kingston Harbour, located on the south-eastern coast of Jamaica, is an elongated bay formed by the Palisadoes tombolo which extends 15 km (eight miles) east to west, with the town of Port Royal located at the very western tip (Figure 1.1a). Apart from providing the only road route to the historic town of Port Royal, the Palisadoes also provides the only access to several other important national institutions located on the peninsula, such as the Norman Manley International Airport (NMIA), Ministry of Agriculture Plumb Point Quarantine Complex, Caribbean Maritime University (CMU, referred to as JMI (Jamaica Maritime Institute) in Figure 1.1a), The University of the West Indies Port Royal Marine Laboratory and Biodiversity Centre, Jamaica Defence Force (JDF) Coast Guard, Royal Jamaica Yacht Club (RJYC), Buccaneer Beach and Gun Boat Beach.

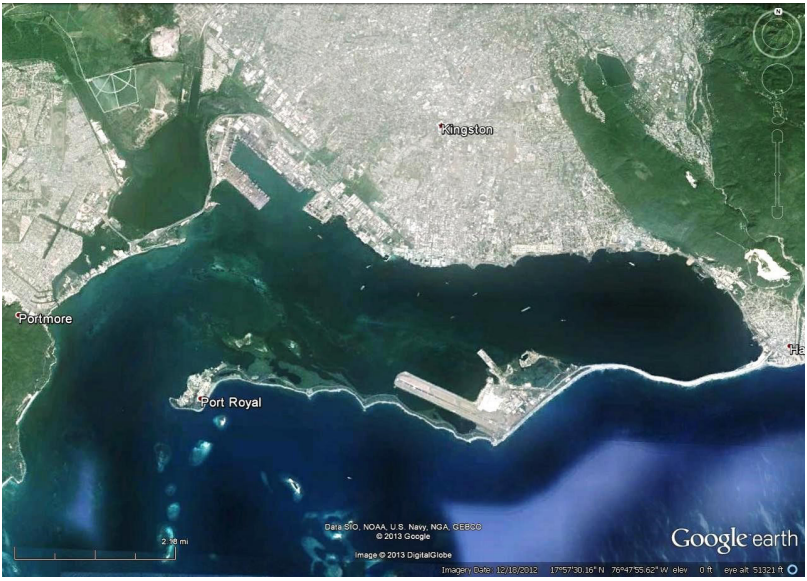


Figure 1.1a
Google image of Kingston Harbour and surroundings

Additionally, the Palisadoes tombolo supports hectares of mangroves which protect the integrity of the narrow spit of land and also provides several ecosystem services to the Kingston Harbour and its users.

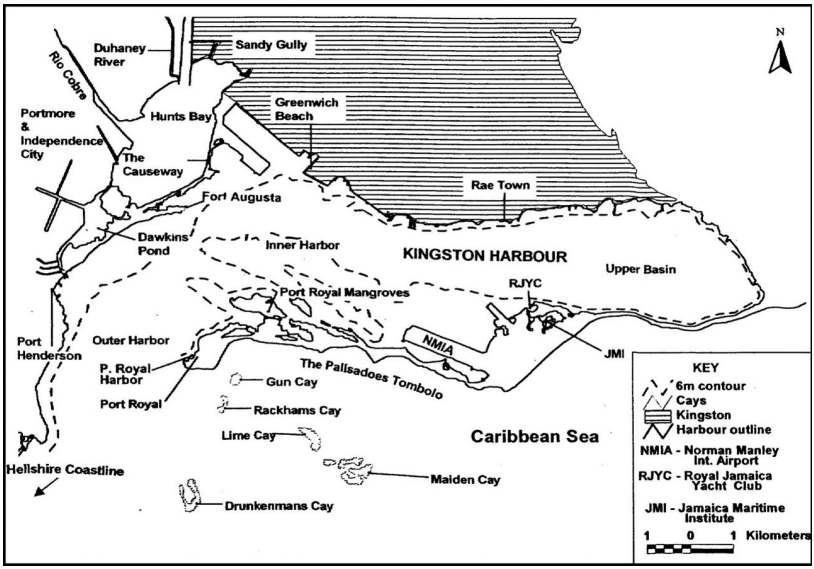


Figure 1.1b
Map of Kingston Harbour showing the major features
Source: Goodbody, 2003

Scientific studies indicate that the Palisadoes tombolo consists mainly of land-derived sediments transported (from the rivers located east of Harbour View) by longshore drift along the coast and deposited amongst a number of derelict cays aligned westwards from Harbour Head out to Port Royal. Because of the nature of the **geomorphological** processes by which

Geomorphological – literally means the study of "earth's form" and is of, or relating to, the form or surface features of the earth.

the structure is believed to have been formed, marine geologists refer to the Palisadoes as a tombolo (Figure 1.2).

Over the years, the shape and configuration of the harbour as well as the extent of its mangroves have been altered by man-made activities such as the construction of the Norman Manley International Airport, the Portmore Causeway, and the Port of Kingston facilities. An earthquake which caused the loss of half of Port Royal in 1692 also significantly altered the configuration of the harbour.

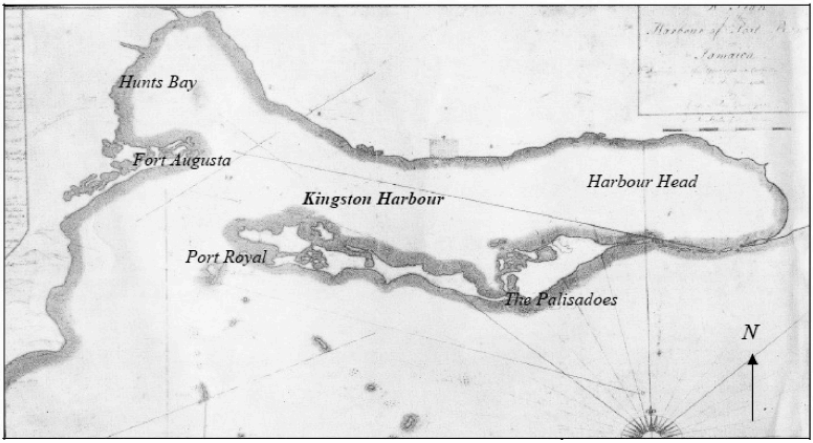


Figure 1.2
Early map of Kingston Harbour
Source: Stanley Consultants, 1967

Situated on Jamaica's south coast at a latitude of 170 57' N and longitude 760 48' W, the Kingston Harbour is a semi-enclosed bay and forms an extensive natural harbour with a surface area of approximately 51 km^2 (including Hunts Bay). The seventh deepest in the world, the harbour consists of three deep basins, the Upper Basin, the Inner Harbour and the Outer Harbour. Extensive sand shoals supporting seagrass meadows and mangrove swamps are found along the southern shore and parts of the western shore. Since 1965, Hunts Bay has been partially cut off from the rest of the harbour by the causeway.

The entrance to the harbour is a 2 km wide channel in the south-west corner (Wade, 1976) and this leads naturally into a deep channel. This channel, usually referred to as “the ship channel”, curves around the north-west side of the harbour, providing navigable access to its inner basins. It is a natural formation, which is most likely maintained by natural water circulation (Goodbody, 1968, 1970). This natural ship channel has undergone modifications to facilitate larger vessels through improvements to the turning arc and deepening to maintain a **draught** of 18 m throughout (Figure 1.3).

Draught – in this context refers to “the depth of water needed to float a vessel”.

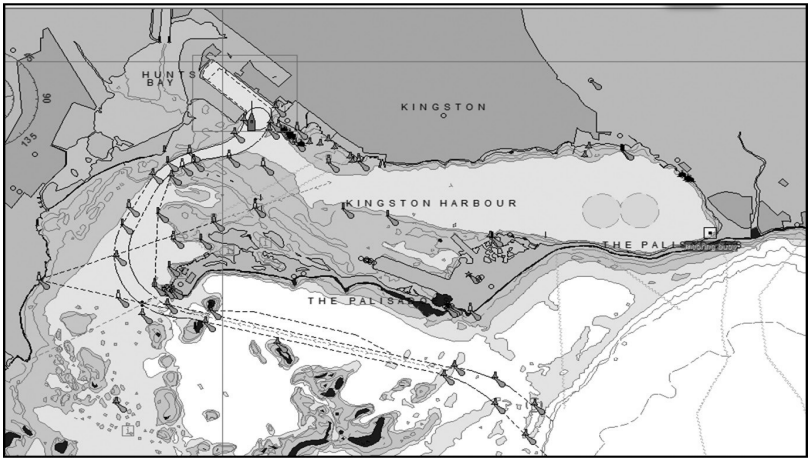


Figure 1.3
British Admiralty chart of Kingston Harbour showing alignment of the ship channel

Bathymetry and Zones

Kingston Harbour is divided into three zones based on **bathymetry** and other features (see Figure 1.1a). The Outer Harbour represents a deep basin just inside the mouth of the harbour between Port Royal in the east and Port Henderson in the west, and Fort Augusta to the north. The Inner Harbour extends along the main central east-west axis of the harbour to just beyond the airport runway, while the Upper Basin represents the deep basin in the easternmost part of the harbour. Somewhat distinct from the main harbour is Hunts Bay to the north-west which, before its enclosure by the causeway, was considered part of the Inner Harbour zone.

Bathymetry – the study or measurement of the depth of water in an ocean, sea, or lake.

The Outer Harbour has a range of depths but reaches a maximum of 18 m in the ship channel. The Inner Harbour has even greater dynamic topography with shoals and deep channels which extend to about 10 m deep. The Upper Basin is a relatively uniform deep basin with narrow, shallow areas (2–5 m) rapidly sloping down to depths of 18 m. By contrast, the average depth in Hunts Bay is 2.4 m (Ranston and Webber, 2003). Similar depths (1 to 3 m) exist in most of the Kingston Harbour mangrove areas, however, deep (6–7 m) lagoons exist in the Port Royal mangroves with one such occurring south-west of Refuge Cay (called Rosey Hole or Hurricane Refuge Lagoon). Here, large vessels are able to find safe anchorage during hurricanes by being in a deep enough channel but virtually surrounded by mangroves which act as natural wind-breakers.

Circulation Patterns

Circulation patterns within the harbour are very important to the dynamics and movement of pollutants throughout the system. Circulation in Kingston Harbour is affected by tides, winds and freshwater flows. Tides in Kingston Harbour are classified as mixed because they vary in periodicity from diurnal to semi-diurnal (Stanley Consultants, 1968; Goodbody, 1970). However, more important, they are also described as micro-tidal because the mean range at Port Royal is 18–20 cm with spring tide ranges of 27–30 cm. However, extreme high-water spring tides can reach an amplitude of 90 cm (Goodbody, 1970). Currents which result from this micro-tidal activity are, therefore, weak.

There are, however, wind-driven currents which may override the tidal currents. Winds in the Kingston Harbour have a diurnal pattern with sea breezes during the day from the east-south-east or south-east, and land breezes during the night from the east-north-east (Webber et al., 2003). The effect of the wind blowing across the sea surface exerts a frictional drag and the resultant surface current is 1–2 percent of the wind speed. In addition to creating surface currents, winds across Kingston Harbour, which can gust as high as 27.5 m/s in July, efficiently move floating debris back and forth across the expanse of the water body.

Webber et al. (2003) described the influence of fresh water flows on the circulation of Kingston Harbour as affecting primarily the Outer Harbour, where outflows from Hunts Bay constantly introduce fresh water. During times of heavy rainfall (> 65 mm), the freshwater flows out of Hunts Bay can be as high as 22 cm/sec and the associated currents influence as deep as 5 m below the surface. It has, therefore, been determined that the circulation patterns of the three major zones of the harbour are driven by different agents (forcing functions), with the Outer Harbour behaving like a typical estuary with currents affected

by freshwater flows; the Inner Harbour being affected more by tides due to the dynamic topography (shoals and deep ship channels); and the Upper Basin affected more by wind-driven currents that are described as strong but "short-lived" (Webber et al., 2003).

Measurements and modelling by Bigg and Webber (2003) have shown the presence of a series of gyres that further exacerbate the retention or expectedly long residence time of a "bottle-shaped" harbour. A counter-clockwise **gyre** (near circular current) exists in the Outer Harbour which, in turn, appears to trigger a clockwise gyre between the Outer and Inner Harbour zones. North of the Norman Manley International Airport, the circulation patterns change again to a counter-clockwise gyre. The modelling suggests that the resultant flushing time for this Upper Basin section of the harbour could be of the order of several months, maybe longer. Flushing times for the Inner Harbour and Outer Harbour (where there is greatest water movement) are still 25 days and 3.3 days, respectively (Sherwin and Deeming, 1980). These times indicate a relatively long retention or residence time for any pollutant that enters the Kingston Harbour.

Gyre – near circular current or any large system of circulating (usually) ocean currents.

Kingston Harbour's Natural Ecosystems

Having considerable aesthetic appeal, the Kingston Harbour remains one of the finest natural harbours in the world and facilitates, among other things, livelihood activities such as artisanal fishery and recreation; port and harbour developments, international air and sea transportation; educational as well as

research institutions. Besides its beauty and its value as “green” space for the cumbersome city of Kingston, it is also renowned as an area of exceedingly high organic productivity (Goodbody, 1968) and biodiversity (Wade, 1972). It is important to note that the Palisadoes-Port Royal Marine Protected Area (which resides within the Kingston Harbour) represents an area of national and international importance owing to its designation as a Ramsar site, of importance to wetland preservation, and a waterfowl habitat.

The natural ecosystems found in the Kingston Harbour have been studied by a range of naturalists and researchers associated with The University of the West Indies (UWI) since 1955 when the Port Royal Marine Laboratory was founded, and even before that in the late nineteenth century by researchers from the Johns Hopkins University who managed a field station at Port Henderson (across from Port Royal). This long history of research provides extensive documentation of the flora and fauna of the area, of which only those associated with the major habitats can be presented. The organisms associated with seagrass, mangrove forest and mangrove lagoon areas, which are currently the most affected by pollution of the harbour, will primarily be described.

Seagrass meadows dominated by *Thalassia testudinum* (turtle grass) exist as discontinuous patches on all shallow shoals within Kingston Harbour, with the exception of the Hunts Bay, where turbidity levels are now too high to allow sufficient light to penetrate to the shallow sea floor. While these meadows previously existed as almost continuous grassed areas within the 6 m depth contour (Figure 1.4), seagrasses now only exist as variegated patches at Mammee Shoal, Pelican Shoal, Middle-ground Shoal, shallow areas south and west of Fort Augusta (Figure 1.5), and in areas associated with, or adjacent to the mangrove forests. The shallow area of Port Royal Harbour east of the Old Coal Wharf is one of the few places where the shoal

grass *(Halodule wrightii)* can be found growing on extremely soft and nutrient-rich muds near the mangroves.

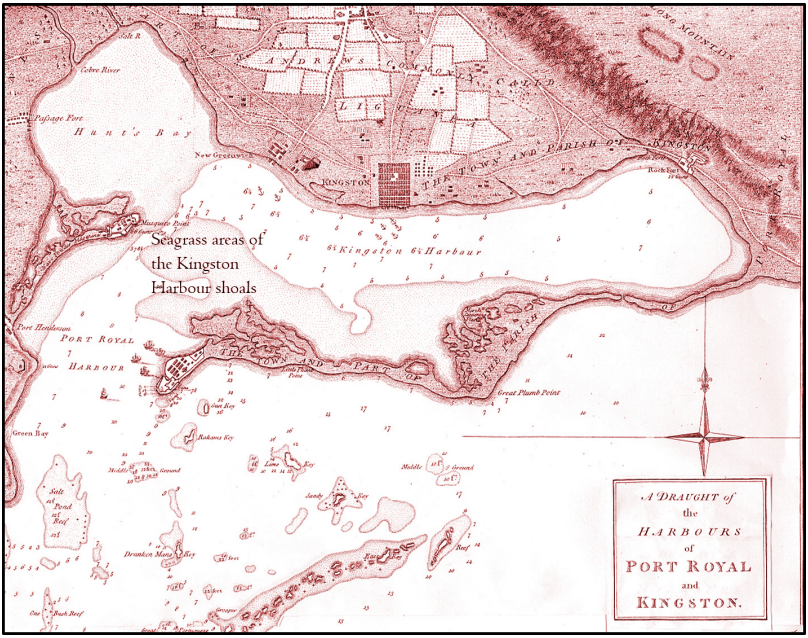


Figure 1.4
Seagrass meadows (stipuled areas) as they existed inside Hunts Bay and on all shoals of the Kingston Harbour
Source: Modified from Wellcome-L0063041.jpg https://wellcomeimages.org/indexplus/obf_images/6b/e2/41aa73fe2dec067c25c4fe70af6a.jpg

The seagrass meadows of Kingston Harbour are poorly studied and so little has been published in recent years about their extent, health/productivity and associated fauna. Greenway (1977) represents the only comprehensive study of seagrasses in Kingston Harbour and this was confined to Mammee Shoal, which she compared to Rackham's Cay in the Port Royal Cays. Nevertheless, she indicated that seagrass meadows covered 1,000 ha of shallow areas in Kingston Harbour and were dominated by turtle grass *(Thalassia testudinium)*. Sean Green, in his study of the effects of varying levels of eutrophication on seagrasses, cited two stations in Kingston Harbour, near Fort

Augusta and the Old Coal Wharf, which represented the most eutrophic stations (Green and Webber, 2003). His study reflected the decline in seagrass density and productivity associated with the eutrophic harbour.

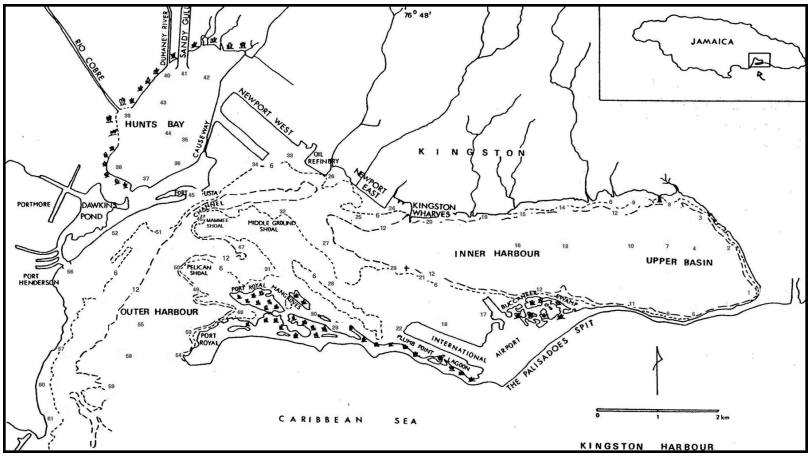


Figure 1.5
Chart of Kingston Harbour showing present positions of the shoals on which seagrasses can be found. Small numbers indicated stations sampled during an assessment of the harbour
Source: Galbraith-Smikle and Webber, 2017

Aiken (2009) gives the most recent indication of the fauna supported by seagrasses in Kingston Harbour. Trawls conducted at the harbour's seagrass meadows indicated 28 species of fin-fish, and 14 species of invertebrates (dominated by the green sea-urchin). Despite its position in the middle of the Inner Harbour, a high species number (21) was found at the severely reduced Mammee Shoal meadow. Despite the state of the harbour's seagrasses, Aiken (2009) found specimens of the rare and endangered goliath grouper (*Epinephelus itajara*), which is considered to be a significant indicator species and which was previously thought to be "commercially extinct", in Kingston Harbour. Aiken described the pairing of mangrove forests with adjacent seagrass beds as a critical habitat for important

keystone species like the goliath grouper as well as the equally rare and endangered yellow-lined seahorse (*Hippocampus erectus*).

Mangrove swamps of the Kingston Harbour exist primarily along its south shore in the shelter of the Palisadoes tombolo. Although Goodbody declared that in its original state, Kingston Harbour was surrounded by mangroves (Goodbody, 2003), there is no historical documentation of mangroves extending beyond the areas of the Palisadoes (to the south), and Hunts Bay and Dawkins Pond to the north-west. As such, we recognize the Buccaneer Swamps, located east of the old airport runway, the Port Royal Swamps stretching from the new airport runway to just east of the town of Port Royal, and the mangroves on the shores of the Hunts Bay/Dawkins Pond complex (Table 1.1 and Figure 1.6). This digitization based on a 2018 Google image yields 318.4 ha for the Kingston Harbour mangrove areas.

Table 1.1
Mangrove areas associated with Kingston Harbour and their extent

Location	Hectares	Acres
Hunts Bay	105.09	259.53
Dawkins Pond	28.7	69.95
Buccaneer Swamp	39.95	98.68
Port Royal mangroves (including airport runway)	144.67	357.51
Total	**318.41**	**785.67**

A few areas of mangrove (~ 6,000 plants consisting of seedlings, trees and shrubs) were located on the harbour-side of the Palisadoes roadway but these were removed during the Palisadoes Road Rehabilitation and Shoreline Protection project, which saw the raising of the road to between 2.4–3.2 m above sea level and the installation of rock revetments on both sides of the road, even the relatively calm and sheltered side adjacent to the Kingston Harbour.

Figure 1.6
Google Image (2019) with mangrove swamps of the Kingston Harbour; outlined in yellow or indicated by yellow lines

Two areas were replanted with ~ 6,000 mangrove seedlings as mitigation for the loss of the equivalent number of plants. The University of the West Indies conducted the re-vegetation in two areas: one just west of the Gypsum Pier (near Harbour Head) and the other just east of the Gun Boat Beach (represented as white lines along the Palisadoes in Figure 1.6). The five-year project commenced in 2014 and continuous assessment of the plants indicated 30 and 60 percent survival at the Gun Boat Beach and Gypsum Pier sites, respectively. This is less than the benchmark of 70 percent survival with the loss being due to erosion of the constructed planting area at the Gypsum Pier site and solid waste smothering the seedlings at the Gun Boat Beach site. The presence of the rock revetments out to the water's edge (Figure 1.7) makes it impossible for mangroves to naturally colonize the harbour-side of most of the rehabilitated Palisadoes shoreline, and the few sites where sand-banks remained from the road construction are smothered in plastic waste and other debris, giving mangrove seedlings no chance of survival.

Figure 1.7
Rock revetments along the Palisadoes
on the Kingston Harbour side of the roadway
Credit: Camilo Trench

Three species of mangrove trees can be found in the Kingston Harbour mangrove areas, described as peat mangroves due to the rich, muddy substrate on which they grow (Alleng, 1990). These are *Rhizophora mangle* (Red mangrove), *Laguncularia racemosa* (white mangrove) and *Avicennia germinans* (Black mangrove). The drier sides of the forests that are adjacent to the Palisadoes roadway may support (on predominantly sandy soil) *Conocarpus erectus* (Button mangrove), grading into sand-dune vegetation on the seaward side of the Palisadoes. However, the button mangrove is not usually found in the swamps located within the harbour.

The mangroves of the Kingston Harbour, especially the Port Royal mangroves, have been extensively studied. Their zonation has been described from as early as Chapman (1944), followed by Warner (1968; 1969) and more recently by Alleng (1990) and McDonald et al. (2003).

Several studies have been conducted over the years by local scientists (staff and graduate students of The UWI) that document important faunal groups of the mangroves. These include Ascidians by Ivan Goodbody, Bryozoans by Marcia Creary, Sponges by Celia Jackson, and George Hechtel before her, Crabs by George Warner, Anemones by Elaine Fisher, and Termites by Pamela Clarke and Dionne Jackson-Miller. However, comprehensive investigation of all faunal types has only been conducted by Gerard Alleng.

Over the years the numerous organisms identified, described and enumerated included new species (for which Port Royal is the "type location" being where the species was first discovered and described). The upside-down jellyfish *Cassiopea xamachana* (Hummelinck, 1968) was first described from the shallow lagoons of the mangrove swamp and the sponge *Haliclonia portroyalensis* (Figure 1.8) was first discovered growing on the red mangrove prop roots of the Port Royal mangrove swamps by Celia Jackson (Jackson et al., 2006).

The new species found for which the Kingston Harbour area is the "type location" are called "type specimens", with the original specimen being lodged at a university or natural history museum. Many of the species found in our waters are kept at The UWI or the Natural History Museum of Jamaica. Table 1.2 (Goodbody, 2004) indicates the animal or plant groups, the number of species found in the area and the number of "types".

Figure 1.8
New species of mangrove root sponge
(*Haliclona portroyalensis* n. sp.) from Jackson et al., 2006

Other notable studies and species of the area include those identified in work by Siung (1976) who described selected fauna with a focus on three species of oysters still found on the red mangrove prop roots, of which the flat oyster (*Isognomon alatus*) is still extensively fished and eaten. Avril Siung's illustration of the internal structures of the flat oyster is still used in UWI laboratory guides today. Creary (2000) documented the little known Bryozoa (moss animals) that occur extensively on the prop roots of the red mangrove and developed a key to the identification of the 18 species she distinguished. Chin (1990) studied the populations of shallow water penaeid shrimps and callinectid crabs, identifying the thriving shrimp fishery that is still supported in Hunts Bay. Clarke (1995) and Jackson-Miller (1995) both studied the termites, *Nasutitermes*

nigriceps, *Procrytotermes coniceps* and *Incisitermes schwarzi* that make nests in mangrove forests, providing the only study of mangrove-dwelling termites for the Port Royal mangroves.

Goodbody (1993a) recorded 17 species of ascidians or sea squirts occurring in the **sessile** communities growing on the red mangrove roots, and among these ascidians is the ubiquitous *Ecteinascidia turbinata*. This species was first harvested from the Port Royal mangroves (Goodbody, 1993b) for the extraction of bioactive compounds called "ecteinascidins" which have been developed into a drug for the treatment of cancers referred to as soft-tissue sarcomas. While fish species have been extensively documented from the harbour, of note is a study by Ross (1982) who documented the occurrence of the juveniles of six important reef species in the mangrove area of Port Royal, indicating that the Port Royal mangroves may be an important nursery for these reef species and other commercially important fish.

Sessile – literally means "attached directly by the base" and refers to organisms or their parts that are permanently attached or fixed to the substrate and not free to move about.

Avifauna or birds are an important group in any wetland or marine area and these have been studied by Alleng (1990) and Morgan (1995) who documented 30 and 43 species, respectively. The mangroves were shown to house a small population of rare birds such as the White Ibis, Glossy Ibis and Clapper Rail, which, along with numerous over-wintering (migratory) birds, indicate a rich bird fauna for a comparatively small area, making the swamps potential attraction for birders.

Overall species richness of the Port Royal mangroves and adjacent areas has been reported to be over 1,150 species (Goodbody 2004, Table 1.2), which is significant, considering

that the total marine species count for the shallow areas around the island of Jamaica is estimated at 3,502 (Warner and Goodbody, 2005).

Table 1.2
Major groups of taxa from Kingston Harbour and the number of type specimens or new species described
Source: Modified from Goodbody, 2004

Taxon	Number of Species	Number of Types
Macroalgae	98+	
Porifera	54+	12
Cnidaria	156+	6
Ctenophora	4	1
Platyhelminthes	3+	
Annelida	26+	6
Crustacea	158+	4
Mollusca	295	9
Bryozoa	18+	1
Chaetognatha	3	
Echinodermata	81	
Hemichordata	2	
Chordata	228 to 278+	2 (Ascidians)
Total	**1,150+**	**41**

The high biodiversity of Kingston Harbour and its mangroves contributes to the overall value of the area. Indeed, mangroves globally have an annual value of US$200–900,000 per ha (Gillman et al., 2008), which is not unexpected since mangroves are now known to offer unparalleled ecosystem services which can be grouped under the following headings (Webber et al., 2016):

A. ***Regulating:*** Sediment trap; water purification by removing nutrients from sewage and fertilizers; shoreline and infrastructure protection and carbon sequestration/climate regulation

B. ***Supporting:*** Nursery area for fish; habitat for other species yielding a high biodiversity; refuge during hurricanes and severe storms

C. ***Provisioning:*** Exploitable resources like medicine/bioactive compounds; food, for example, mangrove honey/shellfish/fish; ~ 80 percent of global fish catch depends directly or indirectly on mangroves; timber/charcoal, tannins for processing leather; 30 percent of the world's rayon comes from mangrove tannins

D. ***Education/Recreation:*** Bird watching/Ecotourism/Teaching ecological principles; recreation, for example, kayaking

Chapter 2

Kingston Harbour: Decades of Use and Misuse

Kingston Harbour borders Kingston, the capital city, and is the country's major port. The very feature that makes Kingston Harbour a safe and sheltered port also contributes to its vulnerability to land-derived pollution.

The harbour was very likely used by pioneering Europeans since the beginning of their exploration and settlement of Jamaica. Initially, the main settlement was at Port Royal. However, following its destruction in the 1692 earthquake, the English founded Kingston and began development of its waterfront. Historically, the harbour was safe from attack owing to the two forts protecting its narrow entrance, one at the tip of the Palisadoes at Port Royal and the other on a small opposite sand spit (Fort Augusta).

Throughout the eighteenth and early nineteenth centuries, Kingston Harbour handled a large local trade and was the chief point of entry for British exports to the Spanish colonies. For the remainder of the nineteenth century its development as a port was retarded by a decline in the Jamaican economy. Nevertheless, throughout this period there was a gradual increase in the number of finger piers and wharves along its long, sheltered waterfront.

With a current population of approximately 670,000, our capital city, Kingston, is situated mainly on the north shore of the harbour. Among its many uses the Kingston Harbour has facilitated the creation of valuable real estate by the removal of several hundred acres of mangrove swamps which have been cleared and reclaimed to site industrial and residential complexes. Many government agencies/entities have buildings on the harbour front, which also houses the corporate headquarters of several major Jamaican companies. Over 60,000 people live within 1 km of the harbour's shore, with

11,237 buildings (including 1,739 businesses) in that range (MGI, 2018).

The Kingston Harbour is intrinsic to life in Kingston city. It facilitates, among other things, artisanal fishery, recreation, port and harbour developments, international air and sea transportation, educational as well as research institutions. As a valuable resource for the people of Jamaica, the harbour provides port and airport facilities and fishing opportunities, and serves as the site for thousands of industrial and commercial enterprises. Its environs provide homes for hundreds of thousands of Jamaicans.

Recreational Use

Gleaner advertisements of the annual Cross the Harbour swimming competition (Figure 2.1) indicate direct recreational use of the Kingston Harbour by Jamaicans.

Figure 2.1
Advertisement for Cross the Harbour Race
Source: Gleaner, October 21, 1963, 14.

Water skiing was also said to be common in the 1960s (Figure 2.2) but the frequency and popularity of such events is difficult to corroborate. However, by the end of the decade of the 1960s to the early 1970s the waters of the harbour were not fit for contact with human skin due to frequent algal blooms and the presence of contaminants (Wade, 1976).

Figure 2.2
Skiing on the harbour
Source: http://nepa.gov.jm/new/services_products/publications/brochures/docs/kgn_harbour2_white.pdf

The bathing beach and recreation park along the Palisadoes Road, in the area known as Gun Boat, was established in 1955. The beach was named after a Haitian gun boat that lay rusting in the sea nearby. It was opened at 5 p.m. on June 30, 1959, by Iris King, Mayor of Kingston. Bathing beauty contestants and water skiing displays were features of the inaugural celebration of the opening of Gun Boat Beach (http://www.jnht.com/disndat_gunboat.php).

Boat races and yachting developed in the harbour with the siting of the Royal Jamaica Yacht Club (RJYC) in the mangrove areas of the Buccaneer Swamps. The RJYC was formed in 1884 by a group of "enthusiastic sailors". The Club has remained very active with races on weekends benefitting from the protected waters of Kingston Harbour which, although sheltered, still have strong winds from the east-south-east. The RJYC traditionally hosts two regattas each year, as well as the Piper-Heidsieck Pirates Race from Port Royal to Grand Cayman (http://www.rjyc.org.jm/ClubHistory.aspx). Noteworthy is the RJYC summer camp for children and young people which has varied over the years to offer exposure to the harbour and its value, and to teaching yachting to the youth.

Fishing Use

The Kingston Harbour supports recreational, subsistence and commercial fisheries. Registered commercial fishers (33,386) operate from 8 fishing beaches and other landing sites that surround the Kingston Harbour (Table 2.1).

Table 2.1
Fishing beaches of the Kingston Harbour

Fishing Beach	# Fishers	# Boats
Greenwich Town	552	167
Rae Town	327	122
Kingston Fishing Complex	424	116
Hunts Bay	831	192
Port Royal	500	179
Hellshire	267	54
Harbour Head	121	28
Port Henderson	346	140
Total	**3386**	**998**

Fifty percent of these fishers depend directly on the harbour for their livelihood. The other 50 percent depend on the harbour for bait to exploit other fisheries outside the Kingston Harbour. The fisheries resources include: lobsters, shrimp, conch, coastal pelagics (for example, herring sprat), reef and reef-associated fin-fish (for example, snapper, parrot) and larger pelagics such as dolphin fish, king fish, mackerels and Jacks. Fishing gears used in the harbour include seine nets, hook and line and fish pots (traps). Although snorkelling is done for collecting some bottom species, use of scuba gear is rare. The unfortunate practice of trawling by dragging a weighted net along the sea-floor through the seagrass beds is a very destructive fishing method and has probably contributed to the damage to the seagrass beds, as evidenced in the area. Trawling today also sees the "catch" being comprised more of plastic waste than fish or shellfish (Personal observation, Webber, 2018).

Most of the Kingston Harbour fishers are artisanal, subsistence fishers who have little or no other economic activity available to them. Many from other sectors turn to the harbour fisheries seasonally, or permanently when faced with unemployment and poverty. Fishing in the harbour has therefore become an employment opportunity for many, especially those in the so-called "inner-city". The commercial activity surrounding fishing includes fish harvesting (done by the fishers), pot making, boat building, and net-making. People also earn money by scaling and gutting fish on the beaches. Others help to load the boats before they go to sea and off-load the catch and equipment when boats return to port. In many cases this is their only or major source of employment.

National Defence Use

The Jamaica Defence Force (JDF) Coast Guard (formerly the Sea Squadron), has been located at the westernmost tip of the Palisadoes tombolo at the entrance to Kingston Harbour since

their inception in 1966. The Coast Guard, as the naval arm of the Force, is tasked with the maintenance of law and order in Jamaica's maritime space (an area ~ 240,000 km^2 (~ 25 times the size of the island itself). The JDF Coast Guard has responsibility for maritime safety (search and rescue, pleasure craft inspections, response spills of oil and other hazardous substances), and maritime law enforcement (fisheries protection, drug interdiction, international maritime communication, customs and immigration). This remit is executed from its headquarters located in the shelter or lee of the tombolo, from which vantage point the expanse of waters surrounding the Port Royal Cays to the south as well as east and west of the harbour's mouth are visible. The Coast Guard maintains outstations but its base at the mouth of the Kingston Harbour significantly helps with the maintenance of flexibility and innovation in its presence in our maritime space. The JDF Coast Guard conducts extensive training of new recruits and also conducts training to upgrade "ordinary seamen" to officers. The waters of the harbour are frequently used for a number of training exercises, including scuba training.

Sited almost opposite the JDF Coast Guard, the Marine Police Division is based on the north shore of Kingston Harbour at Newport East. The Marine Police, an arm of the Jamaica Constabulary Force (JCF), is tasked with patrolling the island's coastal waters to protect Jamaica's sea-borders from organized crime.

The two defence arms tasked with protecting Jamaica from bases on the shores of the Kingston Harbour often benefit from concurrent training to improve techniques, tactics, and procedures on how to conduct counter-narcotics and counterterrorism activities, and "to safeguard Jamaica's sovereign territory and the sea domain from illegal fishing" (https://jis.gov.jm/marine-police).

Transportation Use

The Norman Manley International Airport, Jamaica's second busiest international airport, is located on the southern shore of the Kingston Harbour, approximately mid-way along the Palisadoes tombolo. Both old and new airport runways project into the waters of the harbour and both are connected to airport facilities constructed on areas once covered by mangroves.

Jamaica has an exceptional air network, which provides both international and domestic air travel. There are three international airports: Sangster International Airport in Montego Bay, Norman Manley International Airport in Kingston, and the Ian Fleming International Airport in St. Mary. The Sangster International Airport (SIA), the largest of the three international airports, boasts traffic from over 40 airlines and averages more than 380 flights per week. The airlines include British Airways, United, West Jet and Sunwing. The Norman Manley International Airport (NMIA) has 13 scheduled airlines including Jet Blue, American Airlines, and Caribbean Airlines, and handles over 196 international flights per week. Major international destinations are New York, London, Toronto, Miami, Panama, Atlanta, and other Caribbean countries.

In 2013 the NMIA moved a total of 1,372,602 passengers on an average of 196 flights per week. Cargo movement was 9,684,947 kilograms at NMIA. At SIA, the total passenger movement in 2013 was 3,502,283, on an average of 380 flights per week, while cargo movement was 5,567,939 kilograms.

Jamaica's maritime infrastructure is well developed and there are plans for further modernization. Currently, the maritime network consists of 14 seaports which, in 2013 accommodated 3,572 vessels and 1.2 million passengers. The Port of Kingston has International Ship and Port Facility Security (ISPS) certification and is well served by a comprehensive network of shipping lines. The Port of Kingston lies along main shipping lanes from the Panama Canal, which makes it

very attractive to international shipping companies. Over 30 shipping lines have operations in Jamaica covering all major routes to North and South America, Europe and the Far East.

The Port of Kingston, Jamaica's largest, is one of the most successful container shipment ports in the hemisphere. Before 2015 it was known as the Kingston Container Terminal (KCT) and was owned by the Port Authority of Jamaica (PAJ). The KCT was established in 1975, however on July 1, 2016 it was leased (for 30 years) to Kingston Freeport Terminal Limited (KFTL), a local company formed as a subsidiary of global terminal operators CMA CGM (a French company) which is the third largest container shipping company in the world. Other docks on Kingston Harbour are at the Petroleum Corporation of Jamaica in downtown Kingston and at the Jamaica Flour Mills and the Carib Cement Company at Rockfort. According to the Port Authority of Jamaica, roughly 65 percent of all ships calling on Jamaica in 2017 docked at points along the Kingston Harbour.

KFTL is now one of the leading container transshipment ports and consists of three terminals, the North, South and West terminals. The combined rated capacity is 2.8 million Twenty-foot Equivalent Units (TEUs). Jamaica is ranked number four among the best-connected ports of the 180 within the region. After Cartagena (Columbia), Miami, and Savannah, GA (USA), Kingston Harbour is the 37th most connected container port in the world and the 16th most centrally located container port in the world. Jamaica possesses complementary major port facilities along the north and south coast of the island. On the basis of container traffic, the KFTL is ranked among the top 100 ports in the world.

Part of the concession agreement between KFTL and the PAJ required the development of the port by expanding capacity and deepening the access channels (to maintain a draught of 18 m), allowing the Port of Kingston to accommodate larger New

Panamax container vessels. The works included increase in terminal space, number of gantry cranes and straddle carriers that will see increased capacity to 3.6 million TEU containers. However, it was the deepening and widening of the harbour shipping lanes that had the greatest effect on the Kingston Harbour system. The KFTL was, therefore, required by NEPA to conduct ecosystem restoration as compensation for the effect its dredging activities had on the Kingston Harbour. Among other interventions related to the fishing beaches, the KFTL decided to fund the "Refuge Cay Rescue", a project that was undertaken by The UWI to rehabilitate an important mangrove island in the Port Royal mangroves. We will discuss this in a later section.

Use for Teaching/Outreach/Research

The Kingston Harbour hosts two universities on its southern shore. The University of the West Indies' Port Royal Marine Laboratory (PRML) has, over the years, been extensively used for the teaching of courses in Marine Biology, Coral Reef Ecology, Zoology, Coastal Management, Biology of Coastal Plants and Conservation Biology, among other disciplines. The Department of Life Sciences to which the laboratory is directly attached has 35 percent (14) of its courses and 46 percent (~ 250) of its students benefitting directly for access to habitats of and specimens from the Kingston Harbour and its environs through the PRML.

The Caribbean Maritime University has expanded in size and value since its founding in 1980, with the offering of Shipping and Logistics, Engineering and Applied Technologies, Marine and Nautical Studies as well as Advanced Skills and Professional Development to over 1,000 students (http://cmu.edu.jm/academics/faculties-divisions/). The students are not only taught through direct access to the harbour but student dormitories have now been constructed on the base of what was previously the Admiralty houses located east of the Morgan's Harbour hotel. The CMU students have changed the atmosphere

of the once sleepy town of Port Royal and cookshops and other businesses now thrive due to their daily presence. However, the need created for increased garbage disposal systems is not always met.

Public Education and Outreach Use

The harbour and its ecosystems are used extensively in community outreach and education about ecosystems and biodiversity, their value and threats. NGO, CBO and various educational institutions take students and adults to the source of hands-on learning on the shores of the Kingston Harbour. One of the major hosting facilities is The University of the West Indies' UWI/EFJ PRML Biodiversity Centre which was added to the infrastructure of the long-existing Port Royal Marine Laboratory in 2010 (Figure 2.3). The facility, as an interactive Biodiversity Centre, houses displays of mangroves, seagrass and coral reefs which show the inter-relatedness of these coastal systems. The Centre's display includes information about the harbour and its environs and highlights marine life found in Jamaican waters with a focus on those found in the waters of the harbour and its mangroves. The Centre has aquaria and an extensive touch-tank (Figure 2.4) which allows children as well as adults to handle/touch animals like sea stars, sea urchins, crabs and unusual creatures like sea cucumbers (called the sea penis by locals) while they learn how these creatures help to maintain the unique ecosystems found in Jamaica.

The Centre's live displays which were designed to engage and educate especially children, has weekly visits of over 200 students, some as young as three years old. The objective is to reach the youth who not only are the future but who will help to educate their parents about the value of and need to conserve our coastal and marine systems so they can benefit generations to come. Currently, the Biodiversity Centre also offers tour packages to older students, inclusive of a Mangrove talk and boat

tour (directly using the Port Royal mangroves), and a Pollution boat tour which focusses on the pollution of Kingston Harbour. These tours allow students to take direct measurements of water quality, learn sampling techniques using the mangroves and sand-dunes on the shores of the Kingston Harbour. The Biodiversity Centre tour is based at the laboratory and makes use of the indoor and outdoor displays. The outdoor display includes a miniature mangrove forest (Figure 2.5) that was developed using seedlings from the mangrove nursery located on the property.

Figure 2.3
The Biodiversity Centre at The UWI's Port Royal Marine Lab at its launch
Credit: Spaldings Photo Service

Research Use

Kingston Harbour has supported invaluable research, conducted by premier researchers, commencing as far back as the early 1900s, and it continues to be a research platform for Jamaican and other scientists from all over the world. If these researchers were painters, one could say that Kingston

Harbour is their prized canvas. The harbour offers unique and varied opportunities for scientific research and has, therefore, attracted the well-needed attention of local and international scientists at the highest level of academia.

Figure 2.4
Indoor display with aquaria and touch-tank inside the Biodiversity Centre
Credit: Hugh Small

The Kingston Harbour has been the subject of major biological, ecological, physicochemical and modelling studies conducted over many years. This research has been and continues to be supported by The University of the West Indies' Port Royal Marine Laboratory. The Laboratory is ideally situated at the end of the Palisadoes tombolo and within easy reach of a number of habitats. The Port Royal Cays and Hellshire coast provide coral reef, seagrass and mangrove habitats in relatively pristine conditions. The water column of the harbour and adjacent areas also provide the opportunity for study of planktonic communities which are not only important for forming the base of many marine food chains/webs but also serve as useful indicators of eutrophication.

Figure 2.5
Miniature mangrove forest at the PRML Biodiversity Centre
Credit: Mona Webber

Several biological parameters and ecosystem indicators have been studied over the years and have been used to gauge the environmental health of Kingston Harbour. Table 2.2 lists some of the significant biological attributes studied and major conclusions drawn about the environmental health of Kingston Harbour.

Table 2.2
List of major biological studies conducted on Kingston Harbour

Year	Researcher	Parameter	Significance and Major Findings
1892	Andrews	Mangroves	First recorded study of the area
1944	Chapman	Mangroves	Zonation defined
1961	Goodbody	Marine fauna	Mass mortality of sedentary marine animals has resulted from reduction in surface salinities in the harbour after extensive periods of rain
1965	Steven	Algae	Algal blooms are responsible for the phenomenon known as red tides prior to massive fish kills
1967	Warner	Crustaceans	Twelve species of crabs identified in the mangroves
1968	Government of Jamaica	Coliform bacteria	Inner Harbour and Hunts bay are polluted
1968	Goodbody	Planning development	Expanding physical development around the Kingston Harbour (Dawkins Pond) will negatively impact the harbour
1972	Wade	Benthos (seafloor)	Species diversity linked to environmental stress conditions. Diversity increases as environmental stress decreases
1972	Wade	Coliform bacteria	Inner Harbour, Buccaneer Beach, Dawkins Pond and Hunts Bay are polluted. Low diversity in coliform species is indicative of severe environmental stress conditions
1976	Wade	Pollution stress	Port Royal area is subjected to severe pollution stress
1982	Harvey	Fish	Kingston Harbour pelagic fishery described
1985	Chin	Crustaceans	Crabs and shrimp of commercial value
1990	Alleng	Mangroves and Birds	Kingston Harbour (in particular Refuge Cay, is an important nesting area)

1993	SENTAR	Coliform bacteria	Kingston Wharves, Newport East, Port Royal and Hunts Bay are polluted
1993	SENTAR	Crustaceans	Overall decrease in production of penaeid shrimp in the Kingston Harbour
1993	SENTAR	Fish	No benthic species observed
1993	Goodbody	Ascidian fauna	8 Ascidian species have disappeared from Fort Rocky Lagoon (Kingston Harbour) between 1966 and 1993 due to significant environmental changes (development of wetlands for housing and construction of the causeway)
1996	Green and Webber	Solid waste in the Port Royal mangroves	The first study published on the contamination of the Port Royal mangroves by solid waste
1997	Alleng	Mangal fauna	314 species recorded throughout the Port Royal mangroves
1998	Webber and Webber	Planktonic communities	While physical variables indicated little change in harbour waters and chemical variables indicated significant but erratic changes, the planktonic communities displayed characteristics of eutrophication. Twenty years since the initial ecological assessment in 1971, phytoplankton biomass was 5 to 10 times greater than in 1971. Zooplankton abundances were 4 times greater. The composition of both communities had altered and there were fewer taxa than previously found
2003	Creary	Bryozoa	Key developed
2006	Jackson	Sponges	New species described from Port Royal mangroves
2009	Aiken	Fish	Kingston Harbour functions as nursery for the 21 fish species identified

2014	Francis, Maxam and Webber; Liu, Bromfield, Duncan, Grant, Francis, Webber.	Rapid ecological assessment of Kingston Harbour five years after Soapberry and 15 years after previous baseline	Plankton showed change throughout the harbour compared with 1990s studies with areas near the outflow for the Greenidge and Western sewage treatment plants having highest nutrients and plankton. Sewage treatment plants were either still being used in 2011 or the sediments of the Kingston Harbour were now a source with the most contaminated sediments (near outfalls) providing significant nutrients. Water quality showed no change in BOD5, coliform and nitrates between the 1990s and 2011.
2014	Buddo, Steele and Webber	Invasive mussel	Invasion of Kingston Harbour by *Perna viridis* (Indo-Pacific green mussel)
2015	Green, C.	Refuge Cay birds	First study linking mangrove forest structure with solid waste and birds on Refuge Cay
2017	Galbraith-Smikle	Benthos	Repeat of Wade's 1995/96 study. Only meiofauna found in the Kingston Harbour sediments; loss of macrofauna from most areas

It is true to say that the Kingston Harbour is as famous for its pollution history as it is for its contribution to the field of research in Jamaica. Many well-published as well as aspiring researchers have dipped and waded and have come out with fruitful, informative and instructive literature on the various facets relating to the pollution of the harbour, sources of pollution, effective measures of pollution and solutions to the problem. In 2003, the auspicious *Bulletin of Marine Science* dedicated its Volume 73 Number 2 edition to a collection of studies edited by Webber and Webber (2003), and which were conducted from the Port Royal Marine Laboratory, on the status of the Kingston Harbour, Jamaica, in relation to continued organic pollution (Table 2.3).

Table 2.3
Contents of the *Bulletin of Marine Sciences*,
special volume on Kingston Harbour

Authors	Title of Paper and page numbers
Goodbody, Ivan	Kingston Harbour, Jamaica – An Overview pp. 249–256 (8)
Webber, Dale F.; Kelly, Peter Wilson	Characterization of sources of organic pollution to Kingston Harbour, the extent of their influence and some rehabilitation recommendations pp. 257–271 (15)
Webber, Dale F.; Webber, Mona K.; Williams, Doreen D.	The relative importance of meteorological events, tidal activity and bathymetry to circulation and mixing in Kingston Harbour, Jamaica pp. 273–289 (17)
Bigg, Grant R.; Webber, Dale F.	The impact of coastline change and urban development on the flushing time of a coastal embayment, Kingston Harbour, Jamaica pp. 291–305 (15)
Ranston, Emma R.; Webber, Dale F.	Phytoplankton distribution in a highly eutrophic estuarine bay, Hunts Bay, Kingston Harbour, Jamaica pp. 307–324 (18)
Ranston, Emma R.; Simmonds, Rose-Marie A.; Webber, Dale F.	The phytoplankton distribution in Kingston Harbour, Jamaica pp. 325–342 (18)
Dunbar, Francine N.; Webber, Mona K.	The phytoplankton distribution in Kingston Harbour, Jamaica pp. 343–359 (17)
Webber, Mona K.; Webber, Dale F.; Ranston, Emma R.; Dunbar, Francine N.; Simmonds, Rose-Marie A.	Changes in water quality and plankton of Kingston Harbour, Jamaica, after 20 years of continued eutrophication pp. 361–378 (18)
Persad, Gale; Hopcroft, Russell R.; Webber, Mona K.; Roff, John C.	Abundance, biomass and production of ctenophores and medusae off Kingston, Jamaica pp. 379–396 (18)
Hopcroft, Russell R.; Roff, John C.	Response of tropical marine phytoplankton communities to manipulations of nutrient concentration and metazoan grazing pressure pp. 397–420 (24)

Harvey, Guy C. McN.; Goodbody, Ivan; Aiken, Karl A.	The artisanal thread herring fishery of Kingston Harbour: A review pp. 421–432 (12)
Buddo, Dayne St. A.; Steele, Russell D.; D'Oyen, Emma Ranston	Distribution of the invasive Indo-Pacific green mussel, *Perna viridis*, in Kingston Harbour, Jamaica pp. 433–441 (9)
Green, Sean O.; Webber, Dale F.	The effects of varying levels of eutrophication on phytoplankton and seagrass (*Thalassia testudinum*) populations of the southeast coast of Jamaica pp. 443–455 (13)
Goodbody, Ivan	The ascidian fauna of Port Royal, Jamaica I. Harbour and mangrove dwelling species pp. 457–476 (20)
Creary, Marcia M.	Spatial distribution of epibenthic bryozoans found on the roots of *Rhizophora mangle*, Kingston Harbour, Jamaica, W.I. pp. 477–490 (14)
McDonald, Kerrine O.; Webber, Dale F.; Webber, Mona K.	Mangrove forest structure under varying environmental conditions pp. 491–505 (15)
Thompson, Heather P.; Webber, Dale F.	The sand dune ecology of the Palisadoes, Kingston Harbour, Jamaica pp. 507–520 (14)
Creary, Marcia M.	A simplified field guide to the bryozoan species found on the roots of the red mangrove (*Rhizophora mangle*) in and around Kingston Harbour, Jamaica, W.I. pp. 521–526 (6)

Notably, the conclusions drawn from the comparative studies have all indicated that there has been a general decline in the environmental health of Kingston Harbour since the 1960s. Coliform concentrations, crustacean, fish and plankton abundance, as well as seagrass densities all point towards a deteriorating ecosystem. Many of the researchers attributed this decline to increased nutrient concentrations in the harbour introduced by the numerous Kingston gullies, some of which directly received untreated sewage from malfunctioning sewage treatment plants.

Urban Influences on Kingston Harbour

Kingston Harbour is bordered by urban developments: to the north, the city of Kingston; to the west, Hunts Bay and the municipality of Portmore; to the east, Harbour View, and to the south and south-west, the Palisadoes, consisting of several commercial developments and the town of Port Royal. The harbour has always been "directly connected" to the city of Kingston, with the influence on the harbour and its communities growing at pace with the expanding city. The network of now 19 major gullies which traverse the city (and its environs), and enter the harbour via its northern shore, were designed to quickly remove storm water and prevent flooding of the city. These have, over the years, grown to become a major source of pollution and degradation of the harbour. Figure 2.6 shows where storm-water drains or gullies (indicated by letters A–T, inclusive) enter the Kingston Harbour along the northern shore.

Excess nutrient pollution (eutrophication) has been extensively described as the leading cause of the decline and degradation of the Kingston Harbour. Water quality had been shown to be in decline from as early as the 1960s and has become progressively worse over the years. A plethora of published scientific studies, as we showed in the previous section, have diagnosed the ailing Kingston Harbour as significantly polluted with many signs of failing health owing to excess and growing anthropogenic influences.

In addition to nutrient pollution, the Kingston Harbour has also, from time to time, been contaminated by incidental releases from industrial facilities on its periphery from incidents such as oil spills and chemical spills. Discharge of ballast water, oily waste and garbage from ships are also thought to contribute to the pollution of the harbour.

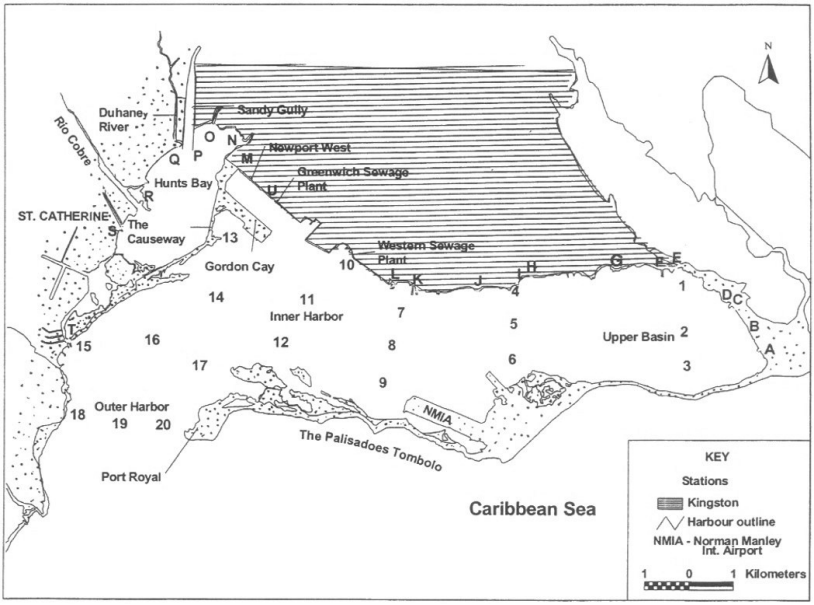


Figure 2.6
Position of gullies (A–T) entering Kingston Harbour. Numbers (1–20) represent stations sampled during the ecological assessment of the harbour (Webber and Wilson-Kelly, 2003).

A. HBV – Gully at Harbour View; B. TML – Thermal Discharge Cement Co. Ltd.; C. SS – Discharge from Carib Cement Company; D. CWE – Gully East of Cement Company; E. CWW – Spring West of the Cement Company; F. SHC – Rockfort Creek; G. MTN – Mountain View Gully; H. BEL – Bellevue Gully; I. RAE – Rae Town Gully; J. GPW - General Penitentiary (Barnes Gully); K. JPS – Tivoli Gully; L. PET – Gully east of Petrojam Oil Refinery; M. JEW – Jew Gully; N. DEN – Gully at Desnoes and Geddes factory; O. TIA – Gully adjacent to Tia Maria; P. SAN – Sandy Gully; Q. DUH – Duhaney Gully + Fresh River; R. RIO – Rio Cobre; S. JAM – Sewage Outfall at Jam World Entertainment Centre; T. SOU – Gully adjacent to Portmore Sewage Treatment plant

The Dynamics of Urbanization

One of the root causes of the environmental problems of Kingston Harbour is urbanization. Urbanization refers to the general increase in population and the amount of industrialization of a settlement. Jamaica has a population of approximately 2.7 million people (STATIN, 2017). The Kingston Metropolitan Area, which consists of the central business district

of Kingston and the surrounding urban areas in the parishes of St. Andrew and St. Catherine, is estimated to have a population exceeding 1 million. The entire population of Kingston makes use of the Kingston Harbour either directly or indirectly. There are densities of over 18,000 people/square mile in some small areas of the Kingston Metropolitan Area. This, therefore, has enormous implications for the health of the Kingston Harbour which, up to today, receives sewage effluent from the major sewage treatment facility serving Kingston and St. Andrew.

The Jamaican population is highly dependent on its natural resource base for both economic development and quality of life. The wise use of the country's natural resources is thus of critical importance to current and future generations of Jamaicans. This is where sustainable development comes into play. The 1987 Brundtland Report on the environment and development defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". When applied to the Kingston Harbour, it can be defined as the use of the resource without causing the degradation of the marine ecosystem or a reduction in the overall health and aesthetic appeal of the area.

It is important to recognize that as countries develop they tend to increase their consumption of environmental resources. Waste disposal and transportation are just two of the means of "consuming" the Kingston Harbour in order to allow for increased economic activity of industries and the city on a whole. For a vulnerable ecosystem such as the Kingston Harbour, even a moderate level of consumption or use tends to cause environmental strain.

The development of Portmore is located in the vicinity of Dawkins Pond and Hunts Bay and is, perhaps, the largest single development that we might see in the area. It is economically and socially desirable (Goodbody, 1968) and consists of

approved residential, commercial and industrial uses which also impact the ecological resources of the Kingston Harbour. Construction of the Portmore community commenced as early as 1969 with the first scheme, Independence City. Following that, several communities were erected over the ensuing 20 years or so (Table 2.4).

Table 2.4
Evolution of Portmore city

Portmore Housing Schemes	Year Erected
Independence City	1969
Edgewater Villas	1972
Bridgeport, Phases 1 and 2	1974
Passage Fort	1974
Waterford	1975
Bridgeport, Phase 3	1976
Portsmouth	1978
Southborough	1979
Cumberland	1980s
Westchester	1980s
Westbay, Phases 1 and 2	1980s
Westbay, Phase 3	1990s
Greater Portmore	1990s

Fewer than 2000 people were living in the Portmore area when developers started construction in the late 1960s (MGI, 2019). By 1970, there was a sharp increase to about 5000 people. In the 1980s, more schemes were constructed as Cumberland, Westchester, and Westbay Phases 1 and 2 were erected. During this period, it is estimated that approximately 77,000 people were residing in Portmore. The beginning of the 1990s saw the construction of Westbay Phase 3 and Bridgeview, with an increase of units at Cumberland. This contributed to growth in the already booming population as it is noted that approximately 93,838 people were residing there. The construction of Greater Portmore in the mid-1990s saw an escalation in population and

the number of residents in Portmore almost doubled to roughly 160,000. Along with the housing schemes came schools, a town centre, churches, and other facilities. As a result of the rapid development, a bill was passed granting Portmore municipal status in 2003. By far, the most considerable aspect of the development of Portmore is its status as the largest residential area in the Caribbean, with over 200,000 residents (Figures 2.7, 2.8a and 2.8b).

The build-out of Portmore over the decades parallels the increase in population over time. Google Earth images clearly show the extent of the expansion between the years 1984 and 2014 (Figure 2.9). As the urbanization of Portmore increased, so did its impact on the Kingston Harbour. The construction of the causeway bridge served to restrict circulation within Hunts Bay and to reduce tidal exchanges between Hunts Bay and the rest of the Kingston Harbour. The restricting of circulation may contain sediments and pollutants that quickly settle out of the water to the sea floor but dissolved or floating contaminants stream out of the bay and into the general areas of the harbour on a daily basis. Indeed, as was seen during the June floods of 1996, under high flow, Hunts Bay's silt-laden waters "stream" across the harbour to the Palisadoes and Port Royal mangroves (Webber et al., 1992).

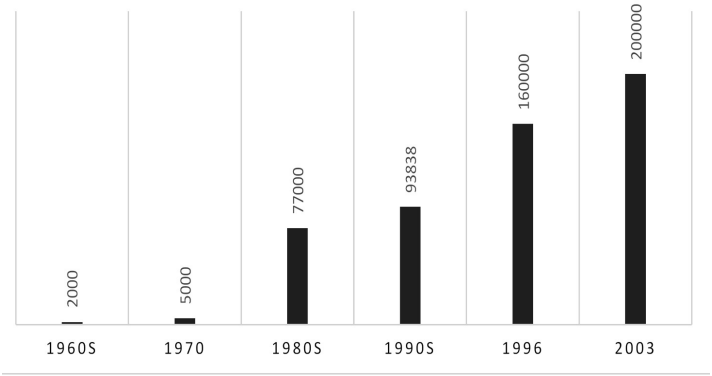


Figure 2.7
Population growth of Portmore city, St. Catherine

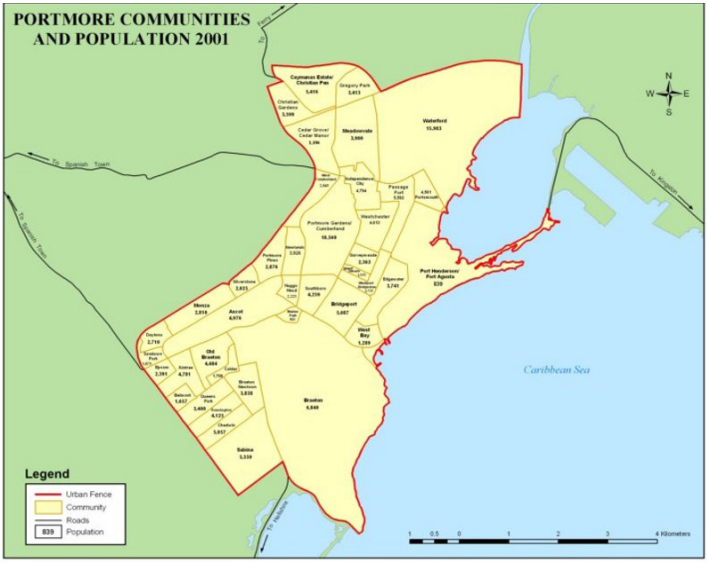


Figure 2.8a
Map of Portmore communities and their population (2001)
Source: STATIN

Figure 2.8b
Map of Kingston Metropolitan Area, 2005
Source: Planning Institute of Jamaica

Figure 2.9
Images showing land-use changes from 1984 to 2014 in the urban areas which drain into the Kingston Harbour. Drastic changes during the development of Portmore are encircled

Environmental Impacts of Urbanization

Urbanization spurs a unique set of issues affecting both humans and the environment. As urban populations interact with their environment, changes occur through their patterns of consumption as well as waste generation. Rapid urbanization, if not properly planned, can lead to degradation of natural resources via eutrophication and solid-waste pollution.

Pollution of the harbour waters has been alluded to from as early as 1968 through research conducted by David Steven who founded The UWI's Port Royal Marine Laboratory (Steven 1968). This indicates that by the 1960s, levels of production (for phytoplankton communities) within the harbour were 50 time as high as that encountered in the water column of the open ocean. Ecological assessments conducted in the early 1970s confirm that the Kingston Harbour was experiencing increasing levels of organic pollution at the time.

As indicated above, the harbour is the main receiving water body for the city of Kingston, accepting inflows from adjacent rivers, gullies, industrial and commercial facilities, as well as sewage treatment plants. As the home to the island's primary port facility with large volumes of marine traffic, the harbour is also exposed to associated vessel-generated wastes and pollutants. The gradual deterioration in the state of Kingston Harbour because of pollution from various sources (sewage, solid waste, urban/river run-off and industrial waste) is directly associated with the large metropolitan area and large number of industrial complexes on its mainland coast.

The city of Kingston lies on the Liguanea Plain and is drained by several gullies and rivers into the adjacent Hunts Bay. The rivers, in particular the Rio Cobre, which drains agricultural lands, are potential sources of excess agrochemicals, inclusive of pesticides, to Hunts Bay. The major and minor storm-water gullies draining residential and industrial areas of the city of Kingston carry solid waste as well as heavy metals and

other contaminants which are also deposited in the harbour. Pollutants in these channels are brought to the bay and harbour from far and wide (Table 2.5 and Figure 2.10) which, because of the semi-enclosed nature and low tidal action, are not actively flushed by natural ocean currents.

Spawning from the dynamics of urbanization, the main degrading impacts on the Kingston Harbour are eutrophication, sedimentation, and solid waste build-up. These factors are made more impactful by the natural ecological design and the tidal dynamics of the harbour (Figure 2.11).

Table 2.5
Major gullies and the area they drain (feeder areas)
Source: Mona GeoInformatics Institute

Name	Area (km)
Sandy Gully	52.47
Hope River	9.30
South Camp Road/Barnes	6.48
Old Hope Road/Jacques	6.19
Jew Gully	5.84
Balmagie	5.81
Mountain View	4.79
Shoemaker Gully	2.97
Admiral Town/Tivoli	2.25

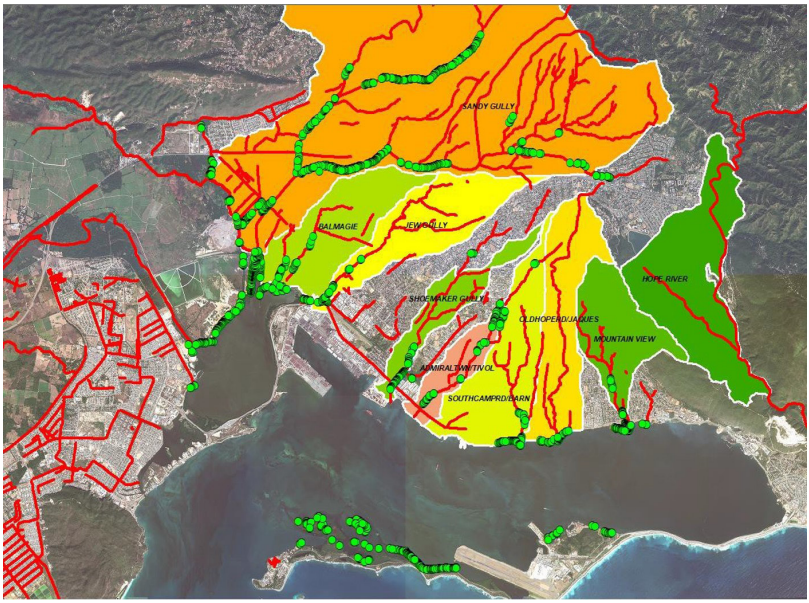


Figure 2.10
Major gullies and the areas they drain (feeder areas)
Source: Mona GeoInformatics Institute

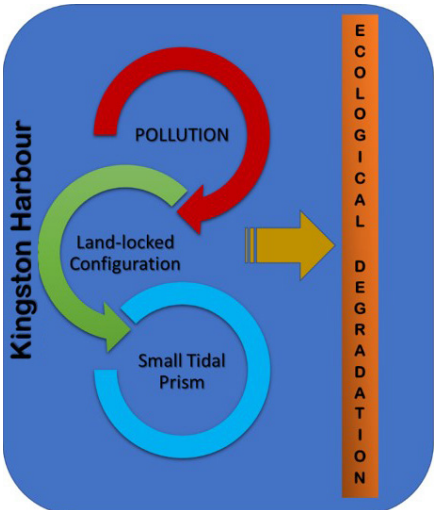


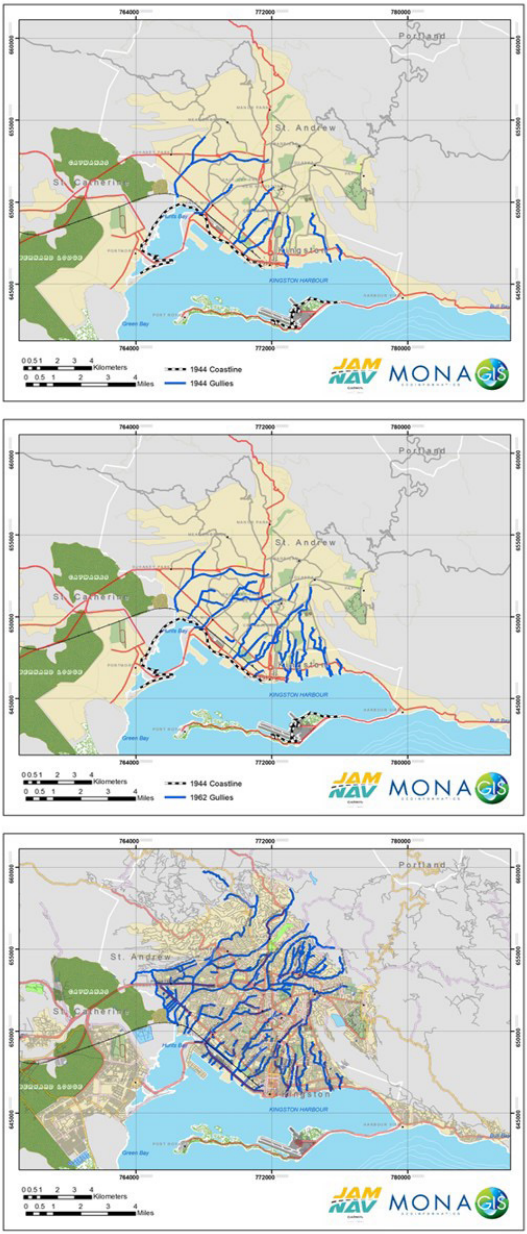
Figure 2.11
Ecological degradation of the Kingston Harbour exacerbated

Eutrophication

The most visible manifestation of the degradation of water quality of the harbour is the frequent recurrence of local **eutrophication**, a condition which develops when there is excessive fertilization of a body of water. Eutrophication leads to depletion of oxygen, causing general deterioration of water quality, foul odour, taste, and decline of biodiversity. "Red tides" or algal bloom is the extreme stage of eutrophication. Red tides have become frequent in the Kingston Harbour, at especially the Upper Basin where the harbour "bottle-necks". Since its inception, the storm-water network has expanded at the same pace as the increased urbanization of the Kingston Metropolitan Area (KMA) (Figure 2.12).

Eutrophication – excessive richness of nutrients in a body of water, frequently due to run-off from the land, which usually leads to dense growth of plant life.

Environmental studies conducted historically showed high levels of faecal coliform bacteria present around the entire harbour and elevated levels of heavy metals in fish. There are also troubling levels of pesticide residues in fish from the harbour as a result of the agricultural runoff being deposited there. Nitrogen levels measured in the harbour are high, which is an important consideration because nitrogen and phosphorus are principal factors in supporting algal growth and, thus, eutrophication of the harbour. Webber and Wilson-Kelly (2003) found that sewage was a major contributor to eutrophication in the Kingston Harbour (Figure 2.13).



1944

1962

current

Figure 2.12
Map showing increase over 75 years in the extent of the storm-water gully network in the KMA
Source: Mona GeoInformatics

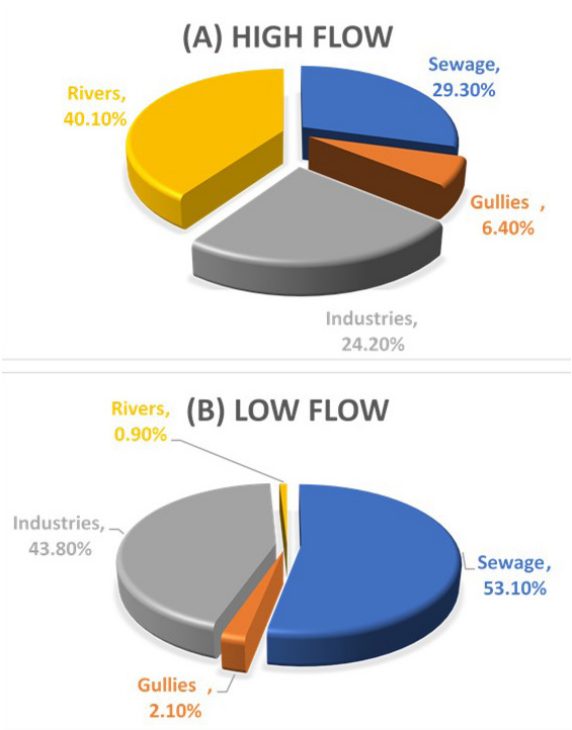


Figure 2.13
Contributors to Biological Oxygen Demand BOD (mg L^{-1})
to Kingston Harbour

The principal source of the nutrients and faecal coliform in the harbour is sewage. Before 2008, poorly treated sewage and sludge from the city was deposited in the Kingston Harbour as most of the area's sewage treatment plants were then out of service and were only providing primary treatment of waste (if any treatment at all) before disposal into the harbour. Heavy metal deposits, mainly from industrial discharges, are also disposed of in the harbour.

One of the major constituents of municipal sewage is decomposable organic material that reduces the amount of dissolved oxygen in the water column, ultimately leading to anoxia (absence of oxygen), which is detrimental to the health

of the marine ecosystem and its organisms. The deposition of sewage in the Kingston Harbour also introduces pathogens such as bacteria and viruses into the ecosystem and poses health risks to humans who use the resource. Some of the pollutants introduced into the harbour are often directly toxic to marine organisms (causing fish-kills, for example) and can result in diminishing carrying capacity of the vulnerable marine ecosystem.

The driving force for Kingston Harbour's high productivity was found to be nutrient enrichment from high sewage inflows of treated or untreated effluent. Extensive work done by Ranston and Webber (2003), Wade et al. (1972), Steven (1968), and Munro (1968) indicate that increased levels of nutrient enrichment had negatively impacted excessive productivity in phytoplankton communities with expanding impact to **benthic** communities. This was found to result in the development of an **abiotic** zone in the sediments of the Upper Basin of the harbour.

Abiotic – physical rather than biological and not derived from living organisms. In Biology and Ecology it refers to non-living (chemical and physical) components or factors of the environment.

Benthic – of, relating to, or occurring at (on or in) the bottom of a body of water (sea, lake or river).

Sedimentation

A common feature of important coastal lands is the re-routing of storm-water runoff and rivers. In the case of the Kingston Harbour, the gully systems are lined with a concrete spillway to the Hunts Bay or the harbour proper. This ensures their channelled deposits enter the coast at specific points while removing the opportunity for the natural infiltration and percolation required to recharge the aquifer. The concretized path also results in a more rapid and violent release of run-off from land and thereby increases sedimentation. Sedimentation

also occurs during the construction phases of the numerous coastal urban infrastructures. The fact that the city is located along the coast means that the harbour is especially susceptible to pollution from the anthropogenic waste generated due to urbanization.

Sand mining, deforestation and poor farming practices lead to soil erosion in the watershed area of the Rio Cobre. The sediment is transported by the river and deposited in the Hunts Bay adjacent to the Kingston Harbour. The Rio Cobre is also a source of industrial and agricultural pollutants from upstream which lead to the further deterioration of water quality in the harbour environment. Studies conducted in the region indicate that the Rio Cobre has the largest negative impact on siltation of the harbour (http://nepa.gov.jm/projects/kingstonharbour, 2004). This has long-term implications for the sustainability of efforts to rehabilitate the harbour. Dredging is another activity, which is potentially detrimental to this coastal marine environment. Deposition of sediment from dredging has adverse effects on coastal water basins and can severely degrade the carrying capacity of large areas of the harbour floor and especially its seagrasses. Up to as late as the 1980s, material dredged from the adjacent ship channel was unashamedly dumped on the Mammee Shoals, providing a temporary island of soft mud, on which birds were seen to perch until wave action re-deposited it from whence it came. Sedimentation can also result from illicit (construction) deposits made in the storm-water gully network which wash out into the harbour during rainfall events.

Few studies have directly measured the relative causes of sedimentation in Kingston Harbour because the effect is usually associated with flooding or high rainfall events, however, Webber and Kelly (2003) identified sewage entering the Kingston Harbour as the major cause of total suspended solids (TSS) under both high flow (flood) and low flow conditions

(Figure 2.14). Suspended solids which eventually settle to the sediment have been identified as the leading cause of death of the harbour's bottom communities.

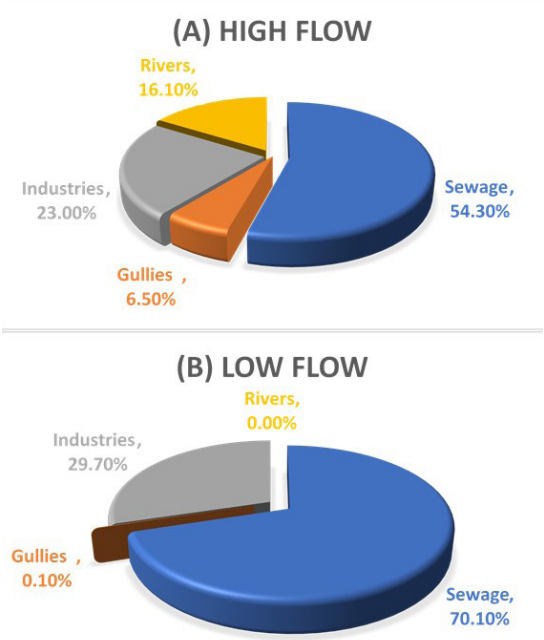


Figure 2.14
Contributions of total suspended solids (TSS) (mg L^{-1}) to the Kingston Harbour
Source: Webber and Kelly, 2003

Few studies have directly measured the relative causes of sedimentation in Kingston Harbour because the effect is usually associated with flooding or high rainfall events, however, Webber and Kelly (2003) identified sewage entering the Kingston Harbour as the major cause of total suspended solids (TSS) under both high flow (flood) and low flow conditions (Figure 2.14). Suspended solids which eventually settle to the sediment have been identified as the leading cause of death of the harbour's bottom communities.

Kingston Harbour's Plastic Pollution Problem

Estuarine ecosystems, as is the Kingston Harbour, have become increasingly threatened by pollution from solid waste that washes out from land via natural and manmade sources. The growing influence of solid waste on the Kingston Harbour (first documented by Wade in the 1970s) has now mushroomed into a constant rain of plastic and other debris that threatens the aesthetics, commercial activity and biodiversity of the entire harbour ecosystem (Figure 2.15a and b).

Figure 2.15a and b
Solid waste, mainly plastic on the Kingston Harbour shoreline near the Gun Boat Beach mangrove replanting site (a) and in the mangroves on Refuge Cay (b)
Credit: Paul Kisson

Marine debris (also called marine litter) has been the subject of research for decades and we now know the major categories and, alarmingly, that there is a universal dominance of plastics. Since its genesis in the 1950s, an estimated 8.3 billion tonnes of plastic has been produced to date worldwide and only fractions of this amount are tallied through efforts such as coastal clean-ups and other recovery activities. In the 2016 International Coastal Cleanup Report, 230,550 items of marine debris were

recovered from Kingston Harbour and its environs. This number continues to grow every year with the 2018 tally being over 600,000 items (Table 2.6), with large proportions of the material being comprised of plastic and Styrofoam (JET, 2018).

The dominance of plastics and Styrofoam in the environment is alarming as these materials are comprised of polystyrene, polyethylene and other chemicals which are toxic to humans and animals and can have far-ranging effects, even in small quantities. Larger marine animals are often victims of entanglement, choking, malnutrition and premature death as a result of their encounters with large pieces of plastic debris during feeding and locomotion.

The 19 gullies of Kingston, which were designed to carry storm-water, and which later carried untreated sewage, have now become infamous for the portage of indescribable quantities of solid waste, from plastic bottles/bags and Styrofoam food containers to refrigerators/freezers, tires and trees/logs cut from the forests. Kingston Harbour is now under a new threat. Ecosystems like the mangroves and seagrasses as well as the water column and sea floor are fouled, and during high rainfall the material even entangles propellers and impedes shipping. Plastics have been shown to suffocate mangrove seedlings, mangrove trees and forest habitats as well as associated animals, like birds. The large volume of debris will render the harbour useless for commerce, research, teaching, outreach and recreation. It threatens to smother the whole system, causing almost irreversible damage to this valuable resource.

The amounts of solid waste entering the harbour are difficult to quantify routinely but activities like International Coastal Cleanup (ICC) days provide an opportunity for the scale of the problem to be demonstrated. Data from the 2017 ICC indicates that in a single day, over 300,000 items of solid waste material was collected, representing a 34 percent increase over

the previous year, from 5 fewer locations. In 2018 locations were more than doubled and, as expected, the total solid waste collected did the same. However, in 2018 when the abundances were converted to numbers per location, the quantities of plastic bags and Styrofoam boxes were respectively, 5 and 4.7 times that collected in 2017 (Table 2.6).

Table 2.6
Summary results from coastal clean-up collection data for Kingston and St. Andrew

	2016	2017	2018	2016	2017	2018
Locations	25	20	52	**Numbers per unit location**		
Total	230,550	309,060	639,184	9,222	15,453	12,292
Plastic bottles	86,659	155,579	263,398	3,466	7,779	5,065
Plastic bags	4,382	3,468	45,263	175	173	870
Styrofoam	3,197	4,697	57,128	128	235	1,099

The avalanche of solid waste near the end of each gully system leads to blockage and has resulted in several incidents of flooding with one of the most noteworthy being in November 2016, when sections of Marcus Garvey Drive were flooded by the blocked Shoemaker Gully. The result was previously unexperienced overflow that flooded the Fisheries Division of the Ministry of Industry, Commerce Agriculture and Fisheries inside and out, destroying everything from cars to decades of irreplaceable fisheries data. The gully-overflow destroyed the consignment of export-bound products at the Wallenford Coffee Company, disrupted activities at other businesses and crippled the road transportation system.

Data on the volumes of solid waste that exist in the gully network that empty into Kingston Harbour has been presented by Mona GeoInformatics (MGI) to illustrate the magnitude of the problem (Figure 2.16). The MGI “waste-scape” also serves to indicate how endless the solid waste stream has become. As

soon as the masses (circles) near the mouth of the gullies are discharged, another load takes its place and the continuum is evident all along “from gully top to gully bottom”.

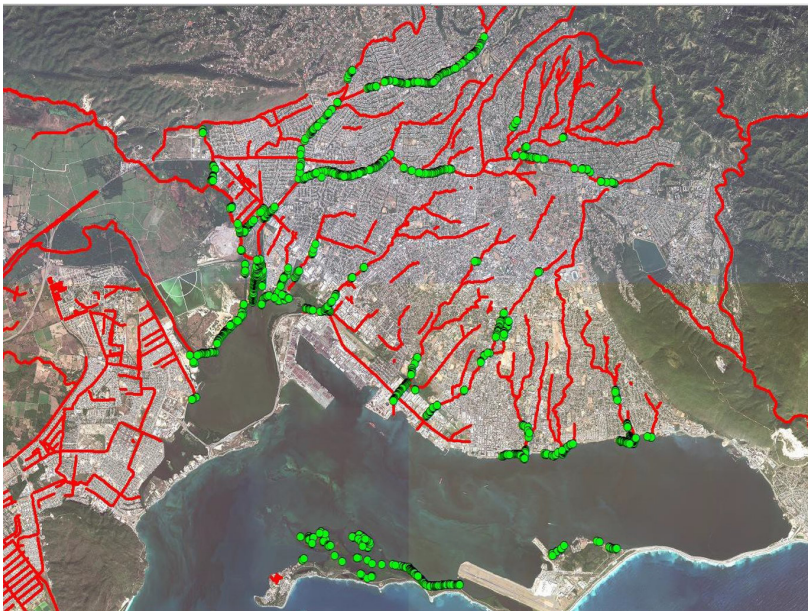


Figure 2.16
Debris (circles) on the shores of the Kingston Harbour
and along the gully network (thick red lines)
Source: Used with the permission of Mona GeoInformatics (MGI)

Marine Debris and Microplastic Pollution

The problem of plastics in marine environments like Kingston Harbour becomes even greater when the plastic breaks up through the action of waves and sunlight into smaller and smaller particles (of plastic) and become what we call microplastic debris. Microplastic is generally defined as plastic particles that have at least one dimension less than 5 mm (Rose and Webber, 2019). They either enter the water as primary microplastics, which were manufactured as tiny microbeads such as those used in cosmetics, or secondary microplastics,

which fragmented from larger debris (such as plastic bags/bottles and Styrofoam). At a size of 5 mm or less, the plastic and Styrofoam fragments floating in the water can be mistaken for food and will be ingested by smaller marine organisms, especially filter feeders that dominate the mangroves.

While microplastics have been documented in marine environments worldwide, they have never been assessed in Jamaican waters. A study was therefore designed to investigate quantities of microplastics in Kingston Harbour because these waters were expected to yield detectable amounts due to the large quantities of plastic and Styrofoam debris found in the mangroves and shores of the harbour. The study assessed the quantities of microplastics as well as plankton because microplastics are the same size as the plankton normally eaten by marine life and it is important to know how the relative quantities compare in our waters so encounter rates (by feeders) can be assessed.

Microplastic marine debris in Kingston Harbour and its mangroves was first assessed between February and May 2017 (Webber et al., 2018) using a modified plankton net (Figure 2.17a) at six stations near the mangroves as well as a control station outside the harbour. Results indicated that there was significant spatial variation across the stations with the greatest concentration of microplastics being found at the station near Gun Boat Beach (adjacent to a mangrove replanting site), while, beside the control station, the lowest abundance of plastics was near the Royal Jamaica Yacht Club. The mangrove stations (near Refuge Cay, Little Refuge Cay and Gallows Point) were all similar with intermediary abundances. The types of microplastics found (fragments, foam, fibres, beads) were very different in abundances with fragments (87 percent) assumed to be from plastic bags being the greatest proportion, followed by foam fragments (9 percent) and then fibres (assumed to be from rope/fabric), being 4 percent. No microbeads were found in Kingston

Harbour in the preliminary study. However, on one occasion during the study, at the station near Gun Boat Beach, one in four particles collected from the water were microplastics.

A second, confirmatory study, conducted fortnightly from September to December 2017, benefitted from the loan of the internationally-accepted device used to sample microplastics in the water column, a manta trawl (Figure 2.17b).

The manta trawl was a loan to The UWI as part of the 5Jyres Trawl Share programme. The arrangement required the researchers to supply data to the global database on marine microplastics. The results revealed microplastic particles in Kingston Harbour as high as 2,697,674/km^2 or a mean of 359,593 /km^2 (Rose and Webber, 2019). Stations were not significantly different but showed high fortnightly variability. While Kingston Harbour was not among the highest globally it compared to other heavily polluted bays. Global comparisons of microplastic quantities are still difficult to interpret because each water body is unique based on hydrodynamics, loading and efficiency of sampling equipment.

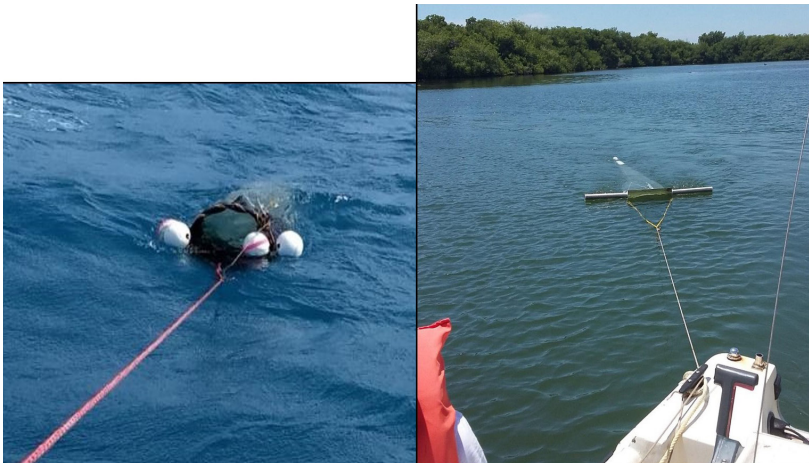


Figure 2.17a and b
Modified plankton net (a) and manta trawl (b) being used in the Kingston Harbour mangroves
Credit: Deanna Rose

The material collected from the Kingston Harbour waters had a range of colours, sizes and types (fibres, flakes), and one sphere (microbead) was found. Infrared spectrometry was able to identify the source material from which the particles originated. This study in Kingston Harbour is significant in that it is a first for Jamaican waters and we now have a baseline against which to judge the effectiveness of the plastic reduction efforts.

More research is needed to contemporaneously sample the sediments and organisms in the harbour, because while microplastic contamination has been seen in planktivorous fish using staining techniques on fish gut contents (Figure 2.18a and b), the levels cannot be quantified without further research.

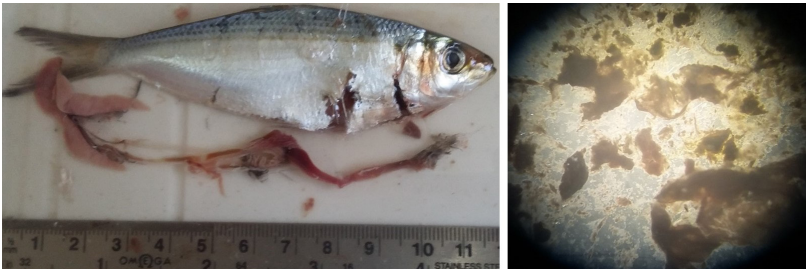


Figure 2.18a and b
Gut content analysis of fish collected
from the water column (planktivores)
Credit: Mona Webber

It is important to assess shellfish (such as oysters), because while fish are gutted and gut contaminants removed before eating, organisms like oysters are eaten whole and so the likelihood of microplastic contamination of humans is greater, especially since oysters are collected from the Kingston Harbour mangroves (Figure 2.19).

Figure 2.19
Oyster fisher in the Kingston Harbour mangroves
Credit: Chauntelle Green

Chapter 3

Broken but Not Destroyed: Kingston Harbour Recovers?

Regulatory Interventions: The Soapberry Treatment Plant Solution

Legislative instruments are among the most effective tools in facilitating compliance. In the case of Kingston Harbour, the grave pollution level was not only a serious concern but warranted regulatory actions for discharges which breached environmental laws and standards. The National Environment and Planning Agency (NEPA) acts under the mandate of the Natural Resources Conservation Authority (NRCA) to protect human health and the environment. As a regulatory agency NEPA processes, issues and enforces the permits and licences granted by the NRCA. The National Water Commission (NWC) has responsibility for the provision of potable water as well as treatment of the resultant effluent. In the case of the Kingston Harbour, the NWC had responsibility for the Western and Greenwich Sewage treatment facilities which discharged sewage effluent into the harbour for decades until they were decommissioned. In keeping with the relevant environmental laws, inclusive of the Natural Resources Conservation (Wastewater and Sludge) Regulations, 2013 and the Natural Resources Conservation (Permits and Licences) (amendment) Regulations, 2015, the NWC requested and received an environmental permit and licence for the operation of a tertiary-level sewage treatment plant – the Soapberry Treatment Facility. Expected to make a positive difference in the water quality of the harbour, the Soapberry Treatment Plant was commissioned to receive untreated or poorly treated sewage effluent that previously flowed directly into the Kingston Harbour. Finally, the 20 mgd (million gallons per day) discharge from Greenwich and Western plants would cease, when in 2007 the Soapberry sewage solution, long envisioned, became a reality.

A rapid ecological assessment conducted in 2011 by Lui et al. (2014) investigated the concentrations biological parameters; biological oxygen demand (BOD5), faecal coliform and nitrate in Kingston Harbour. The objective of the study was to compare the water quality of the Kingston Harbour in 2011 with values obtained in previous studies conducted in the 1990s (Figure 3.1), in order to determine if the water quality of the harbour had shown improvement since 2007 when the Soapberry Wastewater Treatment Facility was commissioned.

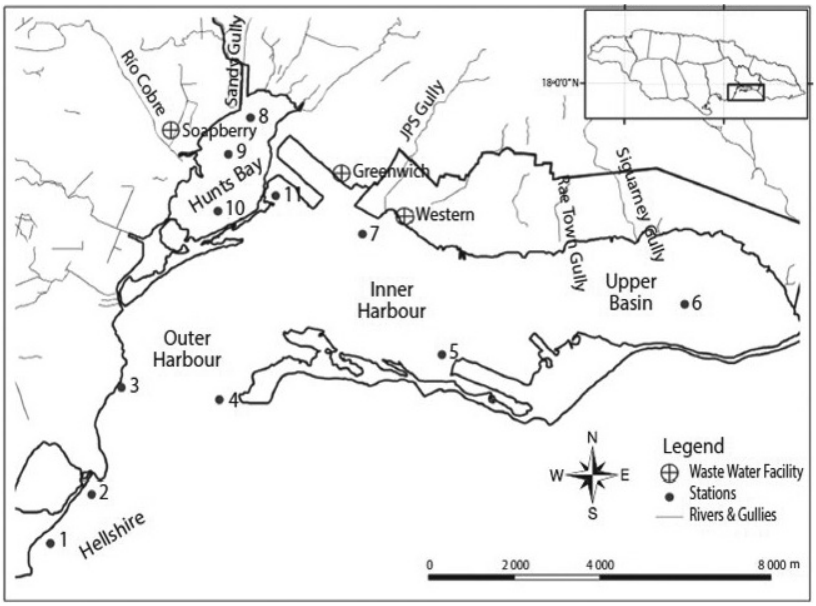


Figure 3.1
Map of the study area showing locations of the sampling stations
Source: Lui et al., 2014

The concentrations indicated minimal improvement in water quality in the Kingston Harbour, that is, stations 3–7, coupled with significantly deteriorating water quality in Hunts Bay, stations 8–10 (Figures 3.2–3.4).

The summary conclusions of Lui et al. (2014) are as follows:

- Lower nitrate values obtained in the Kingston Harbour suggest a reduction in nutrient input or uptake by the biota, which resulted in improved water quality
- Using the faecal coliform bacteria counts as the index, Hunts Bay and the Kingston Harbour are still heavily polluted based on NEPA standards for coastal waters
- By World Health Organization (WHO) standards, the sample area is moderately polluted with Hunts Bay continuing to be extreme
- Kingston Harbour's coliform counts have reduced from the initial 1990s values, indicating some improvement

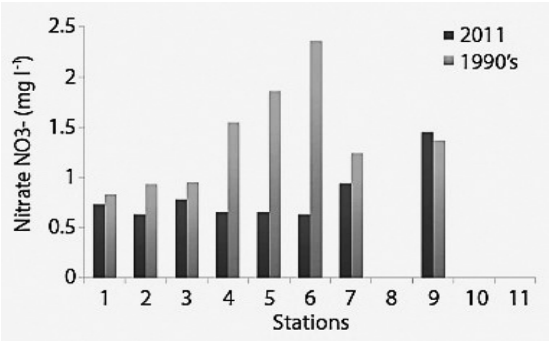


Figure 3.2
Comparison of nitrate NO3 (mgL-1) concentrations in the 1990s and 2011 studies (Lui et al., 2014)

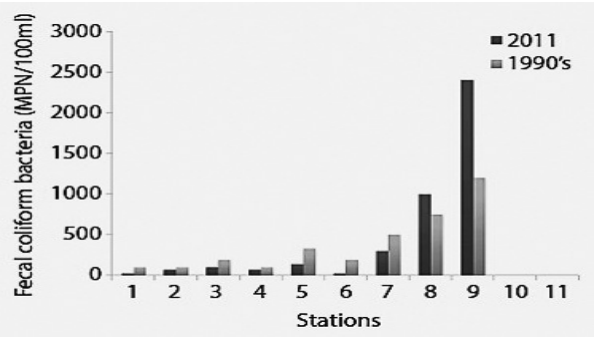


Figure 3.3
Mean faecal coliform concentrations at the stations in the 1990s and 2011 studies (Lui et al., 2014)

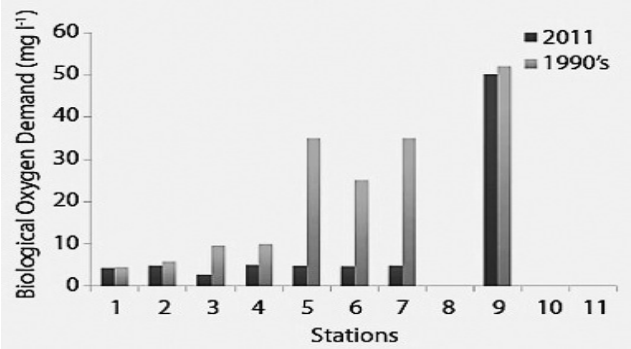


Figure 3.4
Mean Biological Oxygen Demand (BOD) concentrations at stations in the 1990s and 2011 studies
Source: Lui et al., 2014

The implications of these findings are that improperly treated sewage is still entering the harbour area. Improvement in water quality in Kingston Harbour and worsening conditions in Hunts Bay are correspondent with the implementation of the Soapberry Treatment Facility. However, it is now 12 years since the Soapberry Treatment Facility was opened and the expected continued improvement in Kingston Harbour water quality has not been seen. It is postulated that the storm-water gullies have taken over as significant point-sources now carrying sewage as well as plastics.

The Refuge Cay Rescue: Reversing the Destruction

Refuge Cay is the larger of two mangrove islands in the Port Royal mangroves (the smaller being Little Refuge Cay). Refuge Cay forms the northern border of Hurricane Refuge Lagoon (Rosey Hole) and due to its size (8.2 ha/30 acres) and isolation, it has become home to several species of resident and migrant (over-wintering) birds. The mangrove forest supported on Refuge Cay has a mix of red, black and white mangroves distributed in varying zonation patterns according to the degree of shelter experienced by the respective area of the shore. Alleng (1990)

described the Refuge Cay mangrove forest as comprised of fringe *Rhizophora* (Red mangrove) on the south shore, fringe *Avicennia* (Black mangrove) on the north shore (facing Kingston Harbour), with most of the forest between being mixed (red, black and white) mature basin mangrove with a few isolated patches of basin black mangroves.

The death of areas of mangrove forest in the centre of Refuge Cay was first observed in 1968 (Alleng, 1990) with a vegetated salina (200 m^2) being formed in the middle of a stand of basin black mangrove. By 1986 the salina had expanded to 1,560 m^2 and by 2015 it was over 24,000 m^2.

Figure 3.5
Refuge Cay in dry periods showing a salina in the centre
Credit: Dale Webber

The presence and absence of water in the treeless centre of Refuge Cay was based, less so on the tides, and more so on the weather. In dry months the centre of the cay would be described as a salina (Figure 3.5) with soil salinities in excess of 70 ppt, which led to the death of the trees. In wet months, the

cay stagnated as the absence of flushing meant the tannin-filled waters remained (Figure 3.6), covering the breathing roots and causing stress and eventual death of the trees.

Death of mangroves can be related to both too little and too much water, especially where the trees are black mangroves growing in a depression or basin forest. Hence, the Refuge Cay mangrove loss was diagnosed to be due to lack of water movement (tidal flushing) on and off the cay. So during hot dry months/years, evaporation would cause increased salinities on the surface which can become too high even for marine plants that are used to normal salinities (35 ppt).

Figure 3.6
Refuge Cay covered with tannin-coloured water during wet months
Credit: Dale Webber

Prolonged periods of high salinity cause the plants to expend too much energy, keeping salt out of their tissues and so they eventually die (from starvation). By contrast, too much water in the forest covers the pheumatophores or breathing roots and the trees suffocate and die. Furthermore, stagnant water retards seedling recruitment as the seeds cannot take root in the deep water.

The natural hydrology of Refuge Cay, which would see water flowing on and off the forest with the ebb and flood of the tides, was disrupted by a **berm** of plastics that gradually built up over decades on the northern edge of the cay (the side facing Kingston Harbour). It was hypothesized that removal of the berm would restore the free flow of water and allow for the maintenance of "normal" salinities and flushing of the forest floor. The intervention was urgently needed to save the cay from complete forest loss and eventual erosion.

Berm – a raised bank, or terrace bordering a river or canal and can be an artificial ridge or embankment built as a defence or deliberate barrier "berms of shovelled earth".

Figure 3.7
Canoe laden with plastic waste from Refuge Cay
Credit: Paul Kisson

A programme was designed based on funding from the Kingston Freeport Terminal Limited to employ locals to carefully remove

garbage, especially from the northern edge of Refuge Cay. The intervention started in January 2018 with 24 fishers from Port Royal and other fishing beaches associated with the harbour.

Cleaning was done by carefully removing each layer of garbage until the soil and roots could be seen. Small plastic items (plastic bottles and bags) were put in large garbage bags and transported by canoe (Figure 3.7) to the Port Royal Road (Figure 3.8) where a large 30 cubic yard container belonging to Garbage Disposal and Sanitation Systems (GDSS) made daily trips to the Riverton City dump.

Figure 3.8
Material stockpiled for transporting to the Riverton City dump
Credit: Paul Kisson

Where items could not be transported in the canoes, they were towed behind (Figure 3.9).

Figure 3.9
Canoe towing one of the refrigerators found on Refuge Cay
Credit: Paul Kisson

Immediately after cleaning in May 2018 channels and small streams of water could be seen (Figure 3.10)

Figure 3.10
Refuge Cay after cleaning and boom installation
to retard plastics from the most vulnerable areas
Credit: Dale Webber

The quantity of materials (small items in garbage bags) and other debris collected from Refuge Cay is given in Table 3.1 below.

Table 3.1
Tally of material generated after 6 weeks of cleaning of a 725 m length of Refuge Cay (~ 5 m wide)

Items	Quantity
Refrigerator	30
Washing machine	5
Television	15
Tyres	213
Cooking gas cylinder	13
Crates (plastic)	101
Scuba cylinder	1
Car/truck fender	1
Water containers (Igloos)	58
Refrigerator doors	49
Large garbage bags full of plastic material	8,299

With the restoration of water flow on and off the cay, six months after cleaning natural seedlings were observed on Refuge Cay (Figure 3.11) and these are being measured for growth rate and survival. The cay is constantly checked for emergence of new seedlings (Webber et al., 2019).

Figure 3.11
Seedlings colonizing the once bare areas of Refuge Cay
Credit: Mona Webber

Refuge Cay is reflective of the mangroves of Kingston Harbour and demonstrates their progressive destruction. An adjacent area, west of Refuge Cay called Gallows Point (Figure 3.12) (because this is where hangings were carried out in the sixteenth century), has also seen the loss of a large area of forest (~9 ha) due to a similar berm of plastic on the north shore.

Figure 3.12
Gallows Point in 2015 with a bare patch
the size of Refuge Cay (~9 ha)
Credit: Dale Webber

The intervention conducted on Refuge Cay can be replicated at Gallows Point and other areas that have been damaged by the continuous flow of plastic waste into Kingston Harbour and its mangroves.

Refuge Cay also provides hope that the natural environment associated with Kingston Harbour, damaged by the constant input of pollutants, can be restored or at least rehabilitated to carry out the vital ecosystem functions and supply the goods and services on which the communities around its shores have come to depend.

Refuge Cay also illustrates that the problem of pollution and degradation of Kingston Harbour cannot be solved by cleaning but must be stopped at source. Indeed, immediately after cleaning, garbage was again being deposited on the shores of Refuge Cay (Figure 3.13).

While the flushing of the forest will not be immediately affected, the re-deposition of the garbage, if left unchecked, will re-establish the berm that existed before and once again choke the forest. The rain of plastic waste into the sea cannot be stopped at sea. Fixing the problem must start from the communities, practices and people that create, commodify, use and discard the plastic.

Figure 3.13
Refuge Cay north shore two months after cleaning
Credit: Mona Webber

Fixing the Problem: Ban on Single-use Plastics, Straws and Styrofoam

As of January 1, 2019, the Government of Jamaica imposed a ban on:

- Single-use plastic bags ("scandal" bags), made wholly or in part of polyethylene or polypropylene, and with dimensions not exceeding 610 mm x 610 mm (24" x 24") and 0.03 mm (1.2 ml) in thickness
- Plastic drinking straws
- Importation of expanded polystyrene products (Styrofoam)

Exemptions have been granted for single-use plastic bags used to package personal effects and contained in the luggage of a person travelling into or out of Jamaica, and drinking straws manufactured for use by, or used by, persons with disabilities, in accordance with an approval granted by the Minister under paragraph 5.

Exemptions also apply until January 1, 2020, to expanded polystyrene foam in the form of, or used as containers for food or beverage; and until January 1, 2021, to drinking straws made wholly or in part of polyethylene or polypropylene, manufactured for single use, and attached to, or forming part of, the packaging of juice boxes or drink pouches.

These exemptions will facilitate development of viable alternatives for these products.

Two Ministerial Orders provide the regulatory framework for the ban. These were gazetted under the Trade Act and the Natural Resources and Conservation Authority (NRCA) Act. The penalty for breaches of the ban under the Trade Act 2018 is J$2 million, while breaches under the NRCA Act will attract a fine of J$50,000. Breaches of the ban, as stipulated by both Acts, carry the penalty of imprisonment for a maximum of two years.

The success of the ban is imperative if we are to rescue the coastal ecosystems of the Kingston Harbour from the scourge of solid-waste pollution. As we, the citizens of Jamaica, partner and foster voluntary compliance (not based on prosecutions and fines), we can achieve restoration of our valuable marine and coastal assets. This was demonstrated when corporate funding, academia and fishers combined forces to rescue a small mangrove island in the Kingston Harbour.

Fixing the Problem: The Clean Kingston Harbour Project

Cleaning Kingston Harbour involves social interventions, management of waste, facilitation of separation, composting and effective recycling of components of our waste stream, as

well as reducing the generating of plastic waste through bans and restrictions. The GKF and its partners have designed a project to restore Kingston Harbour, one gully at a time. The strategic objectives are in two groups:

Group A – Turning off the tap or stemming the flood of plastics. This includes:

- Implementing educational programmes for separation and proper disposal of garbage
- Helping to institute recycling programmes within the corporate area
- Installing fencing gully traps in all major gullies in Kingston

Group B – Cleaning/ridding the harbour of the plastic waste, which includes:

- Embarking on a comprehensive removal of debris in Kingston Harbour (including mangroves) once interventions from (A) are in place
- Helping to restore fisheries (fish sanctuary designation) and support programmes for rehabilitation of mangrove forest areas within the Kingston Harbour
- Employing methods to ensure sustainability of quality of marine life within the Kingston Harbour
- Monitoring and sampling to indicate improvement

Table 3.2
Key stakeholders of the GKF Clean Harbour Project

Role	Organization	Activity In Area	Project Role
Government Regulator	• NEPA • NSWMA • NWA	• Environmental • Garbage collection and management • Drainage and works	• Member of Consortium • Member of Consortium • Member of Consortium

Government Company	• PAJ • UDC • Petrojam	• Port support operations • Promoting investments and Downtown Kingston redevelopment • Oil refinery	• Member of Consortium • Member of Consortium • Member of Consortium
Private Sector	• GraceKennedy Ltd. • PanJam Investments • Digicel • Scotiabank • PriceWaterhouse Coopers • Jamaica Flour Mills • Caribbean Cement Company Ltd. • Jamaica Public Service Company • Jamaica Producers Ltd. • Kingston Wharves Ltd.	• Corporate HQ • Owner of many Downtown Kingston properties and investments • Corporate HQ • Corporate HQ • Country operations HQ • Operations and HQ • Operations and HQ • Two major power generation facilities • Major shareholder in shipping operations • Operations and HQ	• Project Lead • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium • Member of Consortium
Civil Society/ Academia	• PSOJ • UWI • CMU • NGOs and CBOs		• Member of Consortium /Financial Contributor • Research/ Analysis • Research/ Analysis • Member of Consortium

Multilateral Stakeholders	• IDB • World Bank • United Nations • EU		• Financial Contributor • Financial Contributor • Financial Contributor • Financial Contributor

The project, which is the brainchild of Dr. Fred Kennedy (GKF Chairman), has four phases, two of which have been completed.

Chapter 4

Kingston Harbour: A Natural Capital Stock for Propelling Sustainable Prosperity for Jamaica

Applying Natural Resource Valuation Theory

The Kingston Harbour is an economic asset that provides a flow of goods and services of economic value. These goods and services can be classified, using terminology from the natural resource valuation theory, as direct use values, indirect use values, and non-use values (Emanuel, 2011). The most easily identifiable direct use values of the harbour relate to the provisioning and cultural services, such as fishing, recreation, and transport (shipping). Indirect use values relate to the regulatory function and include economic production, biodiversity, coastal protection of mangroves, waste assimilation and education. Non-use values include the maintenance of wildlife habitats and aesthetics.

Natural resource valuation provides the tools and techniques to assess the economic value of market and non-market environmental goods and services. This enables informed decision making by policy makers with regard to the sustainable use and management of natural resources. Policy makers are provided with the data and information to determine, among other things:

- The allocation of scarce resources towards conservation, preservation or restoration initiatives
- Land use decisions – for conservation or other uses
- Setting priorities and strategic direction for biodiversity conservation
- Limiting biodiversity invasions, for example, setting the boundaries for the Cockpit Country
- Bio-physical cost benefit analysis to inform trade off decision

Studies undertaken in 1997 estimated the value of Kingston Harbour at US$510 million and included values for fishing, recreation, shipping, education, industry and commerce. The estimated value of the harbour in that study, however, did not account for indirect use values such as the values associated with services related to flood prevention and storm surge, which the coral reefs and surrounding mangroves provide.

The pollution of the Kingston Harbour has a detrimental effect on the reputation of Kingston and Jamaica, and carries both economic as well as environmental impacts.

Total Economic Value (TEV) of Kingston Harbour

The flow of goods and services provided by the Kingston Harbour are used directly or indirectly by some of the main economic sectors in the Jamaican economy – tourism, transport/shipping, and agriculture (including fishing). It is widely recognized that the potential of the Kingston Harbour's waterfront zone[1] and its immediate environs to generate economic activities and jobs has not been maximized.

Goods and services produced within the Kingston Harbour can be classified using terminology from the natural resource valuation theory. The total economic value of the harbour is the sum of the use values (UV) and non-use values (NUV), which together make up the Total Economic Value (TEV). Use values relate to the actual use of the good or service produced by the environment while non-use values relate to existence value, that is, the value humans place on the knowledge that a resource exists. Use values can be further divided into direct (DUV), indirect (IUV) and option values (OV), while non-use values can be further classified as bequest value (BV) and existence value (EV). Once these values can be quantified, an estimation of the value of the harbour could be ascertained using the equation below:

$$\begin{aligned} TEV &= UV + NUV \\ &= DUV + IUV + OV + BV + EV \end{aligned}$$

Table 4.1

Total Economic Value of the Kingston Harbour

Use Values			**Non-Use Values**	
Direct Use	**Indirect Use**	**Option Value**	**Bequest Value**	**Existence Value**
Outputs directly consumable	Functional Benefits	Future direct and indirect values	Value of leaving Use and Non-use values to future generations	Value from knowledge of continued existence
Fisheries/Food Tourism/ Recreation Shipping Port Aesthetic	Storm Protection (provided by the Palisadoes tombolo and the mangroves) Waste assimilation and climate modification functions of the mangroves and other wetlands Fish nurseries and habitats provided by the reefs Seagrass beds and mangrove forests, which serve economic production, scientific and educational functions Biodiversity	Active and expanding port coexisting with other uses Accessible parks, beaches, water sports, continuous waterfront pedestrian and bicycle path	Maintenance of wildlife habitat aesthetics	

Table 4.1 presents some direct and indirect uses of the harbour. Based on the natural resource valuation theory, determining the total economic value of the Kingston Harbour requires

placing monetary values on the goods and services provided by the harbour including market and non-market goods and services. Each of the three main ecosystems that make up the Kingston Harbour – coral reefs, mangroves and sea-grass beds – can be valued in monetary terms.

Quantifying the Economic Assets of the Harbour – The Value of the Harbour's Ecosystems

The economic valuation of natural resources puts monetary values to environmental goods and services. The aim of an economic valuation exercise is to determine how much users are willing to pay for the benefits or features provided by a natural resource. Economic valuation in this context refers to the economic value of a change in condition rather the stock value. Therefore, the focus is on the change in the level and mix of goods and services provided by the natural resource as a result of an action or inaction. There are three main economic approaches in natural resource valuation theory (Carson and Bergstrom, 2003):

1. The use of market determined prices where the prices are determined in the market for the goods and services provided by the natural resource. This approach also considers revealed pricing where prices are determined in another market. Revealed preference methods are traditionally used where conventional or proxy market prices exist. This method can be further divided into three approaches:
    - The observed market value and related goods approach
    - The productivity approach
    - Cost-based methods including replacement cost
2. The stated preference approach (also called direct approach) – using willingness to pay estimates derived from questionnaires/surveys, and

3. Benefits transfer, using values "borrowed" from existing studies

The TEV provides a framework to determine the economic value of the Kingston Harbour by placing monetary values on the harbour's use and non-use values using the appropriate natural resource valuation methods. This chapter does not focus on determining the monetary value of the function of the harbour. Rather, the chapter highlights some of the economic contributions of the harbour (actual and potential) by contextualizing its economic functions based on the TEV framework and relevant valuation methods.

Economic Valuation of Direct Uses

Shipping

The strategic location of the harbour in the western hemisphere and transshipment port facilities makes the harbour ideal for international shipping and shipping related activities. The harbour also possesses modern dry bulk terminals for the management of limestone, gypsum, cement and grain cargoes as well as facilities to handle bulk petroleum products of oil refineries.

Shipping activities are classed under the heading Transport, Storage & Communication industry. On average, this industry has contributed approximately 10.6 percent of goods and services production in the Jamaican economy over the last five years. The performance over this period reflects in part activities at the island's sea ports. For 2017, the total volume of cargo (inclusive of petroleum products) handled at the island's ports was 23,948 thousand tonnes. At the Port of Kingston, the total volume of cargo handled was 12,762 thousand tonnes, which represents about 50 percent of total cargo volume handled in the country. The Port of Kingston also accounts for the majority of ship calls to the island's port. For 2017, ship calls to the Port of Kingston was 2,281 relative to 1,218 at the outports.

In 2017, the harbour was deepened by the dredging of the Kingston Access Channel to allow for the accommodation of larger vessels traversing the Panama Canal which has a capacity of 14,000 TEUs. The dredging of the Kingston Access Channel formed part of a 30-year concession agreement for the privatization of the Kingston Container Terminal. Other developments aimed at improving maritime transportation include:

- The acquisition and commissioning of new cargo handling equipment including modern gantry cranes and train tractors
- Installation of new IT infrastructure with high-speed computer systems, fibre-optic communication systems to facilitate modern CCTV, and other security devices
- The rebuilding of Gordon Cay to make it more resilient to severe earthquakes and other disasters as well as to cater to larger container ships being deployed

It is well recognized that shipping, while providing considerable economic value, has also resulted in numerous environmental problems for the harbour which not only affects the health of the harbour but also jeopardizes the shipping industry. The increased shipping traffic has resulted in an increase in the amount of ship waste such as sewerage, oil residues, solid waste and medical waste. The increase in waste also has an impact on ships docking in the harbour which take on ballast water on departure and subsequently release the polluted water at the next port of call. This affects the competitive advantage of the Kingston Harbour and contributes to the degradation of other ports which are critical to international trade and the overall health of the environment.

Over the medium term, activities centred on the development of strategic maritime infrastructure for cargo and passengers have been prioritized in keeping with the national thrust to

expand and diversify maritime infrastructure and services. Some of the prioritized activities to further this national thrust include:

- Facilitating the sustainable development of cruise shipping, including homeporting
- Increasing the capacity of cruise ship berths and facilities
- Establishing Jamaica as an international shipping centre to incorporate the provision of services such as dry docking/ship repairs, bunkering and ship registry

The country continues to work towards positioning Jamaica as a regional logistics hub with multimodal transport linkages. This includes the development and linkage of major supporting logistics centres and facilities islandwide. One of the major actions being pursued is the development of a multi-phased logistics/transshipment port and industrial and commercial zones. The success of these initiatives is inextricably linked to a healthy harbour which offers, among other things, a strategic location and shoreline protection.

Industry and Commerce

A number of commercial and industrial activities including oil refining, cement production, electricity generation, and food production and distribution are linked to the Kingston Harbour. Based on preliminary data from the Tax Authority of Jamaica for 2018, approximately 1,633 entities operate within this area, which represented 12.4 percent of entities operating in Jamaica. With respect to the classification of the entities operating in the Kingston Harbour waterfront zone, 76.1 percent are Micro & Small firms and 23.9 percent represent Medium & Large entities. Most of the entities operating in the zone are classed as Wholesale & Retail Trade; Repair of Motor Vehicles Motorcycles & Personal Household Goods (49.9 percent); Real Estate, Renting & Business Activities (18.1 percent); and Manufacturing (13.5 percent).

Preliminary estimates of total sales of the 1,633 entities operating in the zone for 2018 were $252.4 billion, which represented 23.7 percent of total sales in Jamaica. Medium & Large entities accounted for 97.0 percent of the revenue earned and the remaining 3.0 percent by Micro & Small entities. The industries that accounted for the largest share of revenue were: Wholesale & Retail Trade; Repair of Motor Vehicles Motorcycles & Personal Household Goods" (42.3 percent); Manufacturing (26.2 percent); and Real Estate, Renting & Business Activities (22.1 percent).

These industries own properties of notable value which are partly protected by the Kingston Harbour from storm surges, flooding and other such disturbances. An estimate of the economic values based on costs of avoided damages resulting from lost ecosystem services, costs of replacing ecosystem services, or costs of providing substitute services would provide an approximation of the economic value associated with this function of the harbour. Moreover, production loss due to loss of the protective services of the harbour would also provide an indication of the economic value.

Research and Education

As we saw in Chapter 1, the harbour plays a role in research and education through the institutions sited in its environs – the Caribbean Maritime University (CMU) and The UWI Port Royal Marine Laboratory. The CMU is the only maritime and training institution approved by the International Maritime Organization (IMO) in the Caribbean and it is also certified by the International Organization for Standardization (ISO).

Kingston Harbour Fisheries

The harbour supports recreational, subsistence and commercial fisheries. At the end of 2017, there were 24,315 registered fisherfolk and 7,512 registered boats operating from 187 fishing

beaches and two cays in Jamaica. Over 6, 744 registered fishers and 2,124 registered vessels are sustained by the harbour at beaches and landing sites around it (Fisheries Division, 2018). The harbour had an estimated fish production of 959.15 megatonnes valued at US$3,172,092.3 in 2015 (Fisheries Division, 2019). The total value of fish production in 2015 for Jamaica was US$62.8 million. The fishers depend directly on the harbour for their livelihood as well as for bait to exploit other fisheries outside the harbour. Fishing at the harbour also creates employment for boat builders, boat repairers, net makers, loaders, gutters, vendors and their families.

Figure 4.1 shows areas used by fishers operating from within the Kingston Harbour and the main species fished in each, based on data collected from fishers operating from within the Kingston Harbour. Much of the fishing activity occurs on the western edges, the southern portion of the inner harbour as well as around the Port Royal Cays.

Figure 4.1
Google Earth image of the approximate extent of areas fished by fishers operating within and out of Kingston Harbour
Source: Fisheries Division, 2019

Fish species as well as stocks have experienced declines due to continued deterioration of the water quality. This has contributed to fishers venturing further offshore for their catch. In addition to the external forces of pollution and mangrove removal, the unsustainable practices of some fishers further jeopardize the surviving fish stocks.

The agriculture, forestry and fishing industry accounts for approximately 7 percent of GDP and employs approximately 200,825 people, representing approximately 16 percent of the total labour force in the country (ESSJ, 2017). This industry continues to be a key driver of economic growth and development for Jamaica, contributing to GDP, employment, foreign exchange earnings, rural life, environmental sustainability and food security.

The fishing sub-sector is, however, negatively impacted by a range of issues and challenges, many of which are associated with activities around the harbour. These include:

- Inadequate key infrastructure and equipment support services including development and maintenance of fishing feeder roads and packaging and storage facilities
- A high incidence of larceny in illegal, unreported and unregulated (IUU) fishing
- Threats to the long-term development of Jamaica's marine fisheries, including over-harvesting, habitat destruction and pollution, and incursions by fishing vessels from other countries

Over the medium term, there are several strategies and actions being employed which are geared towards enhancing the competitiveness of the fishing sub-sector. Some of the strategic priorities include:

- Strengthening the framework for greater competitiveness of a diversified range of agricultural products and increased

agricultural output particularly of crops, livestock and aquaculture
- Increasing the resilience of the agriculture sector to natural hazards
- Advancing the development of the Fisheries sub-sector
- Promoting national food and nutrition security and safety.

A rehabilitated Kingston Harbour will have significant positive economic implications for the agriculture sector. Some of these include:

- Growth in the fishing sub-sector
- Increase in employment for fisherfolks and other jobs linked to the fishing industry

Tourism

Tourism is one of the leading sectors in the Jamaican economy and one of the fastest growing in the world. The sector plays a central role in national development by contributing to income generation, job creation and foreign exchange earnings. Gross value added (direct) for the tourism sector has increased from $70.4 billion in 2008 to $171.5 billion in 2017 (STATIN, 2017). Tourism is also the single most important generator of foreign exchange for the Jamaican economy. The loss of wetlands due to construction activities, beach erosion, damage to coral reefs, habitat loss, intensive use of freshwater resources and increased pollution are some of the main issues and challenges facing the sector.

The sustainable management and use of the Kingston Harbour is critical for the continued growth and development of the sector, which has a vested interest in ensuring that the harbour remains clean and healthy.

In the future, the country is expected to implement a wide range of strategies and actions to continue to improve the

international competitiveness of the tourism sector. One of the prioritized strategies is strengthening the integration of tourism development with sustainable land use planning and environmental management. This is based on the importance of environmental resources, particularly those located along the coast, to the sustainability of the tourism sector. Other strategies which will be prioritized and which are linked to a clean and well-functioning harbour are:

- Increase and broaden the participation of local stakeholders in the tourism industry
- Promote investment and economic linkages
- Diversify the country's tourism product, source markets and market segments
- Increase the use of Jamaican inputs and culture in all areas of the industry
- Ensure that activities in the tourism sector are environmentally sustainable and that the sector implements strategies and actions that reduce the effects of a changing climate

Economic Valuation of Indirect Uses

The contribution of the Kingston Harbour extends beyond the direct use value as it provides functional benefits. These include storm protection (provided by the Palisadoes tombolo and the mangroves), waste assimilation and climate modification functions of the mangroves and other wetlands, and fish nurseries and habitats provided by the reefs, seagrass beds and mangrove forests, which serve economic production, scientific and educational functions.

Over 50 percent of the economic assets such as air and sea port facilities and tourism infrastructure are concentrated along the coastal areas of the country. In addition, approximately 60 percent of the population resides within 2 kilometers of the coast.[2] Therefore, maintaining economic viability of operations

centred on the harbour as well as protecting economic assets must be a priority for the country. The Kingston Harbour plays a critical role in this endeavour, providing a form of storm protection in this area.

Coastal ecosystems are valuable to human well-being because of the services they provide. The services may be direct or indirect in nature, and may include food production; water quality enhancement; and coastal protection depending on the particular ecosystem present (see Figure 4.2). There are two main coastal ecosystems within the Kingston Harbour, namely the mangrove and seagrass bed ecosystems. Coral reefs are located in close proximity at the Port Royal Cays.

Figure 4.2
Coastal ecosystem services
Source: https://oceanwealth.org/ecosystem-services/

Mangroves are important to the sustainability of fisheries and food security because they provide breeding and nursery grounds for juvenile fish. They also serve as a feeding ground for some fish species such as the snapper. Some bird species,

such as the cattle egret, also rely on mangroves for habitat roosting, spawning and nesting.

Mangroves play an important role in the decomposition of waste and carbon sequestration (the capturing and storing of carbon), which makes these ecosystems essential to climate change mitigation. Due to their deep roots, mangroves protect the shoreline from erosion and from the damaging effects of strong winds and waves, which makes them critical to disaster risk management. They can absorb between 70 and 90 percent of the energy of a normal wave (International Union for Conservation of Nature, 2005). During the 2004 tsunamis in South Asia, it was observed that only two people died in the village surrounded by 200 hectares of dense mangrove and shrub forests, compared with the 5,000 to 6,000 individuals that were killed in a village surrounded by degraded mangroves (International Union for Conservation of Nature, 2005).

Seagrass beds provide food, nursery and habitat to commercial and recreational fish, as well as to numerous invertebrates. Their extensive root system helps to stabilize the ocean floor and break the force of intense wave action from currents and storms. Seagrass beds also play a vital role in the maintenance of water quality by trapping suspended fine sediments and particles in the water column. They also filter nutrients that enter the sea from surface run-offs and industrial and other wastes before they get to the reefs. An estimated 900 hectares of seagrass beds were within the harbour in 1970 (Aiken et al., 2009).

Coastal weather systems such as hurricanes, cyclones and storm surges have caused significant infrastructure damage, disruption to operations and loss of human life. The damage cost avoided approach can be used to estimate the economic value of the storm protection services provided by the Palisadoes tombolo and the coastal ecosystem (mangroves, seagrass, reefs). This approach uses either the value of property protected, or the cost of actions taken to avoid damages, as a measure of the benefits provided by an ecosystem.

Degradation of Coastal Ecosystems and Implications for Resilience

Comprehensive understanding of the value of coastal ecosystem services is lacking because these services are not traded in markets and there are no prices to reveal real value. The lack of understanding of the benefits that ecosystem services provide has resulted in a general mismanagement and degradation of these fundamental ecosystems. Seagrass beds have been removed to facilitate the deepening and widening of the ship channel to accommodate larger vessels. Hundreds of acres of mangrove swamps along Hunts Bay and the Kingston waterfront have been removed to make way for industrial and residential development, along with the expansion of the Port of Kingston. Mangrove forests have also been removed along the Palisadoes peninsula in favour of development. While economically and socially beneficial, removal of mangroves has negatively impacted the regulating and provisioning ecosystem services they provide, as well as the overall environmental health of the harbour. Approximately 607.6 hectares of mangrove forest remain along the harbour's coastline (Forestry Department, 2019). The largest contiguous area (approximately 270 ha) lies near Port Royal (NEPA, 2013).

Water quality in the harbour has deteriorated significantly from human activity on sea and from nonpoint/land-based source pollution. Discharges from ships, along with industrial effluent from surrounding industries drain into the harbour through many different channels (see Figure 4.3). Pollutants from fertilizers and pesticides used in farming enter the harbour largely through the Rio Cobre, which traverses a number of agricultural communities in St. Catherine. A substantial amount of domestic waste from residences in the densely populated Kingston Metropolitan Area, and wastewater including sewage from inadequate treatment practices, contribute considerably to the pollution of the harbour. It is estimated that roughly 40

million litres of untreated and semi-treated sewage is released into the harbour daily. Moreover, inadequate solid waste disposal practices continue to proliferate as is evidenced by the estimated 15,488 pounds of garbage collected from the Kingston Harbour coastline during International Coastal Cleanup Day 2018. Water quality is also affected by oil spills which affect the flora and fauna. Between December 2016 and July 2017, there were four major spills associated with the oil refinery. These issues, along with coastal erosion, have combined to reduce an important cultural function of the harbour, the loss of bathing beaches that can no longer accommodate swimming. The once popular Cross the Harbour Swimming Race has been halted for years.

Figure 4.3
Map showing Kingston Harbour and major drainage networks in the KMA and parts of St. Catherine

The effects of eutrophication are among the most visible evidence of pollution in the harbour. When nutrient levels in the water become too high, the growth of phytoplankton is accelerated, it increases in abundance and blocks the sunlight that seagrass beds need to survive. In 2012, discolouration (red tide) was observed in the Kingston Harbour near Rae Town, suggesting an abundance of algal bloom. An assessment of the coral reefs in Rackham's Cay, some 1.2 km from the entrance to the harbour, revealed that the area's average coral cover (6–10 percent), recovery and normal succession that would have been expected in 4–6 years, had been stunted by the eutrophication within the Kingston Harbour. Moreover, the health status of the reefs in the Palisadoes Port Royal Protected Area (PPRPA) has remained "critical" since 2016, based on the Coral Reef Health Index (CRHI), also affecting fish biomass (see Table 4.2).

Table 4.2
Coral Reef Health Index in the PPRPA, 2014–2018

Year	**Hard Coral Cover (%100m2)**	**Nutrient Indicating Algae (%100m2)**	**Herbivorous Fish (g/100m2)**	**Commercial Fish (g/100m2)**	**Coral Reef Health Index (CRHI)**
2014	7.5	40.8	618.2	111.1	1.3
2015	n/a	n/a	n/a	n/a	2.1
2016	8.8	36.3	261.5	81.6	1.8
2017	7.4	37.1	1144.3	44.2	1.8
2018	26.91	41.99	120.43	9.11	1.8
KEY:					
	VERY GOOD	GOOD	FAIR	POOR	CRITICAL
CORAL INDEX CRHI	4.3-5	3.4.4.2	2.7-3.4	1.9-2.6	1.0-1.8
Coral Cover (%)	≥40	20.0-39.9	10.0-19.9	5.0-9.9	<5

Coral Recruitment (#/m²)	<0.2	0.2-0.5	0.5-0.69	0.7-0.9	≥0.9
REEF BIOTA INDEX					
Macroalgae Cover (%)	<10	10.0-19.9	20.0-39.9	40.0-59.9	≥60
Herbivorous Fish Abundance (g/100m²)	≥4800	3600-4799	2400-3599	1200-2399	<1200
Commercial Fish Abundance (g/100m²)	≥2800	2100-2799	1400-2099	700-1399	<700
n/a – not available					

Source: NEPA

In keeping with their coastal protection function, any loss in these ecosystems will have implications for the resilience of the nation's capital to coastal erosion and natural disaster hazards such as sea level rise and storm surges. Examples of such erosion lie along the Palisadoes shoreline, parts of which were addressed by the US$65.4M Shoreline Protection Project but others remain, exposing critical assets such as the Bank of Jamaica, the Jamaica Conference Centre, the Seabed Authority and the new Ministry of Foreign Affairs and Foreign Trade buildings. In addition, their function as habitat for marine life means that the destruction of these important ecosystems could have implications on food security for many of the island's poorest residents who rely on fish as their main source of protein.

Jamaica has experienced ten storm events, including seven major hurricanes and several flood events, between 2001 and 2017 that amounted to a total of J$125.8B in losses. In 2004, Jamaica was impacted by hurricane Ivan which cost

the country about J$36.9B in losses and accounted for 8 percent of GDP. This hurricane had a direct impact on the Kingston Harbour as it caused significant damage to infrastructure and disruption to operations around the harbour. Caribbean Terrace, a community in proximity to the harbour, suffered damage to housing infrastructure of $5.96B, about a half of which was in Kingston and St. Andrew. While the community is not located exactly on the harbour, functioning ecosystems in the harbour could have lessened the impact of the storm surge on the community, which experienced both hurricane and storm surge damage.

Over the coming years, concerns related to climate variability due to climate change pose significant threats to the island with an increase in the number and severity of climate hazards. Therefore, action to preserve the natural functions of the harbour must be prioritized to protect the economic assets in and surrounding the harbour. Moreover, new investment in the areas of shipping, tourism (recreational activities), food supply for both the local and international markets logistics which are expected to create employment for many Jamaicans are just some of the areas which require a well-functioning, clean harbour.

Blue Economy ... New Economic Frontier

Contextualising the contribution of the Kingston Harbour within the development objectives of the country calls for an assessment of the economic costs if no action is taken to clean up the harbour. While many activities are carried out in the harbour in its present deteriorating state, there is evidence to suggest that a clean, rehabilitated harbour would significantly enhance and increase the benefits to the country. This assessment looks at the current direct and indirect uses of the Kingston Harbour as well as those to come on stream in support of the blue economy.

Vision 2030 Jamaica recognizes that maximizing the potential of the blue economy – Jamaica's marine and coastal resources will take the country closer to achieving the Jamaica we want and help us to realize our country's national vision – the place of choice to live, work, raise families and do business. Vision 2030 Jamaica recognizes that the sustainable development of the marine environment – its resources and ecosystems – and the sustainable management and use of these contribute to prosperity, for today's generation and for future generations. So, importantly, Vision 2030 Jamaica proposes:

1. That marine resources are managed and used in ways that are sustainable. Indeed, one of our country's 15 national outcomes is the sustainable management and use of environmental and natural resources
2. The advancement of economic growth, social inclusion, and the improvement of livelihoods while, at the same time, ensuring environmental sustainability of our marine environment
3. Paying attention to the goods and services provided by the marine environment – goods such as fish and shellfish, and genetic resources; and services, from shoreline protection to treating waste, providing employment, and maintaining biodiversity
4. That there must be a focus on restoring, protecting, and maintaining the diversity, productivity, resilience, core functions, and intrinsic value of marine ecosystems

Specific activities that are being/or have been implemented across all sectors – public, private, academia, civil society etc. to better capture the benefits to be derived from the blue economy over the medium-term include:

- Environment – Implementation of a coral reef restoration programme; development of a marine spatial plan for Pedro

Cays; implementation of the Pedro Cays Management Plan; finalization of the Dolphins Policy, Trade in Wildlife Policy; and the Queen Conch Management Plan 1994 was revised and approved – these are a few examples

- Fisheries – exploring species diversification for export purposes, such as the sea cucumbers which are in high demand by Asian countries for medicinal purposes and doing this though public private partnership; we are expanding the number of fish sanctuaries – we now have 18; the Fisheries Act, 2018 establishes the legal and regulatory framework that creates the enabling environment for the sector's sustainable growth and promotes the effective management and sustainable development of fisheries and aquaculture
- Tourism – Implementation has begun under the tourism component of the South Coast Sustainable Development Plan; a climate risk atlas has been completed for Negril; the new sustainable tourism master plan is being prepared

Roles and Responsibilities

Key stakeholders involved in environmental and natural resource management have specific roles and responsibilities. As the government's foremost planning agency, the Planning Institute of Jamaica (PIOJ) must work closely with environmental managers to determine methodologies used to collect environmental data to assess the value of the country's natural resources. The Ministry of Finance and the Public Service will have to work with partners especially our international development partners to implement innovative development financing mechanism to fund restoration, conservation and preservation activities. The academic and research institutions are required to conduct research on natural resource valuation techniques and methodologies as well continue to learn more about our natural resources and the values yet to be accounted

for. While there are many other stakeholders including the judiciary and law enforcement, special attention must be given to the role and responsibility of the private sector as it repositions itself as environmental stewards aim to achieve the triple bottom line.

Prescriptions

1. Emphasize the use of economic instruments for environmental management as well as the introduction of environmental management systems by business and the economic benefits of so doing within the pursuit of both natural capitalism and green economy goals
2. Partner with firms in the industries – electrical, cement, oil refining, and so on – operating in and around the harbour to preserve this unique natural resource in order to safeguard their own sustainability, competitiveness and profitability, in keeping with Goal 12 of the Sustainable Development Goals which seeks to ensure sustainable consumption and production
3. Strengthen regulation and enforcement to minimize and deter poor environmental practices
4. Accelerate the revision and approval of the National Policy on Ocean and Coastal Zone Management and the Cays Policy, both of which have been outstanding for some time
5. Enhance public education on the role of the community in maintaining the environment, to build a sense of environmental stewardship among the populace

Strategies and Actions Currently Being Pursued

Vision 2030 Jamaica articulates the importance of the natural environment as core to advancing the country's development. To this end, national actions and strategies towards the sustainable use of our country's natural resources are included in the plan and, moreso, in the implementation framework of

Vision 2030 Jamaica, the Medium Term Socio-Economic Policy Framework (MTF). The sustainable management and use of the country's natural resources remains a national outcome which the country is striving towards achieving. Strategies included in MTF 2018–2021 to further this outcome include:

- Promoting the use of new, clean technologies and clean production for all economic activities to enable greater efficiency, minimize waste generation and foster environmentally sustainable practices towards eliminating waste, aiming for zero waste, by integrating environmental best practices into the manufacturing process. Clean manufacturing is a continuous preventive strategy that concentrates on resources and manufacturing processes to eliminate waste, towards achieving the triple bottom line
- The promulgation of the National Environmental Management System (EMS) Policy, which will support the implementation of EMS within the public and private sectors and will be designed towards improving the environmental management practices of organizations as well as enhancing economic efficiencies within organizations. Such a policy will allow for and facilitate greater levels of investment in clean technologies
- Encouraging companies to adopt sustainable practices and to integrate sustainability information into their reporting
- The implementation of a plastic minimization project. The project focusses on enhancing the capacity of the country to carry out integrated waste management activities and strengthen the policy and legislative framework to reduce and manage plastic marine litter from land-based activities in an integrated and environmentally sound manner. Importantly, this initiative is being undertaken in collaboration with the private sector
- Greater use of traditional economic instruments for environmental management and other measures to

manage various forms of waste such as plastics, pesticides and hazardous materials

- Revisions to the National Waste Management Policy to reflect emerging issues such as hazardous waste, e-waste, medical waste, white waste, agricultural waste, and sewage waste
- Finalize the marine spatial plan for Pedro Bank and Cays to ensure more sustainable use and management of the cays and the activities that are undertaken in and around the cays
- Prepare a spatial plan for Jamaica that also focuses on the exclusive economic zone and provides prescriptions for the sustainable development of the marine environment towards achieving the benefits that can be derived from the blue economy

The advancement of these initiatives will strengthen the integration of economic, social and environmental issues in pursuit of a more sustainable pathway to development.

Economic activity in Jamaica is heavily reliant on the natural environment, particularly the resources which it provides. Sustained economic growth and development can only be enhanced through careful management of the harbour. While there have been studies on the economic value of the direct uses of the harbour, determining the economic values of the many indirect functions of the harbour will be critical for enhancing our resilience to natural disasters especially in the face of a changing climate. The economic value that the harbour plays in the national economy has been highlighted. However, this exercise is only a first step in revisiting the economic value of a clean, rehabilitated harbour to the economy. What is required is an updated study on the economic value of the harbour using natural resource valuation techniques to place monetary values on the direct and indirect uses of the Kingston Harbour.

A concerted effort is required from government, the private sector and citizens to clean up the Kingston Harbour. A vibrant economy within the downtown area and its environs could in the long run reduce crime and violence; improve prospects for businesses; and enhance the aesthetic appeal, thus contributing to the overall impact of attracting more locals and tourists to the nation's capital and importantly, assist us in propelling sustainable prosperity in Jamaica.

Chapter 5

Reclaiming Kingston Harbour by Using its Untapped Human Capital

As one of the finest natural harbours and the seventh deepest in the world, Kingston Harbour is, as we have seen, one of Jamaica's jewels. We can debate whether the harbour is a "pot of gold" or a "pipe dream"; what it is depends, in part, on the people in and around the area, their activities and responses to environmental and economic factors surrounding the harbour. Over the years, changes in the climate and human activities have led to calls for the rehabilitation of the Kingston Harbour, to restore it as the asset that it can be to socio-economic growth and development. If our untapped human capital is not seen as integral to the rehabilitation of the harbour, the government's strategic plan for sustainable development will be futile. As such, we must bear in mind the repercussions if the economic and ecological functions of the harbour are not maintained and enhanced.

Human capital is the "stock of skills that the labour force possesses" (Goldin, 2015). Such a "stock," when invested in, can be regarded as an asset to economic growth and sustainable development and is, undoubtedly, a priority on the agenda for countries around the world. The concept of human capital embraces the aggregates of health, education, training and the skills of a country's population. Indisputably, the quality of a country's human capital is an indicator of national progress and a determinant in the ability to take advantage of innovations that focus on increasing productivity. In Jamaica's case, such an indicator is useful as we strive to achieve prosperity towards Vision 2030 – making Jamaica "the place of choice to live, work, raise families and do business". A *Gleaner* editorial (2018) titled "Fixing Productivity by Fixing the People", reported that a study published by the *Lancet* in collaboration with the World Bank,

revealed that over a quarter century, Jamaica slipped seven places from 81st in the 1990s to 88th in 2016 out of a total of 195 countries in a human capital development survey. This speaks to the quality of the human capital in Jamaica, which includes the communities in and around Kingston Harbour.

Figure 5.1
Section of Kingston Harbour 1962
Source: http://digjamaica.com/m/blog/kingston-harbour-polluted-then-polluted-now/

In its "glory days", the harbour was the site of a range of recreational activities and served as a port of call for cruise ships, which allowed for recreational enjoyment as well as economic empowerment for those living in the surrounding communities. Fast-forward to the twenty-first century when environmental security and climate change are pressing issues for the sustainability and preservation of our natural resources. The question to be asked, then, is, has the consciousness of the people living in and around Kingston Harbour been raised to understand these pressing issues? Has there been any significant behavioural change, brought about by investment in the human capital, the citizens?

The pollution epidemic in and around the Kingston Harbour is undeniably a recurring threat to the sustainability and profitability of this natural jewel. Apart from the improper disposal of **non-biodegradable**, solid waste materials in the harbour, we saw in the previous chapters examples of other issues affecting the harbour, including:

Non-Biodegradable/Biodegradable – non-biodegradable materials, like plastics, take > 450 years to be reduced to the molecular level. By contrast, biodegradable materials are capable of being broken down into innocuous products by the action of living things (especially microorganisms) in weeks and up to two years.

1. The location and importance of the natural resource: close proximity to the city and many communities that practice illegal and harmful waste disposal. In addition, it is the mouth to many rivers and surrounding gullies as well as a natural habitat for marine life
2. Misuse of the natural resources for economic purposes, leading to pollution from the Petrojam oil refinery and passing ships, for example
3. The possibilities for restoration and the accompanying challenges for re-establishing a port of call for cruise ships
4. Destruction of the mangroves and ecosystems
5. Chemical pollution from surrounding agricultural activities
6. River and tombolo sand mining
7. Endangering animal and marine life within and around the harbour

The Role of Law Enforcement and Integrity

Pollution in its varied forms plagues the environment and is a danger to efforts to mitigate and reduce the effects of climate change. We must strongly acknowledge the role of the rule of

law and enforce the laws that apply to address the future of the environment as a whole, not only Kingston Harbour. As it relates to governance, the primary national body responsible for the environment and its sustainability, the National Environment and Planning Agency (NEPA), is tasked with leading Jamaicans in protecting and caring for the environment. The legal framework within which they operate through policies, acts and legislation include the Beach Control Act (1956), Natural Resource Conservation Authority Act (1991), and the National Solid Waste Management Act (2001).

Figure 5.2
Eye sore; the condition of coastal shores
pre-plastic ban across the island
Source: http://nepa.gov.jm/kingston%20harbour/html/slideshow21.htm

Government agencies are not a singular party to this crusade for law and order, however. Citizens have to play their part.

The need for civics, with a key focus on environmental responsibility, to be re-introduced into the school curriculum as a way of building awareness of sustainability is critical, as citizens fail to familiarize themselves with the laws and regulations of the country. A survey conducted in 2002 by the Ridge to Reef Watershed Project reported that most Jamaicans had no knowledge of the environmental laws or regulations with the exception of the Anti-Litter Act (yet to be approved), which was mentioned by fewer than 24 percent of the respondents. Offences under the National Solid Waste Management Act 2001 attract a maximum penalty of J$1,000,000 or 9 months in prison for the unauthorized and illegal disposal of garbage, chemical waste or solid waste in gullies, rivers or streams. In an effort to expand its mandate with regard to public education, NEPA created an easily accessible *Pocket Guide to Environmental and Planning Laws of Jamaica* for civilians. However, while it is readily available, not many people access or utilize it. The task is for the residents of communities within and around the harbour to make the effort to protect their environment by obeying the laws. This is critical in the enforcement of the laws as there is a shared responsibility among civilians and law enforcers as we all co-exist within the same environment. There is a need for better coordination and dialogue between the enforcing agencies and community members as it relates to the enforcement of environmental legislation. This was noted in NEPA's State of the Environment Report (2011) as NEPA continues to face numerous challenges in enforcing environmental laws.

Jamaica's coastal water is mostly polluted with untreated sewage and other pollutants from sources such as habitat modification (dredging and clearing of mangroves), construction works, power plants, and industrial facilities (*State of the Environment Report*, 2011). NEPA's report also revealed that since the implementation of the Kingston

Harbour Environmental Compliance Programme in 2009–2010, 90 percent of the entities served with notices in relation to the pollution of Kingston Harbour, complied with the requirements of the notices.

A Way Forward

Efforts to rehabilitate Kingston Harbour date as far back as the early 1990s. In 2003, the Inter-American Development Bank along with the Government of Jamaica partnered on a US$620,000 project, the "Institutional Strengthening for Enhanced Environmental Management of Kingston Harbour". This project was the implementation phase of a 1996–98 effort, "An Integrated Investment Plan for Rehabilitation of Kingston Harbour". Of the four components or key recommendations, one was central to the development of human capital: Component D – "Public outreach, education and training" (National Environment and Planning Agency, 2005). The need for public outreach, education and training are some of the many ways to improve and tap into the human capital of the citizens living in and around Kingston Harbour. These measures are not only feasible but practical and can be beneficial and effective if each steward plays an active role in conserving the environment through investing in his or her own behavioural change. The ripple effect of tapping into the human capital of the Kingston Harbour communities, would extend beyond the goal for holistic sustainable development and also improve the economy and livelihoods in a vibrant downtown Kingston.

Another viable and practical solution is urgent policy interventions and innovative solutions designed to defeat the underdevelopment of human capital and the environment. In his address on the impending ban on single-use plastics in September 2018, Hon. Daryl Vaz, Minister without Portfolio in the Ministry of Economic Growth and Job Creation with responsibility for Land, Environment, Climate Change and

Investments, stated that the sustainable development of our island is inextricably linked to the health of the oceans and coastal shores. The improper disposal of Styrofoam and single-use plastics across the island is an eyesore as well as a contributor to blocked drains which, in turn, contribute to major flooding across the country. Since the implementation of the ban on January 1, 2019, citizens have been encouraged to utilize reusable grocery bags, paper straws and reusable containers as the enforcement of the environmental legislation takes hold.

Young, innovative entrepreneurs took advantage of the ban by filling the void with creative alternatives to the banned items. A young, dynamic group of four, Those Creative People Tings (TCP Tings), highlighted just how much of a "pot of gold" a "scandal-free" Jamaica can be with catchy signature lines like "One Bag ah Tings", "Scandal Free Life", and "Nuh Inna Di Scandal". They, among others, have joined the many environmentally friendly campaign initiatives across Jamaica to not only raise awareness but also shed light on the responsibility the public has for protecting the environment. Many have commended the Government of Jamaica and pledged their support for the proactive measures they have taken to make the environment a priority and steer the country towards a more sustainable future. These social interventions related to behavioural change have been lauded as the Government of Jamaica adopts best practices drawn from local and international examples that will contribute to the sustainability of the environment we live in.

Building Public Demand

The combined efforts of the private sector, government and citizens are needed for the restoration, conservation and sustainability of the Kingston Harbour as this is a collective responsibility. The harmonization and unification of efforts to restore and revitalize the Kingston Harbour is dependent

on the Jamaican people. Recognizing that each action has a consequence, citizens must play their part in ending the pollution crisis and the illegal dumping into gullies, streams and landfills surrounding the harbour. It takes a village – inclusive of companies and industries that surround the areas – to adhere to the legislation created to protect the environment. The fate of the Kingston Harbour lies in the hands of the communities which must unleash and develop the human capital to maximize this utility to its greatest economic, recreational and industrial levels through sustainable, safe and monitored measures.

Sir Alister McIntyre, in the second GraceKennedy Foundation Lecture, shed light on two practical dimensions of human resource development. The first is concerned with the involvement of human beings in the production of goods and services; in other words, human resources are means to development. Applying this to our present discourse, we can deduce that our Jamaican people can contribute to the production process by applying human effort/human capital and ingenuity to preserving the harbour as one of nature's gems. Moreover, this creativity is the driving factor behind identifying the ideal tools and opportunities available for producing and securing the harbour's existence. The second dimension he described as "the ultimate end of development". This, he explained, is the development of people from both material and non-material points of view. This dimension is centred on the utilization of the returns or benefits of the products/developing human capital for the improvement of people's condition. This goes beyond the creation of opportunities related to the harbour and envisions how tapping into these opportunities can improve income generation, health, education and self-respect. With the application and systemization of technology, both dimensions are enhanced and increase the country's capacity to adapt, secure, produce and utilize technology.

Digital Footprint

It is non-debatable that the digital age and advancements in technology have significantly strengthened the reach and broadened the scope of impact for the development of human capital and resources. Technology, like human resources, can be viewed as a means to development and also an end when we examine the capabilities of its potential to tap into the "pot of gold". Sustainability can be furthered, researched, tested and marketed as a means to an end using technology. McIntyre (1990) contended that if Jamaica is to make any significant progress, there will need to be significant investment in computer-based services and explained the role of the labour force and the skill sets needed at both secondary and tertiary levels. Jamaica has responded and should be applauded for its investment in developing human capital through education and training, for example the exchange programmes for Jamaicans to embark on environment studies, engineering and port management across the world and at our newly accredited Caribbean Maritime University.

The digital world has been an advantageous playground for young 'techies' who pride themselves with launching social media campaigns to support environmental sustainability and security. "Nuh Dutty Up Jamaica" is one of the most popular campaigns, leaving an impactful digital footprint, and many service clubs and organizations engage the citizens of Jamaica in environmental clean-up campaigns. Online social media platforms have also been used by service groups, governments and organizations to promote and educate the population on best practices in environmental health.

Figure 5.3
Nuh Dutty Up Jamaica Campaign ad
https://nuhduttyupjamaica.org/

Sustainability

The call for partnership is more than clear, and the private sector must be commended for its continued, and more recent efforts in environmental stewardship such as using bio-degradable packaging and going paperless. Public–private partnerships are critical elements in this sustainable development agenda. A number of private sector entities have taken meaningful steps to ensure their compliance with this ethos for environmental protection and conservation. Such entities include wholesale clubs and supermarkets which encourage and provide their customers with eco-bags as an alternative to plastic bags. Jamaica National Building Society provides millions of dollars in loans and funds for environment-friendly projects, and GraceKennedy and Sandals/ATL Group have both made environmental protection a part of their corporate social responsibility. The reduction in the use of major non-

biodegradable items that, when disposed of improperly, pollute the ecosystem and environment of the Kingston Harbour is the first commendable step in achieving sustainability. Investment in the areas of education, health and training will tap into the human capital of citizens living in the areas around the Kingston Harbour and, by extension, all Jamaicans and will secure a clear road map to guarantee sustainable development and continuity.

Figure 5.4
Members of staff from the hotel industry
participating in a coastal clean up
Source: loop/https://petchary.files.wordpress.com/2015/02/sandals-nuh-dutty-up-jamaica-2-loop.jpg?w=300

The United Nations Development Programme's Human Development Indices and Indicators for 2018 pointed out that human development through investing in human capital is not sustainable if climate change and environmental degradation are not addressed. The report on the progress of Jamaica's HDI indicates that this has worsened. Their suggestion for genuine sustainable human development is to end the normative

business-as-usual approach and adopt sustainable consumption and production patterns.

The enforcement of the legislation and policies created to protect the harbour and its environs, along with stringent compliance and stewardship of citizens and companies also play a vital role in the sustainability of the Kingston Harbour. Kingston Harbour is our "Pot of Gold". The harbour is ours to harness but, first, we need to rehabilitate, preserve and sustain it. Otherwise, as the potential wealth and socio-economic development we seek will be unattainable. We each have a role to play; let us work together to restore the harbour and claim the pot of gold for this and future generations.

Notes

1. Kingston Harbour's waterfront is divided into six waterfront zones: (1) Port Henderson/Fort Augusta/Causeway; (2) Three Miles/Port; (3) Downtown; (4) Windward/Bournemouth; (5) Harbour View; and (6) Palisadoes-Port Royal.

2. Calculated from the 2011 Population and Housing Census.

Appendix

PLASTIC FACTS

What can we/should we do?

There is **no single solution** and a strategic mix of approaches specific to a given locality will be required

Improved public awareness about the consequences of plastic contamination and how it affects our health and the environment.

The greatest impact can be had through **"prevention"** to significantly reduce the volume of plastic entering the environment in the first place. This means dealing with the problem at source.

Clean-ups are great but investment in prevention at source is required to avoid debris continually returning on the next tide and to provide a long-term solution to plastic pollution.

Reduce the quantities of plastics that we produce, use and discard, particularly those of single use, and reduce the escape of plastic into the environment.

Assign value to used plastic as a resource that is maintained within a "circular economy." For example, the proposed deposit return scheme.

Recycling can also help maintain plastics within a circular loop as they are remanufactured into new products and up-cycling actually increases the value of the "new product".

As citizens, we must welcome **policies that remove/reduce single use plastic** products from the market.
Plastic products that can be re-used are a more resource-efficient option than single-use products.

It is possible to produce plastics with safer chemical components through **green chemistry (bioplastics)**.

PLASTIC FACTS

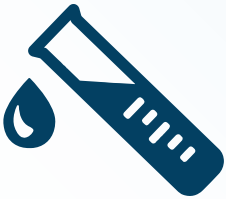
What is the threat?

The chemical ingredients used in over 50% of plastics are described as **hazardous chemicals.**

Plastic debris in the environment adsorb pollutants such as pesticides. Concentrations of these substances can reach over one million times that of the surrounding water or soil.

Ingestion of microplastics by fish, crustaceans and invertebrates leads reduced growth, reduced body size, and reduced performance.

Microplastics have been identified in a variety of commercial fish and shellfish ... and now in humans.



There is **widespread human exposure to plastic-related chemicals**, such as Bisphenol A (BPA), through exposure to plastic products and consumption of food that comes in contact with plastic.

Chemicals in plastics have **impacts on human** reproductive development, neurodevelopment and immune function, adverse birth outcomes, delayed growth and puberty, altered behaviour, obesity, increased risk of allergic diseases, Type II diabetes, cardiovascular disease and can alter the function of the endocrine system.

Without intervention, the **volume of waste** that we produce and the volume of plastics entering the environment will increase exponentially in the coming decades and so action is required NOW, before it is too late.

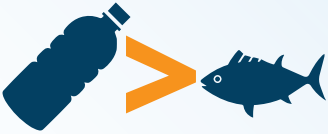
PLASTIC FACTS

How much is there?

Every year, **275 million metric tonnes of plastic** waste is produced globally.

Two billion people worldwide, living within 30 miles of the coast, produce **100 million metric tonnes of plastics.**

8 million metric tonnes of plastic ends up in the ocean every year. This is equivalent to a large garbage truck dumping a load in the ocean every minute.



By the year **2030** there will be **more plastics in the ocean than fish.**

There are **5 trillion pieces of plastic** floating in the global ocean (50 times the number of stars in the galaxy), and 50% of these are microplastics.

Jamaica produces **650 million plastic bottles per year**. Ten percent (10%) are recycled, (30%) collected, and the rest are discarded in the environment.

More than **80% of solid waste** in the marine environment **is plastic**.

PLASTIC FACTS

What is plastic and microplastic?

Plastics are a group of synthetic polymers, mainly derived from fossil fuels (oil, coal and natural gas) and which are made of carbon, hydrogen, silicon, oxygen, chloride and nitrogen.

Plastics are extensively used because of their stability and durability.

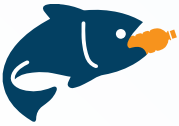
Plastics take between 450 and **1000 years (or more) to break down**, which makes them accumulate in the environment. Instead of breaking down, they break up into smaller and smaller pieces.

Burning of plastics like polyvinyl chloride (PVC) produces **persistent organic pollutants** (furans and dioxins).

Burning of polyethylene, polyurethane, polyvinyl chloride and polystyrene produces toxic irritant products that lead to **immune disorders and lung diseases**, and these products are classified as possible human carcinogens.

Plastic debris weathers in the sun, progressively fragmenting into smaller pieces through exposure to ultra-violet (UV) light and water movement.

Fragments <5mm in size are called "microplastics".



Microplastics have been found in the field (water column and sediments) in collected **fish and invertebrates all over the world.**

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