Nursery Grounds for Fishable Species in Kingston Harbour, Jamaica: Do They Still Exist?

KARL A. AIKEN, A. RACHEL PAL, and GISELLE-ANN PERRY
Department of Life Sciences, University of the West Indies,
Mona Campus, Kingston, Jamaica

ABSTRACT

The Port Royal red mangrove-seagrass complex in a large modified coastal bay known as Kingston harbour, Jamaica was sampled over a 13 month period over 2007 and 2008. The mangrove complex covers >100 ha and has been used for hurricane shelter for smaller vessels and for fishing for many years. Sampling at six stations with a small otter trawl yielded 42 fish and invertebrate species (66% fish). Dominant finfishes were *Archosargus rhomboidalis* (sea bream) 76%, *Diodon holacanthus* (balloonfish) 5%, and *Eucinostomus gula* (silver jenny) 4%. A high percentage of fishes taken were juveniles, and one elasmobranch species (*Urolophus jamaicensis*) was captured. Fishes from the benthic herbivore and benthic carnivore feeding guilds dominated catches. All of the six stations sampled functioned as nurseries for all of the 21 fish species identified, based on their small (juvenile) size distribution and repeated presence over the two year duration of the study. Slightly higher species diversity was found at the two stations nearest the harbor mouth. Notably, all six stations also functioned as refugia for invertebrates such as crabs, and urchins, suggesting that they are important in sustaining the stability and health of the food chains in the harbor near Port Royal at the very least, and possibly for the entire harbor. Two relatively rare indicator fish species, the lined seahorse (*Hippocampus erectus*), and the Goliath grouper, (*Epinephelus itajara)*, were found during the study. These could be used as "poster" species for the conservation of these areas. The Port Royal mangroves with their adjacent seagrass beds should be protected from development.

KEY WORDS: Mangroves, seagrass beds, nursery areas, fishes, conservation, Jamaica

Areas Criadas Marinas en el Puerto de Kingston- ? Existe Ahora?

El el complejo rojo de Puerto Real de manglar-seagrass en una bahía costera, modificada y grande conocida como puerto de Kingston, Jamaica fue probada sobre un 13 período de mes más de 2007 y 2008. El complejo de manglar cubre >100 ah y ha sido utilizado para el refugio de huracán para buques más pequeños y para pescar durante muchos años. El muestreo en 6 estaciones con un pequeño rastreo de la nutria rindió 39 especie. La diversidad de la especie fue sólo tercera parte de que encontrado en Old Harbour (la Bahía Vieja del Puerto), la bahía más grande de Jamaica que 20 km al oeste del Puerto Real por Aiken *et al*. (2001). Finfishes dominante fue *Archosargus rhomboidalis* (besugo), *Holacanthus diodon* (balloonfish), y *Eucinostomus gula* (silver jenny). Un porcentaje alto de peces tomados fue jovenes y sólo una especie de elasmobranch fue capturada. Solamente una especie marina comercialmente importante del camarón (Penaeus notialis), camarón rosa, fue tomado. Los peces del herbívoro de benthic y carnívoro de benthic que alimentan gremios los cogidos dominados. La evaluación general fue que los complejos de cama de manglar-seagrass en el estudio funcionado como áreas criadas marinas para la mayor parte de la especie completa. Las partes del complejo de manglar fueron protegidas como un sitio de RAMSAR y son un Area Protegida bajo el Acto Natural de la Conservación de Recursos de Jamaica. Cuando tan, los resultados de esas áreas estudiadas, indicaron que ellos fueron dignos de gestión continuada protegió como áreas aunque hay contaminacion.

PALABRAS CLAVES: Manglares, areas criadas marinas, peces, conservacion, Jamaica

Les Secteurs de Garderie dans le Port de Kingston, Jamaique—Existent-ils Toujours?

Le complexe de manglier-seagrass rouge Port Royal dans une grande baie côtière modifiée connue comme port de Kingston, Jamaïque a été essayée sur une période de 13 mois plus de 2007 et 2008. Le complexe de manglier couvre >100 ha et a été utilisé pour l'abri d'ouragan pour les plus petits vaisseaux et pour pêcher pour beaucoup d'ans. Essayer à 6 stations avec un petit chalut de loutre a produit 39 espèce. La diversité d'espèce était seulement un tiers de que trouvé dans la Vieille Baie de Port, la plus grande baie de Jamaïque 20 ouest de km de Port Royal par Aiken *et al*. (2001). Finfishes dominant était *Archosargus rhomboidalis* (la brème de mer), *Diodon holacanthus* (balloonfish), et *Eucinostomus gula* (jenny argent). Un haut pourcentage de poissons pris était des juvéniles et seulement une espèce d'elasmobranch a été capturée. Une espèce de crevette marine commercialement importante (Penaeus notialis, la crevette rose) a été pris. Les poissons de l'herbivore de benthic et du carnivore de benthic nourrissant des associations les prises dominées. L'évaluation générale était que les complexes de lit de manglier-seagrass dans l'étude fonctionnée comme secteurs de garderie pour la plupart de l'espèce recueillie. Les parties du complexe de manglier ont été protégées comme un site de RAMSAR et c'est un Secteur Protégé sous l'Acte de Conservation de Ressources Naturel de Jamaïque. Comme tel, les résultats de ces secteurs étudiés, a indiqué qu'ils étaient dignes de direction continuée comme les secteurs protégés.

MOTS CLÉS: Mangliers, secteurs de garderie, poissons, conservation

INTRODUCTION

Tropical bays, lagoons and estuarine areas which have mangroves and seagrass beds can possess high numbers of fishes from freshwater, as well as marine habitats (Parrish 1989, Robertson and Blaber 1992, Nagelkerken 2000). Further, these habitats appear to function as nursery areas for a variety of coral reef (and other) species, and various studies have demonstrated numbers of juveniles of coral reef fishes (Austin 1971, Weinstein and Heck 1979, Baelde 1990, Louis *et al.* 1992, Sedberry and Carter 1993, Nagelkerken 2000, Aiken *et al*. 2003).

Kingston Harbor is a large natural bay, almost surrounded by land, on the north by Kingston the capital city, with light industry, business places, and residential areas, all producing effluents, some highly polluting. On the west there is a series of large residential housing schemes with at least 10,000 houses. The Palisadoes tombolo forms the southern boundary to the harbor and has on its west portion, relatively large tracts of mangroves (See Figure 2). This narrow peninsula forms a natural breakwater separating the harbour from the Caribbean Sea to the south. Kingston Harbour in earlier times, according to Goodbody (2003) the harbour was surrounded by mangrove forest, but only small remnants remain in 2008. He mentioned that the most significant portion of mangrove forested coastline is on the southern part of the harbour just east of Port Royal (Figure 1). Alleng (1990) described the topography and general ecology of this forest, while details of the waterways and passages are provided by Goodbody (2003). Larger mangrove areas exist in West Harbour, Portland Bight (Aiken *et al*. 2003) and small patches can be found around many small bays around the entire coast. Their status is largely unknown but is thought to be threatened due to housing and other coastal development.

Figure 1. Map of Jamaica showing location of Kingston Harbour, near Kingston, at right centre (image from beachbumparadise.com).

A large stand of mangrove forest could be found on the western shore of Hunt's Bay until around 1965, at which time much of this was destroyed during construction of a causeway and of the western townships called Portmore and Independence City. Also contributing to further mangrove loss, were the construction of the Royal Jamaica Yacht Club and the Caribbean Maritime Institute on the southern side of the harbour. Goodbody (2003) opined that all of these mangrove areas would have significantly contributed to the natural maintenance of nutrient balance and oxidative breakdown of organic materials in the harbour, and further, that their loss would have likely contributed to the slow environmental degradation in the harbour.

Kingston harbour receives freshwater inflow from at least three small rives and from a large storm water drainage system serving Kingston. Importantly however, the industrial, residential, storm and sewerage drainage systems surrounding much of the northern boundary provides sources of solid waste, nutrients, heavy metals, and other pollutants, leading, as Goodbody (2003) suggests, to eutrophication and degradation in the water column of the harbour. Much information of this aspect is found in the special publication edited by Webber and Webber (2003). All of these data strongly indicate that the harbour is under a lot of environmental stress from pollution.

Mangrove oysters, penaeid shrimp, and finfish were once abundant in the greater Kingston Harbourea but this gradually changed as industrialization and housing expanded. The eastern Harbour became abiotic (Goodbody 2003), and this affected the limited shrimp and fish stocks identified there by Munro (1968). Snappers which in the 1950s were available to line fishers have disappeared and were replaced in commercial landings (using nets) by sprats and herrings which are the basis of a small but apparently sustainable herring fishery described in detail by Harvey (1986) and Harvey *et al*. (2003).

But what impact has all this had on the fishable species found in the shallow seagrass beds and juxtaposed red mangrove (*Rhizophora mangle*) prop root complexes in the Port Royal remnant mangrove forest ?

OBJECTIVES

Tropical bays like Kingston Harbour, as well as lagoons and estuaries with mangrove and seagrass beds are often found to contain high densities of brackishwater, reef, and even pelagic fishes, suggesting that such areas are especially important as nursery areas. In Jamaica similar observations were noted in Old Harbour, St. Catherine (the largest bay in Jamaica) by Aiken (1998, Aiken *et al*. 2003) and also in the Bogue Islands lagoon, near Montego Bay (Tolan and Aiken, 1991). But, significantly, no major study has been completed in the Kingston Harbour locality. Major developments in the northwest sector of Kingston Harbour, including the government development called

”Highway 2000”, required major modification of harbour boundaries. Additionally, a major hurricane (Ivan) affected the area in September 2004 and another (Gustav) in September 2008. Had these events affected Kingston Harbour fish nurseries?

If the living resources extracted from Kingston Harbour are conservatively valued at a minimum of J$6 million annually (Fisheries Division Pers. communication 2002), how greatly have these been affected and in which ways? This statement is considered significant as the harbour still has a relatively large number of fishers who are dependent on these resources.

Despite the National Coastal Zone Management plans needing to include measures for Kingston Harbour, there is as yet, no specific information related to nursery areas such as the mangrove forest near Port Royal and the adjacent seagrass bed complexes. Therefore, the present project was intended to try to fill this important data gap. So, despite the fact that Kingston Harbour supports a small but valuable fishery, and the adjacent Port Royal reef fish stocks are overfished (Munro 1983, Aiken and Haughton 1987, Koslow *et al*. 1988) there has been no recent study of the nursery role of the mangroves and seagrass beds of the area. Such an ecologically valuable area should have been studied previously, as it appears to have biodiversity value of considerable significance as dolphins and seahorses, among other species, have been observed in the area (Aiken Pers. observation).

So, the four primary objectives of the project were as follows:

i) To determine the importance of Kingston Harbour (KH) mangroves and seagrass beds as nurseries,
ii) To assess the status of mangroves and adjacent seagrass bed habitats in KH as it affects their role as fish nurseries,
iii) To determine whether these two habitats function individually or in tandem as nursery areas, and
iv) To determine how these two habitats could be managed, especially those in the Port Royal area as part of the National Coastal Zone Management Plan, and National Fisheries Plan.

METHODS

Study Area

Kingston Harbour in Jamaica (Figures 1 and 2) 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 $17^0 57'$ N, $76^0 48'$ 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 Marine laboratory of the same name). 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 harbor highly productive biologically.

Sample Sites

The location of the six sampling station is shown in Figure 2 below. Information on all six stations is provided in Table 1.

Equipment

A small otter bottom trawl was used to sample the six stations selected for the project’s research. Table 2 lists the sample sites. 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 kts.) 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.

Figure 2. Satellite image of the location of the six sample stations (yellow pins) used in the present study showing Kingston Harbour, with Port Royal at bottom left and tip of Manley International airport runway at bottom far right. Northeast refuge Cay in centre, is Station 5.(Image from Google Earth).

Table 1. Sample sites used in present study and their ecological features.

Site number	Name & location	Ecological characteristics	Notes
1	Mammee Shoal (part of Middle Ground Shoals) $17^0$57'40.06''N 76^{0} 50'13.36"W	Seagrass beds with turtle grass (*Thalassia*) and abundant *Dictyota* (brown algae) and *Caulerpa* (green algae) and small quantity of *Syringodium* towards east. Depth 1 – 4 m. Scattered patches of biogenic sand, some large. No mangrove nearby. Many green sea urchins (*Lytechinus variegatus*). Lots of old decaying turtle grass.	Oriented northwest to southeast. Near Outer Harbour, not far from western end of Ship Channel and Fort Augusta, located away from all mangroves. Mangrove control site. Drops off at edges into deeper water. Many swimming crabs (*Callinectes* spp.)
2	East Hangman's Point 17deg59'73"N 76deg 58'50.50"W	*Thalassia* beds with small patches of biogenic sand at western end. Red mangrove on shoreline. Depth 1 – 2 m. Holothurians (*Actinopyga agassizi*). Many small (1 - 6cm diam.) *Lytechinus variegatus* (green sea urchins)	Red mangrove, mixed with black mangrove on shoreline, in all successive sites 2 -6.
3	Fort Rocky lagoon 17deg 56'23.78"N 76deg49'20.06"W	Deeper site, muddy bottom, some mature *Thalassia* near Western end. Mangrove branch snags in area. Depth 2 – 3 m. Red mangroves on shoreline. Muddy substrate at east end. H_2S – rich mud, west has some *Caulerpa* (green alga) and *Halimeda* spp. (calcareous green algae)	Grass shrimp, broken mangrove oyster valves, small empty *Murex* shells
4	East Hurricane Refuge Lagoon site 17deg 56'22.79"N 76deg48' 48.79"W	Some *Thalassia* beds towards western end only, 2 - 3 m. Red mangroves on shoreline. Deeper site. Muddy substrate in eastern portion. Solid waste, (plastics). Some snags in form of old mangrove branches. Lots of *Gracilaria?spp?*. Some upside-down jellyfish (*Casseiopia xamachana)*	
5	Northeast Refuge Cay 17deg56.46' 52"N 76deg49'12.29"W	Extensive *Thalassia* beds with small biogenic sand patches, shallow approx 1-2 m. *Dictyota* algae, red mangroves on shore, some solid waste. Brown pelicans and Frigate birds roost in mature mangroves on shore.	
6	1 km West of Norman Manley Airport Runway 17deg 56' 13.50"N 76deg 48'22.77"W	Mature *Thalassia* beds, some red mangrove on shoreline, but black species dominant. Much solid waste on shoreline at water's edge. Depth 1- 2 m. Much *Dictyota* .	Halfbeaks, gars and pipefishes abundant at surface here (family Sygnathidae). In May-June small schools of herrings in area (their main prey).

The trawl was retrieved and emptied and any catch stored in labeled 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%. This figure was taken as acceptable for the present study based on similar size and deployment methods. 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.

We were primarily concerned with understanding:

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:

$$H' = \sum (P_i)\ln(P_i)$$

Where Pi is the proportion of the ith species at each site, and ∑ is summation over all i fish species.

RESULTS

Community Structure (Species Composition)

A total of 42 species of finfish, crustaceans and molluscs, of which 28 or 66% were fishes, were identified in the present study. Invertebrate species totaled 14, of which the commercial species were two species of swimming crab and at least two shrimp species.

Table 2 shows that 28 fish species were collected along with 14 invertebrates species. Zoobenthivores dominated with 46% of all guilds, followed by piscivores at 36%. Much lower were the herbivores and omnivores (both at 7%) while the sole planktivore species, comprised 3.5% of all feeding ecology guilds. Omnivorous invertebrates such as the swimming crabs numerically dominated, with herbivorous green sea urchins next.

Figure 3 shows that the sea bream (*A. rhomboidalis*) comprised 76% numerically of all specimens taken with the balloon fish (*D. holacanthus*) and the silver jenny (*E. gula*) next at 5 and 4% respectively. Fourth most abundant was the greater soapfish (*Rypticus saponaceus*) at 3%.

If we examine the species found at Station 1, we see that it is much like that in Figure 3 but with a larger number of species. Figure 4 shows the relatively high number of species (21) found at Mammee Shoal. This site comprised a narrow band of seagrass shoals almost 1 km long with intervening small sandy areas (see also Table 1, sample site description), located furthest away from the Port Royal mangroves. It is also closest to the harbor mouth and to the Outer Harbour zone. Like the overall

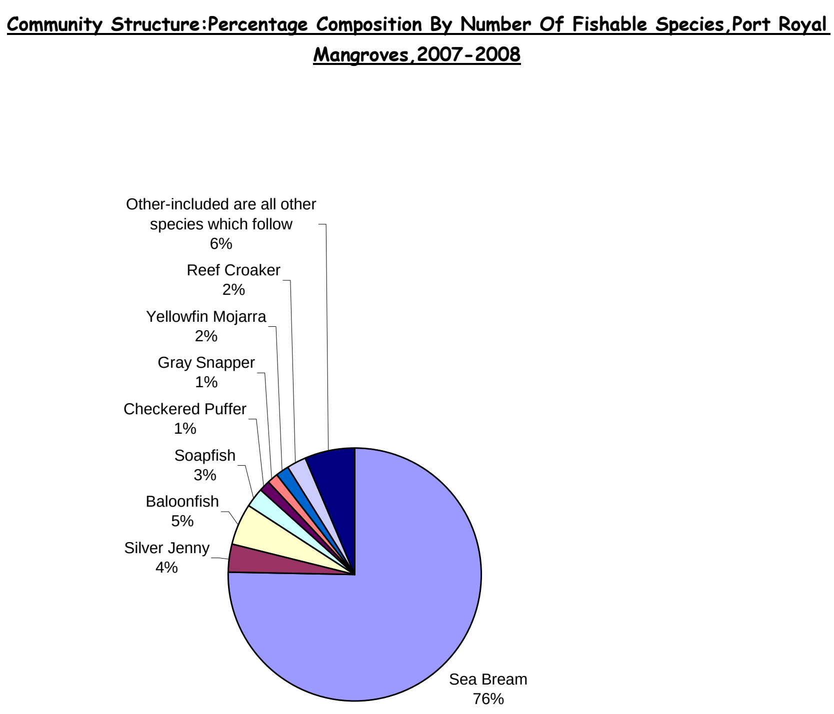

Figure 3. Species composition from all stations (pooled data) in present study.

Table 2. List of all species found in present study with notes on trophic relationships (feeding ecology.).

VERTEBRATES			INVERTEBRATES		OTHER
Scientific (common) Names	**Family**	**Feeding Guild**	**Scientific Name**	**Common Name**	
Scorpaena plumieri (spotted scorpoinfish)	Scorpaenidae	Piscivore	*Lytechinus sp*	Green Sea Urchin	*Halimeda sp*
Archosargus rhomboidalis (sea bream)	Sparidae	Herbivore	*Callinectes ornatus*	Green swimming crab	*Dictyota sp*
Eucinostomus gula (silver jenny)	Gerreidae	Zoobenthivore	*Holothuroidae*	Sea Cucumbers	*Caulerpa sp*
Urolophus jamaicensis (yellowspotted stingray)	Dasyatidae	Zoobenthivore	*Callinectes apidus (exasperatus?)*	Blue swimming crab	*Thalassia sp*
Diodon holacanthus (balloonfish)	Diodontidae	Zoobenthivore	*Penaeus schmitti*	Southern White Shrimp	*Gracillaria*
Rypticus saponaceus (greater soapfish)	Grammistidae	Piscivore	*Oreaster reticulatus*	Reticulated starfish	
Ocyurus chrysurus (yellowtail snapper)	Lutjanidae	Piscivore	*Lytechinus variegatus*	Green sea urchin	
Haemulon sciurus (bluestriped grunt)	Haemulidae	Zoobenthivore	*Luidia clathrata*	Striped sea star	
Lutjanus synagris (lane snapper)	Lutjanidae	Piscivore	*Actinopyga sp*	Sea Cucumber	
Diodon hystrix (porcupine fish)	Diodontidae	Piscivore	*Actinopyga agassizii*	Five toothed sea cucumber	
Sphoeroides testudineus (checkered puffer)	Tetraodontidae	Piscivore	*Penaeus?*	Grass shrimp	
Lutjanus griseus (grey snapper, mangrove snapper)	Lutjanidae	Piscivore	*Aplysia dactylomela*	Sea hare	
Umbrina coroides (sand drum)	Sciaenidae	Zoobenthivore	*Fasciolaria tulipa*	Tulip Shell	
Haemulon aurolineatum (tomtate grunt)	Haemulidae	Zoobenthivore	*Ecteinascidia turbinata*	Mangrove tunicate	
Gerres cinereus (yellowfin mojarra)	Gerreidae	Zoobenthivore			
Odontoscion dentex (reef croaker)	Sciaenidae	Zoobenthivore			
Holocentrus ascensionis (longjaw squirrel fish)	Holocentridae	Zoobenthivore			
Lutjanus apodus (schoolmaster snapper)	Lutjanidae	Piscivore			
Lutjanus analis (mutton snapper0	Lutjanidae	Piscivore			
Chilomycterus antillarum (web burrfish)	Diodontidae	Zoobenthivore			
Bothus ocellatus (eyed flounder)	Bothidae	Omnivore			
Hippocampus erectus (lined seahorse)	Sygnathididae	Planktivore			
Haemulon bonariense (black grunt)	Haemulidae	Omnivore			
Epinephelus itajara (goliath grouper)	Serranidae	Piscivore			
Sparisoma chrysopterum (redtail parrot)	Scaridae	Herbivore			
Serranus tabacarius (tobaccofish)	Serranidae	Zoobenthivore			
Monacanthus ciliatus (fringed filefish)	Monacanthidae	Zoobenthivore			
Cantherinus pullus (orangespotted filefish)	Monacanthidae	Zoobenthivore			

(pooled stations and species) figure it shows the sea bream (*A. rhomboidalis*) by far dominated the fish species in this area. The balloonfish puffer (*D. holacanthus*) and the silver jenny (*E. gula*) followed next. Two species of *Callinectes* (swimming crabs) combined, made a relatively high contribution of 11% to species composition here.

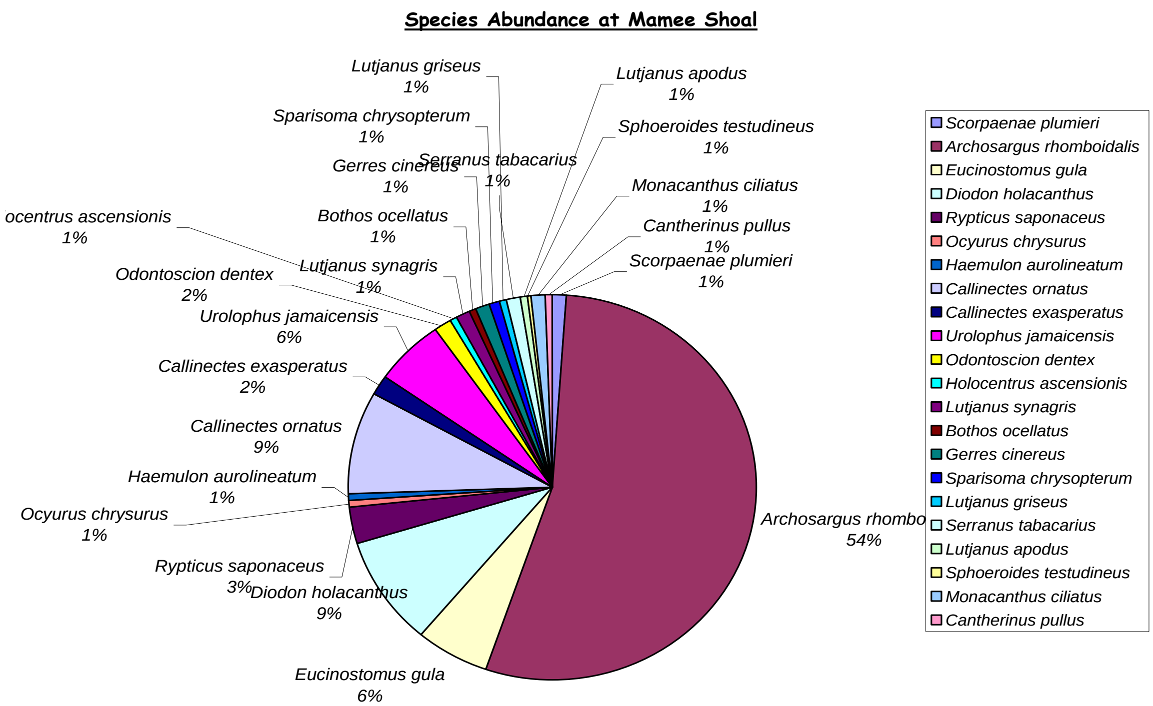

Figure 4. Percent Species composition at Station 1 Mammee Shoal

Size of fishes taken here was relatively small as shown in Figure 5 which gives the length-frequency for the three most abundant species, (sea bream, balloonfish, and silver jenny) at station 1.

Sizes ranged in Figure 5 from 7 cm to 11 cm fork length indicating relatively small individuals predominated there.

With regard to size, the data showed that overall all the stations except Station 3 (70 g) had small fishes suggesting that these locations were functioning as nurseries for juvenile fishes. The range was 10 - 72 g and the mean weight of fish specimens taken at all six station was 29g. In mean individual fish weight, stations 1, 2, 5, and 6 were small and thus strongly indicating a nursery function.

Comparisons of species diversity across stations (west to east) in Kingston Harbour, showed that diversity slightly decreases from west to east (stations 1 to 6), that is as the distance from the outer harbour increases. Highest diversity was found at Station1 Mammee Shoal (westernmost site) and lowest at Station 6 near the NMIA runway, the easternmost location (Figure 6).

Comparisons of Guilds Between Habitats

Greatest number of fish guilds was found at Station 1 Mammee Shoal, where 19 species were identified. Two other species were found but these were invertebrates. This site, like all others stations, was greatly dominated by the abundant herbivore, the sea bream.

Single-species Comparisons

The rare and endangered goliath grouper (*Epinephelus itajara*) (see Appendix image 5) was found at two locations (Stations 2 and 4). These specimens both survived collection and handling to live for several months in captivity at the PRML. This species represents the discovery of a significant indicator species, which previously, was thought to be commercially extinct in Kingston Harbour. Mangroves near seagrass beds are a Critical Habitat for this keystone species. We suggest that this species could become a "poster species" for the conservation of the Port Royal mangroves, along with the much smaller but similarly rare and endangered Yellow lined seahorse (*Hippocampus erectus)*. Indicator species are those whose presence or absence directly infer the relative status of that area.

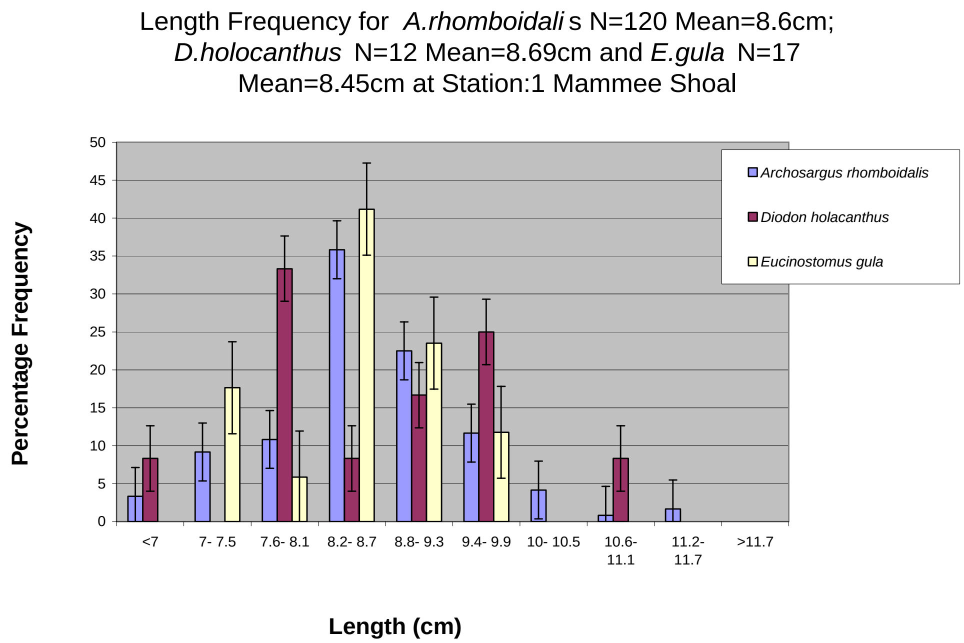

Figure 5. Length-frequency distribution diagram for the three most abundant fish species, sea bream, balloonfish and the silver jenny at Station 1 Mammee Shoal.

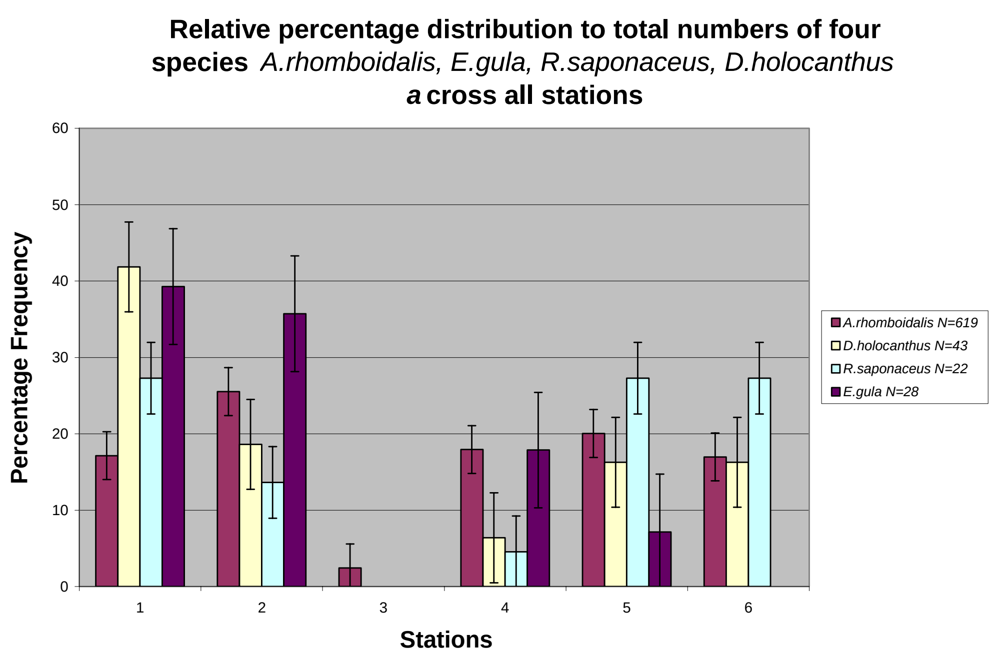

Figure 6. Relative contribution to total abundance (numerically) of four fish species from all six stations, showing standard error bars.

Invertebrate Species

Swimming crabs, green sea urchins, and sea cucumbers were also found at some stations. Figure 7 shows crab numbers across the six stations.

As numbers of crabs caught generally were small, the length-frequency (in maximum carapace width, MCW) can only be shown for the station at which a number exceeding n = 20 was found, (that is, Station 1, Mammee Shoal).

An examination of length-frequency for *C. sapidus*, the blue swimming crab, which was the more common of the two species found, indicated that there was a mode in distribution at 8.5 cm MCW (maximum carapace width). Though some very small crabs were found, generally, most crabs were (small) adults. In January 2005 a few spawning adult females were collected there.

Diversity Indices

Species diversity (biodiversity) was of considerable interest to the present study and Table 4 shows a list of Shannon-Weiner Diversity Indices (H') for the six stations sampled.

Table 4. Shannon-Weiner Species Diversity Indices (H') calculated for the six stations sampled during the present study (fishes only). Mean H' = 6.85 (all six stations).

Station number & location	Shannon-Weiner Diversity Index or H' (fishes only)
1. Mammee Shoal	12.02
2. East Hangman's Point	23.15
3. Fort Rocky Lagoon	2.33
4. Hurricane Refuge	1.41
5. Refuge Cay	0.99
6. Runway site	1.20

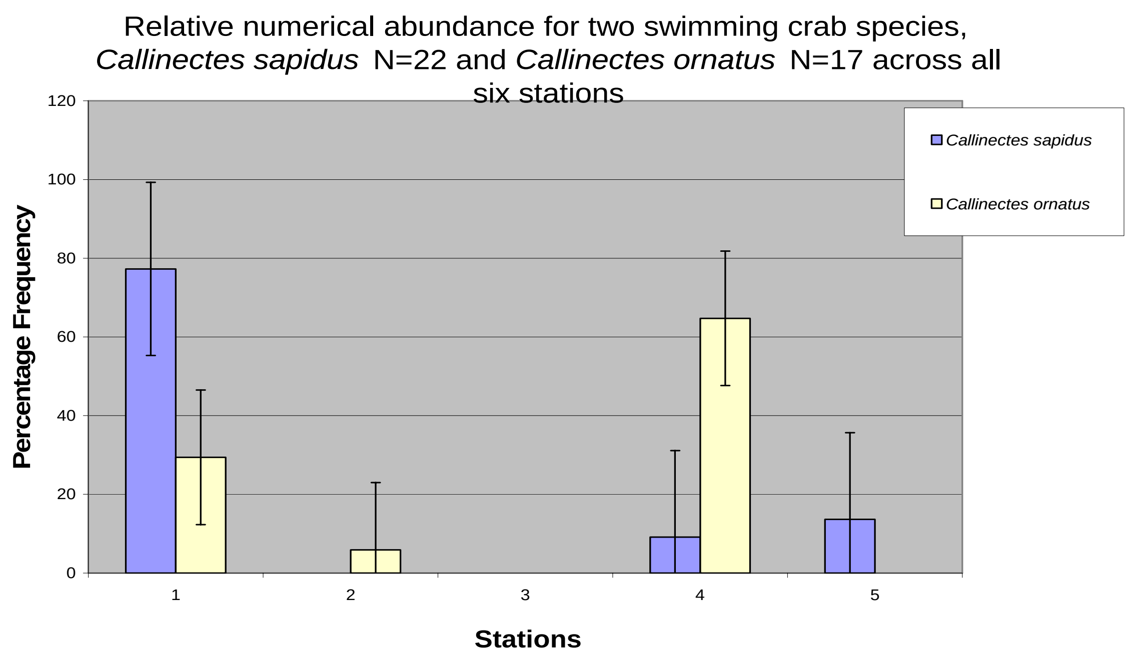

Figure 7. Relative numerical abundance for two *Callinectes* (Portunidae or swimming crab) species at all stations.

DISCUSSION

Mangroves

The role of mangroves as a primary producer in the system is sometimes overlooked. In its original form Kingston Harbour had over 1,000 acres (450 ha) of mangrove swamp (Goodbody 1970, Chapman 1944). Much of this swamp was lost to coastal development. Mangrove is regarded as an important contributor to the overall production mechanism in the harbor, as much of the organic material produced in the leaves of the trees falls to the swamp floor where it is broken down by microbial action. Tidal flow across the swamp floor carries some of this material back into the aquatic ecosystem where it is utilized by suspension feeders or further broken down by microbial action. To a lesser degree organic material is transferred from mangroves by the action of various crabs and other organisms which consume the leaves and fruits, etc . (Goodbody 1970).

Although not reported on specifically, much of the mature mangroves on the Port Royal mangroves was damaged by hurricanes Ivan (2004) and Dean (2007). Observations by the author in the course of this study suggest that the canopies have recovered relatively well up to early 2008, but that Refuge Cay trees had suffered more damage than other areas.

Seagrass Beds *Thalassia* (Turtle Grass)

In 1970, Goodbody estimated there were approximately 2,000 acres (900 ha) of turtle grass (*Thalassia*) in Kingston Harbour, mostly concentrated in the shallow areas of Middle Ground and Pelcan Shoals. But to a lesser extent this was concentrated along the southern shoreline of the Inner Harbour and on the western side of the ship channel. This he said, represented an enormous productive potential but that little was known at that time of its role in the total ecosystem. Much of the energy produced by these plants, he opined, seemed to become locked up in rhizomes beneath the surface, while some, in the form of leaves, are consumed by browsing organisms. He further noted that, apart from echinoids, the precise nature of these browsers was unknown but must include various fish species as well as molluscs.

The present study suggests the major browser on *Thalassia* is the sea bream, *Archosargus rhomboidalis*, and its dominant position numerically and in weight at every site all through the year, suggests that this is so at all locations. Significantly, it suggests that it is more important in this role than echinoids, such as the green sea urchin (*Lytechinus variegatus*), which number was relatively low in all study areas.

Fish Community Structure (& Nursery Function)

One of the earliest studies on the fishable species in Kingston Harbour was done by Munro (1968) who carried out an otter trawl survey (the same gear as the present study). He found that 60% by weight of all catches was the silver jenny (*Eucinostomus gula*) with a mean length of approx. 8 cm. Three species of Sciaenidae (croakers & drums) made up most of the remainder. Of these, the only sciaenid that appears to have survived 40 years in the harbour to be caught at the sites sampled in the present study was *Odontoscion dentex* (reef croaker). Two other species, *Bairdiella ronchus* and *Stellifer colonensis* were not found by the present study (This is not to suggest that it is nowhere present). However, the sampling areas were over mud in Munro's study not seagrass or near mangroves. Small snappers (*Lutjanus synagris* and *L. griseus*) were also caught in some places by Munro. He also took two shrimp species (*Penaeus duorarum* and *P. schmitti*) leading him to suggest that small artisanal shrimp fisheries could be developed in the harbour at that time. Importantly, his study consistently found smaller fish and shrimp in Hunts Bay than elsewhere, and as a result he suggested that this area was a nursery for these species. Goodbody *et al.* (1969) had suggested that Dawkins Ponds had a similar function.

Supporting theories for shoals and mangroves and adjacent seagrass beds acting as nurseries include Nagelkerken (2000) who in researching nurseries in the Dutch Antilles, put forward a useful summary of the various hypotheses which try to explain the abundance and diversity of fishes in mangroves and seagrass beds. These were:

i) The structural complexity of mangroves and seagrass beds provide (increased) shelter from predators,
ii) These habitats are located away from reefs and thus are less frequently visited by reef predators,
iii) The relatively turbid waters of bays, lagoons, and estuaries decrease foraging success of predators,
iv) Mangroves and seagrass beds provide a great source of food for fishes, and
v) Mangroves and seagrass beds often cover extensive areas which intercept planktonic fish larvae more successfully than coral reefs.

Many Caribbean studies have observed reef fish juveniles in mangroves and seagrass beds (Austin 1971, Weinstein and Heck 1979, Baelde 1990, Louis *et al*. 1992, Sedberry and Carter 1993, Nagelkerken 2000, Aiken *et al*. 2003). Also, adults of these species were observed in the coral reefs (or in offshore waters) suggesting that these juveniles migrate from the mangrove and seagrass beds to the reefs and offshore waters (Ogden and Ehrlich 1977, Weinstein and Heck 1979, Rooker and Dennis 1991). Though questioned in the Pacific where some studies do not show similar nursery function (Quinn and Kojis 1985), in the Caribbean, it has been generally accepted that mangroves and seagrass beds form important nurseries for juvenile reef fishes (Ogden and Gladfelter 1983, Parrish 1989 *in* Nagelkerken 2002, Aiken *et a*l. 2003).

It has been found that shallow water biotopes were important as nurseries for economically important reef fish species where a high dependence of juveniles on these biotopes was deduced from the observation that they were exclusively present or highly dominant in these biotopes, and not on the deeper reef (Nagelkerken 2000). It is important to note that seagrass beds and mangroves do not operate in exclusion as nurseries, but shallow reef does also (Nagelkerken 1999 & 2000).

When fishes become too large for optimal protection by the seagrass shoots and mangrove prop-roots they often migrate to the coral reef. This migration pattern has largely described qualitatively for only a few species (Ogden and Ehrlich 1997, Weinstein and Heck 1979, Rooker and Dennis 1991, Nagelkerken 2000). The last author recorded that most of the species studied in Bonaire used the shallow water biotopes as nurseries during their juvenile stage, but migrate permanently to the deeper coral reef when reaching a specific size. This ontogenetic migration, known from many other fishes, undoubtedly occurs here in Jamaica, inferred from the absence of adult fishes from most shallow sites.

Other Caribbean studies, such as that of Louis *et al*., (1992) in Martinique showed 87 species comprising over

100,000 individuals. The small mean individual weight of 9 g, and the predominance of juvenile fishes, strongly indicated a nursery function for the mangrove and seagrass areas sampled in the eastern part of Fort-de-France bay.

Mangrove Versus Seagrass Utilization by Fishes

Florida studies of the utilization of the red mangrove prop root habitat by fishes by Thayer *et al*. (1987) found that the density and biomass of fish were greater in the prop root habitat than in the adjacent fringing seagrass areas. The mean g density of fish in mangroves was 35 times that collected in the immediately adjacent (seagrass) habitat on an areal basis. Mean biomass of fish in the mangroves was about 19 times greater than in the adjacent habitat. The mangrove prop root habitat is utilized by a wide variety of fish, and they felt that greater attention should be given to its contribution to fish production in south Florida and elsewhere.

Catch analyses in the present study showed that the seagrass only site (Station 1 Mammee Shoal) had the highest species diversity (21 species) relative to the other stations (all less than 8). Could the lower diversity near the mangroves be a function of levels of pollution and/or hurricane damage? This station in the western harbor had high numbers of both fishes and invertebrates and it is suggested that its proximity to the harbor mouth and cleaner water may be one reason for its higher diversity. Dominant fish species here and in all other stations, was the sea bream.

Previous Jamaican Nursery Studies

One of the first known studies of fish communities in Kingston Harbour, in direct relation to turtle grass beds, was the work of Greenway (1973). She produced information primarily on turtle grass productivity in Kingston harbour, but also commented on fish species composition found in association with the seagrass areas near Port Royal, mainly at Mammee Shoal. Reliable records of this study could not be located but the species diversity reported was much greater at that time 1972 - 1973 than during the present study 35 years later. A much larger abundance and diverse range of parrot fishes (family Scaridae) was one important difference found by Greenway versus the present study.

The Port Royal cays and the mangroves to some extent, part of Old Harbour Bay, as well as Negril were studies for nursery function by Ross (1982). This study was carried out between 1974 and 1975 when Ross set out to determine the extent to which nearshore reefs of different depths, seagrass beds, rocky shorelines, and mangrove areas act as nursery grounds for juvenile fishes. He found few species of reef fishes at the mangroves in Port Royal, but recorded that juveniles of some species were found in large numbers, such as snook (*Centropomus undecimalis*), mojarras (*Eucinostomus* spp. and *Gerres* spp.), and mangrove or grey snapper (*Lutjanus griseus*). He noted that turtle grass beds (*Thalasssia testudinum*) was important as a nursery environment for juvenile reef fishes.

The Bogue Islands lagoon, Montego Bay (north west coast), and the Port Royal mangroves, were briefly examined in 1989 and 1990 by Tolan and Aiken (1991). Generally, mojarras and sea breams dominated in the seagrass beds adjoining the mangroves of Port Royal. Community composition between study areas did not greatly differ, despite the fact that Bogue lagoon was a large silty muddy area with scattered seagrass, mostly turtle grass with eel grass (*Syringodium*) and several small mangrove islets covering several hectares behind the Seawind resort to the west of Montego Bay. An otter trawl was used to sample these areas. At that time (1990) in Port Royal mangroves-seagrass areas, the sea bream was showing an increase in abundance relative to Ross's study 15 years previously.

Portland Bight, also called Old Harbour Bay, is the largest natural bay in Jamaica and was examined by Aiken *et al*. (2003) who sampling mangrove, seagrass, and nearshore sandy habitats with seine nets over 13 months, collecting 98 species comprising 92 finfish species from 41 families, including three elasmobranch families, plus eight crustacean species from six families, and two molluscan species. Adult, sub-adult and juvenile fishes totaling 2,389 individuals weighing 18.6 kg. The small mean individual weight of 1.2 g strongly indicates that the areas sampled functioned as nurseries. Fully 69% of the 92 finfish species came from mangrove-seagrass habitats, and were represented entirely by juveniles. The five most abundant species numerically were *Anchoa lyolepis* (dusky anchovy), *Eucinostomus gula* (silver jenny), *Sardinella anchovia* (Spanish sardine), *Diapterus rhombeus* (caipita mojarra), and *Haemulon sciurus* (bluestriped grunt). Crustaceans comprised 7.1%, with *Callinectes* spp. (swimming crabs) the most abundant species and molluscs 2% of all species.

Henry (2007) used an otter trawl to briefly sample the benthic community of Fort Rocky Lagoon (near Station 3 of the present study) and found that it was utilized by a diverse fish assemblage at its western end where seagrasses were prevalent, compared to the eastern end where mud dominated and few organisms were present. A total of 314 specimens representing nine families were identified. Of this, 261 were fishes from six families and 53 were invertebrates from three families. Additionally, algae including *Caulerpa* and plant fragments of *Rhizophora* mangle were also present in the lagoon adding to the relatively high diversity value and thus contributing to the overall natural productivity of Fort Rocky Lagoon.

Species Composition

Fish species composition from the present study showed clearly that there was dominance of three species, *A. rhomboidalis, E. gula,* and *Diodon holacanthus*. What is notable is that the sea bream, (*A. rhomboidalis*), a diurnal herbivore from the Sparidae family, always significantly dominated in abundance and was never less than 50% of the species composition, regardless of the site. Tables 5 & 6 show that seagrass beds seem to function as obligate nurseries for sea breams (and others). However, this species is not particularly sought after as a commercial species.

Table 5 summarizes the dominant finfish and crustacean species taken from mangrove-seagrass and related studies from Jamaica and the greater Caribbean (extended in one case to the Florida Keys).

Table 5. Review of top five numerically dominant commercial species from Kingston Harbour compared with studies from related areas around the Caribbean. Key: N/R = not reported

Location	Dominant Finfish Species	Dominant Crustacean Species	Sampling Gear & Substrate	Source & Date
Kingston Harbour (Hunts Bay)	*Eucinostomus gula* (silver jenny) *Odontoscion dentex* (reef croaker) *Bairdiella ronchus* (sand drum) *Stellifer colonensis* (threadfin) *Lutjanus synagris* (lane snapper)	*Penaeus duorarum* (pink shrimp) *P. schmitti* (brown shrimp)	Otter trawl over mainly muddy ground.	Munro 1968
Kingston Harbour (Mammee Shoal & Middle Ground Shoal)	*Sparisoma chrysopterum* (redtail or pink parrot) *S. radians* (yellowtail parrot) *Scarus croisensis* (princess parrot) *Thallasoma bifasciatum* (bluehead wrasse)	*Panulirus argus* (spiny lobster) *Callinectes* spp (swimming crab)	Scuba observation over seagrass beds.	Greenway 1973
Port Royal Cays, Kingston	*Eucinostomus "argenteus" = (gula)* (mojarra) *Gerres cinereus (yellowfin mojarra)* *A. rhoboidalis (sea bream)*	*Panulirus argus* (spiny lobster)	Scuba observation and small-meshed mini fish traps over shallow back reef lagoons with seagrass.	Ross 1974
Bogue Islands lagoon, Montego Bay, St. James	*E. gula* *Gerres cinereus* (yellowfin mojarra) *Archosargus rhomboidalis* (sea bream)	*Callinectes* spp. *Penaeus notialis* (?)	Otter trawl over mangrove-seagrass beds	Tolan & Aiken 1991
Portland Bight, St. Catherine	*Anchoa lyolepis* (dusky anchovy) *E. gula* *Sardinella anchovia* (Spanish sardine) *Diapterus rhombeus* (caipita mojarra) *Haemulon sciurus* (bluestriped grunt)	*Callinectes* spp. *P. argus*	Seine nets over mangroves, seagrass beds and shallow sandy & muddy areas.	Aiken *et a*l., 2003
Fort-de-France Bay, Martinique	*Anchovia surinamensis* (Surinam anchovy) *Diapterus rhombeus* *Anchoa lyolepis* *Bairdiella ronchus* *Harengula clupeola* (red-ear sardine)	N/R	Hoop nets over seagrass and mangrove areas.	Louis *et al*., 1992
Bonaire, Curacao, Netherlands Antilles	*Haemulon flavolineatum* (French grunt) *S. viride* *Lutjanus apodus* (schoolmaster snapper) *Acanthurus bahianus* (doctorfish) *Ocyurus chrysurus* (yellowtail snapper)	N/R	Drop nets and visual census over seagrass beds and mangroves	Nagelkerken 2000
Florida Keys, USA	*Atherinomores stipes (hardhead silverside)* *E. gula* *Anchoa mitchilli* (bay anchovy) *Floridichthys carpio* (goldspotted killifish) *Lucania parva* (rainwater killifish)	N/R	Blocking nets and rotenone over mangroves & seagrass beds.	Thayer *et al*.,1987
Kingston Harbour, Port Royal mangroves.	*Archosargus rhomboidalis* *E. gula* *Diodon holacanthus* (balloonfish) *Rypticus saponaceus* (greater soapfish) *Sphaeroides testudineus* (checkered puffer)	*Callinectes ornatus* *C. sapidus*	Otter trawl over mangrove-seagrass beds.	Present study

The review above of the most numerically abundant species, shows that the following four ranked fishes were most common across the greater Caribbean from mangrove and seagrass areas: *E. gula, A. rhomboidalis, D. rhombeus, and Anchovia spp.* The most numerous invertebrates were *Callinectes* spp. (swimming crabs) and *P. argus* (spiny lobsters). All except *T. bifasciatum* are commercially valuable species.

In the present study, the dominant species at every station was the sea bream. This species, though numerous is not a high valued species. When species composition is compared across stations, (as shown in Figure 3) Stations 5 and 6 are most similar with sea bream most numerous and the balloonfish and greater soapfish next.

Like Nagelkerken (2000) the fish community composition indicates that there at least three groups of fishes in their juvenile stage that utilize the mangrove-seagrass bed biotope in one of three ways:

i) As a nursery, (*H. flavolineatum, H. sciurus, Lutjanus analis, L. apodus, L. griseus, Ocyurus chrysurus, Sparisoma chrysopterum, Gerres cinereus*),
ii) A lifetime habitat,(*Archosargus rhomboidalis, Eucinostomus gula, Gerres cinereus*, and
iii) An extension of the coral reefs on the Port Royal Cays (*Diodon holacanthus, Acanthurus chirurgus*).

Nagelkerken found that various fishes show differing dependence on mangroves and seagrass beds. These findings are summarized in the table below.

Table 6. Role of various habitats for fish species from the Port Royal mangrove-seagrass habitat and Mammee Shoal area (partly adapted from Nagelkerken, 2000).

Biotope	Role	Guild (Reef fishes)	Other Fish Species	Notes
Mangroves and Seagrass beds	Obligate nursery	*Ocyurus chrysurus* (yellowtail snapper)	*Diodon hystrix* (porcupinefish) *Sphaeroides testudineus* (checkered puffer) *Syacium micrurum* (channel flounder)	
Seasgrass beds	Obligate nursery	*Haemulon sciurus* (Caesar grunt), *H. aurolineatum*, (tomtate grunt) *Lutjanus apodus* (schoolmaster snapper) *L. synagris* (lane snapper) *L. griseus* (grey snapper), *Sparisoma chrysopterum* (pink parrot) *Holocentrus ascensionis* (longspined squirrelfish) *Hippocampus erectus* (Lined seahorse)	*Archosargus rhomboidalis* (sea bream) *Eucinostomus gula* (silver jenny) *Rypticus saponaceus* (greater soapfish) *Scorpaena plumieri* (scorpionfish) *Odontoscion dentex* (reef croaker) *Achirus* spp.(eyed flounder) *Serranus tabacarius* (Tobacco fish) *Monacanthus ciliatus* (green filefish)	Soapfishes were found to feed on very small (1cm) shrimp.
Mud flats	Obligate nursery	*L. analis* (mutton snapper)		*Penaeus notialis* (southern pink shrimp)
Mangroves and/or seagrass beds	Obligate nurseries	*Lutjanus griseus* (grey snapper) *H. flavolineatum* (French grunt) *Gerres cinereus* (yellowfin mojarra) *Epinephelus itajara* (goliath grouper)		Bottlenose dolphins (*Tursiops truncatus*) seen repeatedly in Fort Rocky Lagoon.
Sandy patches in seagrass beds	Obligate nursery	*Diodon holacanthus* (balloonfish) *D. hystrix* (porcupinefish) *Chilomycterus* spp. (webbed burrfish)	*Aetobatis narineri* (spotted eagle ray) *Urolophus jamaicensis* (yellowspotted stingray)	Eagle rays were observed repeatedly over Mammee Shoal though never caught. Both spp. consume small molluscs exclusively

An obligate nursery function for sandy patches (as found on Mammee Shoal) for molluscan-consuming elasmobranchs (cartilaginous fishes) *U. jamaicanesis* (yellow-spotted stingray) and *Aetobatis narineri* (spotted eagle ray) is suggested here. The latter species was not collected, but was observed repeatedly over and near sandy ground where molluscs dominate the benthic infauna. The dentition of these two ray species is adapted for crushing hard objects such as shells.

Of considerable interest was the collection of two endangered and rare fish species, the Goliath grouper (*Epinephelus itajara*) and the Lined Seahorse (*Hippocampus erectus*). Stations 2 and 4 provided both species. The two groupers survived collection and survived for several months in aquaria at the PRML, with one growing to 1.5 m and at least 10 kg in 14 months on a fresh herring diet. The seahorses all survived for several weeks in captivity.

Comparisons with Other Jamaican Nursery Studies

In relative species diversity, compared with the Portland Bight (Old Harbour Bay) study, the present study found that fishes comprised 72%, while in the former, they were 92% of all species taken. This lower KH diversity overall (29 species of all types versus 98 species) could be related to the much greater pollution levels in KH relative to Portland Bight (PB). Mangrove and seagrass beds in KH thus possess 71% less diversity than those in PB.

Energy Flow in Kingston Harbour and the Role of Fishes

Although a herbivore greatly dominated numerically, zoobenthivores and piscivores dominated in feeding guild members. If zoobenthivores dominated (46%) feeding guilds in the present study, then it appeared that the 13 fish species in this category found more food material in the study sites, than the piscivores (36%) did. The relatively high percentage of piscivores, suggest that the abundance of small fishes of all types provided food for other slightly larger fishes (see also Table 7 - trophic level assignments below). Of considerable significance is the relative dominance (mean value of 50% of all fishes found) of the herbivore, the sea bream (*A. rhomboidalis*) at all stations in the present study. Goodbody (1970) indicated that fishes had a top (tertiary and quaternary) predator role both as consumers of other fishes and of invertebrates in Kingston Harbour. Fishes are thus the end of the energy flow in seagrass beds and mangroves in Kingston Harbour. Greenway (1973) was able to produce a rough flow chart for the marine neretic zone surrounding Port Royal. She broke the fish groups into trophic levels (grouping of guilds). Table 7 sets out the trophic levels for the marine shallows near Port Royal mangroves and seagrass beds and incorporated the present findings, as well as some from Greenway from the same area.

This table shows that primary consumers were the most common trophic group comprising numerous detritivores, some midwater feeders, occasional coral feeders and the considerably rarer planktivores.

But how have relative abundances of species changed since the studies in the 1970s? Table 8 sets out a comparison of fishes found in the present study, with the ten most common fish species found by Ross (1982).

Table 7. Trophic level assignment for fishes from Port Royal seagrass and mangroves area (adapted from Greenway 1973).

Trophic level	Feeding Guild	Family	Species (common Name)	Observations
Primary consumers	Herbivores, browsers & phytoplankton feeders	Scaridae	Parrotfishes	Uncommon
		Sparidae	Porgies & breams	Sea breams most dominant of all species
		Acanthuridae	Surgeonfishes	
Secondary consumers	Detritivores	Bothidae	Spotted flatfish	Uncommon
	Midwater invertebrate feeders	Pomacentridae	Damselfishes	Uncommon
	Coral feeders			
	Planktivores	Scaridae	Parrotfishes	Uncommon
		Hippocampidae	Seahorses	Rare & endangered.
		Clupeidae	Herrings & sardines	Observed at surface but missed by bottom trawl.
Tertiary consumers	Small piscivores	Lutjanidae	Small snappers	Occasional
		Serranidae	Small groupers	Rare
		Scorpaenidae	Scorpionfishes	Common
Quaternary consumers	Larger piscivores	Lutjanidae	Larger snappers	Rare
		Urolophidae	Rays	Occasional

Table 8. Fish juveniles found in mangrove areas of Portland Bight (St. Catherine) & Port Royal by Ross (1982) and by the present study, with notes on changes in abundance with time.
Key: VC = Very Common; C = Common; R = Rare; NS = Not seen

Species (common name)	Portland Bight (Ross)	Port Royal (Ross)	Port Royal (present study)	Change in abundance since 1974
Eucinostomus gula (silver jenny)	VC	VC	C	Reduced abundance (RA) (since 1970s)
Gerres cinereus (yellowfin mojarra)	VC	VC	C	RA
A. rhomboidalis (sea bream)	C	NS	VC	Increased abundance
Centropomus undecimalis (snook)	C	C	R	RA
L. apodus (schoolmaster snapper)	C	C	U	RA
L. griseus (grey snapper)	C	C	U	RA
Mugil curema (white mullet)	C	NS	NS	Unknown (probably reduced)
Acanthurus chirurgus (doctorfish)	NS	R	R	Unchanged
Epinephelus itajara (goliath grouper)	R	NS	R	Slightly increased abundance?
Haemulon plumieri (white grunt)	R	NS	NS	RA
Diodon holacanthus (balloonfish puffer)	NS	NS	C	Increased abundance
Rypticus saponaceus (greater soapfish)	NS	NS	C	Increased abundance

Table 8 comparing 12 fish species over at least 30 years, shows that 50% were reduced in abundance while 25% showed an increase in abundance. One interesting observation is that Ross (1982) did not observe the sea bream (*A. rhomboidalis*) in the PR mangroves in the 1970s. Could this be an oversight? As this is unlikely, this would strongly suggest that its relative abundance has greatly increased with time, as it is now the most common species by far, of all fishes. The causes of this tremendous increase of the sea bream are unclear at this time, but may be related to a reduction in piscivores (larger predatory fishes) due to overfishing, pollution and mangrove removal, combined with its own increased spawning success. Another factor that may also be partly responsible is reduced inter-specific herbivore competition, as the main seagrass-consuming species, for example the parrot fishes and surgeonfishes, were much less common presently, than in the 1970s.

Species Diversity and Stability

The Shannon-Weiner diversity index (H'), (a classic method of comparing relative species diversity between sites) was calculated for the six stations. Results are shown in Table 4 and Station 2 East Hangman's Point had highest fish species diversity (H' = 23) with Station 1 at Mammee Shoal second (H' = 12). This is due to the fact that although Station 1 had slightly more species, there were only a few specimens of most of those species, with a few exceptions. This was in contrast to Station 2 where the opposite generally applied. Lowest H' value was found at Station 5 Refuge Cay. Simple cluster analysis suggests that Stations 1 & 2 are closely related and least similar to Stations 3, 4, 5 & 6 and that these last-mentioned four sites are closely related to each other. Mean H' value using all six stations was 6.85. Station 3 Fort Rocky lagoon had the lowest absolute fish species number (4) and is perhaps, an unstable site for fishes, due to the low oxygen levels associated with its muddy bottom. Stations 1 and 2 were inferred from their higher H' values to be most stable of all six sites.

Lowest number of fish species and numerical abundance was found at Station 3 Fort Rocky Lagoon. Overall, species diversity was found to be relatively low in the present study, compared with, for instance, the larger Portland Bight area found to the west of Kingston (Aiken *et al.* 2003). Colinvaux (1986) suggests that environmental rigour may be defined tentatively as environmental conditions that are rare and widely dispersed, or short-lived or subject to frequent changes of wide amplitude. When an ecosystem exists under such conditions of environmental rigour, low diversity is to be expected. Colinvaux indicated that the rigour acts either on the immigration rate, or the extinction rate, or both to produce an equilibrium species number that is low. He also mentioned that "familiar patches" of low diversity included brackish estuaries (like the present study area), polluted lakes and abandoned fields. All three are stressed by frequent changes of state as in a tidal estuary (or in the case of our study sites, by large seasonal and storm inflows of freshwater and pollution from the city drainage). Thus, Colinvaux's high 'rigour" conditions appeared to apply during the present study.

Limitations of Sampling Gear and Lack of Variation in Gear Types Used

We should note that an otter trawl collects on average only approximately 20% of the mobile faunal species near the sea floor. Thus, future studies should use a combination of various gears such as nets, traps, as well as trawls, combined with visual and other imaging surveys for an accurate estimation of community structure.

Economic Overview

Salm and Clark (1987) mentioned that the vital roles of the renewable resources of coastal lagoon and estuaries such as those of the Port Royal mangroves should not be overlooked. Cesar *et al*. (2000) estimated that the total yield of the Portland Bight (Old Harbour Bay) fisheries in 1997 was 1,088 t or a unit yield of 0.8 t/km^2/yr. This was approximately 8% of the annual national catch. This latter study estimated that the entire Portland Bight area at that time had a value of over US$52 million. Port Royal produces a relatively tiny amount compared to that estimate, based on personal observation, but it shows that such areas have value. There is need for an economic study of the mangroves of Port Royal and their, 1. fishery yield and 2. social and economic benefits to fishers. Small as it is, the area needs to be managed in a sustainable fashion. Activities that take place in the Port Royal area that need to be valued economically include:

i) Scalefish production (both for subsistence and for hook-and-line bait),
ii) Mangrove and false oyster harvest (*Crassostrea rhizophorae* and *Isognomon alatus*, respectively),
iii) Fighting conch (*Strombus gallus*) fishing,
iv) Mangrove sapling gathering for firewood and for fish trap making, and
v) Mangrove ecology and seabird eco-tours from the UWI's PRML.

Recommendations for Management of Kingston Habour Nurseries

The Palisadoes peninsula was declared a protected area under the Natural Resources Conservation Act in 1998. The mangroves around its fringes support small local finfish, mangrove oysters, and conch fisheries (Fisher 2002). The presence of juveniles and pre-adult fishes suggests the nursery role of mangroves and adjacent seagrass beds in the Port Royal mangroves and the Middle Ground Shoal area of Kingston Harbour still have a nursery function, though perhaps slightly diminished due to overall net reduction in mangrove area and from pollution**.** It is felt that the entire Port Royal mangroves should be protected by making the area a Marine Protected Area. It is also felt that the RAMSAR status should be more regularly publicized and signposted so as to enhance overall conservation and proper management. The Nature Conservancy has published a comprehensive document (Zenny 2006) which sets out a series of conservation recommendations for the Port Royal mangroves and the Palisadoes generally, as well as for all coastal areas of Jamaica.

Protected area implications are that there could be limited (small-scale, low-intensity) fishing in the area and would be allowed only for fighting conch (*Strombus pugilis*) and mangrove oyster. Activities such as mangrove and seabird eco-tours would be allowed on a controlled basis, but should be carried out by qualified personnel. The area's role as a traditional hurricane refuge for decked vessels should not be terminated

The present study found that every one of the six stations sampled functioned as nurseries for all of the 21 fish species identified, based on their small (juvenile) size distribution and repeated presence over the two year duration of the study**.** East Hangman's Pont (Station 2) and Mammee Shoal (Station 1) appear to be especially important due to their higher species diversity and their location nearer the harbour mouth. The Port Royal mangroves with their adjacent seagrass beds should be protected. Notably, all six stations also functioned as refugia for invertebrates, such as swimming crabs and green sea urchins, suggesting that they are important in sustaining the stability and health of the food chains in the harbor near Port Royal at the very least, and possibly for the entire harbor.

Future Research

Future research on the nursery role of coastal areas should be conducted for a longer period with several other gear types in addition to trawls, and at several other sites, all around Kingston Harbour. Improved research design for any future project should include more purely seagrass sites similar to Mammee Shoal, in order to provide a better set of comparative data with that seagrass sites. The western portion of the Harbour is mostly unstudied up to the time of writing (summer 2008) since the 2005 to 2007 modifications to the area during Highway 2000 construction and is thus in need of investigation and monitoring in order to identify and follow any ecological changes due to the roadwork.

ACKNOWLEDGEMENTS

I thank Anita Rachel Pal and Gisele Ann Perry who both assisted me during the project. I am grateful to the Department of Life Sciences, University of the West Indies, and the Port Royal Marine Laboratory for use of its facilities, and I especially thank Terrence Hall of the PRML for his boating skills and information on the mangrove oyster fishery. This project was funded by a generous grant from the Environmental Foundation of Jamaica. I also thank Mr. D. Gayle of the EFJ and Miss J. Parchment of the Department of Life Sciences.

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