UNIVERSITY OF THE WEST INDIES
MONA CAMPUS
CENTRE FOR MARINE SCIENCES

National Ballast Water Status Assessment and Economic Assessment

JAMAICA

October, 2016

This Technical Report was prepared by the Centre for Marine Sciences, University of the West Indies, Mona for the Maritime Authority of Jamaica and the GEF-UNDP-IMO GloBallast Partnerships Programme

The main author was Dr Dayne Buddo, with significant inputs from
Miss Denise Chin, Miss Achsah Mitchell and Mr Stephan Moonsammy
Reviewed by Mr Vassilis Tsigourakos (RAC/REMPEITC) and Mr Antoine Blonce (GloBallast)

Table of Contents

List of Figures

List of Tables

CHAPTER 1.0: SHIPPING

1.1 The role of shipping on the national economy

The island of Jamaica is found in the Greater Antilles of the Caribbean archipelago, 18º 15’ N and 77º 30’ W (Greenwich Mean Time 2009). The island’s proximity to the major international shipping lanes in the Caribbean allows for its participation in several shipping activities between the Panama Canal, North America and South America. The shipping industry of Jamaica is dominated by a major transhipment hub at its largest port on the island, the Port of Kingston. Cruise ship terminals (Port of Ocho Rios, Port of Montego Bay, Port Antonio and the newly added Port of Falmouth) attract the largest tourist market from Jamaica’s northerly neighbour, the United States of America. The size of vessels as well as their traffic is expected to increase at most if not all ports on the island upon completion of the expansion of the Panama Canal in 2014. During the last nine years, the greatest traffic was experienced in 2006 with 4,063 vessels visiting Jamaica’s 14 ports, with 3,621 vessels visiting in 2011. The figure for 2012 (up to September) is 2,744 vessels. Approximately, 80% of the vessels were cargo vessels (see table 1). The Port of Kingston received ~70% of the total vessel visits, and ~40% arrived at the Kingston Container Terminal in the Port of Kingston during the nine years documented. In 2011, a total of 30,413,713 metric tonnes of cargo were handled island wide (see table 2), with 63% (19,035,622 mt) were handled at the Port of Kingston (see table 5). The large majority of vessels calling at Jamaican ports were over 10,000 gross tonnage with the average gross tonnage of vessels being over 40, 000 gross tones (total average ~20,000 gross tonnes). In the out ports where the majority of the bulk cargo exports occur the average gross tonnage of the vessels was 70,000 gross tonnes in 2011. The majority of vessels calling at Jamaican ports are foreign registered vessels with only twenty-three (23) of the cargo ships being Jamaican registered. Several ports export dry bulk (bauxite, alumina, and sugar), while some import crude oil and other petroleum based products. The total amount of exports of bulk cargoes in 2011 was 10.3 M tonnes while imports was a low of 0.7 M tonnes.

The Government of Jamaica through the Maritime Authority of Jamaica, the regulatory agency responsible for shipping, administers an international ship register. There are limited dry-docking facilities in Jamaica however the Government is actively supporting private sector investment in a floating dry-dock facility for vessels up to 30,000 gross tonnage.

Table 1: Ships Registered in Jamaica (Source: GISIS)

Name	Flag	Gross Tonnage	Type	Year of Build	Registered Owner
METROPOLIS	Jamaica	17,261	Passenger/Ro-Ro Ship (Vehicles) (Passenger/Ro-Ro Cargo)	1972	METROPOLIS CRUISE CO LTD (5305251)
REX FORTUNE	Jamaica	9,848	Passenger/Cruise (Passenger)	1974	STAR SAIL INVESTMENTS LTD (5812551)
STARRY METROPOLIS	Jamaica	15,791	Passenger/Cruise (Passenger)	1976	INCOME CHINA INTERNATIONAL (5622990)
CARIBBEAN QUEEN	Jamaica	260	Passenger Ship (Passenger)	1979	B & D TRAWLING LTD (1193384)
SUN RIZHAO	Jamaica	2,574	General Cargo Ship (General Cargo)	2007	CHINA SHENZHOU DEVELOPMENT (5927447)
SUN UNION	Jamaica	3,802	General Cargo Ship (General Cargo)	1995	SUN FLEET INTERNATIONAL CO LTD (5757376)
PAMPERO	Jamaica	4,628	General Cargo Ship (General Cargo)	1995	RPTD SOLD UNDISCLOSED INTEREST (9991942)
PACATU	Jamaica	9,957	Container Ship (Fully Cellular) (Container)	2004	PACATU SCHIFFAHRTS GMBH (5925848)
CFS PALAMEDES	Jamaica	7,578	General Cargo Ship (General Cargo)	2005	PIT PALAMEDES GMBH & CO KG (5939569)
CFS PAFILIA	Jamaica	7,578	General Cargo Ship (General Cargo)	2006	PAFILIA (5366977)
SUN MIRACLE	Jamaica	2,358	General Cargo Ship (General Cargo)	2004	SUN EVERBRIGHT CO LTD (5381293)
SUN HUNCHUN	Jamaica	2,358	General Cargo Ship (General Cargo)	2004	DOUBLE WIN CO LTD (5492156)
OCEANS FOR YOUTH	Jamaica	141	Passenger/Cruise (Passenger)	1976	MAREA MERIDIONALE LTD (5948743)
NEW HUNCHUN	Jamaica	3,354	General Cargo Ship (General Cargo)	2007	ROYAL ARMADAS INTL CO LTD (5323451)
NEW HUNCHUN	Jamaica	3,354	General Cargo Ship (General Cargo)	2007	ROYAL ARMADAS INTL CO LTD (5323451)
SUN RIZHAO	Jamaica	2,574	General Cargo Ship (General Cargo)	2007	CHINA SHENZHOU DEVELOPMENT (5927447)
DONG CHENG 7	Jamaica	2,926	General Cargo Ship (General Cargo)	2009	DONG CHENG SHIPPING LTD

					(5834492)
PAMPERO	Jamaica	4,628	General Cargo Ship (General Cargo)	1995	RPTD SOLD UNDISCLOSED INTEREST (9991942)
SHUN YUE 13	Jamaica	3,745	General Cargo Ship (General Cargo)	2011	MENGXIN SHIPPING CO LTD (5800062)
CFS PANJANG	Jamaica	7,464	Container Ship (Fully Cellular) (Container)	2008	PIT PACIFIC INVESTMENT (5429896)
SHUN YUE 19	Jamaica	6,778	General Cargo Ship (General Cargo)	2011	MENG YUAN SHIPPING HONG KONG (5800059)
CFS PACENO	Jamaica	9,957	Container Ship (Fully Cellular) (Container)	2008	PACENO HARREN & PARTNER (5909896)
SEA GLORY	Jamaica	2,926	General Cargo Ship (General Cargo)	2009	SEA GLORY INTERNATIONAL SHPG (5819721)
NEW GLOBAL	Jamaica	6,609	General Cargo Ship (General Cargo)	2010	ROYAL FLEET CO LTD (5738615)
PARADERO	Jamaica	8,246	Container Ship (Fully Cellular) (Container)	2007	PARADERO (5358067)

Jamaica is a seafarer supply country with the Caribbean Maritime Institute being the only IMO accredited facility for the licensing of officers in the English-speaking Caribbean. Several seafarers have been licensed since the inception of the Institute in 1980 and having regard to the recent expansion of the facilities the current enrolment of cadets is two hundred and fifty five. The control of vessels operating in Jamaican ports is shared between the Harbour Master, The Port Authority of Jamaica and the Maritime Authority of Jamaica. The Harbour Master has the authority to direct the movement of vessels within the harbour limits and approaches while the Port State Control officers of the Maritime Authority are empowered to board and inspect ships for compliance with treaties to which Jamaica is a party. In addition to boarding and inspection the Harbour Master and Port State Control officers are vested with the power to warn, detain and deny access to Jamaican ports.

Source: (JAMPRO 2010)

Figure 1: Map of Jamaica's position in the global shipping industry.

Table 2: Vessel traffic from 2004 – 2012 with most being cargo vessels (PAJ 2008; PAJ 2012).

	Total Vessel Visits	**Cargo Vessels**	**Cruise Vessels**
2004	3,528	2,949	481
2005	3,767	3,076	511
2006	4,063	3,382	562
2007	3,758	3,222	438
2008	3,587	3,016	401
2009	3,397	2,818	333
2010	3,635	3,161	325
2011	3,621	3,064	370
2012	2,744	2,266	288

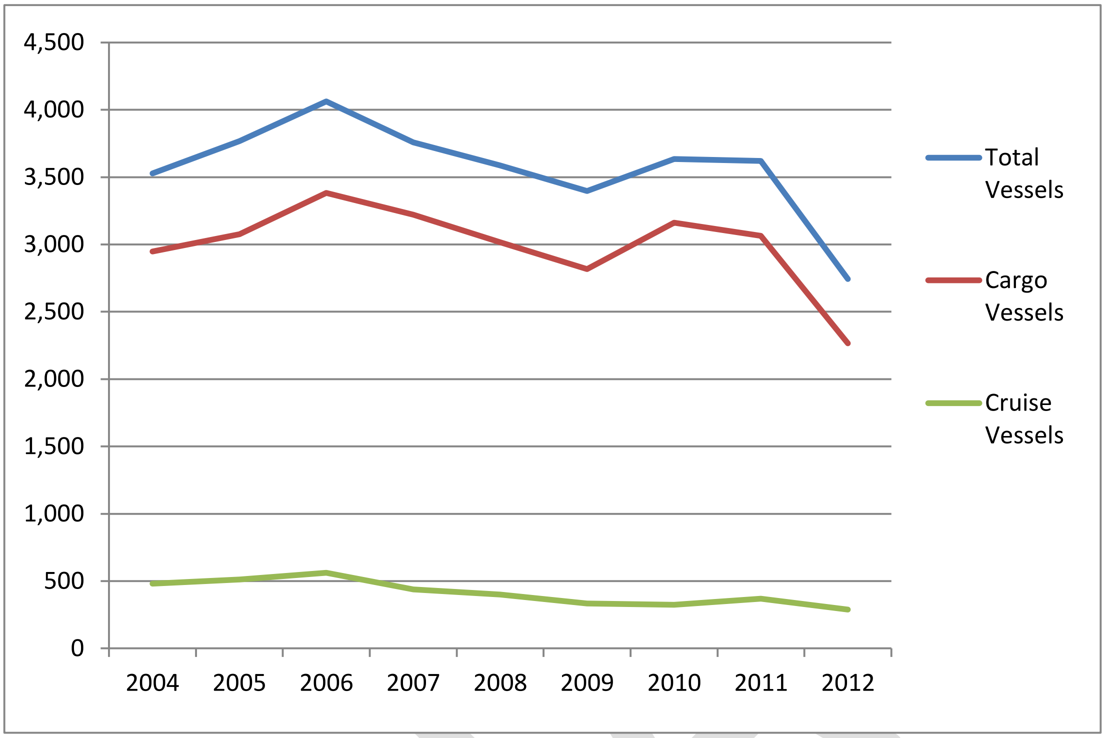


Figure 2: Vessel traffic from 2004 – 2012, with cargo vessels constituting a majority. The rise from 2004 to 2006 has been followed by a general decrease in the number of vessels arriving in the island.

Table 3: The total and average gross registered tonnage (GRT) as well as the amount of cargo handled by all ports from 2004 – 2012 (PAJ 2008; PAJ 2012).

	Total Gross Registered Tonnage	Average Gross Registered Tonnage	Cargo Handled (mt)
2004	86,147,560	24,418	25,989,703
2005	94,347,126	25,046	27,686,029
2006	109,947,741	27,061	31,710,582
2007	99,237.14	26,407	31,422,962
2008	89,473,594	24,944	30,303,308
2009	81,985,305	24,135	24,985,604
2010	87,822,402	24,200	27,069,396
2011	97,228,049	26,851	30,413,713
2012	-	-	17,851,962

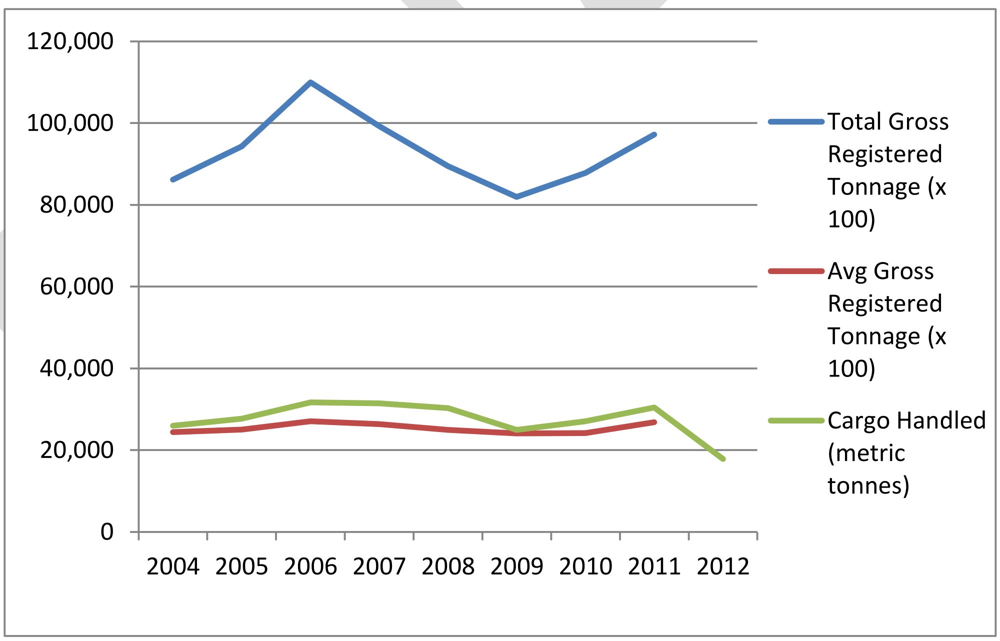


Figure 3: The fluctuation in the total GRT with a high in 2006 and a subsequent low in 2009 produced a steady average from the time period 2004 to 2012. The amount of cargo handled followed the trends of total GRT slightly.

Table 4: Export products of Jamaica from 2004 – 2012 with bauxite as the leading export product (PAJ 2008; PAJ 2012).

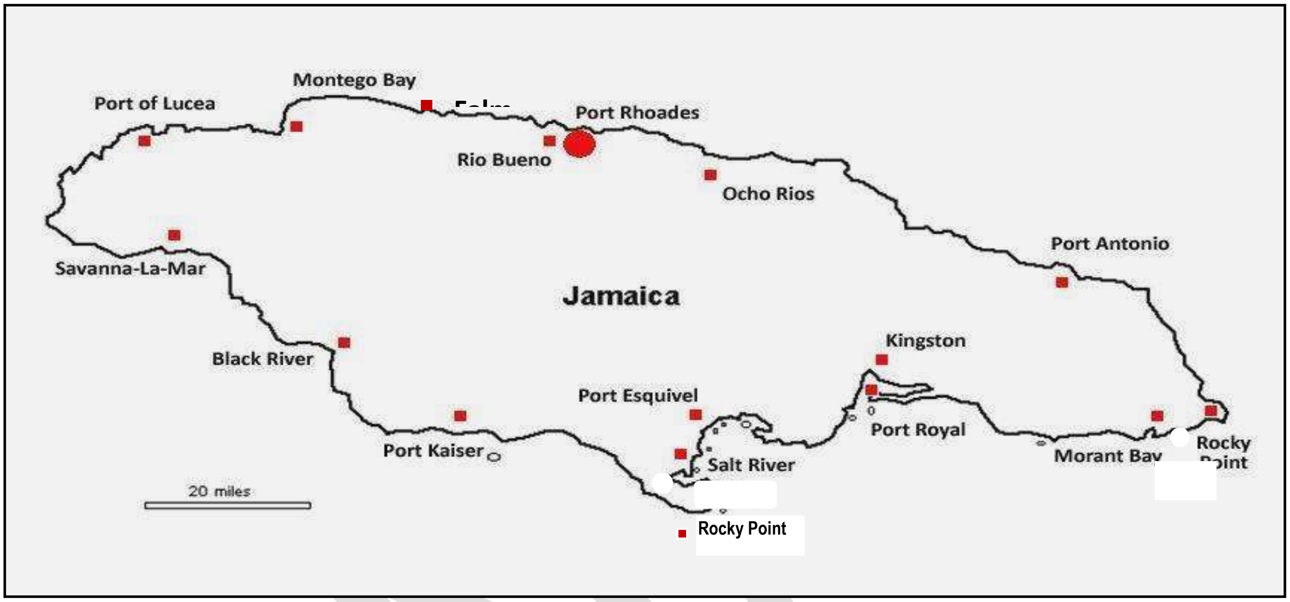
	Export				
	Bauxite	Alumina	Sugar	Motor	Total
2004	8,044,308	3,998,462	156,790	0	12,199,560
2005	9,131,466	4,177,255	112,857	0	13,421,578
2006	9,621,626	4,059,214	140,128	0	13,820,968
2007	9,258,543	3,906,750	153,332	0	13,318,625
2008	9,321,686	4,008,732	135,927	2,406	13,468,751
2009	5,758,797	1,906,170	120,170	1,533	7,786,670
2010	6,816,216	1,566,667	92,605	1,417	8,476,905
2011	8,180,264	2,004,022	110,638	1,383	10,296,307
2012	5,760,401	1,388,215	103,118	1,605	7,253,339

Table 5: Import products of Jamaica from 2004 – 2012. Oil products are the leading products imported in the island (PAJ 2008; PAJ 2012).

	Import			
	Crude Oil	Other Petroleum	Motor	Total
2004	752,810	1,150,859	29,398	1,933,067
2005	387,904	1,679,429	29,116	2,096,449
2006	1,070,511	1,296,423	21,784	2,388,718
2007	1,267,840	1,334,019	19,785	2,621,644
2008	1,166,979	1,215,694	15,932	2,398,605
2009	1,185,886	989,849	7,936	2,183,671
2010	1,179,746	845,193	8,324	2,033,263
2011	92,605	693,075	11,088	796,768
2012	110,638	633,726	13,823	758,187

1.2 Ports and harbours

According to World Port Source (2005-2016), there are 14 ports in Jamaica. There are six ports on the north coast and nine on the south (figure 4).



Source: Modified from Maritime and Coastguard Agency (2003 – 2010)

Figure 4: Map of the 14 Jamaican ports.

1.2.1 The Port of Kingston

The Port of Kingston is ranked a medium port by the World Port Source (2005-2016) and is located within the Kingston Harbour, which is on the south-east coast of Jamaica, between 17^{o} 57' N and 76^{o} 48' W (Goodbody 2003) or 17^{o} 57.0' - 17^{o}57.5' N and 76^{o}48.2' - 76^{o}48.5' W (Ranston, Simmonds, and Webber 2003). It is the largest port on the island and is the 7th deepest natural harbour in the world with a channel depth of 11 to 12.2 metres. Also a major port within the Caribbean, it provides a well-developed trans-shipment terminal, dry bulk cargo loading site and oil-dependent factories. As a result of its natural layout and central location in the region, the Port of Kingston has become a heavily trafficked transhipment port and therefore receives vessels from several international states (Goodbody 2003). The port does not offer services to handle dirty ballast.

The Kingston Wharves Limited is a listed public wharf which is privately owned and operated. Kingston Sufferance Wharves (K.S.W.) is a collective term used to describe the several sufferance wharves that are located in Kingston Harbour. These wharves contribute to the import and export of bulk cargoes mentioned earlier, including gypsum and limestone. The Kingston Container Terminal (K. C. T.) contributes to a majority of the vessels entering the Port of Kingston, and by extension, the entire island. The terminal is one of the leading container transhipment ports in the Caribbean. The North, South and West Terminal have a rated capacity of 2.8 M TEUs. The South Terminal is more than twice the size of the North Terminal which is similar in size to the west Terminal, with 1300 m, 535 m and 475 m of berth respectively.

Source: Google Earth (2012)

Figure 5: Map of the Port of Kingston

Table 6: Vessel traffic at the Port of Kingston, which consists of Kingston Container Terminal (K. C. T.), Kingston Wharves (K. W.) and Kingston Sufferance Wharves (K. S. W.) from 2004 – 2012 (PAJ 2008; PAJ 2012).

	Kingston	K. C. T.		K. W.		K. S. W.	
	Ships Calls	Total Vessel	Cargo Vessels	Total Vessel	Cargo Vessels	Total Vessel	Cargo Vessels
2004	2,340	1,275	1,275	642	549	419	429
2005	2,591	1,575	1,561	638	542	738	377
2006	2,858	1,749	1,749	753	659	356	347
2007	2,653	1,467	1,466	869	808	318	283
2008	2454	1,272	1,272	838	779	347	317
2009	2533	1,429	1,429	762	674	342	290
2010	2762	1,554	1,554	910	841	309	315
2011	2689	1,502	1,502	844	763	348	305
2012	2071	1,135	1,135	627	575	309	262

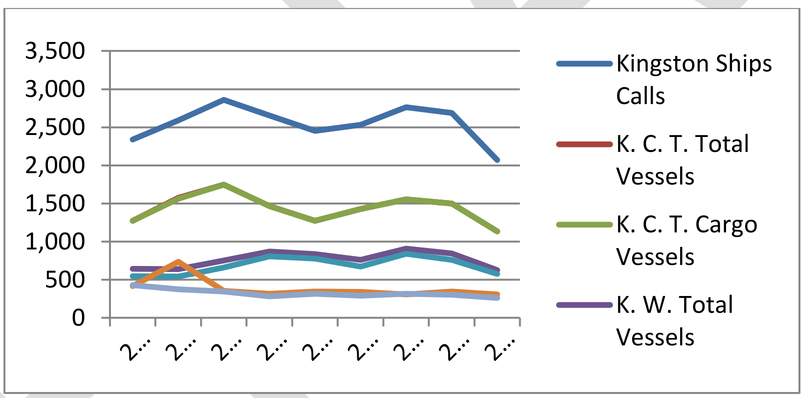


Figure 6: The vessel traffic from 2004 - 2012 at the Port of Kingston resembled that of the entire island, giving evidence the dominance of this port to the nations shipping regime. Most of the vessels entering the Port of Kingston docked at K. C. T.

Table 7: Cargo Handled at the Port of Kingston: Transhipment and Domestic from 2004 – 2012 (PAJ 2008; PAJ 2012).

	Port of Kingston		
	Transshipment	Domestic	Total
2004	8,990,548	4,937,153	13,927,701
2005	9,062,480	5,457,179	14,519,659
2006	11,433,085	6,397,705	17,830,790
2007	11,129,941	6,665,194	17,795,135
2008	10,143,541	6,196,627	16,340,168
2009	10,498,209	5,703,298	16,201,507
2010	11,726,484	5,711,151	17,437,635
2011	13,392,530	5,643,092	19,035,622
2012	6,173,485	3,644,601	9,818,086

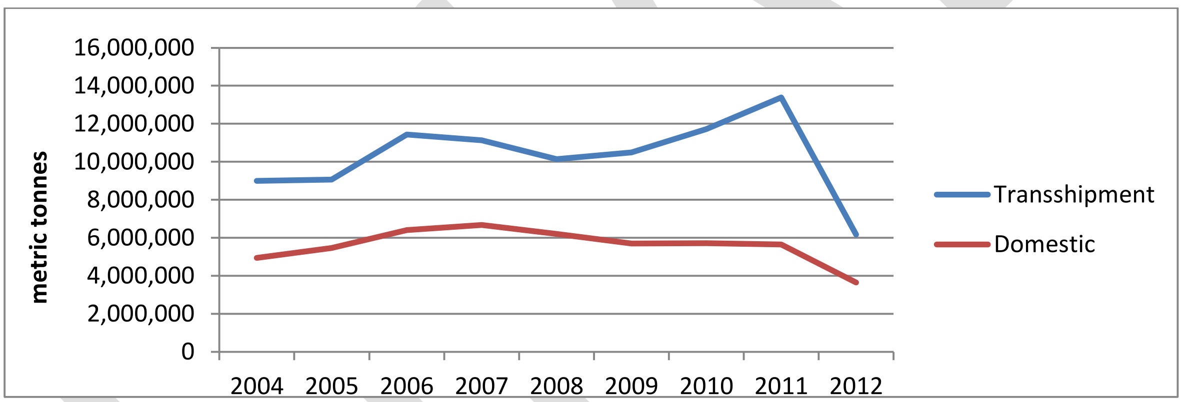


Figure 7: Cargo Handled at the Port of Kingston.

Table 8: Total liquid and dry bulk cargo discharged and loaded at the Kingston Sufferance Wharves (PAJ 2008; PAJ 2012).

	Liquid Bulk	Dry Bulk
2004	2,214,978	946,449
2005	2,359,236	1,230,186
2006	2,883,851	1,206,206
2007	3,007,786	1,060,400
2008	2,732,905	1,105,985
2009	2,498,947	1,029,457
2010	2,379,967	1,103,228
2011	2,171,760	943,716
2012	1,791,591	648,776

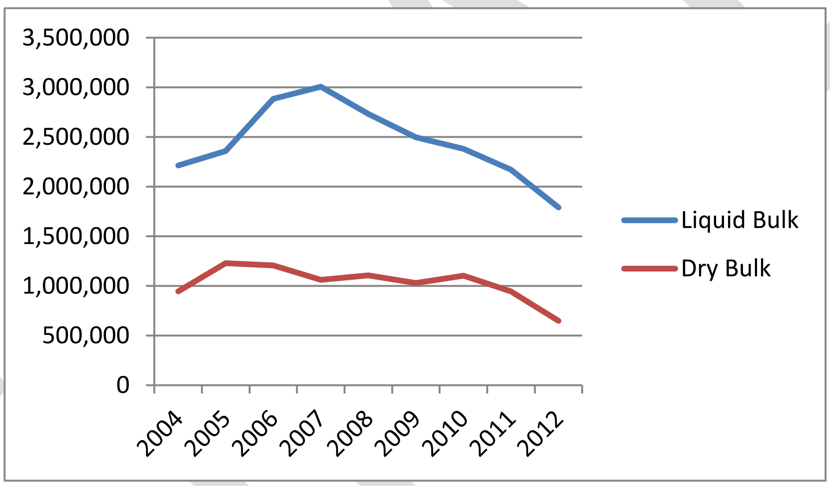


Figure 8: Total liquid and dry bulk cargo discharged and loaded at the Kingston Sufferance Wharves.

Table 9: Types of vessels entering the Port of Kingston from 2004 – 2012 (PAJ 2008; PAJ 2012).

	Container	RO/RO	General Cargo	Dry Bulk	Tanker	Cruise	Other
2004	1,550.0	122	152	175	248	1	92
2005	1,812.0	118	129	200	171	0	161
2006	2,004.0	142	108	306	109	1	108
2007	1,898.0	167	74	246	178	0	90
2008	1,729.0	113	69	211	174	0	157
2009	1,828.0	102	57	179	143	0	222
2010	2,007.0	142	104	236	149	0	123
2011	1,914.0	145	111	225	120	0	174
2012	1,371.0	141	97	144	105	0	213

1.2.2 Port Rhoades

Port Rhoades is located on the north coast of Jamaica, 18° 27.5' – 18° 28.2' N and 77° 25.1' – 77° 24.0' W (Webber et al. 2005) in the south-west corner of Discovery Bay in the parish of St Ann. It is a small port with relatively poor shelter and a channel depth of 11 – 12.2 m and a navigable width of 122m. The channel was dredged in 1969 through a coral bar between Fort Point and One Bush Point. The port exports bauxite which is loaded on one vessel at a time. In 2001, 58 vessels totalling 2,327,711 dwt visited the port. No services to handle dirty ballast are offered. The largest vessel handled at this port was 213 m with a draught of 11.4 m, which berthed on the starboard side. The tonnage of bauxite loaded at Port Rhoades fell from an average of approximately 9,000,000 in 2008 to almost 6,000,000 tones to 2009. A subsequent climb brought it up to 8,500,000 in 2011.

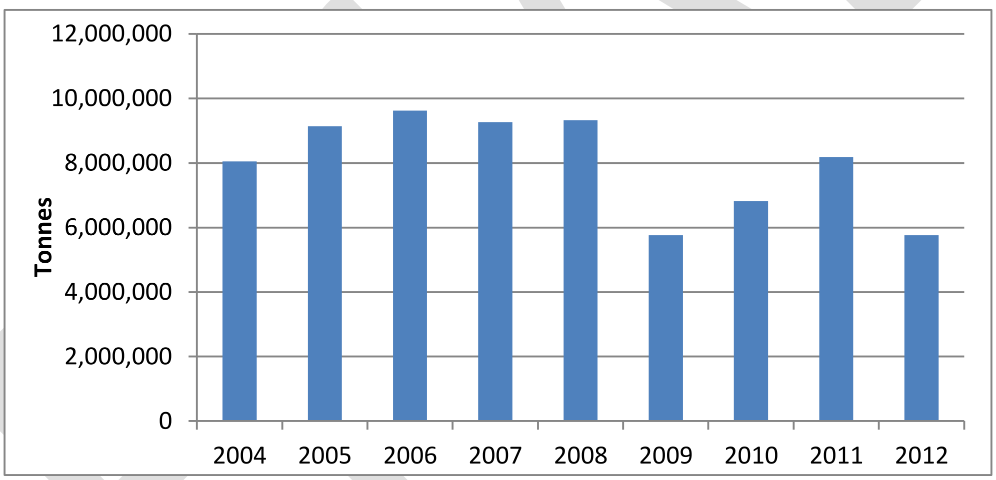


Figure 9: Amount of bauxite (in tonnes) that have been exported from Port Rhoades from 2004 to 2012 (PAJ 2008; PAJ 2012)

Source: Google Earth (2012)

Figure 10: Map of the Port Rhoades

1.2.3 Montego Bay

The Port of Montego Bay is the island's second international port and is located on the north-west coast of Jamaica at 18º 28' 28'' N and 77º 56' 12'' W. It is classified as a small seaport and has relatively fair shelter from the wind and waves. Port Handlers Limited, which manages the port, offers, according to the Port Authority of Jamaica, a 2694 m^2 cruise ship terminal; approximately 427 metres of berth; 1.2 hectares of yard space for container shortage, 1858 m2 warehouse. In 2001, 261 vessels totalling 1,853,894 dwt visited the port, with the maximum size of vessels handled at the port (to date of document) is a cruise ship of 339 m in length with 8.5 m draught. The channel is currently 10.36m deep after previous dredging exercises. The quarantine anchorage is located at Great River Bay which is West-South-West of the port.

Table 10: Vessels that visited at the Port of Montego Bay and cargo handled (in tonnes) from 2004-2012 (PAJ 2008; PAJ 2012)

	Total Vessel Visits	Cargo Vessels	Cruise Vessels	Cargo Handled (tonnes)
2004	369	204	161	694,295
2005	343	154	181	659,031
2006	360	136	219	714,421
2007	333	173	154	715,773
2008	384	225	152	784,697
2009	336	209	117	806,568
2010	330	204	120	698,459
2011	295	187	101	687,612
2012	209	114	85	526,206

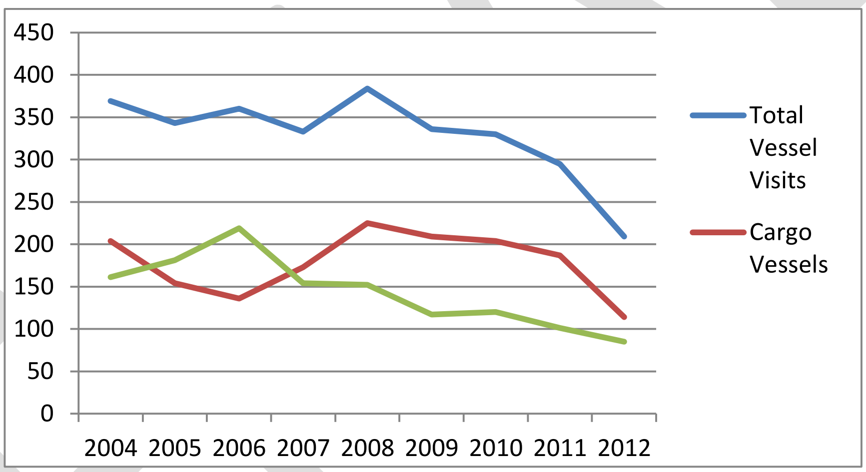


Figure 11: Vessels that visited the Port of Montego Bay from 2004-2012 (PAJ 2008; PAJ 2012)

Source: Google Earth (2012)

Figure 12: Map of the Port of Montego Bay

1.2.4 Ocho Rios

The Port of Ocho Rios is a small, coastal port located 18º 24’ 37’’ N, 77º 6’ 36’’ W and is poorly sheltered from wind and waves. This port is the leading cruise ship terminal in Jamaica, handling 46% of all passengers arriving in the island in 2007, 260 vessels totalling 2,457,217 dwt visited the port. The largest vessel handled was 274 m and had a draught of 12.19m. Lannaman & Morris manages the Port Authority of Jamaica owned port that only receives cruise ships and their passengers. Bauxite and Alumina Trading Company of Jamaica Limited (BATCO) owns and operates a bauxite pier which accommodates cruise ships occasionally. The quarantine anchorage is located “off the wharf”. No dirty ballast services are offered by the Port of Ocho Rios.

Table 11: Vessels that visited at the Port of Ocho Rios and sugar exported (in tonnes) from 2004-2012 (PAJ 2008; PAJ 2012).

	Total Vessel Visits	Cargo Vessels	Cruise Vessels	Sugar (tonnes)
2004	327	16	310	156,790
2005	338	13	321	112,857
2006	345	13	326	140,128
2007	291	14	275	153,332
2008	250	12	235	135,927
2009	222	8	211	120,170
2010	219	14	201	92,605
2011	169	13	156	110,638
2012	114	10	99	103,118

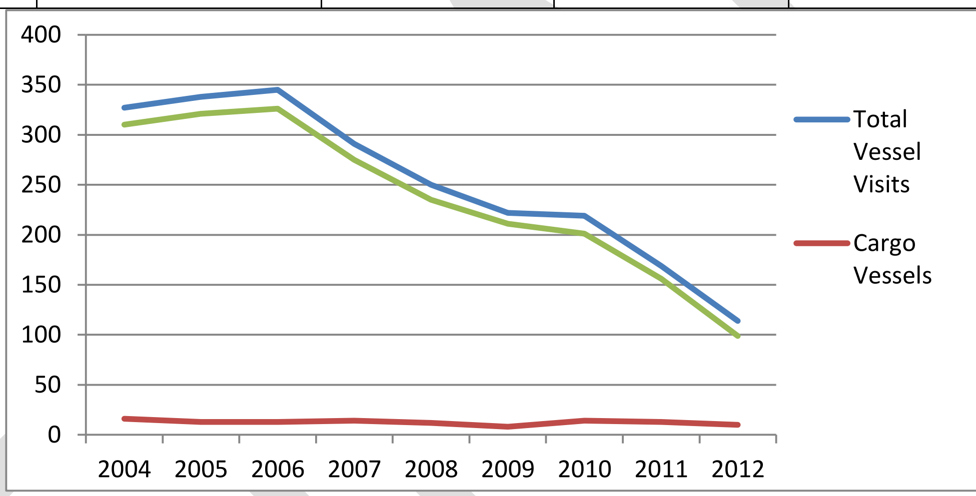


Figure 13: Vessels that visited at the Port of Ocho Rios from 2004-2012 (PAJ 2008; PAJ 2012).

Source: Google Earth (2012)

Figure 14: Map of the Port of Ocho Rios

1.2.5 Port Antonio

Port Antonio, located 18º 10’ 52’’ N, 77º 29’ 10’ W, is one of the three cruise ship terminals in the island, also consisting of two docking facilities. Boundbrook Wharf receives cargo from vessels of no greater than 168 m (500 ft.) and 7.9 m draught. When it was the primary port for the export of agricultural products (namely banana), the volumes of cargo were much larger. The second facility Ken Wright Pier receives cruise ships and their passengers with 8.8 m depth of water alongside. Errol Flynn Marina, a 32 slip facility for large yachts, is located at the West Harbour and owned by the Port Authority of Jamaica, offers a boat yard to service vessels no greater than 9.8 m (65 ft.).

Table 12: Vessels that visited at Port Antonio from 2004-2012 (PAJ 2008; PAJ 2012).

	Total Vessel Visits	Cargo Vessels	Cruise Vessels
2004	47	38	9
2005	46	35	9
2006	18	2	16
2007	14	3	9
2008	18	3	13
2009	10	1	6
2010	4	0	3
2011	3	0	2
2012	2	0	2

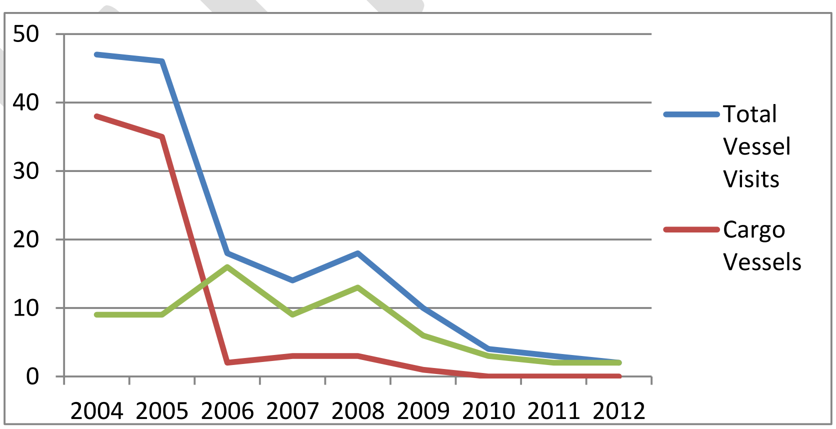


Figure 15: Vessels that visited at Port Antonio from 2004-2012 (PAJ 2008; PAJ 2012).

Source: Google Earth (2012)

Figure 16: Map of the Port Antonio

1.2.6 Port of Lucea

The Port of Lucea is a very small, coastal port with relatively fair shelter and is located 18º 26' 55'' N and 78º 10' 6'' W. A single pier exports cargo of molasses (sugar product), while bananas are loaded at an anchorage by way of lighters. The channel is 6.4 – 7.6 m deep while the depth alongside the cargo pier is 9.4 – 10 m. The largest vessel anchoring measured 137 m length and 7.3 m draught, with the largest berthing vessel measured 146.3 m with 9.3 m draught. No dirty ballast services are offered.

Source: Google Earth (2012)

Figure 17: Map of the Port of Lucea

1.2.7 Port of Falmouth

The Port of Falmouth, located 18º 30' N and 77º 39' W, is a cruise ship pier which has been newly added to the nation's ports, developed by PAJ and Royal Caribbean Cruise International. The new Oasis class of mega cruise vessels, that have a capacity of 8,000 passengers and 2,000 crew members, can be accommodated at the pier. The first ship called at the Falmouth Pier on February 17, 2011. The shipping channel at this port has been dredged to over 8.9 m depth. Vessels anchor at Great River Bay when quarantined, which is 20 miles west of the port.

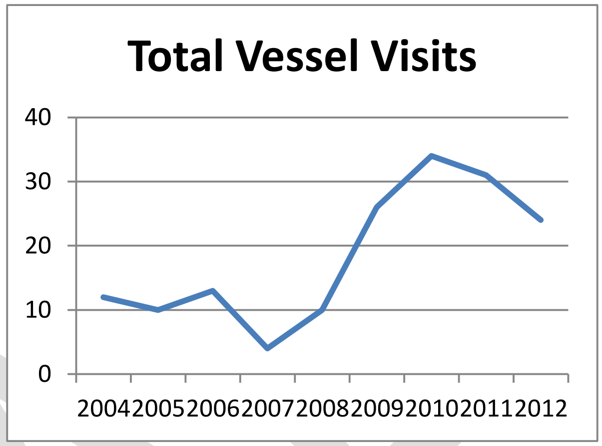
Figure 18: Map of the Port of Falmouth

1.2.8 Rio Bueno

Rio Bueno is a very small, coastal port with relatively poor shelter and is located 17º 53' 28'' N and 77º 7' 53'' W at the mouth of the Rio Bueno river. There is a jetty for receiving cargo such as grain. In 2001, 8 vessels totalling 40,483 dwt visited the port with the largest vessel measuring 107 m in length and 7 m draught, with 122 m length and 7.9 m draught at the anchorage point. The depth alongside the cargo pier is 7.1 to 9.1 m deep. No dirty ballast services are offered.

Table 13: Vessel traffic and exported Alumina

	Total Vessel Visits
2004	12
2005	10
2006	13
2007	4
2008	10
2009	26
2010	34
2011	31
2012	24



Source: Google Earth (2012)

Figure 19: Map of the Rio Bueno

1.2.9 Port Morant

Port Morant is a very small, coastal port with relatively excellent shelter and is located 17º

51’ 45’’ N and 76º 20’ 45’’ W. Vessels approach the port between Simonds Point and Palm Point. The channel is 7.1 – 9.1 m deep while the depth alongside the cargo pier is 4.9 – 6.1 m. No dirty ballast services are offered.

Source: Google Earth (2012)

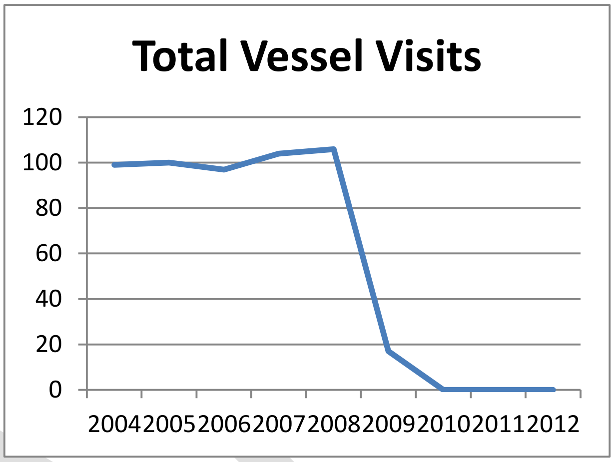
Figure 20: Map of the Port Morant

1.2.10 Port Esquivel

The Port of Esquivel, known locally as Alumina Marine Terminal, is a small, open roadstead port with relatively good shelter. It is located 17º 53’ 28’’ N and 77º 7’ 53’’ W at the head of Portland Bight and has a jetty as well as a cargo pier for handling alumina. The channel and the water alongside the cargo pier are both 11 to 12.2 m deep. In 2001, 131 vessels totalling 3,178, 257 dwt visited the port. The largest vessel handled at the port was 198 m long with a draught of 11 m. No dirty ballast services are provided.

Table 14: Vessel traffic and exported Alumina

	Total Vessel Visits	Alumina (tonnes)
2004	151	1,254,574
2005	138	1,236,595
2006	159	1,201,517
2007	162	1,234,231
2008	162	1,209,453
2009	81	232,218
2010	66	238,513
2011	97	593,019
2012	69	459,791



Source: Google Earth (2012)

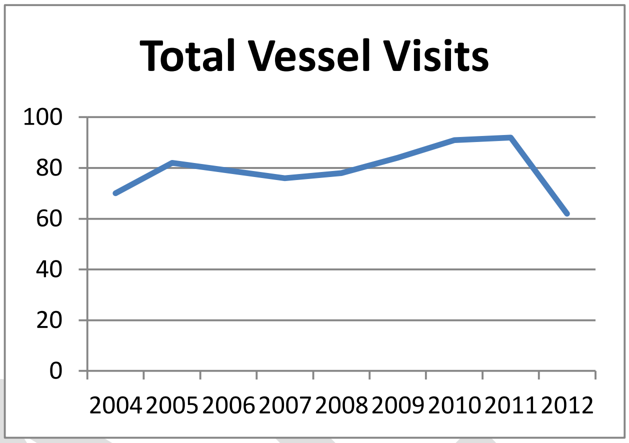
Figure 21: Map of the Port Esquivel

1.2.11 Rocky Point

The Port of Rocky Point is a very small, coastal port with relatively good shelter and is located 17º 49’ 4’’ N and 77º 8’ 31’’ W. There is a jetty for receiving cargo such as grain and exporting alumina. In 2001, 58 vessels totalling 1,867,434 dwt visited the port with the largest vessel measuring 213 m length and 10.6 m draught. The channel is 11 – 12.2 m deep while the depth alongside the cargo pier is 7.1 to 9.1 m. No dirty ballast services are offered.

Table 15: Vessel traffic and exported Alumina

	Total Vessel Visits
2004	70
2005	82
2006	79
2007	76
2008	78
2009	84
2010	91
2011	92
2012	62



Source: Google Earth (2012)

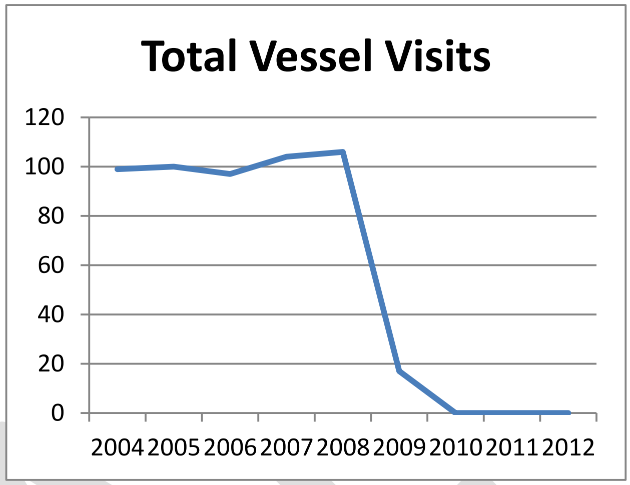
Figure 22: Map of the Port of Rocky Point

1.2.12 Port Kaiser

Port Kaiser is a very small, open roadstead port with relatively fair shelter and is located 17º 51' 40" N and 77º 36' 18" W at Little Pedro Point. The port exports primarily alumina. In 2001, 97 vessels totalling 3,220,549 dwt visited the port with the largest vessel measuring 213 m in length and 11 m draught. The depth alongside the cargo pier is 7.1 to 9.1 m deep. No dirty ballast services are offered.

Table 16: Vessel traffic and exported Alumina

	Total Vessel Visits	Alumina (tonnes)
2004	99	1,593,060
2005	100	1,664,390
2006	97	1,565,747
2007	104	1,617,889
2008	106	1,678,265
2009	17	280,524
2010	0	0
2011	0	0
2012	0	0



Source: Google Earth (2012)

Figure 23: Map of the Port Kaiser

1.2.13 Savanna La Mar

The Port of Savanna-La-Mar is a very small, open roadstead port with relatively poor shelter. The port can receive vessels up to 500 ft. in length. The channel depth is 14 – 15.2 m and the depth alongside the cargo pier is 1.8 – 3 m deep. No dirty ballast services are offered. The Port of Savanna-La-Mar was once the main port for exporting on the western end of the island, mainly sugar.

Source: Google Earth (2012)

Figure 24: Map of the Port of Savanna-La-Mar

1.2.14 Port of Black River

The Port of Black River is a very small, open roadstead port with relatively poor shelter. The port can receive vessels up to 500 ft. in length. The channel depth is 6.4 – 7.6 m and the cargo pier is 1.8 – 3 m deep. No dirty ballast services are offered. The main export goods at the Port of Black River are logwood and sugar, with two sugar factories, Holland and Appleton, being located in St Elizabeth, home parish of the port.

Source: Google Earth (2012)

Figure 25: Map of the Port of Black River

1.3 Ballast water uptake and discharge

The use and management of ballast water in Jamaican waters is currently a voluntary arrangement between shipping agents and shipping authorities in Jamaica. This is because the necessary legislation required to regulate and manage the threat of invasive aquatic species though ballast water has not been promulgated. However, much has been done in the right direction by several stakeholders, led by the Maritime Authority of Jamaica that Chairs and convenes the Ballast Water Management National Task Force (NTF). The NTF is currently discussing voluntary reporting of Ballast Water Management activities by ships calling at Jamaican ports and it is expected that the ships will be formally advised of this shortly. The discharge and/or uptake of ballast water in Jamaica are currently unregulated and unreported.

Preliminary research has also been funded by the Environmental Foundation of Jamaica (EFJ) and conducted by the University of the West Indies to determine the degree of threat that exists for the Jamaican scenario.

1.4 Ecological characteristics of source and destination ports

1.4.1 Port of Kingston

The Port of Kingston is located in the Kingston Harbour which covers an area of 51 km^2 (Wade 1976) on the south-east coast of Jamaica. The outer harbour is naturally deep basin and its greatest depth is 18.3 m. The inner harbour is almost a constant depth of 15 m. The upper basin of the inner harbour, however, can get as deep as 18 m also (Goodbody 1970; Wade 1976). Both sections of the harbour are sheltered by the Palisadoes tombolo, which is bordered by sand dunes and mangrove forests near and at Port Royal, which is a town located at the western end of the tombolo. Fishing villages can also be found here and on the north shore for example Greenwich Farm and Rae Town (Harvey et al 2005).

Man-made structures, other than port facilities and factories, can be found along the harbour. The main ones are a modern airport on the Palisadoes tombolo, towns such as Port Royal, Portmore, Hellshire and Independence City, housing complexes, and the Corporate Area of Down Town, Kingston along the northern shore. The Caribbean Maritime Institute (CMI) and the Royal Jamaica Yacht Club as well as a bridge that stretches over the mouth of Hunt's Bay can also be found along the shore. Hunt's Bay receives drainage from several densely populated urban areas and rural areas, in and around within Kingston. Rivers Rio Cobre and Duhaney also empty into the bay. Therefore this locale, as well as other drainage outlets that empty into the harbour, contribute significantly to pollution levels within the harbour. This has been estimated to be as much as 50 times greater than water bodies outside the harbour. Poor circulation, due to the excellent shelter provided by the southerly tombolo and the shape to the harbour compounds the problem.

1.4.2 Port Rhoades

Unlike the larger ports of the island Port Rhoades, which is located approximately 40 km west of Ocho Rios, is surrounded by moderate levels of undisturbed environments. It is sheltered by a reef crest teeming with marine flora and fauna with coral reef patches, sandy bottoms and sea grass beds spanning the lagoon. The reef crest was breached to allow the passage of vessels. North East trade winds, however, generate swells at the opening of the channel before the reef bar. No rivers empty into Discovery Bay. However, several ground-water springs surface within the bay and contribute low freshwater input. A noteworthy sponge bed can be found at depths of 15-23m near Columbus Park which is west of the port. A mangrove forest type covers some of the shore east of the port.

The presence of Noranda Jamaica Bauxite Partners, however, is a large and conspicuous landmark within the Discovery Bay, located south of the bay with a single pier for loading bauxite ore. Other structures or facilities include the University of the West Indies Marine Research Lab, and a restaurant and tourist attraction on the western shore with holiday homes lining a moderate portion of the eastern shore.

1.4.3 Montego Bay

The Port of Montego Bay faces west-north-west, on the north-western coast and is surrounded by Montego Bay, Jamaica's 'second city' as well as the tourism capital of the island. Montego Bay Freeport was constructed on Bogue Island located to the west of the harbour, which was once claimed by mangrove swamps that can be seen in other locales in the bay. The Montego Bay Marine Park, which covers a land area of 15.3 sq. km, contains the Montego Bay Yacht Club as well as piers deep enough to receive cruise and freight vessels, mangrove forests (including juvenile fish, birds and other fauna), islands, beaches, river estuaries, sea grass beds and corals. The coral cover, which was on average 55% in the 1960s to 1970s, was reduced by nutrient and sediment loadings generated by a growing population, Hurricane Allen, and the widespread death of a key herbivorous sea urchin. Nearby facilities provide for a significant fruit (banana) trade market and several resorts provide for the heavy flow of tourists arriving by both cruise ships and by air. An obelisk as well as two tall buildings and a cross serve as landmarks to seafarers upon approach.

1.4.4 Port of Ocho Rios

The town of Ocho Rios is one of the major tourist destinations in the island and is located near the centre of the north coast. Notable development has occurred in this area to accommodate the growing tourist interest, including the dredging of land to construct new hotels, apartment blocks, shopping areas and a marina. The Ocho Rios Marine Protected Area, which grew in size from 1999 from its original size in 1960, has on its western end Mammee Bay and Drax Hall and on its east Frankfort Point. The park extends northerly and seaward to 1,000 metres depth.

1.4.5 Port Antonio

Port Antonio is located in the parish of Portland, in the capital of Port Antonio. The capital is known for it exquisite natural aesthetics such as theatrical tropical coastline vegetation, the white sand beaches, and hidden coves. The port is divided into East and West Harbour by the Titchfield Peninsula which has Old Fort Point at the end, similar to the position of Port Royal on the Palisadoes tombolo on the south coast. The East Harbour is larger than the West Harbour with a 'U' shape and two headland boundaries. It is no longer used because of a build up of silt. The eastern headland of East Harbour is called Folly Point. Navy Island can be found north of the headland in between the two harbours with coral reefs located to the west of the island. These reef structures may be threatened by reduction in water quality caused by the release of sewage from the outfall at Soldier's Bay (~1 km east of Folly Point). Tidal levels in the harbours have a mean spring range about 0.3 m and northerly winds pick up in the winter. Landmarks include Old Fort Point, Mitchell's House (large concrete house in ruins), School (on Old Fort Point), Dome of Court House, Spire of a church at Sommers Town, White Building, Masts and a hotel.

1.4.6 Port of Falmouth

The Port of Falmouth is located in a deep basin of the Falmouth Harbour, which is accessed by vessels through a break in the reef near North Rock, which is north-east of the Customs Wharf. The town of Falmouth is located between the two major tourist destinations Montego Bay and Ocho Rios. The Donald Sangster Airport in Montego Bay is only 25 miles away, providing close proximity to the influx of tourist in the island to view the centuries old heritage sites. Such sites are linked to the time of the prized commodities, molasses, rum and sugar.

1.4.7 Rio Bueno

Rio Bueno is a ‘U’ shaped bay located north of the town of Rio Bueno, on the eastern border of the northern parish of Trelawny, beside St Ann. The Rio Bueno River discharges both fluvial and terrigenous outputs as drainage from agricultural lands. The river originates from a karstic spring located 16 km inland. The coastline, which is lined with coral reefs on both western and eastern sides and mangrove forests on the west, is exposed to north easterly trade winds which results in a high energy surf zone. The coral reef can be described as transitional as it experiences a lot of stress from the high energy environment, above average sediment loadings from the river and fluctuations in salinity between a marine and brackish nature. Rio Bueno experiences a mixed tidal regime (Gayle and Woodley 1998). Despite the stresses experienced, the condition of the reef is above average for the island, with a notable reef wall which starts to descend at 8 m in depth.

1.4.8 Port of Lucea

Landmarks for the Port of Lucea are a flagstaff and radio mast (31 m high), large school building and hospital, Lucea Church, spire truncated by damage in 1957 (26 m high), court house, yellow building surmounted by clock tower, grey concrete water tank on hillside, two prominent green tanks, near the root of the pier.

1.4.9 Port Morant

Three miles offshore, between Morant Point and Port Royal, is a current that usually flows with speeds as high as 4km in a westerly direction, and 2 to 3 km in a south, or south-easterly direction about 2 miles south-east of Morant Point. About 2 or 3 days of south-westerly winds generate a slight north-easterly or easterly flow. Landmarks are a conspicuous water tower, prominent white cliffs, referred to as White Horses, Yallahs Hill and the Blue Mountain Peak at times.

1.4.10 Port Esquivel

Located at the head of Portland Bight in Clarendon, this port experiences a mean tidal spring range of 0.2 m.

1.4.11 Port of Rocky Point

The port of Rocky Point is located on the south coast of the parish of Clarendon, at the tip of what looks like a large tombolo stretching eastward. Located nearby is the Rocky Point Fishing Village, which was renovated after the passage of Hurricane Dean.

1.4.12 Port Kaiser

Port Kaiser experiences prevailing southerly winds during the day with a force of 3 to 5. Wind force of 7 during July and August can cause delays for vessel arrivals or berthings.

1.4.13 Port of Black River

The Port of Black River is located south of the town of Black River, which can be found at the mouth of its name sake, The Black River. The historic town became the capital of St Elizabeth in 1773 and gradually became the main commercial area. The Great Morass, which is a wetland teeming with bird and animals, namely crocodiles, and covered with islets, reeds, rushes and trees, is known to attract tourists to the parish.

1.4.14 Port of Savanna-La-Mar

The Port of Savanna-La-Mar lies south of the coastal town of Savanna-La-Mar in the parish of Westmorland which is the western most parish on the south coast of Jamaica. A fort that was used for defence against pirates during the 18^{th} century can be found along the coastline.

CHAPTER 2.0: MARINE AND COASTAL ENVIRONMENT

2.1 Marine and coastal ecology

As an island nation, a significant portion of Jamaica's area can be considered coastal or marine. Coastal formations and ecosystems vary greatly across the island and include mangrove forests, seagrass beds, coral reefs and sandy beaches and salt marshes. These coastal areas are rich in biodiversity and are characterized by the presence of a number of endemic and endangered species. Furthermore, many of these habitats play an important role in Jamaica's fishing and tourism industries. Finally, many of these areas provide a number of ecosystem services such as coastal protection, coastal land building, and water quality improvement. While the state of these ecosystems has declined in the past, recent efforts to restore reefs, mangroves, and fish stocks have the potential to improve the condition of these fragile areas and protect Jamaica's endemic species.

2.2 Jamaica’s coastal areas and waters

Jamaica is the third largest Caribbean island, with a maximum length and width of 230 km and 80 km respectively. The coastline of the nation measures 891 km, all bordered by the Caribbean Sea, also known as the Western Atlantic. Additionally, there are several shallow banks within Jamaica’s Exclusive Economic Zone (EEZ): Pedro Bank, Burne Bank, Morant Cays and Formigas Bank (NEPA, 2008). These coastal areas are comprised of a variety of different ecosystems, including mangroves, wetlands, rocky shores, coral reefs, and seagrass beds. Approximately 2% of the coastline is termed wetlands, mostly located in the southwestern portions of the island (NEPA, 2003). Thirty per cent (30%) of the coastline can be considered sandy beaches, mostly concentrated on the northern parts of the island. Many of these beaches have been developed to support the growing Jamaican tourism industry, however the majority of beaches are considered fishing beaches for use in the fishing industry (NEPA 2000). An additional 1240 km^2 area of coral reefs surrounds the island, concentrated on the banks, north, and south eastern portions of the island (NEPA, 2008).

Offshore depth and incline varies with location around the island. In the south, the continental shelf is much broader. In these areas, the seas are shallower and the seafloor slope is less pronounced than other areas of the island. Additionally, there are many small cays on the south coast of Jamaica due to the broader continental slope. The northern shore of the island is frequently lined with fringing reefs which are followed by steep increases in depth as the continental shelf drops off into the ocean floor. Additionally, the aforementioned banks are offshore areas featuring considerably shallower waters than their surroundings. A number of small cays may also be found in these regions, some of which are important locations to the Jamaican fishing industry (i.e. Pedro Banks) (NEPA, 2008). The continental shelf area of Jamaica totals to 13,401 km^2, while the island's EEZ is much larger, totalling 263,283 km^2.

Jamaica has many off shore cays of varying sizes, Pedro Cay being one of the most economically and biologically significant of these. Located to the southwest of the main island within the area known as Pedro Banks, the cay is one of the most pristine coral reef ecosystems left within the country's EEZ. In addition, this area is of particular importance as a productive fishing and conch harvesting grounds (Nature Conservancy).

Also in the southwest of the island is the Black River Lower Morass, which contains large amounts of endemic and endangered species. Additionally it is an important nesting and feeding ground for over 50% of Jamaican's birds. A total of 150 vertebrate species have been catalogued in the area, making it one of the most important centres of wetland biodiversity on Jamaica (RAMSAR, 1997).

2.3 Oceanographic conditions: weather patterns

Jamaica's climate shows little seasonal variability due to the nation's close proximity to the equator. The few observed seasonal changes can be attributed to the movement of the North Atlantic High (NAH) northward and southward depending on the current season. During winter months, when the NAH is at its southern-most latitude, Jamaica is subject to the strongest tradewinds and least precipitation of the year. In contrast, as the NAH moves northwards, the tradewinds weaken and easterly waves cause increased precipitation on the island. The movement of the NAH also contributes to the formation of tropical storms and hurricanes in the eastern Atlantic that frequently impact Jamaican precipitation, offshore currents, and wave patterns. Jamaica experiences little seasonality, with average air temperatures ranging between 25-30ºC throughout the year and sea surface temperatures averaging between 28-29 ºC annually.

2.3.1 Winds and currents

Wind patterns are variable in Jamaica, with winds strongest during the months of January-April and July (the driest months of the year). Average strongest winds are found in the areas of Portland and St. Thomas, Manchester and St. Elizabeth. While the strongest wind influence comes from the prevailing tradewinds (from the north or northeast direction), Jamaican winds are typically a combination of prevailing winds, sea breezes, and mountain and valley winds.

Jamaica's rainfall and wind patterns are predominately influenced by the North Atlantic High, a semi-permanent area of high atmospheric pressure located between 30º and 35º N, just south of the Azores. This area is the furthest south during the winter, producing the strongest eastern trade winds of the year. As the NAH moves northward in the spring and summer, winds decrease and rainfall in Jamaica increases due to the action of easterly waves and convection within the Atlantic. Additionally, these easterly waves may produce storms and hurricanes under high sea-surface temperatures and low vertical-wind sheer occurring between the 10º and 20º N latitudinal bands (PIOJ, 2012).

The predominant oceanic current near Jamaica is the Caribbean current, which passes to the Southwest of the island, weakening as it enters an oceanic trough. Additionally, currents flowing through the passage between Jamaica and the island of Cuba may form eddies of 100-200km in size. Offshore currents are often variable with weather and wind conditions (Gyory et al.). Currents in Kingston Harbour were found to be density or salinity, wind, and tidal driven (Webber et al. 2003).

2.3.2 Tides

Tides in Jamaica contribute little change in sea surface height. In Discovery Bay, tidal amplitude was measured as no more than 1 metre (Leitcher et al. 2006). Similarly, tidal amplitude in Kingston Harbour was measured at a maximum of 0.25m with a mean of 0.12m. Tidal range observed in Kingston Harbour was 0.122-0.457m. Tide patterns however, fluctuate based on the position of the moon, with semi-diurnal tides observed in Kingston Harbour when the moon is over the equator. This pattern becomes diurnal when the moon moves to the north or south of the equator (Webber and Roff, 1996).

2.3.3 Temperature and salinity

Little information is available regarding trends in sea surface temperature (SST) around Jamaica as a whole. However, data from Discovery Bay indicate SST is relatively stable, showing a mean of 27.84ºC and a range of 25.58-30.70ºC. Temperatures did not show diurnal variability like other areas in the Caribbean (Leitcher et al. 2006). SST is highest in September, and historical data suggest that prolonged high temperature anomalies around this month have occurred (Barton and Casey, 2006). Sea surface temperature along the south coast from Hellshire to the Kingston Harbour showed very little variability, ranging from 28-29 ºC (Webber and Ruff, 1996).

Salinity in Jamaica may be variable in shallower areas throughout the year. Influxes of fresh water during the rainy season have been shown to decrease salinity in shallow waters in the Kingston Harbour. This effect however was negligible in deeper waters where currents may contribute to mixing and maintenance of constant salinity (Webber et al. 2003). Additionally, salinity readings from Hellshire to the mouth of the Kingston Harbour found a range of 30.8 to 36.2% salinity. Variation in salinity may also be due to fresh water percolations through limestone beds along the coast (Webber and Roff, 1996).

2.4 Habitats and biological communities

2.4.1 Sandy beaches

Sandy beaches are coastal environments composed of a soft substrate and frequent wave action. These environments are continuously changing as waves moves sand off the beach to shallower waters in the winter and spring, and then return the sand in the spring. Tides and longshore currents may also contribute to continual change in this ecosystem (Anderson 2003).

Of Jamaica's 891km of shoreline, approximately 30% can be classified as sandy beaches. These beaches can be separated based on their use (recreational, tourism, fishing), with the majority of beaches designated as 'fishing beaches'. These fishing beaches are evenly distributed across the coast, however long stretches of beaches used for tourism and recreation are concentrated on the north shore of the Island near Negril, Ocho Rios, and Montego Bay.

Jamaica's sandy beaches are important nesting sites for species of sea turtles, sea birds and shore birds, some of which are endangered. Additionally the numerous small cays found around Jamaica are an important ecosystem for a wide range of flora and fauna, including crustacean species. Finally these beaches are important commercially as sources of income for the tourism and fishing industries (NEPA 200).

2.4.2 Wetlands and mangrove swamps

Wetlands are characterized as any piece of land which is subjected to periodic or permanent flooding by brackish or fresh water. The predominant species found in theses habitats are described as adapted to this flooding regime. This term can apply to marshes, swamps, mangroves, bogs, and other low-lying coastal areas. They are among the most biologically productive coastal ecosystems in the Caribbean area (NEPA, 1997b).

Wetlands comprise approximately 2% of Jamaica's total surface area and are found mostly along the south coast in low lying, near-shore areas. These areas can be divided into two main categories: swamps (including mangroves and freshwater swamps) and marshes (both saline and fresh). Some of the prominent areas of wetlands include the Negril Morass, Great Morass and the Upper and Lower Black River Morass.

Coastal wetlands contribute to coastal stability by preventing erosion and damage from wave action. They are capable of absorbing and storing large amounts of water, which prevents flooding. Additionally, extensive roots systems can trap sediments which increases nearby water quality (NEPA, 2003). In trapping sediments, mangroves contribute to coastal build up, creating additional shoreline through the accumulation of organic matter and sediment (NEPA, 1997b).

Ecologically, wetlands are important habitats for a large array of biodiversity. This includes a number of endemic species including *Grias cauliflora*, *Roystonea princeps* (swamp palm), *Sabal jamaicensis* (thatch palm), and *Manikara sideroxylon* (naseberry bullet). Additional species found in wetlands include the American crocodile, and various crustaceans, fish, and invertebrates. These areas are of particular importance to water birds, including the flamingo, and to commercially important fish. Fish species such as jacks and tarpons use the area as a breeding and nursery area. Mangroves are also an important ecosystem for the commercial harvesting of shellfish (NEPA, 1997b).

2.4.3 Seagrass meadows

Seagrasses as a group consist of submerged marine angiosperms which are typically found in shallow, coastal areas in tropical and subtropical regions (Den Hartog, 1970). Despite the use of the word 'grass' in their name, these plants are not true grasses. Three species of seagrass are found in Jamaican ecosystems: *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass) and *Halodule wrightii* (shoal grass). *Thalassia testudinum* is the most common of these species (NEPA, 1996). These grasses are typically found in near shore, shallow environments as light is one of the two major factors restricting the growth of these species (the other being nutrient load) (Dennison 1987; Short 1987).

These ecosystems are an important habitat for commercially and ecologically important fish species in Jamaica as well as urchins and small crustaceans. The grasses provide food and protection for commercially important fish in the juvenile stage. Additionally, these beds are a foraging ground for adults of several commercially important fish species. Seagrasses produce large amounts of organic matter annually which comprises the base of the detritus food web in many coastal ecosystems. Finally, these beds provide coastal protection from erosion and absorb excess nutrients, improving water quality and benefiting nearby coral reefs (NEPA, 1996).

2.4.4 Coral reefs

Coral reefs cover an approximate area of 1240km^2 of the Jamaican coastline, though this area is not evenly distributed around the island. While most of the north and east coasts are lined with developed fringing reefs, the southern coast is limited to patch reefs which are interspersed on the broad southern coastal shelf. Additionally, a considerable amount of coral reef ecosystem is concentrated on banks with in the Jamaican Economic Exclusive Zone, mostly on the Pedro and Burne Banks to the south, Morant Cays to the southwest, and Formigas Bank to the northeast of the island.

Jamaican coral reefs have been noted for their decline in coral coverage in recent years. Hard coral coverage ranges from 2.2 to 37.5 % and averages at 14.79% on reefs around the island. Coverage is less on shallower reefs and tends to increase with depth. Additionally, algal coverage on Jamaican reefs is considerably higher than that of coral, with a range of 0% to 62.9% and an island-wide average of 24.2%. This may be attributed to low densities of herbivorous fish on most reefs (average of 19 fish per $100m^2$) (NEPA, 2008).

Despite low percent coverage of corals on Jamaica coasts, some diversity of coral species may still be found at reefs around the island. Sixteen species were catalogued on reefs at Discovery Bay, though five species contributed disproportionately (*Agaricia agaricites, Diploria strigosa Montastrea annularis, Porites astreoides,* and *Siderastrea siderea*). This is in contrast to historical studies which found Jamaican reefs to be dominated by now rare Acroporid corals (*A. cervicornis* and *A. palmata*). Now, *Montastrea annularis* has been reported to be the dominate coral, though it has declined significantly in recent years. However, similar to coral coverage, diversity of species increases with depth as well (Andres and Whitman, 1995).

Historically, Jamaican reefs have held significant socio-economic and ecological value, despite their declining condition. The reefs provide coastal protection and stability, particularly during periods of high wave activity associated with hurricanes and tropical storms. By acting as a break for waves, reefs prevent coastal erosion and may even contribute to beach building through the action of parrotfish. Reefs are also home to a large amount of biodiversity, including up to 3000 different species of organisms. Reefs, seagrass beds, and mangroves together serve as a connected habitat network for commercially important fish species. Reefs form shelter and provide food for a variety of fish and crustaceans which may be harvested to support Jamaica's fishing industry. Finally, Jamaica's reefs are an important part of the tourism industry and a popular recreation destination for snorkelers and SCUBA divers (NEPA, 1997a)

2.5 Sensitive and vulnerable coastal environments

2.5.1 Black River Lower Morass

Located in the southwestern region of Jamaica, the Black River Lower Morass is the largest herbaceous wetland in the country, covering approximately 5700 hectares. It is located around the lower segment of the Black River and in the associated coastal floodplains. The region is primarily classified as a mangrove swamp composed of *Rhizophora mangle* (Red Mangrove), *Avicennia germinans* (Black Mangrove) and *Laguncularia racemossa* (White Mangrove) plant species. Additionally, areas are covered by *Cladium jamaicensis* (sawgrass) and small portions of swamp forest remain dominated by *Grias cauliflora* (Anchovy Pear) and *Roystonea princeps* (Endemic Swamp Cabbage). The substrate is primarily marsh and peat in the wetlands, with an underlying layer of clay.

Another important feature of the Lower Morass is its characteristic limestone islands which support a different ecosystem from the surrounding marshlands. These limestone islands are naturally dominated by *Sabal jamaicensis* (Bull Thatch), though most has been replaced by logwood and other commercial species.

The Black River Lower Morass is particularly important due to the large biodiversity found within the area. Over 150 vertebrate species have been characterized in the areas, including 50% of Jamaica's birds. Additionally the mangroves are an important nursery for commercially important shrimp and fish species such as tarpon and snook. The Black River Lower Morass was declared a protected area under the Natural Resources Conservation Authority (NRCA) and is also identified as a RAMSAR site (RAMSAR, 1997).

2.5.2 Negril Marine Park

Designated in 1998 by the Jamaican Protected Areas Trust, the Negril Marine Park consists of 160km^2 on the northwestern coast of Jamaica. The park extends from Davis Cove River in the Parish of Hanover to St. John's Point in Westmorland and 3.2km out to sea within these boundaries. Ecosystems within the park include coral reefs, mangroves, and seagrass beds which contribute to coastal protection and maintaining stocks of commercially important fishes. The park is available for snorkelling and SCUBA and also includes six areas where no fishing or recreation of any kind is allowed (designated fish replenishment areas). The area is managed by the Negril Coral Reef Preservation Society.

2.5.3 Ocho Rios Marine Park

The Ocho Rios Marine Park consists of a stretch of coast 13.5km in length between Drax Hall and Mammee Bay (18 26.15N, 77 10.19W) and Frankfurt Point (18 25.11N, 77 03.17W) on the northeastern coast of Jamaica. The park extends seaward to the point where the seafloor reaches a depth of 1000 meters. The park is lined by continuous reef crest, with few breaks for vessel access to the developed coastline. Numerous hotels, villas, entertainment facilities, and a cruise terminal have been built along the shore of the marine park. Four major rivers (Dunns, Turtle, Roaring, and White), as well as a number of gullies feed the bay. Major ecosystems within the park include coral reefs, sandy shores, sea grass beds, rocky shores, and small stands of mangroves (UWI, 2001).

According to 1997 estimates there is approximately 398,529.5m^2 of coral coverage and 145,775.6 m^2 of seagrass bed coverage within the park. Additionally Atlantic and Gulf Rapid Reef Assessment (AGRRA) surveys conducted in 2001 found six types of commercially and ecologically fish species including grouper and parrotfish, which were the most dominant species. Hawksbill turtles have also been reported in areas of the marine park. In addition to the vast biodiversity, the marine park has been estimated to have a fisheries net present value (NPV) of 213 million J$ and a US $2.679 billion tourism NPV (UWI, 2001).

2.5.4 Port Antonio Marine Park

The Port Antonio Marine Park is a proposed marine park that would extend from North East Point to just west of Snow Hill, encompassing 30km of Jamaican shoreline on the eastern coast of Jamaica. The park would extend out to 200m of depth and includes coral reef ecosystems. While not yet designated an official marine park, the area is managed by The Portland Environment Protection Association (PEPA) and is designated a priority site by NCRA (Environmental Solutions, 2002).

2.5.5 Montego Bay Marine Park and SFCAs

The Montego Bay Marine Park (MBMR) was Jamaica's first designated marine park. It consists of approximately 15.3 km^2 along 9 km of coastline from Tropical Beach (18° 30 19N; 77 ° 55 00W) to Rum Bottle Bay (18° 27' 8"N; 77° 59' 00"W). It extends seaward along this stretch of coast for distances ranging from 350 m to 2.3 km. The park includes ecosystems such as sandy beaches, mangrove swamps, sea grass beds and coral reefs. Management allows for recreational and commercial activities in designated zones including boating, fishing, swimming, SCUBA and snorkelling. The Montego Bay Marine Park Trust (MBMPT) serves as the primary governing agency of the area.

A 1992 study of the park found a wide diversity of animal and plant species, including 41 species of coral, 41 species of sponge, and 82 species of fish. Species of fish found included both commercially important species (snapper, lobster, conch, etc.) and ecologically important species, including parrotfish. This wide array of flora and fauna increases the appeal of the area to tourism, making the marine park commercially important to the tourism industry as well as the fishing industry (NEPA, 2013).

MBMP contains two designated Special Fisheries Conservation Areas (SFCAs), formerly called Fish Sanctuaries: Bogue Islands Lagoon and Montego Bay Point. The Bogue Islands SFCA is a marine protected area consisting of the entire Bogue Islands Lagoon, bordered by a 1.6km long line from the Montego Bay Freeport roundabout, across the lagoon to the Montego Bay to Lucea main road. Tropical Beach's Jetty. In these areas, fishing is restricted to the removal of invasive species and for research and educational purposes; however other recreational activities are permitted.

2.5.6 Pedro Cays Protected Area

The Pedro Bank area is one of the largest offshore banks in the Caribbean. Located 80km southwest of Jamaica, the bank consists of a wide variety of ecosystems including coral reefs, coral cays, and seagrass beds. In addition to being an essential area for the Queen Conch and fishing industries, the ecosystems at Pedro Banks support a number of endangered and threatened species. The cays are important nesting grounds for boobies, terns, and several species of sea turtle. Additionally, the area may possibly serve as a refuge for and important source of larvae of reef building Acroporid corals which have almost completely disappeared from reefs along the main coast of Jamaica.

This area is protected under the Morant and Pedro Cays Act, which protects the islands' birds and turtles from human perturbation. Additionally, the Nature Conservancy and NEPA have created the Pedro Banks Conservation Project to protect the area's fragile ecosystem (The Nature

Conservancy). In addition, there is a Special Fisheries Conservation Area, the Southwest Cay SFCA, located in the Pedro Cays Protected Area. No fishing is permitted in this area, with the exception of the removal of invasive species (Fishing Industry Act, 2012).

2.5.7 Palisadoes-Port Royal Protected Area

The Palisadoes-Port Royal Protected Area consists of 13,000 hectares of marine environment located south of Kingston including various offshore cays and mangrove and coral reef ecosystems. The area is protected under the Natural Resources Conservation Act (NRCA-1991) and is a Ramsar site. The area is biologically important as a nesting site for sea turtles and birds and as breeding grounds for many fish species. Additionally, the offshore islands and cays provide protection for Kingston Harbour from wave action and erosion.

2.5.8 Portland Bight Protected Area and SFCAs

The Portland Bight Protected Area is an 1876 km^2 area on the southern coast of Jamaica protected under the NRCA Act as of 1999. 1356 km^2 of the protected area is marine, comprising almost half (47.6%) of Jamaica's shallow shore environment. An additional 82 km^2 of the park is comprised of wetlands. The area is important habitat for many vulnerable and endangered vertebrate species such as manatee, crocodiles, marine turtles and many species of fish. Additionally, the area is home to a large human population and various commercial infrastructure. Management of the area is conducted by the Caribbean Coastal Area Management (C-CAM) Foundation which has adopted a policy of 'co-management' to handle conflicting issues in the region, according to the Jamaica Protected Areas Trust.

The Portland Bight Protect Area also includes three SFCAs: Galleon Harbour (11.7km^2), Salt Harbour (10.7km^2) and Three Bays (12.0km^2). Fishing is restricted in these areas to removal of invasive species so as to conserve the area's biodiversity.

2.5.9 Bluefield's Bay Fish Sanctuary

This SFCA (designated in 2009) is Jamaica's largest, encompassing 3,054 acres and covering 6.5 miles of Jamaica's south-western coastline. Its surrounding communities are home to some

25,000 persons, 400 of whom are fishers. This protected area includes mangroves, seagrass beds, coral reef and even artificial reefs, thus providing habitats (to shelter, feed and grow) for many marine organisms including very important Jamaican fisheries such as shell fishery (spiny lobster and queen conch) and fin fishery such as parrots, grunts, snapper and jacks to name a few (CARIBSAVE, 2013).

2.5.10 Oracabessa Bay Fish Sanctuary

The Oracabessa Bay Fish Sanctuary is a SFCA that covers 3.1km of coastline along 73% of the Oracabessa Bay in northeastern Jamaica. The entire area totals approximately 96.1 hectares. However 71% of the coastline in the SFCA is privately owned, with a portion used for the tourism industry. The area is mostly rocky cliff shoreline, with two natural beaches, 3 manmade beaches and one river flowing into the sanctuary (Jacks River).

This area is predominantly coral reef ecosystem, which covers nearly 75% of the protected shoreline. The reefs are interspersed with shallow lagoons and other areas that serve as important fish nurseries and feeding grounds for smaller fish. Additionally, Gibraltar Beach is a nesting beach for three different species of marine turtles and has been designated as an environmentally important area by NEPA. The Bay is habitat for at least 6 endangered animal species: West Indian Manatee (*Trichechus manatus*), Green Sea Turtle (*Chelonia mydas*), and Loggerhead Sea Turtle (*Caretta caretta*), Hawksbill Sea Turtle (*Eretmochelys imbricate*), Elkhorn Coral (*Acropora palmata*), and Staghorn Coral (*Acropora cervicornis*) (OBFS, 2011).

2.5.11 Discovery Bay Fish Sanctuary

The Discovery Bay SFCA is located on the north coast of Jamaica (18° 22’ 00”N; 77° 24’ 30”W). It consists of a dry bay with no major fresh water outlets, approximately 1.5km in diameter. The seaward side of the Bay is protected by a once continuous reef crest that was interrupted for the purpose of constructing a major shipping channel to allow ships into the bay where a major bauxite port is located. Maximum natural depth of the Bay outside the shipping channel is 55m. Once an area with a thriving reef ecosystem and plentiful fish, overfishing has depleted fish stocks and natural disasters such as Hurricane Andrew permanently damaged the reef. The SFCA was developed to allow fish stocks to recover to their previous levels of rich biodiversity and abundance (Viera et al. 1995).

2.5.12 Galleon, St. Elizabeth Fish Sanctuary

The Galleon, St. Elizabeth Fish Sanctuary is a 625 acre SFCA located in southwestern Jamaica near the outlet of the Black River and the town of Whitehouse. Ecosystems present include coral reefs, mangroves, and sea grass beds. Endangered species present include manatees and juvenile turtles. The sanctuary is also home to dolphins, coastal and marine birds, and comprises a major breeding and nursery ground for juvenile fish (Seacology, 2010).

2.5.13 Sandals Boscobel Fish Sanctuary

The Sandals Boscobel SFCA is a .5km^2 marine protected area encompassing the Beaches Boscobel resort in northeastern Jamaica. The area is a privately funded and managed biodiversity conservation area consisting mainly of coral reefs. Management of the SFCA is conducted by the Sandals Foundation.

2.6 Value of Jamaica's Marine Biodiversity

The primary habitat type that will be affected by marine invasive alien species is coral reefs. The most important area from an economic value standpoint is also the coral reefs. The ecological services provided by coral reefs have been valued by several authors; however, the most recent assessment will be used in this report.

The World Resources Institute (WRI) produced the latest economic valuation on Jamaican coral reefs in June, 2011, Coastal Capital: Jamaica – The Economic Contribution on Jamaica's Coral Reefs. The ecosystems services provided by the coral reefs include coastal protection, sand production for beaches, fisheries for both artisanal and commercial sectors, and diverse wildlife for dive tourism. Tourism, fisheries, and shoreline protection are just three of the many culturally and economically important services provided by reef ecosystems in Jamaica.

A significant portion of the tourism in the coastal areas of Jamaica is directly dependent on the health of the beaches. The travel and tourism sector is estimated to contribute 24% of Jamaica's GDP in 2011. It also supports over 30% of the work force in Jamaica, both directly employed to the sector, as well as persons who are employed providing indirect services. In 2009, Jamaica drew 1.8 million overnight visitors and an additional 900,000 cruise tourists. Loss of beaches due to reduction in beach protection from coral reefs is estimated to cost the country 23M USD/year at its current rate. This is based primarily on the reduction in visitors to the island due to poor coastline health.

Coral reef-related fisheries is one of the other major services provided by coral reefs. The linkage between coral reefs, seagrass beds and mangroves is important, and the relationship between these ecosystems is mutually beneficial. The health and resilience of the three determine the value of the fishable resources derived from the habitats, especially the coral reefs. Reef-related fisheries support between 15,000–20,000 active fishermen, most of whom are artisanal; in addition, support 100,000 people's island wide doing support services e.g. ice-makers, gear builders, etc (WRI, 2011). Fish sales (local and export markets) contribute US$34.3 million per year, a value equivalent to 0.3 percent of Jamaica's annual GDP.

2.7 Case Studies on Marine Bioinvasions

There are three notable marine invasions documented in Jamaica, which are present in the waters of or near the ports in Jamaica. These are the Indo-pacific green mussel, *Perna viridis*; the Indo-pacific red lionfish, *Pterois volitans*; and the Asian Tiger Shrimp, *Penaeus monodon.* Research has been conducted by the University of the West Indies (UWI-Mona) on these species dating back to 1998, when *P. viridis* was first documented. This also marked the start of research in marine invasive species in Jamaica. A Marine Invasive Species Laboratory was established by the University in Discovery Bay, St. Ann (north coast of Jamaica) which currently conducts research on marine invasive alien species, including ballast water management.

2.7.1 The Indo-pacific green mussel, *Perna viridis*

The green mussel, *Perna viridis* (Figure 26) was first documented in Jamaica in 1998 from the Port Royal Mangroves that lie along the southern margin on Kingston Harbour. Kingston Harbour is the most shipping traffic in Jamaica. The Port Royal Mangroves is a part of the Palisadoes and Port Royal Protected Area, and is also a Ramsar site – wetland of international importance.

Figure 26: Green mussel, *Perna viridis* (L. 1758)

Ballast water is highly speculated as the pathway for the introduction of the species in Kingston Harbour (Buddo, 2008).

The populations of green mussels were monitored throughout early years of the invasion (1999-2001) in Kingston Harbour, (Buddo *et al.* 2003). The green mussel colonized a wide variety of living and non-living substrata including mangrove prop roots (Figure 27), seagrass beds (Figure 28), sandy/muddy bottoms, submerged rocks (Figure 29), wharf pylons, pier walls, wooden logs, plastic buckets, among others. The species fully established itself throughout the entire Kingston Harbour within the first two (2) years of the invasion, with the exception of Hunt's Bay, which receives significant amounts of freshwater and suspended particles from a large river, the Rio Cobre. Densities of the mussel ranged from 32.46-1,427.21 mussels/m^2 at the sites where the mussels had colonized (Buddo *et al.* 2003).

Figure 27: Green Mussels on mangrove prop root (Buddo et al. 2003)

Figure 28: Green Mussels in seagrass bed (Buddo, 2008)


Figure 29: Green mussels on submerged rocks (Buddo, 2008)

The green mussel showed a high growth rate in experimental cages in Kingston Harbour with individuals growing as much as 4.07cm in 6 months (Buddo, 2008). This showed that the green mussel thrived in Kingston Harbour, being an area abundant in phytoplankton. Mature green mussels (capable of reproducing) with ripe gonads were found throughout an annual cycle with two (2) peaks in the annual cycle. In addition, spat (the newly settled phase) of the green mussel was found at all monitoring stations throughout the annual cycle. This suggested that the green mussel populations were now fully established in Kingston Harbour and were reproducing all year round (Buddo, 2008).

The green mussel is firmly established in Kingston Harbour, which is notably one of the more polluted harbours in Jamaica. During the early stages of the invasion, mussels were harvested by artisanal fishers and sold to the general public. This raised concerns for risks to public health through consumption of contaminated mussels. Research conducted by the University of the West Indies – Department of Life Sciences showed the presence of four (4) potential toxic dinoflagellates in the gut contents of the mussel, though the concentrations were low (Buddo et al. 2003). These species are known to cause paralytic shellfish poisoning (PSP). Further research findings showed that coliform bacteria and heavy metals were also a concern (Buddo et al. 2012).

Though not explicitly valued, the maintenance costs reported by the power stations in Kingston Harbour increased, due to colonization of the mussel in the seawater cooling systems. These costs were increased labour for cleaning, replacement of pipelines and loss of generation time during cleaning.

In 2010, surveys in Kingston Harbour showed a significant decline in the population. As the mussels are still present, it is probable that the population would explode once again to levels seen during the peak of the invasion.

2.7.2 The Indo-pacific red lionfish, *Pterois volitans*

The lionfish, *Pterois volitans* was first documented in the Atlantic and Caribbean region in 1985 along the east coast of the USA. The aquarium trade has been identified as the pathway for the transfer of this species from the Indo-pacific region. It was first recorded in Jamaica in 2008 on the north-coast reefs, and since then, it has established itself in every marine environment in Jamaica. The lionfish has been found on coral reefs, seagrass beds, mangrove lagoons, ports and harbours, as well as other artificial structures.

Figure 30: The Invasive lionfish, *Pterois volitans* (Photo: D Buddo)

The lionfish has been documented to consume large quantities of reef fish, shellfish and molluscs, both ecologically and commercially important species. It is now regarded as one of the greatest threats to marine fisheries in Jamaica, due to its impact on juvenile fish populations.

There have been several cases of envenomation from contact with the lionfish, reported mainly from the fishers. This serious injury often results in the victim requiring advanced medical assistance which has an economic impact, including loss of income during their medical recovery period.

Five (5) years into the invasion, there has been a decline in the lionfish populations around the island. A massive campaign to consume the lionfish as a control mechanism started, and has encouraged a large portion of the population to consume lionfish. Fishermen have been trained by the University of the West Indies in safe removal and handling techniques, which has helped them to exploit this species. The intent has been to unsustainably utilize this fish, in an effort to reduce the population substantially.

Research on the biology, ecology, economic and social impacts is being conducted by the University of the West Indies. This will continue to yield important information relevant to the control of this species in Jamaica and the Caribbean.

2.7.3 The Asian Tiger Shrimp, *Penaeus monodon*

The species has been sighted in the waters surrounding Hawaii and off the Gulf and Atlantic coasts of the continental United States. While no official report has been made, the sightings in the Atlantic regions have been attributed to accidental release from an aquaculture facility in South Carolina. On February 2nd, 2012, one specimen of *P. monodon* was found near Kingston Harbour, Jamaica. This is the first recorded sighting of the species in Jamaica and has potentially significant ecological impacts. The species is much larger and more rapidly growing than native shrimp species, which suggests that *P. monodon* has the potential to outcompete Jamaica's native shrimp for food and other resources. Additionally, *P. monodon* is a known carrier of many aquatic diseases affecting shrimp and other crustaceans. Therefore, the invasion of *P. monodon* may introduce new pathogens to Jamaica's native crustaceans with significant impacts on population dynamics. Further research is imperative to develop the appropriate management strategy for *P. monodon* in the Western Atlantic.

Figure 31: Asian Tiger Shrimp

CHAPTER 3: LEGAL, POLICY AND INSTITUTIONAL ARRANGEMENTS

3.1 Regional and international obligations

Table 17 below summarizes the major International Conventions concerning the protection of the marine environment. It also outlines Jamaica's signatory status of each.

Table 17: Jamaica's position on major marine-related conventions

No.	Convention	Date of Accession	Entry into Force for Jamaica
1	Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matter (as amended), London, 1972	March 22, 1991	April 21, 1991
2	International Convention for the Prevention of Pollution from Ships, London, 1973 [MARPOL]	June 13, 1991	Sept. 12, 1991
3	Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, London, 1973	June 13, 1991	Sept. 12, 1991
4	United Nations Convention on the Law of the Sea Montego Bay, 1982 [UNCLOS].	March 21,1983	Nov. 16, 1994
5	Convention on Biological Diversity, Rio de Janeiro, 1992	Jan. 6, 1995	April 6, 1995
6	Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Montreal, 2000	Signed (June 4, 2001)	December 24, 2012
7	Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)	April 23,1997	July 22, 1997

No.	Convention	Date of Accession	Entry into Force for Jamaica
8	Protocol to the International Convention on the Prevention of Pollution from ships, 1997	May 29, 2008	August 29 , 2008
9	Convention on Wetlands of International Importance especially as Waterfowl Habitats [RAMSAR]	Oct. 7, 1997	Feb. 7, 1998
10	Convention on Transboundary Movement of Hazardous Waste and their Disposal [Basel Convention] Basel, 1989	January 23, 2003	April 23, 2003
11	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, Cartagena de Indias, 1983 [Cartagena Convention]	May 1, 1987	April 1, 1987
12	Stockholm Convention on Persistent Organic Pollutants, Stockholm, 2001	June 1, 2007	Not to date
13	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, Rotterdam, 1998 [BASEL]	August 20, 2002	Feb. 24, 2004
14	International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM)	Not to date	Not to date

3.2 National policies and legislations

Policies and legislations	Year	Field and objectives	Competent body
National Environmental Policy (Draft)		In order to ensure that the principles set out Jamaica's environment are advanced, the Government has adopted a number of objectives for its environmental policy, including: • Ensuring that Jamaicans are aware and committed people to their environment; • Using non-renewable resources wisely; • Using renewable resources in a sustainable manner; • Ensuring good air quality; • Ensuring adequate supplies of good quality water; • Proper planning of land use preserving bio-diversity; • Promoting global cooperation; • Enhancing the natural environment; • Preserving the marine environment; • Developing tools for sustainable development	Natural Resources Conservation Authority (NRCA)
Jamaica Coral Reef Action Plan		This Action Plan builds on the International Coral reef Initiative (ICRI). This document focuses on Five main areas: • Integrated coastal zone management and related institutional policy and legal issues; • Environmental education and awareness; • Co-management of coastal resources; • Prevention and reduction of sources of marine pollution; • Research and monitoring for the management of coral reef and coastal resources.	National Environment and Planning Agency (NEPA)
The Natural Resources Conservation Authority Act	1991	The Natural Resources Conservation Authority Act provides for the management, conservation and protection of the natural resources of Jamaica. The Act establishes the Natural Resources Conservation	NEPA Ministry responsible

Policies and legislations	Year	Field and objectives	Competent body
		Authority, a body of persons appointed by the Minister of the Environment. The functions of the Authority include the taking of such steps that are necessary to ensure the effective management of the physical environment of Jamaica; and the management of marine parks and protected areas. Section 10 of the NRCA Act gives the NRCA the power to directly request EIAs from any applicant for a permit or (even more broadly) from any person who is doing any undertaking in a prescribed area where it is of the opinion that the environment is likely to have adverse effects due to the activities. The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order, 1996 and the Permits & Licensing Regulations was passed pursuant to section 9 of the Natural Resources Conservation Authority Act, 1991. The Order provides that the entire island of Jamaica is a prescribed area and lists specified categories of enterprise, construction or development that require a permit. The Act also addresses Sewage and Trade Effluent discharges as well as air emissions. Regulations are being developed to specifically address these sources of pollution. Under the new regulations the polluter pays principle will be incorporated.	for environment
The Watersheds Protection Act	1963	The purpose of this Act is to provide for the protection of watersheds and areas adjoining watersheds and promote the conservation of water resources. The entire island however is considered to be one watershed, but for management purposes is divided into smaller units. The Act makes provision for conservation of watersheds through the implementation of provisional improvement schemes whereby soil conservation practices are carried out on land. A Watershed Policy is now under consideration with a view to taking watershed management to another level of greater effectiveness. This includes a review of the Act and the development of regulations.	NEPA
The Maritime Areas Act	1996	This Act covers (among other issues):	Jamaica Constabulary

Policies and legislations	Year	Field and objectives	Competent body
		- Declaration of Jamaica as an Archipelagic State Definition of archipelagic and internal waters of Jamaica - Right of innocent passage and sea lanes in the archipelagic waters - Sovereignty in the territorial sea - Movement of ships of war and other government vessels operated for non-commercial purposes - Jurisdiction over the Continental shelf	Force (JCF) Jamaica Defence Force (JDF) Fisheries Division- Ministry of Agriculture and Fisheries NEPA Jamaica Customs Department
The Harbours Act	1874	This Act covers the safe and efficient use of Harbours and defines the roles of the regulators. It provides the legal basis for declaring and delimiting the harbours od Jamaica and establishes the Harbour Master who regulates the movement of vessels within the harbour limits	The Harbour Master and the Maritime Authority of Jamaica
The Shipping Act	1998	The Shipping Act consolidated the maritime legislation received into Jamaican law from the United Kingdom and implemented fourteen international conventions relating to the safety of shipping, the training, certification and welfare of seafarers, salvage, and the limitation of liability for maritime claims.	Maritime Authority of Jamaica (MAJ)
The Exclusive Economic Zone Act	1991	The Exclusive Economic Zone Act, 1991 establishes Jamaica's 200 nautical mile zone within which Jamaica may exercise jurisdiction in respect of the preservation and protection of the marine environment and the prevention and control of marine pollution.	MAJ JDF JCF

Policies and legislations	Year	Field and objectives	Competent body
The Wildlife Protection Act	1945	This Act is primarily concerned with the protection of specified species of fauna. This Act has also undergone review particularly in the area of increased fines and the number of animals now enjoying protected status. Further amendments are being undertaken to address a variety of other issues relating to the management and conservation of these natural resources, and the inclusion of flora.	NEPA JCF Ministry of Agriculture and Fisheries

3.3 Port State Control

Port State Control is carried out by Inspectors employed to the Maritime Authority of Jamaica who board and conduct inspections on foreign flagships calling at Jamaican ports. Inspections are conducted on at least 15% of all foreign ships in accordance with the Caribbean Memorandum of Understanding on Port State Control. Inspectors board vessels and make the routine checks according to the requirements of the various legal obilgations of the vessels. These inspections can be time-consuming based and is dependent on the level support that the Inspector receives from the crew. But, all efforts are made to avoid undue deay of the vessel. In the event that there is a significant breach, ships may be detained.

These Inspectors will have the responsibility for inspecting ships for compliance with the Ballast Water Management Convention in Jamaica. This will include mainly the perusal of the Ballast Water Record Book and the Ballast Water Management Plan. If there is a suspicion of a false declaration or missing information, an indicative sample (eg. salinity) would be taken. Detailed inspection may be required if the indicative sample is not compliant, and this would warrant detaining a vessel.

3.4 National Institutions

The following are the national institutions that play key role in managing ballast water, and describes each institution responsibilities. The Ballast Water National Task Force is comprised of many of these institutions:

Institution	Duties
Maritime Authority of Jamaica	• To administer the registration of ships and to regulate the certification of seafarers. • Regulate the safety of shipping as regards the construction of ships and navigation. • Inspect ships for the purposes of maritime safety and prevention of marine pollution.

	• Make enquiries as to shipwrecks or other casualties affecting ships, or as to charges of incompetence or misconduct on the part of seafarers in relation to such casualties. • Establish maritime training and safety standards. Administer policy for the development of shipping in general.
National Environment and Planning Agency	• To promote sustainable development by ensuring protection of the environment and orderly development in Jamaica through highly motivated staff performing at the highest standard.
Ministry of Transport, Works and Housing	• Regulate the safety of all modes of transportation, whether publicly or privately operated.

CHAPTER 4.0: KINGSTON HARBOUR BASELINE SURVEY

Kingston Harbour is the most studied Harbour in Jamaica. This research has been conducted over several decades predominantly by the University of the West Indies (UWI). Species inventories have been conducted by the UWI over these decades mainly in the sensitive Port Royal Mangroves, and also in the seagrass areas, sandy and muddy bottoms, and port facilities.

Kingston Harbour in Jamaica is as described by Goodbody (2003), often considered to be one of the finest natural harbours in the world. It is an elongated bay or lagoon, on the south coast of the island, which extends 16.5 km from east to west and 6.5 km north to south with a surface area of approximately 51 km^2 and is located at 170 57' N, 760 48' W.

The city of Kingston lies on the northern boundary, with business, industrial and some residential developments, and on the western end are major residential developments which has at least 10,000 family homes. Also emptying into this area is the city's largest storm drainage system, the Sandy Gully. Much of an adjacent shallow area on the southern edge of Hunt's Bay, called Dawkin's pond, largely disappeared in the course of recent roadway development. The southern margin of the harbour is formed by a shingle spit or tombolo called the Palisadoes, formed by longshore sediment drift and is 15 km long (Hendry 1978).

The harbour entrance is a 2 km wide channel in the southwestern section, adjoining which is the small town of Port Royal (the location of the UWI Port Royal Marine Laboratory - PRML). This entrance leads to a 12 m depth dredged ship channel which was originally a former natural passage maintained by natural circulation patterns. Goodbody (1970) and Wade (1976a) defined an Inner Harbour, a deeper muddy area to the east and an Outer Harbour adjoining the area near the mouth of the harbour near Port Royal.

The maximum depth of the Outer Harbour is 18 m and the Inner Harbour was 15 m with the latter area having scattered turtle grass (*Thalassia testudinum*) and some eel grass (*Syringodium filiforme*) shoals. The eastern end of the inner harbour had a mean depth of 18 m and predominantly soft anoxic muddy sediment.

Goodbody (1970) described the Port Royal swamp as comprising 100 ha of mangrove lying to the east of Port Royal and enclosing a number of lagoons and channels. It was an essentially marine ecosystem with salinities of 34 and 35 ‰ with brackish conditions seldom occurring. Consequently, the biota is largely marine and not estuarine. Associated with the Port Royal swamp is an area of *Thalassia* or turtle grass extending over approximately 1,000 acres (450 ha) in some of the lagoons and over much of Middle Ground Shoal. The combined system of mangrove and turtle grass makes this region of the harbour highly productive biologically.

This section summarizes the various methods used for these species inventories, and the taxonomic lists of the species currently in the Kingston Harbour. It serves as a very useful and validated baseline survey of the biological components of the Kingston Harbour.

4.1 Methods

Trawling was used to sample benthic and demersal organisms mainly along seagrass and muddy bottoms. This is a useful sampling technique and covers a wide spectrum of taxonomic groups of organisms.

A small otter bottom trawl was used to sample the selected stations (Aiken 2009). Three trawls were executed at each station. The trawl was deployed for exactly three minutes at each site at a speed of 1 - 1.5 m/s (2 – 3 knots) at each station. The short towing time and slow speed was a function of the relatively small size and boundaries of sample sites. Each trawl was carried out a minimum of 100 m away from the previous one. The trawl was done as close to the mangroves as feasible, in the adjacent fringing seagrass areas and normally took place 10 – 15 m from shoreline in an area not disturbed by earlier boat movements to the sample site. The otter trawl measured 4 m at the head rope and 3 m at the foot rope. The trawl was retrieved and emptied and any catch stored in labelled containers, then taken to the PRML for data analyses. A similar size trawl used by Thayer *et al*. (1987) in the Florida Keys had an approximate efficiency of 20%.

Total volume fished in three minutes was approx. 628 m^3. Samples were collected from January 2007 to June 2008. Data collected species, frequency, fork and standard length or total weight (mm), weight (g) and sex where possible. Photographs were taken where possible. Weight was measured with an Ohaus model 2610 “Dial-o-gram” triple beam balance indoors, which was accurate to $1/100^{th}$ g and maximum capacity of 2610 g.

Focus was placed on:

i) The community composition,

ii) The ecological characteristics of each station,

iii) If there was temporal variation in the structure of the community taken by the trawl, and

iv) If the community structure differed between the mangrove and seagrass habitats.

Species richness and diversity were of interest to the project. The Shannon-Weiner diversity index (H') was calculated as follows:

$$H' = \Sigma (Pi)\ln(Pi)$$

Where Pi is the proportion of the i^{th} species at each site, and Σ is summation over all i fish species.

Plankton hauls is a very useful method to sample phytoplankton and zooplankton communities. Russell and Roff (1998) conducted surveys in Kingston Harbour. The study site was located in the outer region of Kingston Harbour in an area with a relatively constant depth of 15 m. Depths inside the harbour do not generally exceed 15 m (max. depth 18m), and average between 5 and 10 m.

Previous studies have indicated the eutrophic nature of this region of the harbour (Wade *et al.,* 1972; Webber *et al.,* 1992). Temperature and salinity vary little annually, generally ranging from 27 to 30°C and from 34 to 36‰, respectively. Some depression of these parameters is possible after extremely heavy rains due to the outflow from Hunt's Bay, a shallow embayment that receives the harbour's only river (Webber *et al,* 1992). Plankton samples were collected fortnightly between July 1992 and December 1993. Zooplankton collections were taken using 64 and 200 urn mesh plankton nets of 0.5 m mouth diameter (modified, WP2 pattern). Each net was hauled vertically from 12 m depth to the surface at -0.3 m s"1. Duplicate samples were killed immediately in 2% formalin, and later preserved in 10% formalin. Concurrent collections for phytoplankton were taken by replicate Niskin bottle casts at 1, 5 and 10 m; 2 1 from each cast were filtered serially through 20 um Nitex, GF/D (nominal pore size ~2 um) and GF/F (-0.4 um) filters under low pressure to determine size-fractionated chlorophyll (net-, nano- and picoplankton, respectively), using fluorometric techniques [see Hopcroft and Roff (1990) for further details]. Light attenuation was determined for most occasions using a Licor quantum sensor.

Larvaceans from 64 um net samples on each date were identified with the aid of Buckman and Kapp (1975), then enumerated and measured using the Zoop-Biom software and digitizing system of Roff and Hopcroft (1986). Sample aliquots were obtained using the beaker split method (Van Guelpen *et al,* 1982), with up to 120 individuals of a given taxon measured; increasingly larger aliquots were examined for less abundant species when they were common. Flowmeters were employed inside and outside of the plankton nets, and the average filtration efficiency of 45% was used to estimate abundance; similar values for filtration efficiency have been obtained previously for these nets (Chisholm and Roff,1990a).

Biomass, expressed as ash-free dry weight (AFDW), was calculated for each individual based on trunk (lower lip to back of trunk) length-weight regressions from Hopcroft *et al.* (1998a). To estimate shrinkage after preservation, freshly collected killed individuals were measured five times, repositioning after each measurement. After 4 months in 10% formalin, the same individuals were measured five times. The before and after preservation trunk lengths were analysed by species, using an NOVA with individuals considered as blocks. Growth rates were taken from Hopcroft *et al* (1998a), with rates pooled by 558 Downloaded from http://plankt.oxfordjournals.org/ by guest on May 5, 2012 family (i.e. Oikopleuridae, Fritillaridae).

With few exceptions, growth rates of Fritillaridae were only available from nearby Lime Cay, but we limited our use of data to rates obtained in experiments where chlorophyll concentrations, produced by nutrient enhancement, were within the range observed in Kingston Harbour. Similarly, because growth rates estimated by our techniques may be sensitive to extremely high concentrations of total zooplankton (Hopcroft and Roff, 1995; Hopcroft *et al,* 1998a), data were also restricted to those observations when larvacean biomass was within the range normally encountered in the harbour. Thus restricted, there was no significant difference between species within families (f-test, $P > 0.05$).

The mean daily specific growth rates employed for this study were: 2.49 ± 0.14 day-1 (*n* = 21, range = 1.2-3.3) for the Oikopleuridae and 2.03 ± 0.07 day1 *{n* = 35, range = 1.5-2.8) for the Fritillaridae. Estimates of annual production were obtained by the instantaneous growth rate method, with daily production calculated as the product of an individual's biomass and the instantaneous growth rate *(Pr* = *B* X *g;* see Hopcroft *et al.,*1998a). Daily production was averaged over the entire sampling period, assuming an energy density of 20 kJ g"1 AFDW calculated from the biochemical composition of Thaliaceae (Madin *et al.,* 1981).

Mangrove root communities were studied by Creary, 2003. Mangroves occur at several locations in and around Kingston Harbour. The Port Royal mangroves were selected as the primary study site in which *R. mangle* dominates the fringes. Additional sites containing *R. mangle* were selected for comparison; these were the Great Salt Pond, Dawkins Pond, and Hunts Bay. The Great Salt Pond has experienced stable conditions as predicted by Reeson (1971) since it was permanently opened to the sea in 1975 (Goodbody, 1989; Clarke, 2000), while Dawkins Pond and Hunts Bay are areas that have been severely impacted by coastal modification as well as pollution from land based sources (Webber and Wilson-Kelly, 2003).

Density currents as a result of fresh water inflows from Hunts Bay and other sources dominate the circulation patterns in the surface layers of Kingston Harbour, with tide playing an insignificant role in the surface circulation pattern (Williams, 1997). Dawkins Pond, once connected to Hunts Bay, but now sealed off, is connected to the harbour through a narrow channel and receives freshwater inputs from a series of canals. The Great Salt Pond receives pulses of freshwater from the surrounding wetlands and saline waters from the harbour through a narrow boat channel (Clarke, 2000). A stratified random sampling method (Green, 1979) was used to determine the location of sample stations.

Using a map of Kingston Harbour and environs (scale 1:50,000) the coastline containing mangrove vegetation was divided into 1 km segments and a sampling station randomly located in each. Six stations were then selected from Port Royal and two each from the Great Salt Pond, Dawkins Pond and Hunts Bay based on physical setting and the presence of mangrove prop roots suitable for sampling. Field sampling started in September 1994 and was carried out every two months until March 1995 when sampling frequency was increased to once every month until December 1995.

The choice of an appropriate sample size (number of roots collected at each sample station) was based on the procedure described by Bros and Cowell (1987). Preliminary evaluation of the number of bryozoan species occurring on the mangrove prop roots was obtained from 128 roots collected during an initial assessment of the study area. These were used to calculated repeated estimates of the standard error (SE) for samples sizes between two and eight. From this exercise the minimum acceptable sample size was determined to be five.

Sampling stations were marked on a map and located in the field by boat. A distance of 10 m was marked on either side of each sample station to give a band of 20 m from which roots were to be collected. As a general guide, the starting point along the band was selected by choosing a random location between 0-4 m. A root was then taken from the starting point and every 4 m thereafter until all five roots were collected. This helped to ensure that on each sampling occasion, roots were collected from different locations along the band. Roots with sessile communities were collected and stored in buckets of seawater and transferred to tanks with running seawater at the Port Royal marine Laboratory. A total of 720 roots was collected and analysed.

Root density (i.e., number of roots per m^2) was measured at each station using a 1 m^2 quadrat with one side removed. Ten estimates of root density were carried out starting at 0-1 m and every other meter for the entire 20 m band. The quadrat was placed around the roots and the number of roots falling within the frame were counted and recorded. Water depth at each site was measured using a pole marked off in centimetres. Water quality data were collected at all the stations at the time of root collection. The parameters measured included temperature, dissolved oxygen, transparency, salinity and suspended solids. Temperature and dissolved oxygen were measured in the field using an USI Model 55 Digital DO Meter. Measurements were made by placing the probe close to the roots and approximately 15-20 cm below the water surface.

Transparency was determined in the field by using a secchi disc. The disc was lowered vertically into the water and the point at which it just disappeared was noted. On the occasions when the disc was visible to the bottom, the transparency was recorded as greater than depth. Water samples were collected for the determination of salinity and suspended solids by submerging a 1000 ml plastic bottle 15-20 cm below the water surface. Salinity was ascertained in the field using a hand-held refractometer while suspended solids were measured in the laboratory using the method for suspended solids in seawater described in Parson et al. (1984). Salinity and suspended solids were recorded for the entire study period (September 1994 to December 1995), while temperature and dissolved oxygen were recorded for the period May to December 1995. No data were collected for February and October 1995.

The estimate of abundance of the bryozoan species and other sessile invertebrate groups were carried out using a modified point intercept method. The procedure involved the inventory of the species intercepting points established over the epiphytic community (Foster et al., 1991; Diaz et al., 1992;) using a template of transparent Perspex with 100 points arranged in a 5 x 20 cm grid. For root communities longer than 20 cm, this exercise was repeated along the entire length of the root (Bingham, 1990). Twelve categories were selected for classification of the sessile community; ten of these were taxonomic groups and included the Bryozoa, Hydrozoa, Amphipoda, Cirripedia, Porifera, Ascidiacea, Bivalvia, Anthrozoa, Polychaeta, and Algae. The category ‘Other” was used in cases where it was not possible to discern the taxon from the accumulated detrital material while 'Bare Root' was included to represent the unoccupied portions of root.

Post larvae collectors for *Panulirus argus* (Caribbean Spiny Lobster) were used by Meggs, L.G.C., R.D. Steele and K.A. Aiken (2011) to examine settlement in Kingston Harbour. In this study, data on settlement rates at selected sites around Jamaica were investigated. Pueruli and postlarvae were sought when sampling; pueruli being transparent individuals measuring 6 – 7mm CL and postlarvae being opaque individuals or individuals with pigmentation measuring between 6 – 15mm CL. It was very difficult to give figures for what was considered to be high or low postlarval settlement rates. This was because there are too many variables that affected the accurate and comprehensive sampling of large water bodies. Collections at different sites were made to determine high and low rates of settlement within Jamaica's coastal waters.

Each collector began with a 30.28 litre or 8-gallon bucket, 35 cm in length and 30 cm in width, for its frame. Nylon rope 1.6 cm in diameter was wrapped around this frame so that its surface, with the exception of the top and bottom, was covered. Small holes were then drilled into the bucket using an electric drill and plastic cable ties threaded through these holes and the rope in order to secure the rope to the bucket.

Tassels of rope were then added. These were the most important part of the collector as they actually formed the post larval shelter. The tassels were black in colour as previous research revealed a preference by the pueruli for dark coloured habitats. They were made by shredding nylon rope 0.94 cm in diameter and placing this shredded rope into bundles 0.5 cm in diameter. Tassels were 35 cm in length. In all, one hundred and ten tassels were tied to the rope encircling each of the buckets of each collector, and allowed to hang from it as stated in 1.9.1 *(a)* (Booth & Phillips, 1994).

To complete the collector, two holes opposing each other were cut close to the rim of the bucket. Rope was then pushed through one of these holes, pulled across the midline of the bucket and through the hole at the opposing end. The rope was knotted at both ends to prevent it from sliding through the holes. Through this rope, approximately in the middle of the bucket, a clamp was pushed allowing for easy clipping on and off during subsequent retrieval of the collectors. In some cases, the clamp was substituted with a loop made from a thin piece of rope.

Anchors were made in addition to the collectors to allow for the suspension of the collectors in the water column and also to prevent them from drifting while in the water. These were made by mixing and pouring cement into cardboard boxes no less than 1 cubic foot in size and allowing the mixture to set. A piece of PVC pipe (1" or 2.5 cm in diameter) was placed in the middle of each of these boxes, allowing a small passage to be present after the cement had set. Rope was subsequently pushed through this passage and on one end a clamp was added to allow attachment of the anchor to the collector.

Postlarval settlement occurs throughout any given month; however, the number settling appears to be strongly related to lunar periodicity. Greatest settlement rates have been recorded at times of the new moon and first quarter (Witham et al, 1968; Phillips, 1985; Young, 1993). For this reason, sampling sites, four of which were situated in rural Jamaica, were visited once a month and collectors checked three to four days after every new moon at the time of maximum settlement.

In the month of March 2000, a series of GUSI collectors was deployed in the waters of the five different locations around the island. They were all left for a period of two months prior to the first collection to allow adequate fouling to take place. Fouling enhances the collectors' ability to simulate the postlarval habitat. After the first collection, previously fouled collectors were deployed for one month, between sampling, allowing time to be fouled again as well as attract settling pueruli.

Collectors were put out in duplicate at each location and they were always approximately ten meters apart. The locations collector deployment included Orange Bay, Portland and Discovery Bay, St. Ann, both on the North Coast of the island; and Bowden Harbour, St Thomas; Little Bay, Westmoreland and the Port Royal Cays/Kingston Harbour, Kingston, all on the south coast.

Sampling continued for fifteen lunar months at each location. Sampling activities included visiting each location once per month to pick up collectors, counting individuals found and deploying new collectors for the following month. Upon reaching any one location, the sites of the different collectors were accessed by boat. At some sites a brief swim was required to retrieve collectors. At others, collectors were close enough to structures to be tied to them and were therefore just pulled onto the boat.

Collectors were retrieved by clipping them off their anchors and placing them into mesh bags made from old plankton nets. This prevented the escape of captured young lobsters. Having retrieved the collectors, they were thoroughly searched by hand for spiny lobster postlarvae. Having collected and tallied postlarvae found, another set of collectors was deployed for collections a week after the following new moon. This method allowed enough time for the newly deployed collectors to be fouled. Individuals from the collectors that were placed in the mesh bag were then counted and relevant observations of other organisms, such as possible prey and predators, were recorded.

In the first two months of the study there was repeated loss of collectors at the Port Royal Cays. As a result, research there was discontinued. A site in nearby Kingston Harbour was soon chosen to replace the former site and to obtain results from this area of the south coast. GUSI collectors were deployed at this site in August of the year 2000 and the first collection was made in September 2000. Sampling continued at this site for fourteen months after September 2000.

In September 2002, after completion of the initial settlement study, GUSI and Witham Collectors were deployed duplicate in the Kingston Harbour to test the catch ability of the two collectors.

A major focus throughout this study was the effectiveness of the Modified GUSI collector relative to the collectors used by Young from 1990 – 1992. In September 2002, Witham and GUSI collectors were deployed in duplicate in the waters of the Kingston Harbour in order to investigate the catchability of the two collectors. Both of these collectors are surface collectors that simulate algal habitats of postlarvae, however, their designs and the material used to make them differ considerably.

The Modified Witham collector used by Young had a rectangular, floating PVC frame with six horizontal cross bars and leaves of fine nylon bait mesh hanging from each of these cross bars simulating the algal habitat.

Unlike the Witham collector, the GUSI collector had a cylindrical frame in the form of an eight-gallon bucket. The length of the bucket was 35 cm while its width was 30 cm. Tassels of shredded nylon rope hung from this frame simulating the algal habitat. Tassels hung 35 cm from their points of attachment to the frame.

The Modified Witham collector used for this study had the same design as that used by Young in 1992. In fact, the frames and mesh used to construct these collectors were left back from Young's study. Frames were made from PVC piping and elbows. Using a commercial PVC adhesive and PVC piping; rectangular, floating frames, each having six horizontal crossbars, were made.

Leaves of fine nylon bait mesh were used to simulate the algal habitat of the *Panulirus argus* postlarvae. The bait mesh, the same type used in Young's study, is used by fishermen and has 3mm apertures. It was used in Young's study instead of the air conditioning filter material because of the filter's expense and unavailability (Young, 1993). The mesh was cut in segments/leaves 40 x 62 cm in dimension. Three of these leaves were then placed together and folded equally over each of the six crossbars. Their shorter side ran along the crossbars while their longer side hung from the bars. Leaves were made to hang some 30 cm from either side of the bars of the floating frame. The mesh segments were secured to their crossbars using cable ties.

A weight was also hung from the centre of this collector; aiding stability and preventing it from floating directly at the surface thereby reducing the chances of it being thrown around by waves. This feature was not used in Young's collectors. The GUSI collectors used in this study were the same as those used in *PART I* and as such the method of construction was the same as outlined. Collectors were anchored to the pier at the Port Royal Marine Laboratory so that they could be removed from the water quickly and without one having to enter the water.

a) Surface Area of the Witham collector

The Modified Witham Collector had six horizontal crossbars, each with three sheets of bait mesh folded over it. Because each sheet was divided into two segments, crossbars were left with three segments of bait mesh on either side. Each segment had two surfaces and therefore there were 12 surfaces per crossbar, six on either side.

The surface area of the Modified Witham Collector was calculated as follows:

Width of Collector x Depth or Height of Collector = Area of each surface/leaf.

$$0.47m \quad \times \quad 0.31m \quad = \quad 0.15m^2$$

Each Crossbar had 12 surfaces exposed for settlement. Each collector had 6 crossbars and therefore had 72 surfaces exposed for settlement.

Therefore the Total Surface Area of the Witham Collector is the area of one surface x the number of surfaces.

$$0.15m^2 \quad \times \quad 72 \quad = \quad 10.80\ m^2$$

Although in theory there should have been 10.8 m^2 of surface available for postlarval settlement, it is doubtful that the total area calculated was actually available as once collectors hit the water, the "leaves" of the collector stuck together thereby reducing potential available surface for settlement.

b) Surface Area of the GUSI collector

The surface area of the GUSI collector, because of its peculiar framework, could only be calculated as a cylinder. This was as follows:

Πd (circumference) x h = Surface area of collector.
"d" is the diameter of the top of the bucket and "h" is the height of the bucket.

$$3.14\ (30) \quad \times \quad 35 \quad = \quad 3297\ cm^2 \text{ or } 0.33m^2$$

Though the surface area of this collector appears to be much less than that of the Witham collector, this calculation is not a true representation of the real surface area of the GUSI collector. The GUSI collector consists of tassels of rope, the surface area of which is difficult to quantify. The formula used was for the cylindrical bucket, which does provide some amount of settlement surface for postlarvae; the tassels that simulate algae, provide additional surface that is intricately designed and very dense.

This investigation was conducted over a period of six months. In September 2002, a set of modified GUSI and Witham postlarval spiny lobster collectors were deployed in the Kingston Harbour for the purpose of fouling. The first collection was made three to four days after the first quarter lunar phase in November 2002 and collections followed at this time every month until

April 2003.

Upon arriving at the site, GUSI and Witham collectors were lifted out of the water and placed into separate mesh bags. The tassels of the GUSI collectors and the leaves of the Witham collectors were then thoroughly searched for postlarvae.

Postlarvae were placed into buckets containing seawater and counted. Individuals caught were put back into the water, but in a separate area of the Harbour so as not to influence subsequent readings. The collectors that were removed from the water were replaced and left in the sun for defouling (killing of fouling algae by air drying) for one month after which they would be deployed again.

An important consideration was replication of experiments in following years. This replication is important as it proves that data obtained was not as a result of abnormal or atypical conditions at the time. Though not an initial objective of the study, settlement data for GUSI collectors obtained during the period of November 2002 – April 2003 during the collector comparison investigation, allowed for such an investigation to be conducted using this dataset and that for the corresponding months of 2000 – 2001. Simply put, this set of GUSI collectors, being anchored in the same location as the initial investigation, allowed for a comparison to be made between the number of postlarvae settling in the corresponding months of the years 2000-2001 and 2002-2003 on the GUSI collector.

Results for these months in the year 2001-2002 were not included in the analysis as there was no fieldwork being done in this period.

Photo transects for benthic substrate (mainly coral reefs) have been used effectively to capture data on species composition without the need for extractions or damage to the marine life. Mendes (1992) employed the use of a camera framer to guide the underwater photography to keep the area photographed constant.

The camera framer (figure 31) with base dimensions of 0.75m x 0.5m was used to maintain the dimensions of each photo. Area and percentage coral cover were assessed and a species list was made. The camera framer was constructed from 2cm cold water PVC (White and Porter 1985). The small framer was held together with PVC t-joints. Holes of approximately 2cm in diameter were then placed in the corners of each joint. Additional support was given to the frame by attaching steel wires to opposite corners of the frame until the frame became rigid. On the base of the framer 10cm was intervals were measured and marked with a permanent marker.

The camera plate was made of a 4mm thick fibreglass sheet (20 X 25cm) with a 64mm hole drilled in it was clamped to the top of the frame. Bungee cords were used to clamp the camera onto the framer to prevent the camera from moving and for easy centring of the lens opening. A Canon Power Shot G5 Digital camera housed in a waterproof casing was used to capture the contents of the frame. Pictures were taken along the entire length of the reef in the direction parallel to the shoreline. Transects were done in replicate per station.

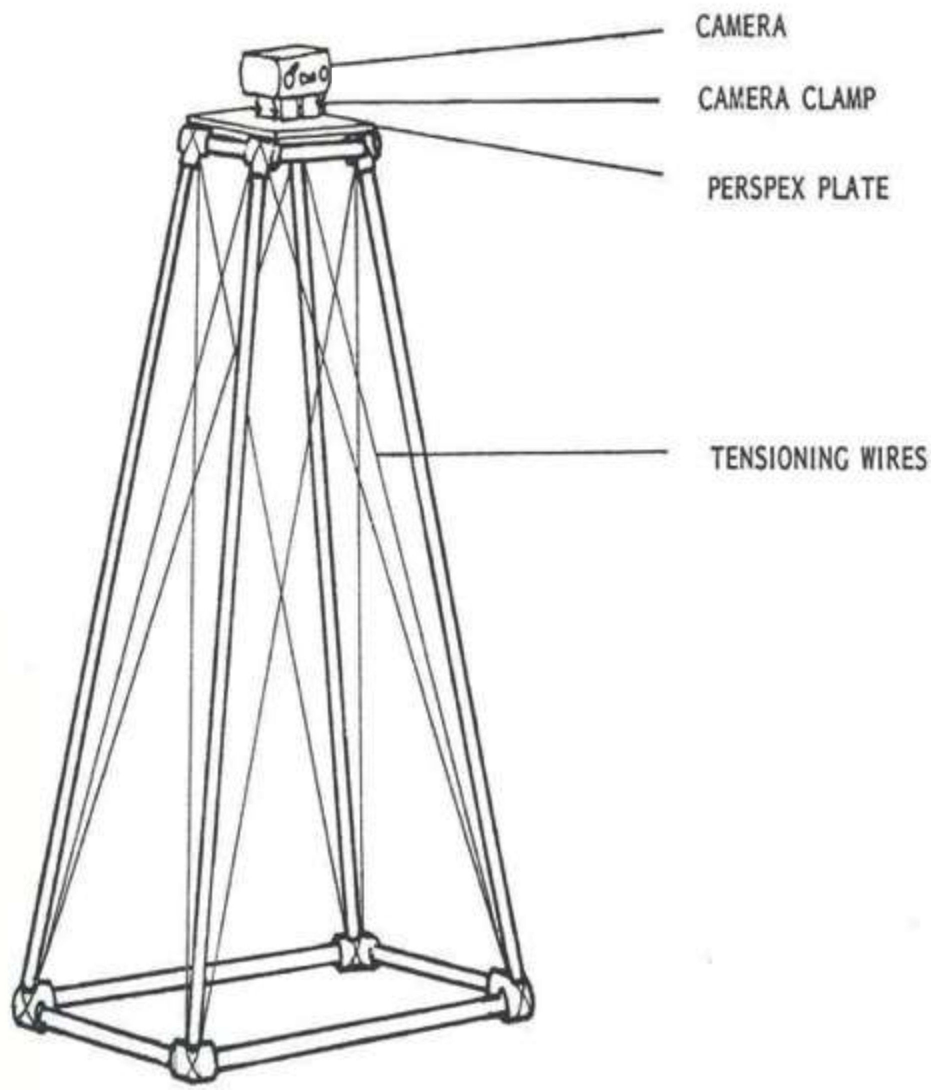


Figure 32: Photograph showing camera framer. Reproduced from Mendes 1992, figure 14.

Coral Point Count with Excel Extensions (CPCe) version 3.5 software (Kohler and Gill 2006) was used to analyse the photographs. A total of twenty randomly positioned dots were generated on each photograph. The substrate type overlain by each dot was identified to the level of the following substrate categories: coral, gorgonian, sponge, algae, rock, sand, and dead coral with algae. In addition, coral was identified to species level with the aid of Paul Humann's *Reef Coral Identification*. Excel data sheets were produced using CPCe version 3.5 for statistical analysis.

Methods of Statistical Analyses

Shannon- Weaver Index

Coral species diversity was calculated using the Shannon- Weaver Index (H´):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where:

n_i = the number of individuals in species i; the abundance of species i

S = the number of species (species richness)

N = the total number of all individuals

p_i = the proportion of individuals of a given species to the total number of individuals in the community: n_i / N.

Identification

The species was first identified based on morphological characteristics (Siddall, 1980). The shell colour in both the juveniles and the adults was compared. Forty mussels were dissected also to examine the scar patterns left from the adductor muscle.

Cytological confirmation of the species was then done in collaboration with D. Hicks (Lamar University, Texas). Specimens between 30-40 mm were collected and the gill tissue dissected and isolated. They were then prepared using a modified colchicines-Giesma technique (Holland et al., 1999 as per Ingrao et al., 2001), in which specimens were first placed in 0.05% colchicines solution for a period for 12 hours and then placed in a hypotonic solution of 0.8% sodium citrate for 40 min.

Replicates of the gill tissue were then fixed twice in freshly prepared solutions of three parts ethanol and one part glacial acetic acid for 20 min. periods. Finally, they were stored in freshly prepared mixtures of the identical fixative solution and sent off for cytological analysis (as per Ingrao et al., 2001).

In July 1999, a preliminary survey was carried out at 29 random sites around Kingston Harbour to observe the absence, or presence of the mussel. Ten of these sites were selected to study distribution patterns and are called 'distribution sites.' The density was monitored monthly over a one year period (February 2000 to January 2000) at each of these ten distribution sites. Sites showed variation in the type of substrate on which the mussels were found; hence, the density was ascertained using slightly different techniques. For flat substrates, such aspire walls and seagrass beds, a 20 x 20 cm quadrat was employed. With cylindrical surfaces, such as mangrove prop roots and wharf pilings, only a defined upper segment was counted using a reference pole. Three random counts were done at each of these sites, and the mean of these values expressed per unit surface area. Simultaneously with the sampling, several physicochemical parameters were also taken using a Hydrolab multi-parameter data logger. These parameters included salinity, dissolved oxygen and temperature.

Nutrition

Enumeration and Identification of Phytoplankton from stomach contents of green mussels

Samples taken from the water directly surrounding the mussels were collected from ten of the 13 study sites using 250 ml plastic bottles. Three of the ten distribution sites (GSP, HB, and PS) were not used in this aspect as the mussel density was too low for extraction, or absent. Three other sites were then chosen to replace these sites.

Three ml of Lugol's iodine solution was added to each water sample for immediate preservation and staining of the microalgae, in the samples for later identification and enumeration (Vollenweider, 1969; Steidinger, 1979). The gut contents from three small and three large mussels from each of the ten sites were washed using filtered seawater into separate bottles containing two ml of Lugol's solution.

Lugol's preserved site water and gut contents were gently homogenized by inversion and 10-100 ml aliquots of each used to fill settling chambers. The chambers were left to stand overnight to allow settling of the phytoplankton before examination. Examinations were conducted using a Leitz Labovert (model no. 020-435.025) inverted microscope (Utermohl, 1958). Phytoplankton cells were identified and enumerated from 50 random fields of view to remove the edge effect in the settling of phytoplankton cells (Sangren and Robinson, 1984). The presence/absence of microalgae in both the gut contents and water samples was recorded and the number of cells per liter of any potentially toxic species was determined.

Estimation of Suspended Solids- One-liter water samples were taken from each of the ten distribution sites adjacent to the mussels (or suitable substrate in the case of Hunt's Bay), which were used to determine the total amount of suspended solids present. This was done by vacuum filtering the sample through Whatman 1 mm glass fibre filters. The filters were then dried and weighed to determine the total suspended solids.

The full list of species found in Kingston Harbour is shown in Appendix I.

CHAPTER 5.0: Economic Assessment

The economic impacts of marine invasive alien species on Jamaica's GDP is understudied as a whole. The value of the marine resources to the various economic sectors based on the ecosystem services they provide is better understood. The major sectors that contribute significantly to GDP and depend on the marine ecosystem services directly are tourism and fisheries, while social benefits (e.g. recreation), and other benefits such as disaster mitigation, carbon sinks, etc are not easily and quantitatively classified as contributors to GDP.

This economic assessment employed the use of a comparison of the direct and indirect impacts of the most recent marine invasion in Jamaica (the lionfish) with the value of fisheries and tourism to Jamaica's GDP. We then compared this value to the cost of implementation of the BW Convention in Jamaica for Year 1 and subsequent years in perpetuity.

The Lionfish *(Pterois volitans and Pterois miles*) in the Caribbean Sea has been categorized as the most deleterious marine finfish invasion in history with the potential to devastate the fragile marine sector of the Caribbean (Morris et al. 2008). Although the channels of entry into the Caribbean Sea are not entirely certain, majority of scholars agreed that the vector of the Lionfish was from the aquarium pet trade on the Eastern Sea Board of North America (Ruiz-Carus *et al.* 2006). The two species of Lionfish thrive in the Caribbean Sea for two main reasons; its efficiency as an apex predator feeding on a variety of small fish and crustacean (Fishelson 1997, 392) and it is not a prey for many species in the Caribbean Sea (Buddo, pers. comm..). In addition, the Lionfish has a rapid reproduction rate, with one female producing approximately 2 million offspring annually (Buddo, pers. comm.).

The Lionfish is a concern to marine resource stakeholders because of its potential threat to fisheries, biodiversity, fish nurseries, numerous microhabitats and human health (Morris 2009, 15). The economies of Caribbean islands like Jamaica are vulnerable to the Lionfish invasion because of the extensive use of natural resources to maintain domestic livelihoods (WRI 2005). The fisheries sector in Jamaica contributes approximately 0.4% to its total Gross Domestic Product

(GDP) and affects the livelihood of approximately 20,000 persons (FAO 2012). The most prevalent impact identified in the Lionfish invasion in Jamaica is the threat to the marine biodiversity (Sealy et al. 2008).

The coastal area of Jamaica is dominated by coral reef habitat (NEPA 2007, 2). The coral reef habitat in Jamaica is an important for tourism and maintaining fish stocks. In 2006, the predatory Lionfish was first sighted and since then, it has established in the country's reef habitat. As a result, the full impact of the IAS on the biodiversity of the reef habitat due to competition and predation as well as the socioeconomic impact on the users of the fishery remain to be determined. A decline in fish stocks in the reef habitats from the Lionfish population growth can cause significant losses to the value of the marine biodiversity and the quantity of fish landings of the commercial fisheries sector of Jamaica. Research has shown that the Lionfish can potentially reduce the species composition of a coral reef habitat by 79% (Morris et al. 2008). Should the trends of the Lionfish population growth remain unchecked, then the potential cost of the Lionfish Stock would exceed the total value of the reef fish stock in Jamaica. The purpose of this study was to determine whether the cost of the potential damages caused by the Lionfish to the fishery sector in Jamaica exceeds the value of the biomass in its reef habitats.

5.1 MATERIALS AND METHODS

In order to determine the value of the potential damages to the reef habitats in Jamaica caused by the Lionfish, all the potential impacts have to be classified. According to Evans (2003), the impacts of an IAS can be expressed as either direct or indirect. The direct impacts are the immediate effects of the IAS on ecological, economic or human processes; for example, the loss in reef biomass daily due to the Lionfish consumption. The indirect impacts are effects that occur as a result of changes brought on by the IAS. This causes a subsequent change in a sequence of ecological, economical and socio - cultural events; for example, decline in overall marine biodiversity as the Lionfish decrease reef species populations (Hosein 2010, 96). An analysis of the economic impacts should therefore, include the cost directly incurred from the invasive species' presence and the indirect costs incurred from secondary and tertiary effects of the invasive species' presence (Evans 2003, 2).

A combination of primary and secondary data sources were required to calculate the potential direct and indirect impacts. The primary data was obtained using a contingent valuation questionnaire. The questionnaire was used to value the marine biodiversity of the reef habitats of Jamaica. The marine biodiversity was identified by the researchers as the total stock of reef fish in Jamaica. The secondary data was obtained from several sources. including institutions such as the Fisheries Department of the Ministry of Agriculture, the National Environmental Protection Agency (NEPA), the Marine Invasive Species Lab of the University of the West Indies Mona Campus, the Ministry of Health in Jamaica, Jamaican Association of Dive Operators (JADO), the National Statistics Office of Jamaica (STATIN) and the Montego Bay Marine Park. The International institutions included the Caribbean Regional Fisheries Mechanism (CRFM), Caribbean Community Fisheries Policies, Gulf Caribbean Fisheries Institute (GCFI) and the Food and Agriculture Organization (FAO).

A survey was conducted along the Northern and Western Coastline of Jamaica. Using a random sample of citizens, questionnaires were distributed to five stakeholder groups between the 16th and 30th of July 2011. The targeted groups were surveyed in the parishes of St. James, St. Anns and Trelawny along the Northern and Western Coasts of Jamaica. The stakeholder categories represent all individuals within the coastal communities of the three parishes. A sample size of 366 respondents representing the population of marine stakeholders in the parishes of St. Anns, St. James and Trelawny was collected. The data acquired from secondary sources included the market prices for commercial fish species in Jamaica, Lionfish gut content from specimens captured in the reef habitats of the Northern to Western Coastline, the biology and ecology of the Lionfish invasion, fisheries data and GDP data for the past 10 years.

The direct costs of the biological impacts as a result of the Lionfish invasion in Jamaica were identified as the potential losses in reef fish stock from consumption. In calculating the direct impacts, a simulation was used to model the typical consumption pattern of the Lionfish invasion. Using biological parameters of the Lionfish invasion, the population spread and consumption patterns were simulated to estimate a total quantity of biomass consumed annually. In determining an estimated quantity of commercial species consumed, the estimated population of Lionfish (N) had to be determined. By identifying the population density within square kilometre span of reef habitat, an estimated total population was derived using the following functional expression:

$$N = n * A \quad \text{.......................................} (1)$$

Where, the estimated population (N) is a function of the estimated population density per square kilometre (n) and the total area of reef habitat on the Northern and Western Coastline (A).

Based on the gut content samples attained from secondary data sources, the researchers were able to establish an average daily consumption of reef biomass (Bm_{Cons}^{-1}**).** The potential losses were calculated based on the assumption that the total volume potentially consumed by the Lionfish will have a market value. Based on this assumption, an aggregated market value per kilogram was derived for all commercial species. The aggregated market value per kilogram was calculated using total quantity of reef species caught (tonnes) within one year. The functional expression used for the aggregated market value (P):

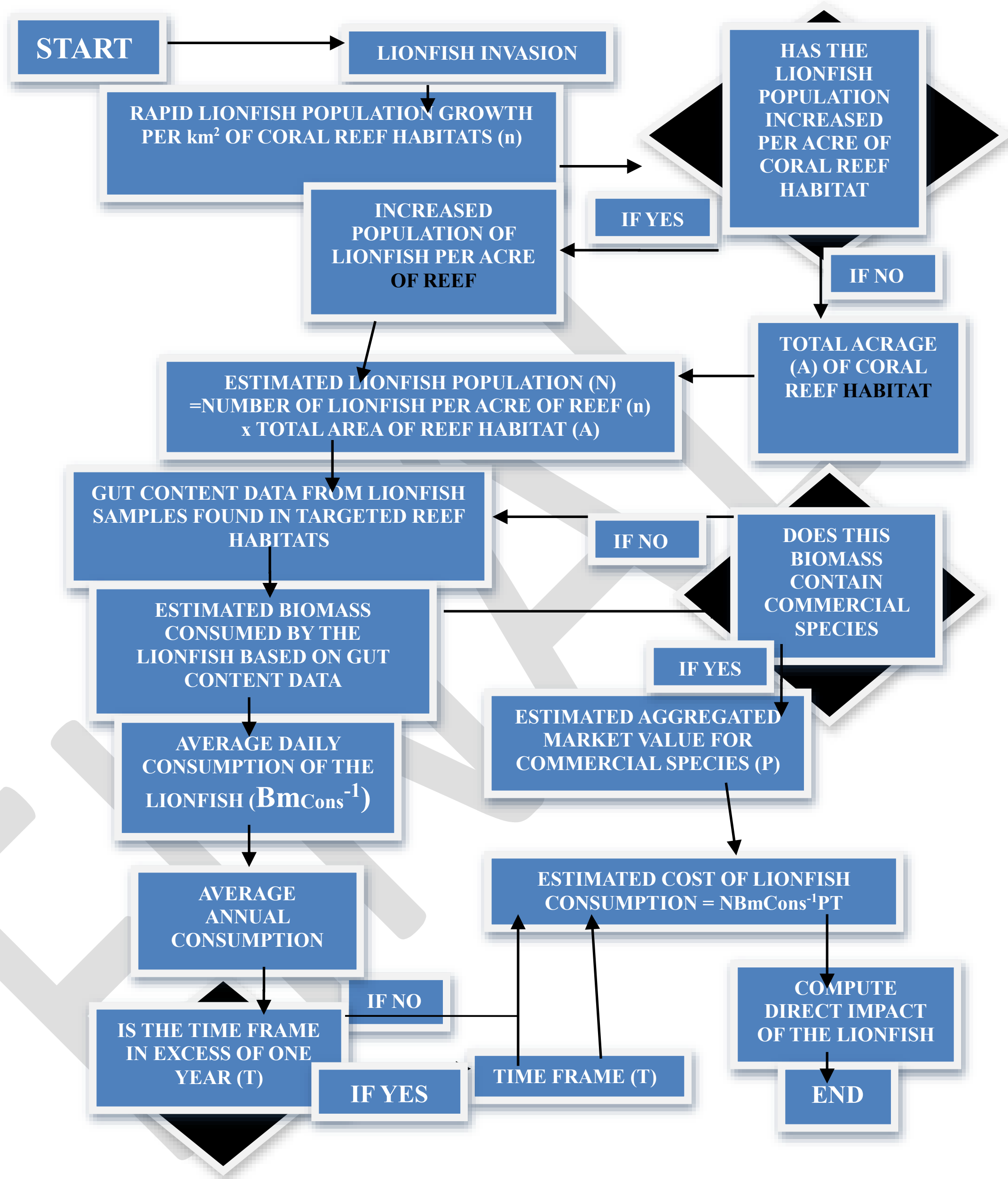
$$P = Q_t / V_Q \quad \text{.......................................} (2)$$

Where, Qt represents total quantity of commercial reef species caught in tonnes for one year and V_Q is the monetary value of Qt. All calculations for P were converted to a unit cost per kilogram and then a unit cost per gram.

The simulation was developed based on the product of functions. Therefore the product of the functional expressions (1) and (4) was compiled with the average daily biomass consumed by the Lionfish (Bm_{Cons}^{-1}), to form the functional expression for the total cost of biomass consumed:

$$Cost_{Cons} = NBm_{Cons}^{-1}PT \quad \text{.......................................} (3)$$

Where: $Cost_{Cons}$– Total Cost of Biomass Consumed; N – Estimated Lionfish Population in Jamaica; Bm_{Cons}^{-1} – Average Daily Biomass Consumed per Lionfish; P – Estimated Market Price for Commercial Fisheries in Jamaica; T – Timeframe measured in days.



Flow Diagram for the Simulation used to assess the Direct Impacts of the Lionfish

The indirect cost of the Lionfish invasion in Jamaica looks at the potential loss in marine biodiversity from the reef habitats. The marine biodiversity impacts are assessed based on the decline in the biomass stock of eggs, juveniles and non-commercial reef species. Based on the premise that the Lionfish poses the greatest threat to marine biodiversity (Sealey et al. 2008), then an inverse relationship between the Lionfish population increasing and marine biodiversity decreasing can be established. Translating this into an economic cost, the study adapts the premise established by Sealey et al. (2008) to assume that as the Lionfish population increases; the value of the marine biodiversity in the reef habitats will decrease.

There are no market prices for the marine biodiversity of the reef habitats in Jamaica; therefore a hypothetical value has to be established. The hypothetical value for marine biodiversity is based on the 'Willingness To Pay (WTP) to protect it' concept. The WTP concept derives a variety of value categories for which the importance of the marine biodiversity to the study population is categorized. The mean willingness to pay to protect the marine biodiversity in Jamaica was deduced by calculating the probability that someone will agree to contribute a stated bid to protect it for a year from a sample. To calculate the WTP, a Logistic regression model entitled the bid function was used and expressed as:

$F_{(Bid)}$: Log (Yes/1-Yes) = $\gamma_0 + \gamma_1$ (Bid)..(6)

Where: Log (Yes/1-Yes) – Logs Odd Ratio of willing to pay to not willing; γ_0– Coefficient of auto generated constant; γ_1– Coefficient of the Bid Variable; and Bid – Bid offered to respondents. According to Hanemann (1989), the mean willingness to pay (WTP) of the sample is calculated using the coefficients of the bid function where:

Mean WTP = ln (l + exp (γ_0)) /γ_1..(7)

The bid function assumes non-negativity for the mean willingness to pay (WTP). The mean (WTP) was multiplied by the study population of the three parishes to derive the Total Willingness to Pay (TWTP) for marine biodiversity. The study population comprised of the following stakeholders; fishermen, tourist, dive operators, environmental officers and local residents from the parishes of St. Anns, Trelawny and St. James.

TWTP = Mean WTP * Study Population...(8)

The Total Willingness to Pay will be considered the value for the marine biodiversity for the sample areas.

The study outlined the direct and indirect biological impacts associated with the Lionfish invasion in Jamaica. Using the functional expression for total cost:

$F_{(DC,IC)}$: TC = DC + IC..(9)

Where TC represents the sum of all the costs for the direct and indirect biological impacts, DC represents the sum of all the direct costs and IC represents the sum of all the indirect costs associated with the impacts of the Lionfish invasion. From functional expression (9), a value for the total impacts on the fishery sector in Jamaica caused by the Lionfish was identified.

5.2 RESULTS

Biological and ecological data associated with the Lionfish invasion in Jamaica was used for the direct impact analysis of the invasion. The data used included the estimated population of Lionfish per square kilometre (km^2) of reef, total area of reef habitat affected by the Lionfish and estimates from compiled Lionfish gut content data sourced from the Lionfish pilot project conducted by the National Environmental Planning Agency and the Marine Invasive Species Lab (Table 1).

Table 1: Summary of the Biological Data Sourced from the Lionfish Project in Jamaica

PARAMETER	SYMBOL	QUANTITY
Estimated number of Lionfish per km^2 of Reef in Jamaica	n	24,711
Total Area of Reef Habitat Affected by Lionfish in Jamaica	A	1240 km^2
Average Biomass Consumed in a day by a Lionfish	Bm_{Cons}	0.98g
Average Lifespan of a Lionfish	Ls	10 – 15 years

The Lionfish Pilot Project in Jamaica conducted gut content research which was utilized to verify the estimated biomass consumption levels and determine the variety of commercial species consumed by the Lionfish. From a sample 459 specimens of Lionfish, 12 different species of commercially important fish and crustacean were identified.

An aggregated market value based on per kilogram units was calculated for all commercial species caught in the reef habitats of Jamaica. According to the FAO (2012) country fisheries profile, 90% of marine fishing operations in Jamaica comprise of reef species. The FAO (2012) fisheries profile estimates that Jamaica fishermen catch approximately 8,702 tonnes of marine fish and crustacean annually. Therefore, the expected quantity of reef species (E (Qrf)) caught within a year will be 90% of the total catch for a year. The expected quantity of reef species caught in a year is 7831.8 tonnes and the Landing value according to the FAO (2012) is USD20.7 million

(Appendix 11). Therefore, the overall aggregated market value per kilogram (P) of commercial reef fish in Jamaica is USD2.64 per kilogram.

The simulation outlined in Figure 1 was designed to represent the potential loss in reef biomass caused by Lionfish predation within one year. The simulation utilized selected biological and ecological parameters of the Lionfish invasion to estimate a potential cost using a product of functions model. The product of functions model defined functional expressions for selected biological and ecological parameters distinct to the Lionfish invasion based on the available data (Table 1). For every biological and ecological parameter outlined, an estimated value was derived and substituted into an expression for the potential cost of the biomass consumed.

The estimated Lionfish population in Jamaica (N) was calculated by using the secondary data sourced from the Lionfish pilot project conducted by the Marine Invasive Species Lab and the National Environmental Planning Agency (NEPA). The estimated Lionfish population in Jamaica (N) = estimated population of Lionfish per square kilometre of reef (n) * total area of reef affected (A). Given that n = 24,711 Lionfish per square kilometre and A = 1,240 km^2 of reef, then the estimated population of Lionfish in Jamaica (N) is 30,641,640.

The Secondary data sources identified the estimated biomass consumed by a Lionfish **(**Bm_{Cons}^{-1}) is 0.98 g daily (Table 1). Given the estimated population (N), the estimated total biomass consumed daily (TBm_{Cons}) by the Lionfish was calculated. The Lionfish population consumes approximately 30,028.81 kg daily. Using the overall aggregated market value per kilogram (P) of commercial reef fish is USD2.64, the losses were derived for one year thus T = 365 days to correspond the measurement units. Therefore, the potential losses to the commercial fisheries sector ($Cost_{Cons}$**)** as a result of the Lionfish invasion is estimated at US $28, 935,761.32 per year.

Considering that the analysis highlighted deals with potential impacts, several situations can be simulated from the model presented (Figure 1). For example, if the Lionfish population growth remains unchecked, then there is potential for an increase in the population density of Lionfish per acre of reef. Assuming a 5% population density growth rate annually, then this new information can enter the simulation system (Figure 1) to generate the new volume and cost of biomass loss (Table 2) in the reef habitats assuming all other parameters hold constant.

Table 2: Non Expansion Simulation Output for a Change in Population Density

Time lapse (Years)	**Annual Growth Rate per year**	**Population Density # Lionfish per square kilometre (n)**	**Reef Area (km^2)**	**Estimated Total Population of Lionfish (N)**	**Daily Biomass Consumption**	**Total Daily Consumption (kg)**
Present	-	24,711	1,240	30,641,640	0.98 g	30,029
1	5%	25,947	1,240	32,174,280	0.98 g	31,531
2	5%	27,244	1,240	33,782,560	0.98 g	33,107
3	5%	28,606	1,240	35,471,440	0.98 g	34,762

As the population density of the Lionfish increases annually, then the estimated total population of Lionfish also increases. Substituting the new population density levels (n) in the function for the estimated population of the Lionfish (N), a new estimated total population of the Lionfish (N) was calculated. The estimated total population of Lionfish was used to calculate the estimated total daily consumption of the Lionfish **(**TBm_{Cons}**).** The average daily biomass consumed by the Lionfish (Bm_{Cons}) and the aggregated market value per kilogram (P) remains unchanged from the initial simulation because it is assuming a change in one specified parameter (population density increase annually) ceteris paribus. The changes occurring within the non-expansion simulation are at one year intervals, therefore, the time frame (T) used was 365 days. The new T Bm_{Cons} was used to calculate the new costs of the biomass loss (Table 3) due to consumption ($Cost_{Cons}$**)** with a 5% annual increase in the population density of the Lionfish.

Table 3: Non Expansion Simulation Output for a Change in Biomass Consumed

Time lapse (Years)	Total Daily Consumption by Lionfish Population (kg)	Aggregated Market Value per kg (P) USD	Time Lapse (days)	Cost of The Total Biomass Consumed Within a Year ($Cost_{cons}$) USD
Present	30,029	2.64	365	28,935,944.40
1	31,531	2.64	365	30,383,271.60
2	33,107	2.64	365	31,901,905.20
3	34,762	2.64	365	33,496,663.20

The analysis of the indirect impacts on marine biodiversity is based on the premise that as the Lionfish population increases, marine biodiversity of the reef habitats will decline. Based on this premise, a contingent valuation was utilized using a bid function to derive a mean Willingness To Pay (WTP) value for the marine biodiversity. The value was based on a one year valuation time frame which translates into a potential loss in marine biodiversity for a year given the continued increase in the Lionfish population.

The contingent valuation was conducted using starting bids that the respondents were asked to agree whether they were willing to pay. The responses were analysed using a Logistic Regression Model known as the bid function which compared the ratio of responses to the bid amount. Based on the results, 72% of the persons sampled were willing to pay their respective bid to protect the marine biodiversity for a one-year period. Using a Logistic Regression Model, the probability of a persons' willingness to pay is calculated using the Log Odds Ratio between willing to pay and not willing to pay. The Logistic Regression Model or the bid function showed willingness to pay as a function dependant on the bid.

Table 4: Results Generated from the Logistic Regression Model

VARIABLE	γ – VALUE	P - VALUE	WALD VALUE
Constant	γ_0:-1.364	0.000	58.041
Bid	γ_1:0.01	0.002	9.998

The results generated from the Logistic regression model stated that the coefficient of the bid variable (γ_1:0.01) has a positive influence on whether a person was willing to pay or not. The constant coefficient has a negative effect on whether a person was willing to pay because if no bid (bid = 0) was offered, then the respondents will not be willing to pay. The coefficients for the bid and constant were used to calculate the Mean willingness to pay (WTP). Before the Mean WTP was determined, the statistical significance of each coefficient and the overall Logistic Regression model was determined. In testing the statistical significance of the coefficient parameters, the following hypothesis was established:

H_0: $\gamma_n = 0$……………………………………………………..……………………………….(10)

H_A: $\gamma_n \neq 0$……………………………………………………..……………………………….(11)

Therefore, for each coefficient in the Logistic Regression Model to be statistically significant, the null hypothesis has to be rejected. In testing the statistical significance for each parameter, the p – value derived from the analysis was utilized. If the p –value < the significance level (α) of 0.05, then the null hypothesis is rejected. Based on the results generated from the analysis, the p – value of the coefficient for the constant (**γ_0**) is 0.000 and the p – value for the coefficient of the bid (γ_1) is 0.002. Therefore, for both hypothesis tests, the null hypothesis is rejected. Thus the coefficients generated are statistically significant. In further validating the statistical significance of the constant coefficient, the Wald Chi – Square test was applied. The Wald Chi – Square test was developed specifically to show the statistical significance of the constant coefficient. The test proposes the null hypothesis that:

H_0: $\gamma_0 = 0$……………………………………………………………………………………….(12)

H_A: $\gamma_0 \neq 0$……………………………………………………………………………….………(13)

The Wald Chi – Square test states that if the Wald Value > X^2 critical value at 1 d.f. with $\alpha = 0.5$, then the null hypothesis is rejected. The test is conducted for the constant at 1 d.f. only since there is only one predictor in the model. Based on the analysis derived (Table 4), the Wald value of 58.041 > the X^2 critical value of 3.84 for 1 d.f. at $\alpha = 0.5$. Therefore, the null hypothesis is rejected. The constant in the model is statistically significant. The Hosmer and Lemeshow test was used to measure the goodness of fit for logistic regression models. The Hosmer and Lemeshow test hypothesizes:

H_0: The current model fits well……………………………………….........................………(14)

H_A: The current model does not fit well…………………………………………….....……..(15)

The test uses a Chi – Squared distribution with a d.f. = g – 2. Since the data has five (5) stakeholder groups, then the d.f. = 3. Unlike most hypothesis tests for statistical significance, the Hosmer and Lemeshow test tries to fail to reject the null hypothesis in order for the model to be significant. Using α = 0.5, the Chi – Square (X^2) value with d.f. = 3 computed for the Hosmer and Lemeshow test was 1.171. The Chi – Square (X^2) value for the logistic regression model < the critical Chi – Square (X^2) value of 7.82 at 3 d.f. with α = 0.5. Therefore, do not reject the null hypothesis. The Hosmer and Lemeshow test showed that the overall model is significant.

The estimated indirect impact was calculated using the total willingness to pay to protect the marine biodiversity within the three parishes used for the sample. The total population was identified as the population of the three parishes used for the sample (Table 5) which totalled to approximately 434, 483.

Human Population Size in the Parishes St. James, St. Anns and Trelawny

Sample Area	Population
St. James	184, 854
St. Anns	173, 830
Trelawny	75, 799

The mean WTP was calculated by substituting the coefficients derived from the logistic regression model into the equation for mean WTP (equation 7). The mean WTP derived from equation (7) was approximately USD22.76. Therefore, the total willingness to pay to protect the marine biodiversity for one year from 2011 is USD9,888,833.08.
With the potential cost of the direct biological impacts of the Lionfish invasion is USD28, 935,761.32 and the TWTP for protecting the marine biodiversity of the reef habitats in Jamaica is USD9,888,833.08, then **the total cost of the impacts identified for the Lionfish invasion in Jamaica is USD38,824,594.40**.

5.3 DISCUSSION

The study wanted to determine the potential cost of the biological impacts associated with the Lionfish invasion on the fishery sector in Jamaica. The study outlined that there can be either direct or indirect impacts each having a particular cost. Fish and small crustacean from the coral reef habitats in Jamaica are major components of the diet for locals and tourists. It was estimated by the FAO (2012) that 90% of the fish caught and sold in Jamaica markets are reef dwelling fish.

Therefore, majority of the fisheries sector in Jamaica is dependent on the biodiversity of the reef habitats. The total biomass consumed daily by a Lionfish was identified as an estimated 0.98 g. The results showed the estimated population of Lionfish in the reef habitats in Jamaica approximated to 30 million consuming an estimated 30,000 kg of biomass daily. Extrapolating these averages for one year, the estimated Lionfish population can potentially consume approximately 11 million kg of biomass annually. This loss in biomass, when compared to the aggregated market value for the reef biomass, can potentially cost USD28, 935,761.32. A potential loss of 11 million kg of biomass annually is a disquieting indicator of a potential future decline in reef biodiversity. The potential cost to the economy is actually larger than the current value of all fish landings in Jamaica for one year which is approximately USD20,700,000.00 annually (FAO 2012).

According to Morris (2008), the Lionfish population can potentially diminish up to 70% of the marine biodiversity of the reef habitats. The marine biodiversity for Jamaica encompasses the species compositions that do not have an observed or direct market value. Based on the results, the population of the northern and western coastal communities is willing to pay an estimated USD22.76 per person to protect the marine biodiversity of the reef habitats from the Lionfish in Jamaica for one year. Considering this estimate for the entire study population, then the value of the marine biodiversity of the reef habitat estimated around USD9,888,833.08.

Based on the results generated, the total economic cost potentially incurred within a year due to the Lionfish invasion is calculated by finding the sum of the direct and indirect impacts. Based on the results, the potential cost of the Lionfish invasion is approximately USD38,828,090.40. Using this value as the estimated potential cost of the impacts associated with the Lionfish invasion in Jamaica, the actual cost of the impacts of the Lionfish invasion can potentially exceed the value of the reef biomass. From the information generated about the Lionfish invasion in Jamaica, it can be concluded that if the Lionfish population growth remains unchecked, then the losses to the economy from the fisheries sector will exceed total contribution that the fisheries sector makes to gross domestic production (GDP).

5.4 Budget for Implementation of IMO Ballast Water Management Convention

For the BWM Convention to be implemented effectively, financial resources should be made available and sustained indefinitely, if Jamaica is to manage ballast water effectively. These indicative costs are outlined in the Table below:

Table 18: Budget for BW Convention Implementation

Item	Description	Year 1 Cost (USD)	Recurring Annual Cost (USD)
Training of personnel	Training in ballast water sampling and analyses, compliance monitoring, ships' ballast water system inspection, etc.	25,000	5,000
Field Equipment	Used for sampling ballast water and analyses of some parameters on-board (e.g. salinity)	45,000	10,000
Lab Equipment	Used to provide detailed analyses of ballast water collected	40,000	5,000
Dedicated staff	Staff (x2) required to sample and analyse ballast water in a timely manner	40,000	40,000
Part-time Contracted Staff	To provide field and lab assistance to dedicated staff during large scale activities	20,000	20,000
Meetings and Workshops	To provide a medium to share findings and constantly improve mechanisms for management of ballast water	18,000	6,000
Ballast Water National Task Force (NTF)	Administrative support for the activities of the NTF	5,000	5,000
International Conferences	Attendance of key national stakeholders to international ballast	15,000	8,000

Item	Description	Year 1 Cost (USD)	Recurring Annual Cost (USD)
	water meetings and conferences to improve knowledge and share experiences		
Research and Monitoring (including Port Biological Baseline Surveys for Key Ports)	Research into ballast water management techniques, sampling and analyses, species' invasion characteristics, etc.	70,000	50,000
Total (US$)		278,000	149,000

5.5 Comparison of Costs of BWM Convention and Impacts of the Lionfish to GDP

Estimated Value of Marine Biodiversity's to Tourism and Fisheries: USD 9,888,833.08/year

Estimated Impact of Lionfish: USD 38,828,090.40/year

Cost to Implement BW Convention: USD 278,000 in first year

USD 149,000 per year

Though BW is not the only cause of marine invasions, it is the main cause. Preventing marine invasions by managing ballast water release in Jamaica will result in significant reduction in introductions of marine invasive alien species.

6.0 RECOMMENDATIONS

1: *Conduct Port Biological Baseline Surveys*

Port Biological Baseline Surveys (PBBS) should be conducted at all major ports around Jamaica. In order to prioritize, the ports with the highest amount of exports (including transhipments) should be given a higher rating. These ports would receive more ballast water releases pre-loading cargo, and would be more vulnerable to invasions of marine alien species. PBBSs require extensive amounts of technical expertise especially in the area of taxonomy. However, it would still be useful to conduct multi-target biological sampling and store reference specimens for identification at a later date. It is realistic that special projects would have to be implemented to conduct these PBBSs, as oftentimes, regular budgetary support would not have allowances to conduct these surveys. Partnerships in academia could play a significant role in making these PBBSs occur.

2: *Conduct Training Courses for Key Stakeholders*

To date, only one training programme has been conducted on ballast water sampling in Jamaica. This was conducted by the University of the West Indies in 2006. More training programmes would result in an increase in technical capacity to sample and analyse ballast water in Jamaica. The participants for these training programmes should be taken from the various stakeholder groups. In Jamaica, participants should be the University of the West Indies, the National Environment and Planning Agency, the Maritime Authority of Jamaica, The Port Authority of Jamaica, The Caribbean Maritime Institute, The Institute of Jamaica, The Ministry of Health, The Jamaica Coast Guard, The Marine Police, and selected environmental NGOs.

3: *Strengthen Marine Invasive Species Research Programmes*

Research into biology, ecology and control strategies is crucial to the management of bioinvasions. Currently, there are five (5) research topics for marine invasive species research being conducted by the UWI Discovery Bay Marine Laboratory – Marine Invasive Species Lab; two of these are on ballast water management. This programme should be strengthened with more ongoing funding and research personnel. In addition, other agencies in Jamaica should be encouraged to include research on marine invasive species into their work programmes. This would lend valuable support to the management of ballast water by the Maritime Authority of Jamaica.

4: *Strengthen the Work of the Ballast Water National Task Force*

Jamaica established its first National BW Task Force in 2009, and is chaired by the Maritime Authority of Jamaica. The members include the major stakeholders in ballast water management in Jamaica. It is important that budgetary support be given to this Task Force to effectively carry-out its functions.

5: *Establish Ballast Water Testing Facilities*

Ballast Water testing facilities should be established in Jamaica. For now, it would be useful to establish one on the south coast (preferably near Kingston Harbour) and another near a bulk carrier port on the north coast. The facilities should be equipped to implement a ballast water monitoring programme, and also have the capacity to respond to urgent requests to sample ballast water and provide timely results. This would require at least two (2) full time technicians with appropriate field sampling gear, transportation and laboratory equipment.

6: *Strengthen Legislative Support*

It is useful to enact appropriate legislation to adequately manage ballast water entering Jamaica. Currently there is no significant legislative support and compliance is now voluntary. In Jamaica, legislation is currently being drafted and it's anticipated that Jamaica will quickly become a party to the IMO Ballast Water Management Convention (2004). This would allow more stringent management of ballast water in Jamaica.

In the interim, ships should be encouraged to implement ballast water management guidelines, such as open-water exchange of ballast water. They should also be encouraged to provide timely reports of their ballast water management activities, such as coordinates of ballast water exchange and volumes exchanged, etc. This could include making the ballast water record book available to the Port State Control Officers during their regular ship inspections.

7: *Improve Regional Cooperation*

Jamaica's status as a Lead Partnering Country of the Globalist Partnerships Project in the

Caribbean has placed it a position to provide some level of coordination of efforts. Jamaica now chairs the Regional Ballast Water Task Force, as well as the Regional Marine Invasive Species Working Group. The UWI as the main research entity in Jamaica has campuses in 14 countries around the region, and can provide a regional platform to increase the capacity for ballast water management in countries with less capacity.

A mentoring programme should be considered, whereby a specific country is mentored by another country in the region with greater capacity for a specified time period. During this period, certain key targets for capacity-building should be mutually agreed upon. However, this requires funding on the part of both countries.

References

Aiken, K.A., A. R. PAL and G. PERRY. 2009. Nursery Grounds for Fishable Species in Kingston Harbour, Jamaica: Do They Still Exist? Proceedings of the Gulf and Caribbean Fisheries Institute 61: 358- 74.

Anderson, G., (2003). Sandy Beach Processes. Section 3.3.1.

Anderson, N.G. & Witman, J.D. (1995). Trends in community structure on a Jamaican reef. *Mar. Ecology Prog. Series*. 118: 305-310.

Barton, A.D. & Casey, K.S. (2006). Climatological context for large-scale coral bleaching. *Coral Reefs*. 24: 536-554.

Buddo, D St. A., R. Steele, MK Webber 2012. Public health risks posed by the invasive Indo-Pacific green mussel, *Perna viridis* (Linnaeus, 1758) in Kingston Harbour, Jamaica. Bioinvasions Record 1:3 171-178.

Buddo, D. St. A., K.A. Aiken. 2012. Occurrence of the Invasive Asian Tiger Shrimp, *Penaeus monodon* in Jamaica. Biological Invasions. *In Prep*

Buddo, D. St. A. 2008. The Biology and Ecology of the Invasive Indo-Pacific Green Mussel, *Perna viridis* in Kingston Harbour, Jamaica. Ph.D. Thesis. University of the West Indies, Mona; 309pp

Buddo, D. St. A., R. D. Steele, and E. R. D'Oyen. 2003. Distribution of the invasive Indo-Pacific Green Mussel, *Perna viridis*, in Kingston Harbour, Jamaica. Bulletin of Marine Science: Vol. 73, No. 2, pp. 433-441.

C-FISH. Portland Bight. <http://c-fish.org/where-we-work/portland-bight/>.

Creary, M. 2003. Spatial distribution of epibenthic bryozoans found on the roots of *Rhizophora mangle*, Kingston Harbour, Jamaica, W.I. Mar. Bull. Sci. 73(2): 477-90.

Den Hartog, C., (1970). The Seagrasses of the World. North Holland Publishing Co. Amsterdam. 275 pp.

Dennison, W.C., (1987). Effects of light on seagrass photosynthesis, growth and depth distribution. *Aquat. Bot*. 27:15 – 26.

Dunbar F.N. and M.K. Webber. 2003. Zooplankton distribution in the eutophic Kingston Harbour, Jamaica. Bull. Mar. Sci. 73(2): 343-59.

Environmental Management Unit, UWI, (2001). Socio-economic valuation study of the Ocho Rios Marine Park.

Francis, P.A. 2011. A resurvey of the zooplankton associated with key sections of the Kingston

Harbour, Jamaica. MSc Thesis, University of the Indies, Mona 30p.

Gayle P.M.H., Peter Wilson-Kelly and Sean Green. 2005. Transplantation of benthic species to mitigate impacts of coastal development in Jamaica. Rev. Biol. Trop. (Int. J. Trop. Biol. 53 (1): 105-15.

Goodbody, I. 1968. The Impact od development on Kingston Harbour. Jam. Arch. 2:442-47.

Goodbody, I. 2003. Kingston Harbour, Jamaica- An Overview. Bull. Mar. Sci. 73(2):249-55.

Goodbody, I. 2003. The ascidian fauna of Port Royal, Jamaica I. Harbour and mangrove dwelling species. Bull. Mar. Sci. 73(2): 457-76.

Grahame, J. 1979. A new species of Exumella fosshagen (Copepoda, Calanoida), from Kingston Harbour, Jamaica. Crustaceana 36(1):15-22.

Green, S.O. And D.F. Webber. 2003. The effects of varying levels of eutorphication on phytoplankton and seagrass (*Thalassia testudinum*) populations of the southeast coast of Jamaica. Mar. Bull. Sci. 73(2): 443-56.

Gyory, J., Mariano, A.J., & Ryan, E.H. "The Caribbean Current." Ocean Surface Currents. < http://oceancurrents.rsmas.miami.edu/caribbean/caribbean.html>.

Harvey, G. C. McN. 1986. Aspects of the biology and artisanal fishery of three Caribbean Clupeids (Pisces: Clupeidae) in Jamaican waters. Ph.D. Thesis, University of the West Indies, Jamaica. xxiv, 522 p.

Harvey, Guy C.M.c.N.; Goodbody, Ivan; Aiken, Karl A. 2003. Theartisanl thread herring fishery of Kingston Harbour: A review. Bull. Mar. Sci. 73(2): 421–432.

Hopcroft, R.R. and J.C.Roff. 1998. Production of tropical larvaceans in Kingston Harbour, Jamaica: are we ignoring an important secondary producer? Journal of Plankton Research 20(3) 557-569.

JPAT. Portland Bight Protected Area. <http://www.jpatjm.com/virtour/portland/portlandbight.html>

Leitcher, J.L., Helumth, B., & Fischer, A.M. (2006). Variation beneath the surface: Quantifying complex thermal environments on coral reefs in the Caribbean, Bahamas and Florida. *J. of Mar. Research*. 64: 563–588.

Linton, D. M. and G.F. Warner. 2003. Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. Ocean & Coastal Management 46:261–276.

Lynn D.H. and G.L. Gilron. 1993. Strombidiid ciliates from coastal waters near Kingston Harbour, Jamaica (Ciliophora, Oligotrichia, Strombidiidae). Journal of the Marine

Biological Association of the United Kingdom 73: 47-65.

Manning, J.R. 2006. Phytoplankton as indicators of water quality in mangrove lagoons (southeast coast, Jamaica). Mphil Thesis, University of the West Indies, Mona. Pp. 151-6.

Mason, M. The palisadoes-port royal protected area (PPRPA). <http://www.nepa.gov.jm/Water_ Quality_Monitoring/The_Palisadoes_Port_Royal_Protected_Area.pdf>.

McDonald, K.O., D.F. Webber, M.K. Webber. 2003. Mangrove forest structure under varying environmental conditions. Mar. Bull. Sci. 73(2): 491-505.

Meggs, L.G.C., R.D. STEELE and K.A. AIKEN. 2011. Settlement Patterns of Spiny Lobster (Panulirus argus) Postlarvae on Collectors in Jamaican Waters and Culture of Juveniles. Proceedings of the 63rd Gulf and Caribbean Fisheries Institute 63: 472-81.

Mendes, J.M. 1992. A description of the fringing reef of Lime Cay, (Port Royal Cays, Jamaica), with long term monitoring. M.Phil. Thesis, University of the West Indies, Mona.

Moses, S.M. 2006. The effects of artificial corals on small reef fish populations in the Port Royal Cays, southeast Jamaica. Mphil Thesis, University of the West Indies, Mona. Pp. 170-200.

NEPA, (1996). National policy for the conservation of seagrasses.

NEPA, (1997a). Coral reef protection and preservation policy and regulation.

NEPA, (1997b). Draft policy & regulation for mangrove & coastal wetlands protection.

NEPA, (2000). Beach policy. 16-17, 28-29pp.

NEPA, (2003). National strategy and action plan on biological diversity in Jamaica.

NEPA, (2007). Coral reefs of Jamaica: Status and trends 2007.

OBFS, (2011). Oracabessa bay fish sanctuary management plan.

Persad G., R.R. Hopcroft, M.K. Webber and J. C. Roff. 2003. Abundance, biomass and production of cntenophores and medusae off Kingston, Jamaica. Bull. Mar. Sci. 73(2): 379-96.

PIOJ, (2012). The State of the Jamaican Climate. 3.5-3.13pp.

RAMSAR, (1997). Information sheet on RAMSAR wetlands: Black River Lower Morass.

Ranston, E.R. 1998. The Phytoplankton community and water quality of a highly eutrophic estuarine bay, Hunts Bay, Kingston Harbour, Jamaica. M.S. Thesis, University of the West Indies, Mona. 249p.

Ranston, E.R. And D.F. Webber. 2003. Phytoplankton distribution in a highly eutrophic estuarine bay, Hunts Bay, Kingston Harbour, Jamaica. Bull. Mar. Sci. 73(2): 307-24.

Russell, R. And J.C. Roff. 1998. Production of tropical larvaceans in Kingston Harbour, Jamaica: are we ignoring an important secondary producer? *Journal of Plankton Research* Vol.20 no3 pp.557-569.

Sea Around Us Project. EEZ Waters of Jamaica. <http://www.seaaroundus.org/eez/388.aspx>.

Seacology Island Projects, (2010). Galleon Fish Sanctuary Project. <http://www.seacology.org/projects/individualprojects/JAMAICA_galleon2012.htm>.

Short, F.T., (1987). Effect of sediment nutrients on seagrasses: Literature review and mesocosm experiment. Aquat. Bot. 27: 41 – 57.

Simmonds, R.A. 1997. The phytoplankton community ans water quality of a eutrophic embayment: Kingston Harbour, Jamaica. M.Phil Thesis, University of the West Indies, Mona. Pp. 188-95.

The Nature Conservancy. The Pedro Bank Preserve. <http://www.nature.org/ourinitiatives/regions/Caribbean/Jamaica/placesweprotect/the-pedro-bank.xml>.

Turner, J.T. 2004. The Importance of Small Planktonic Copepods and Their Roles in Pelagic Marine Food Webs. Zoological Studies 43(2): 255-266.

Viera, A., Black, K.L., Woodley, J.D., & Sary, Z. (1995). The Discovery Bay Fishing Reserve: Its development, management, monitoring plans, and current status. Proceedings of the Forty-Eight Annual Gulf and Caribbean Fisheries Institute. 241-255pp.

Webber M.K., D.F. Webber, E.R. Ranston, F.N. Dunbar and R.A. Simmonds. 2003. Changes in water quality and phytoplankton of Kingston Harbour, Jamaica, after 20 years of continued eutrophication. Mar. Bull.Sci. 73(2): 361-78.

Webber, D. 1990. Phytoplankton Populations Of The Coastal Zone And Nearshore Waters Of Helshire: St. Catherine, Jamaica. PhD Thesis, University of the West Indies.

Webber, M.K. 2009. Biodiversity of Jamaican mangrove areas. Mangrove Biotype v: The Zooplankton. Vol:6.

Webber, D.F. & Roff, J.C. (1996). Influence of Kingston harbor on the phytoplankton community of the nearshore Hellshire coast, southeast Jamaica. *Bull. of Mar. Sci.* 59: 245-258.

Webber, D.F., Webber, M.K, & Williams, D.D. (2003). The relative importance of meteorological events, tidal activity and bathymetry to circulation and mixing in Kingston Harbour, Jamaica. *Bull. of Mar. Sci.* 73: 273-289.

Appendix I

Species found in Kingston Harbour

KINGDOM:BACTERIAE
- PHYLUM CYANOBACTERIA
  - Class Cyanobacteria incertae sedis
    - *Pseudoanabaena limnetica*
  - Class Cyanophyceae
    - Order Chroococcales
      - Family Chroococcaceae
        - *Chroococcus dispersus*
        - *Chroococcus dispersus var. minor*
        - *Chroococcus limneticus*
        - *Chroococcus minor*
        - *Chroococcus minutus*
        - *Chroococcus turgidis*
        - *Chroococcus sp.*
      - Family Microcystaceae
        - *Gloeocapsa aerunginosa*
        - *Gloecapsa sp.*
        - *Microcystis incerta*
      - Family Cyanobacteriaceae
        - *Gloetheca sp.*
      - Family Gomphosphaeriaceae
        - *Gomphosphaeria aponina var. gelatinosa*
        - *Gomphosphaeria lacustris var. compacta*
    - Order Oscillatoria
      - *Lyngbya sp.*
      - *Lyngbya contorta*
    - Order Oscillatoriales
      - *Phormidium sp.*
      - Family Phormidiaceae
        - *Microcoleus sp.*
        - *Trichodesmium thiebautii*
        - *Trichodesmium spp.*
      - Family Oscillatoriaceae
        - *Oscillatoria amphibia*
        - *Oscillatoria angustussima*
        - *Oscilatoria articulata*
        - *Oscillatoria chalybea*
        - *Oscillatoria lacustris*
        - *Oscillatoria limnetica*
        - *Oscillatoria limosa*

Oscillatoria nigra
Oscillatoria nigra-viridis
Oscillatoria princeps
Oscillatoria tenuis
Oscillatoria spp.
Order Pseudoanabaenales
Family Pseudoanabaenaceae
Spirulina laxa
Spirulina major
Spirulina nordstedtii
Spirulina princeps
Spirulina subsala
Spirulina sp.
Order Nostocales
Family Nostocaceae
Anabaena spp.
Anabaenopsis circularis
Raphidiopsis curvata
Family Stigonemataceae
Stigonema sp.
Order Synechoccales
Family Merismopediaceae
Merismopedia glauca
Merismopedia punctata
Merismopedia tenuissima
Merismopedia sp.

KINGDOM PLANTAE
PHYLUM RHODOPHYTA
Class Florideophyceae
Family Acrochaetiaceae
Rhodochorton sp.

PHYLUM CHLOROPHYTA
Class Bryopsidphyceae
Order Bryopsidales
Family Bryopsidaceae
Bryopsis pennata
Family Halimedaceae
Halimeda sp.
Class Trebouxiophyceae
Order Chlorealles
Family Chlorellaceae
Actinastrum gracilimum

Actinastrum hantschii
Class Chlorophyceae
Order Sphaeropleales
Family Selenastraceae
Ankistrodesmus falcatus var. mirabilis
Ankistrodesmus sp.
Kirchneriella contorta
Kirchneriella lunaris
Kirchneriella obesa
Kirchneriella obesa var. major
Selenastrum capricornutum
Selenastrum minutum
Selenastrum westii
Family Scenedesmaceae
Coelastrum reticulatum
Scenedesmus acuminatus
Scenedesmus armatus var. bicaudatus
Scenedesmus bernardii
Scenedesmus bijuga
Scenedesmus bijuga va. flexuosus
Scenedesmus dimorphus
Scenedesmus longus
Scenedesmus opoliensis
Scenedesmus quadricauda
Scenedesmus quadricauda var. quadrispina
Scenedesmus quadrcauda var. westii
Scenedesmus sp.
Family Neochloridaceae
Golenkinia paucispina
Golenkinia sp.
Planktosphaeria gelatinosa
Family Hydrodictyaceae
Pediastrum boryanum
Pediastrum duplex var. tertaodon
Pediastrum sp. A
Pediastrum sp. B
Pediastrum sp. C
Order Tetrasporales
Family Palmellopsidaceae
Asterococcus sp.
Order Volvocales
Family Chlamydomonadaceae
Carteria cordiformis
Carteria sp.
Chlamydomonas angulosa
Chlamydomonas dinobryoni

Chlamydomonas epiphytica
Chlamydomonas globosa
Chlamydomonas gloegama
Chlamydomonas spp.
Family Dunaliellaceae
Dunaliella salina
Order Oedogoniales
Family Oedogoniaceae
Oedogonium sp.
PHYLUM MAGNOLIOPHYTA
Class Bryopsidphyceae
Order Bryopsidales
Family Caulerpaceae
Caulerpa sp.
PHYLUM RHODOPHYTA
Class Florideophyceae
Order Gracilariales
Family Gracilariaceae
Gracillaria sp.

PHYLUM SPERMATOPHYTA
Class Liliopsida
Order Hydrocharitales
Family Hydrocharitaceae
Thalassia testudinum
Order Potamogetonales
Family Cymodoceaceae
Syringodium sp.
Class Magnoliopsida
Order Myrtales
Family Combretaceae
Conocarpus erectus
Laguncularia racemosa
Class Phaeophyceae
Order Dictyotales
Family Dictyotaceae
Dictyota sp.
Class Ulvophycaceae
Order Cladophorales
Family Cladophoraceae
Chaetomorpha linum
Stenocereus hystrix

SUBKINGDOM VIRIDAEPLANTAE
PHYLUM CHAROPHYTA
Class Charophyceae

Order Zygnematales

Family Desmidiaceae

Cosmarium connatum
Cosmarium erosa
Cosmarium impressulum
Cosmarium punctulatum var. subpunctulatum
Cosmarium quinarium
Cosmarium rectagularis
Cosmarium subreniforme
Cosmarium tinctum
Cosmarium sp. A
Cosmarium sp. B
Cosmarium sp. C
Cosmarium sp. D
Cosmarium sp. E
Cosmarium sp. F
Cosmarium sp. G
Cosmarium sp. H
Cosmarium sp. I
Cosmarium spp.
Euastrum sp. A
Euastrum sp. B
Euastrum sp. C
Euastrum sp. D
Euastrum sp. E
Micrasterias sp.
Phymatodocis nordstedtiana
Pleurotaenium sp.
Tetmemorus laevis
Tetmemorus smithii

Family Closteriaceae

Closterium sp.

Family Zygnemataceae

Spirogyra tenuissima
Spirogyra sp.

PHYLUM CHLOROPHYTA

Class Chlorophyceae

Order Chlamydomonadales

Family Haematococcaceae

Chlorogonium euchlorum

Order Sphaeropleales

Family Ankistrodesmaceae

Kirchneriella contorta

Order Chlorococcales

Family Chlorococcaceae
Chlorococcum sp.
Family Treubariaceae
Echinosphaerella limnetica
Treubaria sp.
Family Radiococcaceae
Radiococcus sp.
Family Sphaeropleaceae
Radiofilum flavescens
Order Tetrasporales
Family Palmellopsidaceae
Asterococcus sp.
Order Cladophorales
Family Cladophoraceae
Cladophora sp.
Class Trebouxiophyceae
Order Trebouxiophyceae ordo incertae sedis
Family Trebouxiophyceae incertae sedis
Crucigenia sp.

KINGDOM CHROMALVEOLATA
PHYLUM DINOFLAGELLATA
Class Dinophyceae
Order Noctilucales
Family Ceratiaceae
Ceratium buceros
Ceratium contortum
Ceratium contortum var. contortum
Ceratium contortum var. karstenii
Ceratium declinatum
Ceratium furca
Ceratium furca var. eugrammum
Ceratium fusus
Ceratium hircus
Ceratuum lineatum
Ceratium longirostrum
Ceratium macroceros
Ceratium symmetricum
Ceratium teres
Ceratium trichoceros
Ceratium trichoceros
Ceratium tripos var. atlanticum
Ceratium furca var. berghi

PHYLUM HETEROKONTOPHYTA

Class Bacillariophyceae

Pennate diatoms spps.

Order Bacilarialles

Family Bacillariaceae

Cylindrotheca closterium
Nitzchia accuminata
Nitzschia angularis
Nitzschia angusta
Nitzschia bilobata
Nitzschia closterium
Nitzschia constricta
Nitzschia delicatissima
Nitzschia dubia
Nitzschia dubiformis
Nitzschia habirshawii
Nitzschia littoralis
Nitzschia longissima
Nitzschia obtusa
Nitzschia obtusa var. scalpelliformis
Nitzschia pacifica
Nitzschia pandurifirmis
Nitzschia paradoxa
Nitzschia pungens
Nitzschia seriata
Nitzschia sigma
Nitzschia sigma var. intercedens
Nitzschia sigma var. rigida
Nitzschia ventricosa
Nitzschia vermicularis
Nitzschia visurgis
Nitzschia sp. A
Nitzschia sp. B
Nitzschia sp. C
Nitzschia sp. D
Nitzschia sp. E
Nitzschia sp. F
Pseudo-nitzschia delicatissima
Pseudo-nitzschia sp.

Order Anaulales

Family Anaulaceae

Eunotogramma sp.

Order Corethrales

Family Corethraceae

Corethron hystrix

Order Coscinodiscales

Family Coscinodiscaceae

Coscinodiscus centralis
Coscinodiscus granii
Coscinodiscus kutzingii
Coscinodiscus lineatus
Coscinodiscus marginatus
Coscinodiscus radiatus
Coscinodiscus sp. A
Coscinodiscus sp. B
Coscinodiscus sp. C
Coscinodiscus sp. D
Coscinodiscus sp. F
Coscinodiscus wailesii
Coscinodiscus sp.

Order Hemiaulales
Family Hemiaulaceae
Hemiaulus hauckii
Hemiaulus membranaceus
Hemiaulus sinensis
Hemiaulus sp.

Order Melosirales
Family Stephanopyxidaceae
Stephanopyxis sp.

Order Thalassiosirales
Family Lauderiaceae
Lauderia sp.
Family Thalassiosiraceae
Planktoniella sp.
Thalassiosira sp.

Order Thalassionematales
Family Thalassianemataceae
Thalassionema nitzschioides
Thalassionema sp.
Thalassiothrix frauenfeldii
Thalassiothrix longissima
Thalassiothrix nitzschoides

Order Leptocylindrales
Family Leptocylindraceae
Leptocylindrus danicus
Leptocylindrus sp.

Order Licmophorales
Family Licmophoraceae
Licmophora gracilis var. gracilis
Licmophora abbreviata
Licmophora ehrenbergeii
Licmophora flabellata

Licmophora lyngbyei
Licmophora spp.
Order Lithodesmiales
Family Lithodesmiaceae
Lithodsmium sp.
Tropidoneis elegans
Tropidoneis maxima
Tropidoneis vanheurckii
Tropidoneis vitrea
Tropidoneis sp.
Order Mastogloiales
Family Mastogloiaceae
Mastoloia sp.
Order Melosirales
Family Melosiraceae
Melosira spp.
Order Paraliales
Family Paraliaceae
Paralia sulcata
Paralia sp.
Order Surirellales
Family Surirellaceae
Surirella comis
Surirella fastuosa
Surirella gemma
Surirella ovalis
Surirella ovata
Surirella patella
Surirella smithii
Surirella spp.
Order Triceratiales
Family Triceratiaceae
Triceratium favus
Triceratium sp.
SubClass Bacillariophyceae incertae sedis
Perissonoe cruciata
Order Rhaponeidales
Family Rhaponeidaceae
Rhaphoneis sp.
Order Rhabdonematales
Family Rhabdonemataceae
Rhabdonema sp.

KINGDOM CHROMISTA
INFRAKINGDOM ALVEOLATA

PHYLUM HAPTOPHYTA
Class Prymnesiophyceae
Order Coccolithophorida
Family Prymnesiophyceae
Coccolithophora sp.
Class Prymnesiophyceae
Order Coccosphaerales
Family Calyptrosphaeraceae
Calyptrosphaera sp.
Order Coccolithales
Family Coccolithaceae
Coccolithus sp.

PHYLUM CRYPTOPHYTA
Class Cryptophyceae
Order Pyrenomonadales
Family Chroomonadaceae
Chroomonas norstedtii

PHYLUM MYZOZOA
INFRAPHYLUM Dinoflagellata
Class Peridinea
Order Dinophysida
Family Dinophysiaceae
Dinophysis caudata
Dinoflagellate sp.
Dinophysis acuminata
Dinophysis caudata
Dinophysis diegensis
Dinophysis fortii
Dinophysis ovum
Amphisolenia sp.
Ornithocercus thumii
Ornithocercus sp.
Oxyphysis oxytoxoides
Order Gymnodiniida
Family Gymnodiniaceae
Cochlodinium sp.
Amphinidium extensum
Amphinidium galbanum
Amphinidium gladiolus
Amphinidium lacustre
Amphinidium phaeocysticola
Amphinidium sp.
Gyrodinium adriaticum
Gyrodinium fuciforme

Gyrodinium wulfi
Amphinidium sp.
Massartia glauca
Family Polykrikaceae
Polykrikos lebourae
Polykrikos schwartzii
Family Warnowiaceae
Erythropsis sp.
Warnowia pulcharia
Warnowia sp.
Order Gonyaulacida
Family Gonyaulacaceae
Alexandrium minutum
Alexandrium extensum
Alexandrium margalefi
Alexandrium minor
Alexandrium monilatum
Alexandrium ostenfeldii
Alexandrium sp. A
Alexandrium sp. A
Alexandrium sp. B
Alexandrium sp. B
Alexandrium sp. W
Alexandrium tamarense
Gonyaulax apiculata
Gonyaulax cateneta
Gonyaulax diacantha
Gonyaulax diegensis
Gonyaulax digitale
Gonyaulax fragilis
Gonyaulax orientalis
Gonyaulax perpusilla
Gonyaulax polygramma
Gonyaulax polyhedra
Gonyaulax scippsae
Gonyaulax spinifera
Gonyaulax verior
Gonyaulax spp.
Family Goniodomataceae
Heteraulacus acuminata
Heteraulacus sphaericus
Family Ostreopsidaceae
Ostreopsis sianemsis
Order Prorocentrida
Family Prorocentraceae
Exuviaella apora

Exuviaella cassubica
Exuviaella compressa
Exuviaella marina
Exuviaella oblonga
Exuviaella ovum
Exuviaella spp.
Prorocentrum compressum
Prorocentrum gracile
Prorocentrum hentsheli
Prorocentrum lima
Prorocentrum mexicaum
Prorocentrum micans
Prorocentrum minimum
Prorocentrum obtusidens
Prorocentrum scutellum
Prorocentrum triestinum
Exuviaella
Porella globulus

Order Peridiniida
Family Dinosphaeraceae
Diplosalis lenticula
Family Oxytoxaceae
Oxytoxum belgicae
Oxytoxum gladiolus
Oxytoxum parvum
Oxytoxum sceptrum
Oxytoxum scolopax
Oxytoxum tesselatum
Oxytoxum sp. A
Oxytoxum sp. B
Oxytoxum sp.
Family Podolampadaceae
Podolampas bipes
Podolampas palmipes
Order Pyrocystida
Family Pyrocystaceae
Pyrocystis sp.

INFRAKINGDOM HETEROKONTA
PHYLUM OCHROPHYTA
Class Bacillariophyceae
Order Achnanthales
Family Achnanthaceae
Achnanthes longipes
Achnanthes exigua

Family Cocconeidaceae

Cocconeis disculus
Cocconeis sublittoralis
Cocconeis sp. 1
Cocconeis sp.

Order Bacillariales

Family Bacillariaceae

Denticula elegans f. valida
Denticula lauta
Denticula thermalis

Order Biddulphiales

Family Biddulphiaceae

Biddulphia alternans
Biddulphia aurita
Biddulphia aurita var. aurita
Biddulphia dubia
Biddulphia longicruris
Biddulphia obtusa
Biddulphia rhombus
Biddulphia vesiculosa
Biddulphia sp. A
Biddulphia sp. B
Biddulphia spp.
Isthmia nervosa
Isthmia sp.

Order Climacospheniales

Family Climacospheniaceae

Climacosphenia moniligera
Climacosphenia sp.
Climacosphera

Order Chaetocerotales

Family Chaetocerotaceae

Bacteriastrum cosmosum
Bacteriastrum delicatulum
Bacteriastrum hyalinum
Bacteriastrum sp.
Chaetoceros atlanticum
Chaetoceros atlanticum var. audax
Chaetoceros coarctatum
Chaetoceros convolutos
Chaetoceros costatus
Chaetoceros curvisetis
Chaetoceros danicus
Chaetoceros decipiens
Chaetoceros diversus
Chaetoceros glandazii

Chaetoceros lorenzianus
Chaetoceros pendulus
Chaetoceros pepusillum
Chaetoceros peruvianus
Chaetoceros pseudocrinitus
Chaetoceros radicans
Chaetoceros simplex
Chaetoceros socialis
Chaetoceros vistulae
Chaetoceros wighami
Chaetoceros sp. A
Chaetoceros sp. B
Chaetoceros sp. C
Chaetoceros sp. D
Chaetoceros sp. E

Order Coscinodiscales
Family Hemidiscaceae
Hemidiscus sp.
Palmeriana hardmanianus

Order Cymbellales
Family Cymbellaceae
Brebissonia boecki
Cymbella amphicephala
Cymbella angustata
Cymbella diluviana
Cymbella gracilis
Cymbella haukii
Cymbella inaequalis
Cymbella lunata
Cymbella minuate
Cymbella minuta var. pseudogracilis
Cymbella rupicola
Cymbella turgidula
Cymbella ventricosa
Cymbella sp. A
Cymbella sp. B
Cymbella sp. C
Cymbella sp. D
Cymbella sp. E
Cymbella sp. F
Cymbella sp. G
Cymbella sp. H

Family Gomphonemataceae
Gomphonema sp.

Family Anomoeoneidaceae
Anomoeoneis sphaerophora

Order Hemiaulales

Family Hemiaulaceae

Cerataulina bergonii
Cerataulina sp.
Climacodium sp.
Eucampia sp.

Family Bellerocheaceae

Bellerochea sp.
Streptotheca tamesis
Streptotheca thamensis

Order Naviculales

Family Amphipleuraceae

Amphiprora sp.
Amphiprora alata
Amphiprora alata var. alata
Amphiprora costata
Amphirprora ornata
Amphiprora pulchara
Amphiprora robusta
Amphiprora sp. A
Amphiprora sp. B
Amphiprora sp. C

Family Naviculaceae

Caloneis westii
Ephemera planamembraceae
Navicula arenaria
Navicula bahusiensis var.
bahusiensis
Navicula brittanica
Navicula bulneheimii
Navicula cancellata
Navicula cincta
Navicula clavata
Navicula cruciculoides
Navicula cryptocephala var. cryptocephala
Navicula cuspidata
Navicula delicatula
Navicula digito-radiata
Navicula directa
Navicula distans
Navicula elegans
Navicula ergadensis var. minor
Navicula exigua
Navicula expansa
Navicula f delicatula

Navicula finmarchica
Navicula flanatica
Navicula florinae
Navicula forcipata
Navicula gotlandica
Navicula hennedyii
Navicula inclementis
Navicula inflexa
Navicula latissima
Navicula longa
Navicula lyra
Navicula lyroides
Navicula maculosa
Navicula marina
Navicula meniscus
Navicula mutica
Navicula palpebralis
Navicula pavillardi
Navicula phyllepta
Navicula planamembranacea
Navicula plicata
Navicula quarnerensoides
Navicula rostellata
Navicula salinarum
Navicula salinicola
Navicula subsalina
Navicula subtilissima
Navicula transitrans
Navicula tripunctata
Navicula vermicularis
Navicula sp. A
Navicula sp. B
Navicula sp. C
Navicula sp. D
Navicula sp. E
Navicula sp. F
Navicula sp. G
Navicula sp. H
Navicula spp.
Trachyneis aspera
Trachyneis sp.

Family Neidiaceae

Neidium affine
Neidium dubium

Family Diploneidaceae

Diploneis crabro

Diploneis didyma
Diploneis smithii
Diploneis smithii var. smithii
Diploneis vetula
Diploneis sp. A
Diploneis spp.

Family Pleurosigmataceae

Donkinia recta
Gyrosigma attentuatum
Gyrosigma balticum
Gyrosigma hippocampus
Gyrosigma littorale
Gyrosigma prologatum
Gyrosigma prolongatum var. prolongatum
Gyrosigma scalpoides
Gyrosigma spencerii
Gyrosigma tenuiisum
Gyrosigma wansbeckiial
Gyrosigma sp.
Gyrosigma sp. A
Gyrosigma sp. B
Pleurosigma aesturii
Pleurosigma angulatum
Pleurosigma delicatulum
Pleurosigma elongatum
Pleurosigma finnmarchicum
Pleurosigma formosum
Pleurosigma intermedium
Pleurosigma itium
Pleurosigma marinum
Pleurosigma naviculaceum
Pleurosigma normanii
Pleurosigma rigidum
Pleurosigma strigosum
Pleurosigma spp.

Family Pinnulariaceae

Pinnularia ambigua
Pinnularia rectangulata
Pinnularia trevelyanna
Pinnularia spp.

Family Stauroneidaceae

Stauroneis amphioxys

Order Pennales

Family Diatomaceae

Dimerogramma minor

Order Rhopalodiales
Family Rhopalodiaceae
Epithemia sp.
Order Striatellales
Family Striatellaceae
Grammatophora angulosa
Grammatophora hamulifera
Grammatophora marina
Grammatophora oceania
Grammatophora spp.
Striatella unipunctata
Striatella sp.
Striatella sp. 1
Order Thalassiophysales
Family Catenulaceae
Amphora acutiuscula
Amphora coffeaeformis var. coffeaeformis
Amphora hyalina
Amphora marina
Amphora ovalis
Amphora ovalis var. pediculus
Amphora spp.
Amphora spectabilis
Amphora birugula
Amphora sp. A
Amphora sp. B
Amphora sp. G
Amphora sp. H
Amphora sp. W
Amphora sp. Y
Amphora sp. Z
Amphora sp. 1
Amphora sp. 2
Amphora sp. 3
Amphora sp. 4
Amphora sp. 5
Amphora sp. 6
Amphora sp. 7
Amphora sp. 8
Amphora submontana
Amphora ventricosa
Order Surirellales
Family Surirellaceae
Campylodiscus ovata
Campylodiscus sp. A

Campylodiscus sp. B
Campylodiscus sp. F
Campylodiscus sp. R
Campylodiscus sp. V
Order Asterolamprales
Family Asterolampraceae
Asterolampra sp.
Order Cocsinodiscales
Family Heliopeltaceae
Actinoptychus sp.
Order Rhizosoleniales
Family Rhizosolenaceae
Guinardia flaccida
Guinardia spp.
Rhizosolenia acuminata
Rhizosolenia alata
Rhizosolenia alata f. gracillama
Rhizosolenia alata var. indica
Rhizosolenia cal-car avis
Rhizosolenia delicatula
Rhizosolenia fragilissima
Rhizosolenia hebatata
Rhizosolenia imbricata
Rhizosolenia pungens
Rhizosolenia robusta
Rhizosolenia setigera
Rhizosolenia shrubsolei
Rhizosolenia stolterfothii
Order Thalssiosirales
Family Skeletonemaceae
Skeletonema costatum
Skeletonema subsalum
Skeletonema sp.F
Family Stephanodiscaceae
Cyclotella bodanica
Cyclotella sp. a
Cyclotella sp. b
Order Fragilariales
Family Fragilariaceae
Asterionella japonica
Asterionella spp.
Fragilaria pinata
Fragilaria sp. A
Fragilaria sp. B
Fragilaria sp. C
Fragilaria sp.

Opephora martyii
Synedra ulna var. amphirynchus
Synedra sp.

Class Chrysophyceae
Order Chromulinales
Family Dinobryaceae
Epipyxis calciforme
Epipyxis tabellariae
Family Chrysothallaceae
Phaeoplaca sp.
Order Heterogloeales
Family Heterogloeaceae
Gloeochloris sp.
Order Synurales
Family Mallomonadaceae
Synura spp.
Class Phaeophyceae
Order Dictyotales
Family Dictyotaceae
Dictyota sp.
Dictyota sp. A
Class Dictyochophyaceae
Order Dictyochales
Family Dictyochaceae
Distephanus sp.
Mesocena polymorpha

KINGDOM PROTOZOA
INFRAKINGDOM EXCAVATA
SUPERPHYLUM PANARTHROPODA
PHYLUM EUGLENOZOA
Class Euglenoidea
Order Euglenida
Family Euglenidae
Euglena gracilis
Euglena acus var. rigida
Euglena convoluta
Euglena deses
Euglena elongata
Euglena minuta
Euglena schmitzii
Euglena sp. 1
Euglena sp. A
Euglena sp. B
Euglena sp. C
Euglena sp. D

Euglena sp. F
Euglenoid spp.
Family Phacaceae
Phacus sp.
Family Euglenaceae
Trachelomonas pulcherrima
var. tenue
Trachelomonas sp.
Order Eutreptiida
Family Astasiaceae
Rhabdomonas incurvum

SUBKINGDOM PROTOZOA
Class Ebriophyceae
Order Ebriales
Family Ebriaceae
Ebria tripartita

SUBKINGDOM BICILIATA
INFRAKINGDOM ALVEOLATA
PHYLUM MYZOZOA
Class Dinophyceae
Order Gymnodinales
Family Gymnodiniaceae
Gymnodinium attentatum
Gymnodinium bioconicum
Gymnodinium bogoriense
Gymnodinium breve
Gymnodinium coerulum
Gymnodinium dogieli
Gymnodinium filum
Gymnodnium fuscum
Gymnodinium lantzschii
Gymnodinium lohmanni
Gymnodinium mikimoitoii
Gymnodinium minor
Gymnodinium opressum
Gymnodinium ovulum
Gymnodinium paulseni
Gymnodinium profundum
Gymnodinium pygmaeum
Gymnodinium rhomboides
Gymnodinium rotundatum
Gymnodinium scopulosum
Gymnodinium situla
Gymnodinium sphaericum

Gymnodinium splendens
Gymnodinium uberrimum
Gymnodinium variabile
Gymnodinium viride
Gymnodinium viridiscens
Gymnodinium voukii
Gymnodinium sp.
Gymnodinium sp. A
Gymnodinium sp. B
Gymnodinium sp. C
Gymnodinium sp. D
Gymnodinium sp. E
Gymnodinium sp. F
Gyrodinium adriaticum
Gyrodinium attentuatum
Gyrodinium aureum
Gyrodinium bioconicum
Gyrodinium capsulatum
Gyrodinium caudatum
Gyrodinium citrinum
Gyrodinium cornutum
Gyrodinium fasciola
Gyrodinium fissum
Gyrodinium fusiforme
Gyrodinium lachyryma
Gyrodinium ochraceum
Gyrodinium ovatum
Gyrodinium ovoideum
Gyrodinium paulseni
Gyrodinium pellucidum
Gyrodinium pingue
Gyrodinium scalproides
Gyrodinium spirale
Gyrodinium truncatum
Gyrodinium varians
Gyrodinium wulffii
Gyrodinium spp.
Gyrodinium sp. A
Gyrodinium sp. B
Gyrodinium sp. C
Gyrodinium sp. D
Gyrodinium sp. E
Gyrodinium sp. F
Gyrodinium sp. G
Gyrodinium sp. H
Gyrodinium sp. I

Gyrodinium sp. W

Order Peridiniida

Family Peridiniaceae

Scrippsiella trochoidea
Glenodinium foliaceum
Glenodinium lindemanni
Glenodinium quadridens
Glenodinium rotundum
Glenodinium sp.
Peridinium okamurai
Peridinium sp.

Family Protoperidiniaceae

Protoperidinium bispinium
Protoperidinium breve
Protoperidinium brevicepes
Protoperidinium cerasus
Protoperidinium claudicans
Protoperidinium coincoides
Protoperidinium conicum
Protoperidinium crassipes
Protoperidinium curtipes
Protoperidinium depressum
Protoperdinium divergens
Protoperidinium elongatum
Protoperidinium excentrum
Protoperidinium fimbriatum
Protoperidinium globulus
Protoperidinium globulus
var.
quarnerense
Protoperidinium goslaviense
Protoperidinium granii f mite
Protoperidinium
inconspicuum
Protoperidinium leonis
Protoperidinium nipponicum
Protoperidinium obesum
Protoperidinium oblongum
Protoperidinium obscurum
Protoperidinium obtusum
Protoperidinium oceanicum
Protoperidinum okamurai
Protoperidinium ovatum
Protoperidinium ovum
Protoperidinium pallidum
Protoperidinium

pedunculatum

Protoperidinium pellucidum
Protoperidinium pentagonum var.
latissimum
Protoperidinium pyriforme
Protoperidinium quadridens
Protoperidinium
quinquecorne
Protoperidinium roseum
Protoperidinium sinaicum
Protoperidinium sp. A
Protoperidinium sp. B
Protoperidinium sp. C
Protoperidinium sp. D
Protoperidinium sphaericum
Protoperidinium steini
Protoperidinium subinerme
var.
punctulatum
Protoperidinium sp.
Protoperidinium trochoideum
Protoperidinium tuba
Protoperidinium venustum

Order Gonyaulacales

Family Gonyaulacaceae

Pyrodinium bahamense
Pyrodinium bahamense var. compressa
Pyrophacus horologicum

Class Dinoflagellata

Family Phytodiniaceae

Hypnodinium sp.

Class Noctilucida

Family Protodiniferaceae

Pronoctiluca sp.

PHYLUM CILIOPHORA

Class Spirotrichea

Order Tintinnida

Family Metacylididae

Helicostomella sp.

KINGDOM FUNGI

Microspora willeana

KINGDOM ANIMALIA
PHYLUM ARTHROPODA
SUBPHYLUM CRUSTACEA
Class Branchipoda
Order Cladocera
Family Daphniidae
Daphnia sp.
Order Diplostraca
Family Podonidae
Evadne tergestina
Family Sididae
Penilia avirostris
Class Malacostraca
Order Decapoda
Family Luciferidae
Lucifer faxoni
Family Paniluridae
Panilurus argus
Family Penaeus
Penaeus schmitti
Family Portunidae
Callinectes apidus
Callinectes ornatus
Callinectes sp.
Order Mysidia
Family Mysidae
Mysidium columbae
Class Maxillopoda
Order Calanoida
Family Pseudocyclopidae
Pseudocyclops sp.
Family Pseudodiaptomidae
Pseudodiaptimus sp.
Family Acartiidae
Acartia lillejeborgi
Acartia tonsa
Acartia spinata
Family Calanidae
Undinula vulgaris
Family Centropagidae
Centropages furcatus

Family Eucalanidae
Eucalanus subcrassus
Eucalanus sp.
Family Paracalanidae
Calocalanus pavo
Paracalanus aculeatus
Paracalanus crassirostris
Paracalanus parvus
Paracalanus spp
Parvocalanus crassostris
Family Pontellidae
Calanopia americana
Labidocera sp.
Family Ridgewayiidae
Exumella tuberculata
Exumella fosshagen
Family Temoridae
Temora stylifera
Temora turbinata
Order Sessila
Family Balanidae
Balanus eburneus
Order Cyclopoida
Family Oithonidae
Oithona nana
Oithona oculata
Oithona plumifera
Oithona davisae
Oithona similis
Order Harpacticoida
Family Miraciidae
Macrosetella sp.
Family Ectinosomatidae
Microsetella norvegica
Microsetella sp.
Family Euterpinidae
Euterpina acutifrons
Family Longipediidae
Longepedia helgolandica
Family Metidae
Metis holothuriae
Family Peltidiidae
Clytemenestra sp.
Order Poecilostomatoida
Family Clausidiidae
Saphirella sp.

Family Corycaeidae

Corycaeus amazonicus

Corycaeus spp.

Farranula gracilis

Family Oncaeidae

Onacaea meditteranea

Onacaea sp.

Family Sapphirinidae

Saphirinia sp.

Copilia mirabilis

PHYLUM BRYOZOA

Class Gymnolaemata

Order Cheilostomatida

Family Bitectiporidae

Hippoporina verrilli

Family Bugulidae

Bugula neritina

Bugula stolonifera

Family Candidae

Scrupocellaria regularis

Family Epistomiidae

Synnotum aegyptiacum

Family Lepraliellidae

Celleporaria sp.

Family Membraniporidae

Membranipora arborescens

Family Schizoporellidae

Schizophorella pungens

Family Watersiporidae

Watersipora subtorquata

Order Ctenostomatida

Family Alcyonidiidae

Alcyonidium gelatinosum

Family Vesiculariidae

Amathia distans

Bowerbankia gracilis

Bowerbankia maxima

Bowerbankia sp.

Zobotryon verticillatum

Order Stolidobranchia

Family Savignyellidae

Savignyella lafonti

Family Nollelidae

Nolella stipata

Order Cyclostomida

Family Cytididae

Sundanella sibogae

PHYLUM CHORDATA

SUBPHYLUM TUNICATA

Class Appendicularia

Order Copelata

Family Fritillaridae

Appendicularia sicula
Fritillaria borealis sargassi
Fritillaria haplostoma
Fritillaria pelucida
Fritillaria sp.

Family Oikopleuridae

Oikopleura dioca
Oikopleura fusiformis
Oikopleura longicauda

Class Ascidiaceae

Order Aplousobranchia

Family Clavelinidae

Clavelina oblonga

Family Didemnidae

Didemnum candidum
Didemnun cineraceum
Didemnum conchyliatum
Didemnum duplicatum
Didemnum halimedae
Didemnum psammatodes
Diplosoma listerianum
Lissoclinum abdominale
Lissoclinum fragile
Lissoclinum glandulosum

Family Holozoidae

Distaplia bermudensis

Family Polycitoridae

Eudistoma hepaticum
Eudistoma olivaceum

Family Polyclinidae

Polyclinum constellum

Order Phlebobranchia

Family Ascidiidae

Ascidia curvata
Ascidia interrupta
Phallusia caguayensis
Phallusia nigra

Family Corellidae

- *Rhodosoma turcicum*
- Family Perophoridae
  - *Ecteinascidia minuta*
  - *Ecteinascidia styeloides*
  - *Ecteinascidia turbinata*
  - *Perophora bermudensis*
  - *Perophora carpentaria*
  - *Perophora multiclathrata*
  - *Perophora viridis*
- Order Stolidobranchia
  - Family Molgilidae
    - *Molgula occidentalis*
  - Family Pyuridae
    - *Herdmania momus*
    - *Microcosmus exasperatus*
    - *Microcosmus helleri*
    - *Pyura munita*
    - *Pyura vittata*
  - Family Styelidae
    - *Botrylloides nigrum*
    - *Polyandrocarpa tincta*
    - *Polycarpa spongiabilis*
    - *Styela canopus*
    - *Styela plicata*
    - *Symplegma brakenheilmi*
    - *Symplegma rubra*
- Class Chondrichthyes
  - Order Myliobatiformes
    - Family Urotrygonidae
      - *Urolophus jamaicensis*

SUBPHYLUM VERTEBRATA

- Class Actinopterygii
  - Order Albuliformes
    - Family Albulidae
      - *Albula vulpes*
  - Order Aulopiformes
    - Family Synodontidae
      - *Synodus saurus*
  - Order Clupeiformes
    - Family Clupeidae
      - *Cetengraulis edentulus*
      - *Harengula humeralis*
      - *Harengula jaguana*
      - *Opisthonema oglinum*

Sardinella aurita
Sardinella braziliensis
Sardinella sp.

Order Mugiliformes
Family Mugilidae
Mugil curema

Order Perciformes
Family Acanthuridae
Acanthurus bahianus
Acanthurus chirurgus
Acanthurus coeruleus

Family Carangidae
Caranx ruber

Family Chaetodontidae
Chaetodon capistratus

Family Haemulidae
Haemulon bonariense
Haemulon aurolineatum
Haemulon carbonarium
Haemulon flavolineatum
Haemulon sciurus

Family Grammatidae
Gramma loreto

Family Labridae
Halichoeres bivittatus
Halichoeres garnoti
Halichoeres poeyi
Thalassoma bifasciatum

Family Lutjanidae
Lutjanus analis
Lutjanus apodus
Lutjanus griseus
Lutjanus synagris
Lutjanus sp.
Ocyurus chrysurus

Family Scaridae
Sparisoma chrysopterum
Sparisoma atomarium
Sparisoma aurofrenatum
Sparisoma croicensis
Sparisoma rubrpinne
Sparisoma viride
Scarus coeruleus
Scarus criocensis
Scarus taeniopterus
Scarus vetula

Family Sciaenidae
Odontoscion dentex
Umbrina coroides
Family Serranidae
Epinephelus itajara
Epinephelus cruentatus
Serranus tabacarius
Rypticus saponaceus
Rypticus maculatus
Hypoplectrus indigo
Hypoplectrus nigricans
Hypoplectrus puella
Family Gerridae
Gerres cinereus
Eucinostomus gula
Family Pomacentridae
Abudefduf saxatilis
Microspathadon chrysurus
Stegastes fuscus
Stegastes leucostictus
Stegastes partitus
Stegastes planiforns
Family Pomacanthidae
Pomacanthus arcuatus
Pomacanthus paru
Family Mullidae
Pseudopeneus maculatus
Order Tetraodontiformes
Famiy Diodontidae
Chilomycterus antillarum
Diodon holacanthus
Diodon hystrix
Family Monacanthidae
Cantherinus pullus
Monacanthus ciliatus
Family Tetraodontidae
Sphoeroides testudineus
Canthigaster rostrata
Order Scorpaeniformes
Family Scorpaenidae
Scorpaena plumieri
Family Sparidae
Archosargus rhomboidalis
Order Beryciformes
Family Holocentridae
Holocentrus ascensionis

Holocentrus rufus
Order Syngnathiformes
Family Syngnathidae
Hippocampus erectus
Family Aulostomidae
Aulostomus maculatus
Order Pleuronectiformes
Family Bothidae
Bothus ocellatus
Class Aves
Order Pelecaniformes
Family Pelecanidae
Pelecanus occidentalis

PHYLUM CNIDARIA
Class Anthozoa
Order Scleractinia
Family Acroporidae
Acropora cervicornis
Acropora palmata
Acropora prolifera
Acropora sp.
Family Agaricidae
Agaricia agaracites
Agaricia fragilis
Agaricia grahamae
Agaricia tenuifola
Agaricia undata
Helioseris cucullata
Family Astrocoeniidae
Stephanocoenia michelinii
Family Caryophyllidae
Cladocora arbuscula
Family Faviidae
Colpophyllia breviserialis
Colpophyliia natans
Diploria clivosa
Diploria labrynthiformes
Diploria strigosa
Diploria sp.
Favia fragum
Montastrea annularis
Montastrea cavernosa
Montastrea sp.
Solenastrea bournoni
Solenastrea hyades

Family Meandrinidae
Dendrogyra cylindrus
Diochocoenia stellaris
Diochocoenia stokesi
Eusimilia fastigiata
Meandrina meandrites
Family Mussidae
Isophyllastrea rigida
Isophyllia sinuosa
Mussa angulosa
Mycetophyllia aliciae
Mycetophyllia daniana
Mycetophyllia ferox
Mycetophyllia lamarckiana
Mycetophyllia reesi
Scolymia cubensis
Scolymia lacera
Family Oculinidae
Oculina diffusa
Family Pocilloporidae
Madracis decactis
Madracis mirabilis
Family Poritidae
Porites asteroides
Porites branneri
Porites divaricata
Porites porites
Family Siderastreidae
Siderastrea radians
Siderastrea siderea
Siderastrea sp.
Class Cubozoa
Order Carybdeida
Family Carybdeidae
Carybdea xaymacana
Class Scyphozoa
Order Rhizostomeae
Family Cassiopeidae
Cassiopeia xamachana
Cassiopeia sp.
Class Hydrozoa
Order Anthoathecata
Family Protiaridae
Protiara sp.
Family Corynidae
Sarsia sp.

Family Corymorphidae
Steenstrupia nutans
Family Cladonematidae
Cladonema sp.
Family Pandeidae
Stomatoca sp.
Order Anthomedusae
Family Euphysidae
Euphysa sp.
Order Leptothecata
Family Aequoreidae
Aequorea floridana
Family Campanulariidae
Clytia sp.
Family Eirenidae
Eutima gracilis
Family Lovenellidae
Lovenella sp.
Family Campanulariidae
Obelia sp.
Phialidium sp.
Order Siphonophora
Family Abylidae
Abylopsis sp.
Family Agalmatidae
Aglama sp.
Family Diphyidae
Eudoxides sp.
Lensia sp.
Muggiaea sp.
Family Physallidae
Physalia physalis
Order Trachymedusae
Family Rhopalonematidae
Aglantha sp.
Aglaura hemistoma
Family Geryonidae
Liriope tetraphyllia
Liriope spp.

Order Narcomedusae
Family Solmarisidae
Solmaris sp.
Order Semaeostomeae
Family Pelagiidae
Chrysaora/ Dactylometra sp.

Family Linuchidae
Nausithoe sp.
Family Cyaneidae
Cyanea sp.
Family Ulmaridae
Aurelia aurita

PHYLUM CTENOPHORA
Class Tentaculata
Order Beroida
Family Bolinopsidae
Beroe ovata
Mnemiopsis mccradyi
Bolinopsis vitrea
Family Ocryopsidae
Ocryopsis crystallina

PHYLUM ECHINODERMATA
Class Asteroidea
Order Valvatida
Family Oreasteridae
Oreaster reticulatus
Order Paxillosida
Family Luidiidae
Luida clathrata
Class Echinoidea
Order Camarodonta
Family Toxopneustidae
Lytechinus variegatus
Tripneustes sp.
Order Diadematoida
Family Diadematidae
Diadema sp.
Class Holothuroidea
Order Aspidochirotida
Family Holothuriidae
Actinopyga agassizi
PHYLUM MOLLUSCA
Class Bivalvia
Order Arcoida
Family Arcidae
Arca imbricata
Order Ostreoidea
Family Ostreidae
Crassostrea rhizophorae

Ostrea edulis
Order Pterioida
Family Isognomonidae
Isognomon alatus
Order Mytiloida
Family Mytilidae
Perna ciridis
Class Gastropoda
Order Anaspidea
Family Aplysiidae
Aplysia dactylomela
Order Neogastropoda
Family Fasciolariidae
Fasciolaria tulipa
Family Muricidae
Murex sp.
Nucella lapillus
PHYLUM CHAETOGNATHA
Class Saggittoidea
Order Aphragmophora
Family Krohnittidae
Krohnitta subtillis
Family Sagittidae
Sagitta enflata
Sagitta hispida
Sagitta minima
PHYLUM CILIOPHORA
Class Spriotrichia
Order Oligotrichida
Family Strombidiidae
Cyrtostrombidium longisomum
Cyrtostrombidium wailesi
Strombidium bilobum
Strombidium dalum
Strombidium epidemum
Strombidium eurystomum
Strombidium inclinatum
Strombidium ioanum
Strombidium maedai
Strombidium onstrictum
Strombidium pollostomum
Strombidium sphaericum
Strombidium wulffi
Family Totoniidae
Laboea strobila
Totonia simplicidens