# Transplantation of benthic species to mitigate impacts of coastal development in Jamaica

Peter M.H. Gayle [1], Peter Wilson-Kelly [2] & Sean Green[2]

1 Discovery Bay Marine Laboratory, Centre for Marine Sciences, University of the West Indies, P.O. Box 35, Discovery Bay, St. Ann, Jamaica; peter.gayle@uwimona.edu.jm

2 National Environmental Protection Agency, 11 Maurescaux Rd. Kingston, Jamaica; pwilsonkelly@masaka.com, sean.green@uwimona.edu.jm

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**Abstract:** Maintaining regional competitiveness and economic viability for Port Bustamante - Kingston Harbour, Jamaica, required improved accessibility to "Post Panamax" (too large to pass through the Panama Canal) container vessels. Removal of the northern portion of the shallow coral reef at Rackham's Cay, which was partially obstructing the western end of the east ship channel, was proposed. This aesthetically valuable reef was used by local fishermen and comprises part of the declared Palisadoes – Port Royal Protected Area. The proposal to transplant certain of the benthic species was advanced to mitigate loss of viable reef components. Between December 2001 and February 2002, sixty thousand items, consisting of reef building massive and branching corals; gorgonians; urchins (*Diadema* and *Tripneustes* spp.) and *Thalassia* meristems were relocated. During dredging, sedimentation rates from suspended solids in the water column were 0.003 g/cm$^2$/day at the control site and 0.008 g/cm$^2$/day at the dredge site. Coral cover in the relocation area increased from 15% to 20% while bare substrate decreased from 27% to 21%. This paper documents the mitigation required; some factors controlling the ecology of Rackham's Cay reef; the methodology of the relocation process; and the level of post-dredging survivorship of relocated corals. Political and economic realities of some proposed developments often override ecological considerations. Transplantation of important marine benthic species although time consuming, technically challenging, and expensive, may be one way for developers and ecologists to achieve sometimes disparate goals. This project cost US$1.7 million. The "items" moved were neither unique nor endemic and remain vulnerable to natural and anthropogenic impacts. This project increased public awareness and interest regarding the ecological and economic importance of reef ecosystems. It is anticipated that future coastal and inland developments will benefit from the lessons taught by these mitigative interventions.

**Keywords:** Kingston Harbour, transplant, corals, impacts, dredging.

The East Ship Channel, providing the main access for large shipping traffic to Kingston Harbour was approximately 150 m wide and 13 m deep at its narrowest point between Rackham's Cay and Gun Cay. Larger "Post Panamax" ships (of 8000 TEU's [Transport Equivalent Units] and more) currently under construction, have beams in excess of 40 m and a draught of at least 14.5 m. They were only able to negotiate the corner around the tip of Port Royal with difficulty since they had to leave the main transit bearing for the centre of the channel, traverse a dog-leg in between Rackham's and Gun Cays and then make a deep turn to starboard to enter the harbour (Fig. 1).

The inherent risk of this manoeuvre during entry to or egress from the Harbour is confirmed by a record of repeated groundings that have occurred on Gun Cay and Beacon Shoal.

At the regional level, shipping activity has doubled in the last five years and is projected to triple over the next ten years. Vessels now under construction are larger than those currently in use. If Jamaica's Kingston Harbour port was to remain competitive with other

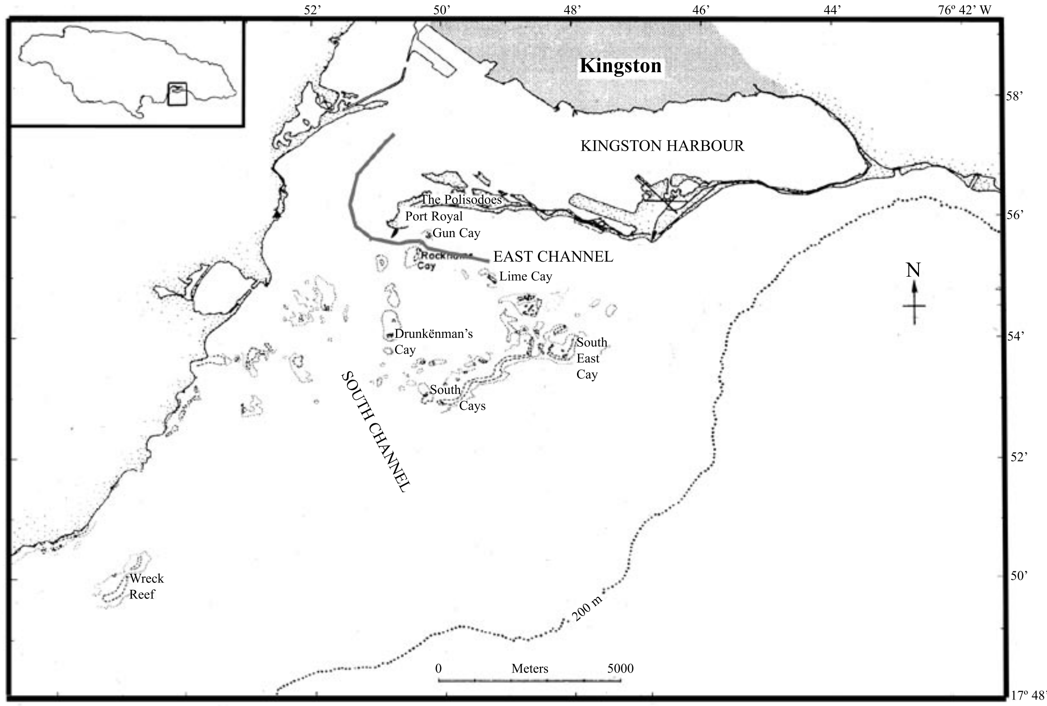


Fig. 1. Area around Rackham’s Cay. Arrow: point at which dog-leg manoeuvre around Rackham’s Cay is required by ships entering Kingston Harbour through the East Ship Channel.

regional ports and avoid significant loss of revenue to the country then the port facilities had to be upgraded. This included improving the accessibility of the port to larger ships. The choice of which channel to upgrade was primarily an economic decision. The South Ship Channel had more coral heads to remove and was generally shallower than the East Channel. It would require more modification than the East Channel which was generally deeper and most of the work would be concentrated in the vicinity of Rackham’s Cay. The lower cost and reduced level of environmental impact in the declared Palisadoes-Port Royal Protected Area, meant that modification of the East Channel was the rational choice. In the vicinity of Rackham’s Cay therefore, the proposal was to remove the northern portion of the cay (Fig. 2) so as to increase the width of the channel to 200 m and its depth to 18 m with a planned 1:1 slope along the newly created edge of the Cay. Dredge spoil was to be placed in shallow water adjacent to other cays in the protected area.

## Site and project description

Prior to the start of dredging June 8, 2002, some of the features controlling substrate composition around Rackham’s Cay included water depth; ambient light levels and level of disturbance from prop wash and wave action. The amount of substrate area receiving light is one of the most important limiting factors for coral reef ecosystems (Benayahu and Loya 1981, Schumacher 1988). This principle was demonstrated on the north side of the Cay where repeated passage of ships continually disturbed bottom sediments, ambient light levels were low at depth (1.5 m horizontal visibility at 10-15 m water depth) and little growth was observed except for the odd clump

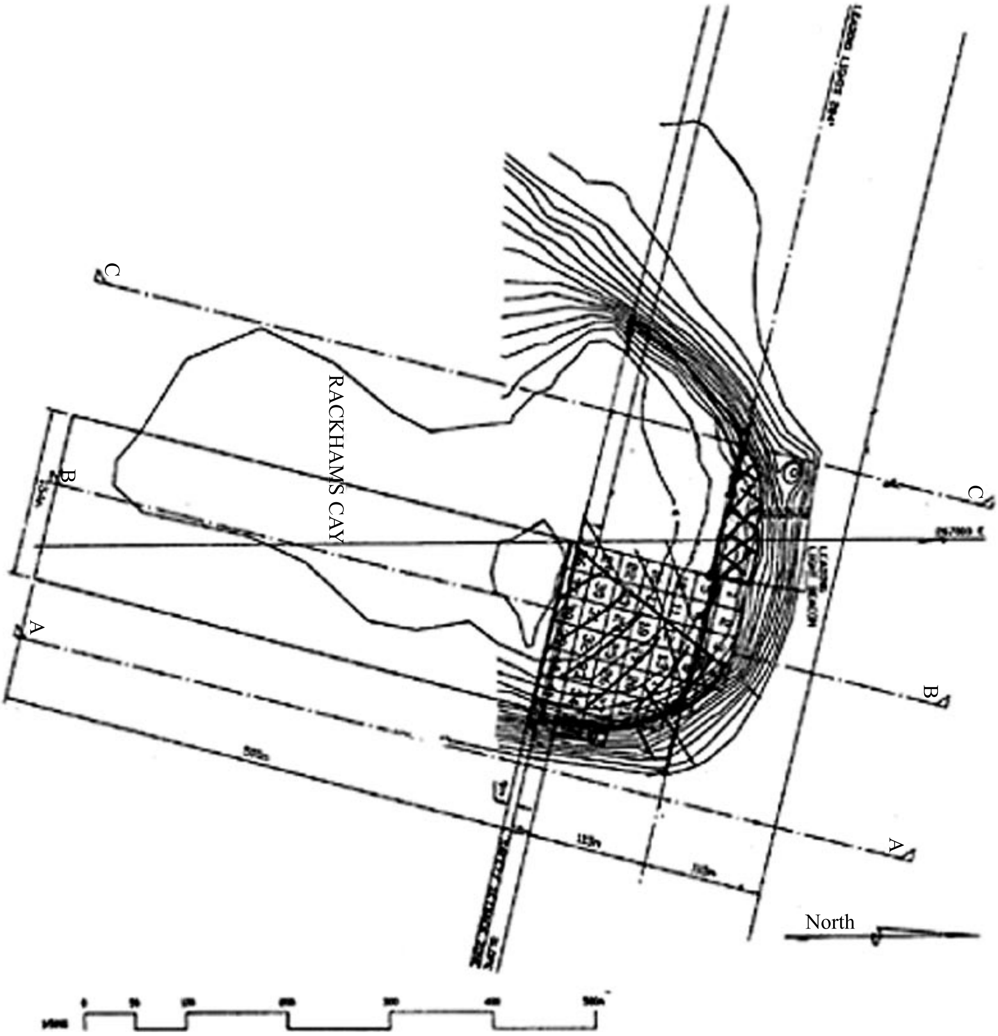


Fig. 2. Rackham's Cay prior to dredging: 600 x 300 m section to be removed.

of turf algae growing on the occasional lumps of coral debris left scattered over the unstable, soft, muddy substrate from previous episodes of dredging. At 15 m on the east side of the Cay, where the level of physical disturbance was less and the light levels were higher (4-5 m visibility), significant coral growth and associated benthic species occurred in patches. In shallower (6-10 m) water on both the east and north sides of the Cay, where light levels were still greater, a healthy reef community existed containing *Montastrea, Diploria, Siderastrea* and *Acropora* spp., numerous species of Plexauridae, Gorgoniidae, Zoanthidea and Demospongiae, *Diadema* and *Tripneustes* spp. and *Thalassia testudinum*. The problem was therefore whether or not to allow dredging of a productive reef community where the reef components would suffer immediate mortality and those nearby would be subjected to heightened levels of suspended solids in the water column for the duration of the dredging exercise. Some reef habitat (approximately 0.18 $km^2$ from the reef crest down to 18 m depth) would be destroyed by the dredge and therefore be permanently lost to fishermen.

EIA recommendations and mitigation required by the Jamaican Government-National

Environmental Planning Agency (NEPA) called for the relocation of sixty thousand items of benthic flora and fauna from the northern (channel side) part of the reef prior to the commencement of dredging operations. These items were to include massive and branching reef building corals (with >10 cm diameter of healthy tissue), all urchins (*Diadema* and *Tripneustes* spp.) and seagrass (*Thalassia testudinum*) meristems. They were to be moved from the immediate dredging area to other sites with physical characteristics similar to their places of origin so that their continued health and growth would, barring unforeseen circumstances, be facilitated.

## MATERIALS AND METHODS

A local company, Diving Technologies Ltd., was contracted by the Port Authority of Jamaica to carry out the relocation exercise in the few weeks remaining before the scheduled commencement of dredging activities. They used surface-supplied diving gas as well as SCUBA gear to support more than forty local, foreign, commercial and recreational divers. Flash cards, projector presentations and classroom lectures were used to teach the divers to differentiate between the various morphs of important reef building corals as well as gorgonians and other benthic species such as sponges and anemones. Training dives were carried out with team leaders to familiarize core personnel with the differences between healthy and diseased corals. These leaders were then expected to pass on this knowledge to their team members.

The divers were divided into collection and replacement teams and were given plasticized identification cards to facilitate ready recognition of coral species while underwater. Live reef-building and Acroporid corals >10 cm diameter, were prioritised for relocation based on the following criteria: i) those that would suffer immediate mortality from the dredging activity, ii) those that were not diseased or already suffering partial mortality, iii) those that could be moved without the use of special equipment – e.g. rock splitters or lift bags, iv) those requiring special equipment were to be considered on a case by case basis depending on how much of their living tissue was likely to be damaged in the relocation process.

In order to minimize disturbance of bottom sediments, corals were removed by divers wearing helmets and supplied with air directly from the surface and walking on the soft bottom using their hands or crow bars to detach the relatively labile coral heads from the muddy bottom substrate. Hydraulic drills, rock splitters and chain saws were used to cut large massive corals into manageable pieces for removal while minimising destruction of live coral tissue. Most corals were collected from the terrace at 7.5 m depth along the northern edge of the Cay. Other corals and gorgonians, which were mainly attached to larger boulders requiring mechanical means of detachment, were collected from the northeastern quadrant of the Cay at depths approaching 20 m.

One hundred metal baskets (2.5 m x 1.5 m x 1 m) were constructed and lined with a 5 cm thick layer of soft foam to protect against accidental abrasion with the sides of the basket during transport. The baskets were floated with lift bags so that specimens remained underwater at all times – thus minimizing handling by divers and the physiological stress from elevated temperatures and exposure to air. Full baskets were moved between collection and relocation sites during the early morning and late evening hours when the weather was calmest. This served to minimize the risk of toppling or rolling of the specimens inside the baskets and therefore of abrasion due to rough wave action. On the southeastern side of Rackham's Cay a large sandy patch (8 m depth) with little but sand and patches of seagrass in it was designated as the main relocation area where divers on SCUBA replaced the collected corals by wedging them in the sand between existing corals; pinning or epoxying their bases to hard/dead substrate; or casting the bases of larger pieces (*A. palmata*) in discs of marine cement approximately 0.3 m in diameter. Care was taken to replace corals, gorgonians and

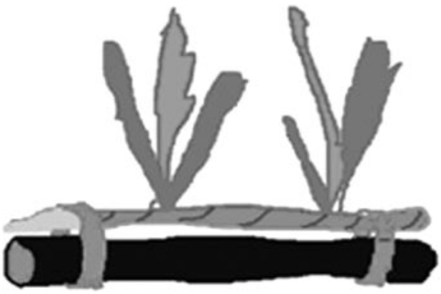

Fig. 3. Seagrass meristem unit secured to iron rebar using rubber bands.

urchins at a depth that was not greater than that from which they were initially taken (2-18 m depth) and to avoid placing antagonistic species of corals too closely together (*sensu* Lang and Chornesky 1990) or to facilitate temporal reversals (Chornesky 1989).

Seagrass meristems were dug from the muddy bottom sediments with the aid of a hand operated suction dredge. They were bundled into "units" consisting of two or three meristems held to a piece of iron rebar (0.7 cm x 15 cm - construction iron) with rubber bands to act as a weight (Fig. 3). These units were placed in a second relocation area, a sandy clearing to the south west of Maiden Cay (17º54'N and 76º48.8'W) with a unit placed at each 1 m x 1 m intersection within a 30 m x 30 m area. The pieces of rebar were buried approximately 5 cm in the sand to aid resistance to wave energy and to help maintain the upright orientation of the seagrass blades in the water column so as to facilitate growth.

Dumping of spoil was not permitted in the originally proposed sites adjacent to other cays in the Port Royal Protected Area. Dredged material was moved via a submerged pipeline to an irregularly shaped 0.56 $km^2$ site in the centre of the south channel adjacent to West Middle Shoal where the substrate was primarily soft mud inhabited by common polychaete worms and starfish.

An impact assessment carried out on this site indicated that the ecological impact of depositing dredged material (clean coral rubble) in this area would be negative and direct but short term and minimal in comparison to using other nearby sites within the Port Royal Protected Area. A silt curtain was placed on the eastern side of Rackham's Cay (east-west orientation) between the dredge site and the relocation area. A second silt curtain was placed in between West Middle Shoal and the area in the South Ship Channel where dredge spoil was dumped (Fig. 4). By this means it was hoped to minimize the effect of currents carrying sediment laden water from dredging activity over adjacent healthy corals and other benthic species.


Fig. 4. Positions of silt curtains and movement of sediment plume, 14 June 2002. Red arrow: direction of plume movement three days earlier.

Monitoring consisted of repeated examinations of several parameters, periodic onsite inspections, aerial surveys and photography; evaluating sedimentation rates, total suspended solids and turbidity, random video transects and post dredging monitoring of the health of selected transplanted individuals.

### Periodic inspections

These inspections involved diving with the working crews at the harvesting and relocation sites to ensure that the correct items were being selected for relocation, that the transport process minimised stress to the corals and that the replanting techniques being used were appropriate to the species concerned. Twice weekly aerial flights at 300 m to 450 m altitude were used to inspect and photograph sediment plumes created by the dredging activity. Silt screens were installed, or moved, as necessary to minimise the effect of turbid plumes of water on existing or newly created reef areas.

### Sedimentation rates

Sedimentation rates of material resuspended during dredging were determined using straight sided plastic jars (10 cm high x 8.3 cm diameter) secured to stakes and held at 50 cm and 10 cm above the substrate at four locations immediately adjacent to the dredge and dump sites and including a control site upstream of all dredging activity. This allowed the determination of the actual amount of sediment being transported in the water column (Settling Component) by the actual dredging in contrast to the amount of sediment being resuspended from bottom sediments (Bedload Component) by wave action. Sediment collection traps were placed at 3-6 m depths at Rackham's Cay, Gun Cay, West Middle Shoal and Drunkenman's Cay, the latter as the control site (Fig. 5). At six day intervals the jars were sealed at depth and brought back to the lab where the samples were filtered through a dried, pre weighed filter. After filtration, the filter paper was dried to

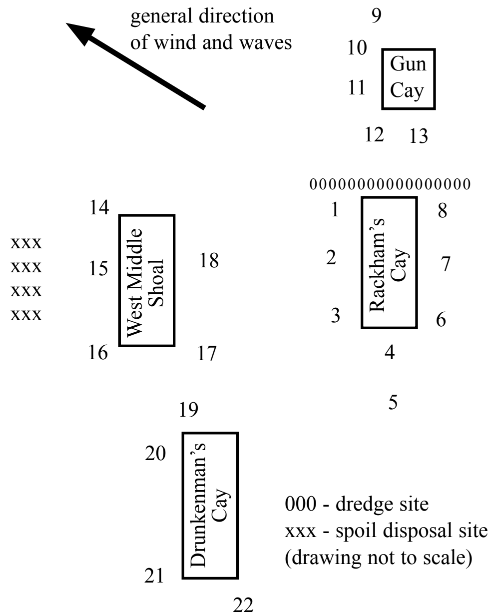


Fig. 5. Positions of sediment traps relative to dredge and dump sites and adjacent cays.

constant weight and re-weighed. Sedimentation rates were calculated as:

$$\frac{\text{weight of sediment x } \pi r^2}{\text{number of days deployed}}$$

where r = radius of the sample collection jar. Data from a total of twenty two trapping stations (n=66) were analyzed to identify significant differences between settling and bedload components from samples at, and between sites.

### Total suspended solids and turbidity

Water quality parameter such as Total Suspended Solids (TSS) and Turbidity were collected from eight stations near, adjacent to and upstream of the dredge site. Surface (T), mid-depth (M) and bottom (B) samples were collected using a Van Dorn sampler and analysed by the Geological Survey Division laboratory. TSS mg/l was determined by filtration of a known sample volume through a dried, pre


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weighed filter which was then dried to constant weight and re-weighed with TSS equalling the weight difference before and after filtration. Turbidity was determined colorimetrically and reported in FAU (formazine attenuated units) which incorporates a correction for colour.

**Post dredging survival**

Stratified random sampling of the relocation area was carried out using underwater video from eight transects each 25 m long and taken according to CPACC methods (Chevannes-Creary 2001). Image frames, 40 cm x 40 cm, were extracted from the videotaped transects and subjected to random dot analysis using ten dots per image, for the determination of substrate composition at approximately seven and eighteen month intervals respectively, post relocation.

Three hundred and fifty individual, relocated corals were tagged so as to track individual survivorship. Periodic video taping of transects from the seagrass and coral relocation sites is planned to continue for ten years after the cessation of dredging activities, to track the survival of relocated corals, gorgonians and the rate of infilling of the established seagrass bed.

## RESULTS

Moving a total 62 631 "items" required 9 720 underwater man-hours over 54 days from Nov 2001 to Jan 2002. This total consisted of 40 597 corals, including eight large colonies of *A. palmata* that were cemented in place, 12 404 urchins; 8 918 gorgonians and 712 *Thalassia* meristem units.

Aerial surveys documented the silt plumes and formed the basis of judgements regarding the placement of the silt curtains. The plume direction was determined by ambient wind and current direction which varied from day to day. Dredging took place for 18 days during the period June 8-27, 2002. During this time, general wave conditions rendered the silt curtains useless at both sites on several occasions (Fig. 4) because they were undercut by tidal driven.

Ranges of values of the Settling Component Sedimentation Rate (SCSR) and the Bedload Component Settling Rate (SCSR) at four locations are provided in Table 1. At three of these locations, (Gun Cay, West Middle Shoal, Drunkenman's Cay) neither the SCSR nor the BCSR mean values exhibited any significant statistical differences among samples (t-Test: $t<T_c$). In each of these three cases, however, a statistical difference was found between the SCSR and BCSR mean values (t-Test: $t>T_c$), indicating that wave action was stirring up bottom sediments in these areas and adding to potential stress from sediments that corals and other flora and fauna may have been experiencing. In all three of these cases, suspended sediments appeared to originate from bottom sediments, and this stress was therefore not regarded as directly attributable to the dredging activities and was assumed normal for the area.

The situation at Rackham's Cay was different. The means of the SCSR and he BCSR indicated no significant differences within their groups, just as at the other sites, neither did they indicate differences between SCSR and BCSR rates, unlike the other sites (t-Test: $t<T_c$).

TABLE 1
*Settling Component Sedimentation Rates (SCSR) and Bedload Component Settling Rates (BCSR) at monitoring stations*

| Location | SCSR g/cm$^2$/day | BCSR g/cm$^2$/day |
|---|---|---|
| Drunkenman's Cay | 0.0007 – 0.0071 | 0.0088 – 0.0228 |
| West Middle Shoal | 0.0036 – 0.0126 | 0.0038 – 0.0358 |
| Gun Cay | 0.0008 – 0.0151 | 0.0091 – 0.0581 |
| Rackham's Cay | 0.0001 – 0.0176 | 0.0001 – 0.0176 |

Sediments arriving in the water column were comparable to those stirred up from the bottom by wave action, indicating that dredging in the vicinity was impacting the amount of sediment arriving via the water column. It was assumed that this situation was not the norm for the area (Table 1). These results are consistent with aerial survey observations of dense sediment plumes around Rackham's Cay, while the plumes at Gun Cay and West Middle Shoal were lighter in colour or shorter in duration, and none were observed at the Drunkenman's Cay control station.

The results presented for Total Suspended Solids (Table 2) indicate a range of 2-298 mg/l for all the stations monitored and are typical of those obtained throughout the monitoring period when the dredge was working at Rackham's Cay. The NEPA-proposed Coral Reef Standard for suspended solids is 10 mg/l. The highest values were obtained from samples taken at the dredge and dump sites.

Seven months after completion of the relocation exercise and one month after the dredging was finished, data from the random video transects indicated that coral cover at the relocation site was 5% more than it had been prior to the relocation exercise. Eleven months later, or 18 months after completion of relocation and

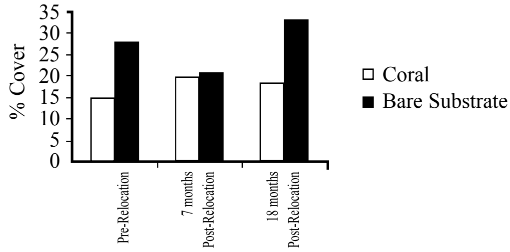


Fig. 6. Changes in coral and bare substrate composition at Rackham's Cay Coral Relocation Site before and at seven and 12 months after dredging.

12 months after dredging, coral cover at the relocation site was almost the same (18.5%) as it was at the previous monitoring period (Fig. 6). No data are available for the gorgonians, urchins or seagrasses that were moved.

## DISCUSSION

Sedimentation and water quality data indicate that the actual sediment load was less than might have been expected from the visual impression of merely looking at the aerial photographs. Rogers (1990) indicates that sedimentation rates of 2 $mg/cm^2/day$ are tolerable for coral recruits while rates above 10 $mg/cm^2/day$ are tolerable for most coral

TABLE 2

*2 Monitoring for Turbidity (TUR) and Total Suspended Solids (TSS) at Rackham's Cay/Dump Site, Jun 18, 2002.*
*T – surface sample; M – middle sample; B – depth sample; FAU = Formazine Attenuated Units*

| Station | Location | Depth (m) | TUR (FAU) | TSS (mg/l) |
|---|---|---|---|---|
| 1T | Bow of the Da Vinci (Towards land) | - | 35 | 39.0 |
| 1M | Bow of the Da Vinci (Towards land) | 8.0 | 74 | 36.0 |
| 1B | Bow of the Da Vinci (Towards land) | 17.0 | 97 | 110.0 |
| 2T | Dump Site (West side of pipe) | | <14 | 8.5 |
| 2M | Dump Site (West side of pipe) | 8.0 | <14 | 17.0 |
| 2B | Dump Site (West side of pipe) | 15.0 | 509 | 298.0 |
| 3T | Dump Site (Western edge) | | <14 | 20.0 |
| 3M | Dump Site (Western edge) | 7.0 | <14 | 2.0 |
| 3B | Dump Site (Western edge) | 13.0 | 260 | 128.0 |
| 4T | Dump Site (East side) | | <14 | 17.0 |
| 4M | Dump Site (East side) | 7.0 | 14 | 29.0 |
| 4B | Dump Site (East side) | 13.0 | 17 | 10.0 |
| 5T | Bow of Da Vinci (Towards reef) | - | 353 | 255.0 |
| 6T | Rackham Cay at screen (Landward side) | - | <14 | 17.0 |
| 7T | Rackham Cay at screen (Reef side) | - | <14 | 9.5 |
| 8T | Rackham Cay along S.E. border – restoration site | - | <14 | 16.5 |
| 8Ta | Duplicate | - | <14 | 23.0 |

species. The maximum sedimentation rate of 0.0088 g/cm$^2$/day in this program is well below the levels quoted and did not appear to have any significant, negative, long-term impact on corals or other benthic components at the relocation site. The exposed nature of the site as well as the fact that dredging operations were not continuous, but were discontinued at night, also reduced sedimentation and facilitated the natural ability of corals to remove sediments from their surfaces.

Many of the relocated corals, especially the Acroporids, initially showed evidence of some stress in the form of partial bleaching, but recovered within a matter of days and have continued to survive. Aerial photographs taken on June 27, 2002, approximately 12 hr after dredging ceased at Rackham's Cay showed that the plumes had dissipated so that the cut line was clearly visible.

The shape of Rackham's Cay at the end of the dredging exercise is radically different from the start of the project. An almost straight edge (Fig. 7) and vertical face along its northern border exposes the layers of partially cemented coral rubble comprising the substrate.

Beginnings of colonisation are now being seen on this cut face with gorgonians, ascidians and various encrusting sponges now being found on the exposed pieces of rubble at varying densities. Presumably these are highly dependent on the amount of surface light able to filter through the turbid channel waters to reach the particular depth on the cut face. The cut face was supposed to have a 1:1 slope. This is not evident. Two terraces (each 2-3 m wide) at 10 m and 14 m depth respectively form breaks in the face of the cut that has a slope of between ten and twenty degrees from the vertical instead of the planned forty five degrees. The long-term stability of the cut face of the Cay will need to be carefully monitored.

Transplantation of benthic reef species with a view to the restoration of areas damaged in some way (e.g. ship groundings) or to protect flora and fauna in areas scheduled for dredging or other destructive activity is not a new concept (Jaap 2000). Bouchon *et al.* (1981) cite several instances where US Federal and State Agencies have rescued corals from areas about to be dredged. Harriott and Fisk (1988) summarised results of five transplantation studies

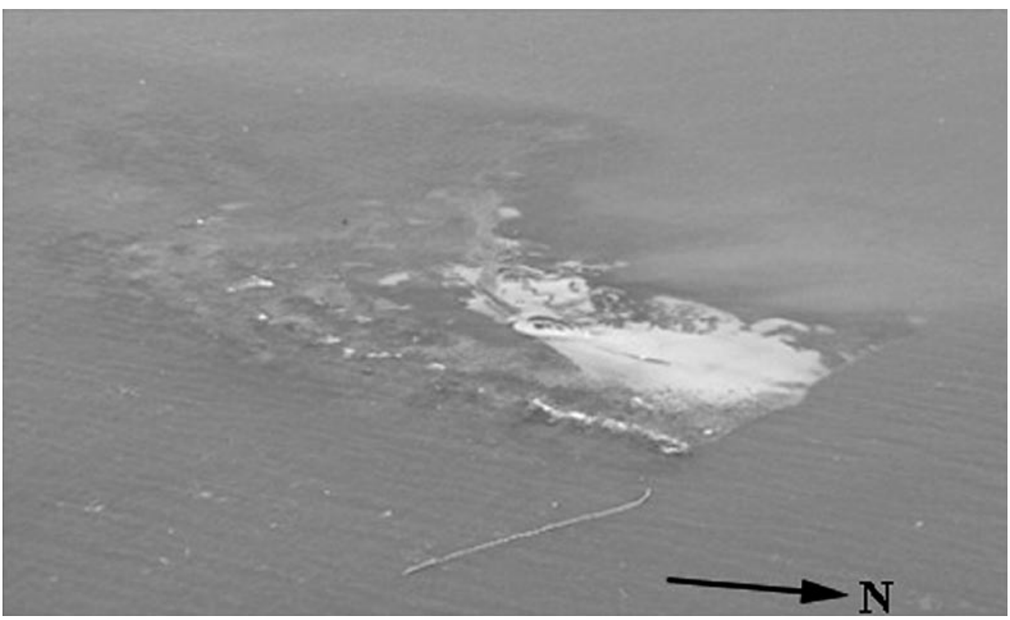


Fig. 7. Present day view of Rackham's Cay with northern tip removed.

and concluded that despite a 1-100% range for survival, the success of the effort depends on the species moved, environmental conditions, the type and shape of the transplant and whether or not they were attached to the substrate. At least three small coral transplantation projects have been expressly required in Jamaica by NEPA in recent years. One project took place in Discovery Bay as the result of a beach development proposal while the others occurred in Ocho Rios and Montego Bay as part of activities surrounding the installation of a marine outfall for a new sewage treatment plant and fibre optic communication cables at each site, respectively. Unfortunately, they were extremely limited in scale and no monitoring of these events has taken place since their occurrence.

The relocation project reported here cost US$1.7 million and despite previous projects of its kind, represents a landmark case in Jamaica's environmental process in terms of the location involved, the number of items moved and the money spent on the project. It can be safely regarded as the first significant attempt at mitigation by Jamaican environmental professionals who took the lead in calling for this type of mitigation and received full support from their Government counterparts. It is worth differentiating between the actual ecological and socio-economic gains realised by this exercise and the expenditures made to secure them. None of the "items" that were relocated to other areas were endemic or particularly unique to Jamaican waters. In their present location they are still vulnerable to both natural and anthropogenic impacts. However, there now exist a heightened public and corporate awareness as well as stakeholder interest regarding the sensitivity and vulnerability of our nearshore marine life to adverse impacts and the need that exists to offer as much protection as possible through serious efforts at mitigation. Having set a precedent with this action, it is likely that future mitigation can address some of the issues discussed by Jaap (2000) who suggested some appropriate alternatives to restoration, namely, improving navigation aids, public education programs, restoration on orphaned sites, adjacent area restoration and research in restoration and monitoring.

## CONCLUSION

For the first time, significant action has been required and subsequently undertaken to mitigate the negative impacts associated with a large-scale development project taking place under close public scrutiny in Jamaica. The exercise showed that it was possible to educate nonscientific divers to quickly and efficiently recognize specific benthic species underwater and coordinate their activities so as to move these species with techniques that minimized physiological stress. Attempts to minimize stress during the relocation process appear to have been effective. Enough of the corals have survived to be able to significantly increase the percent cover of coral at the relocation area. Data on their long-term survival will be critical to the proper evaluation of the real success of this project so as to facilitate the answering of the three basic questions posed by Jaap (2000), i.e.

- Are the transplanted organisms still secured to the reef?
- Is the vitality of the transplanted organisms equivalent to the organisms in the reference sites?
- Is recruitment similar in the restored areas and the reference areas?


## ACKNOWLEDGMENTS

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## RESUMEN

Para mantener la competitividad regional y la viabilidad económica del Puerto de Bustamante - Kingston Harbour, Jamaica, se requería mejorar la entrada de buques de contenedores "Post Panamax" (nombre dado a los buques que son demasiado grandes para pasar por el canal de Panamá). Se propuso remover la parte norte del cayo coralino Rackham que obstruía parcialmente el lado oeste del canal del este. Este arrecife, estéticamente valioso, era usado por pescadores y forma parte del Área Protegida Palisadoes – Port Royal. Se propuso transplantar algunos organismos bentónicos para mitigar las pérdidas de elementos arrecifales. Entre diciembre 2001 y febrero 2002, se reubicó unos 60 000 organismos de corales constructores de arrecifes masivos y ramificados, gorgonaceos, erizos (*Diadema* y *Tripneustes* spp.) y meristemos de *Thalassia*. Durante el dragado las cantidades de sedimentos en suspensión fueron de 0.003 $g/cm^2$/día en el sitio testigo y 0.008 $g/cm^2$/día en el sitio de dragado. La cobertura de coral aumentó en el sitio de reubicación de 15% a 20% mientras que el sustrato desnudo disminuyó de 27% a 21%. En este trabajo se documentan los requerimientos para la mitigación; algunos factores que controlan la ecología del arrecife del Cayo Rackham; la metodología del proceso de reubicación; y el nivel de supervivencia de corales reubicados. Es común que se dé más importancia a consideraciones políticas y económicas de algunas propuestas de desarrollo que a las consideraciones ecológicas. El transplante de especies marinas bentónicas importantes, aunque consume mucho tiempo, es técnicamente desafiante y costoso, es una forma en que los "desarrollistas" y los "ecologistas" pueden alcanzar objetivos dispares. Este proyecto costó EEUU$1.7 millones. Los organismos trasladados no eran únicos ni endémicos y siguen siendo vulnerables a impactos naturales y antropogénicos. Sin embargo, este proyecto aumentó la percepción e interés en la importancia ecológica y económica de los arrecifes coralinos. Se anticipa que futuros proyectos de desarrollo costeros y de tierra adentro se van a beneficiar de las lecciones aprendidas durante esta intento de mitigación.

**Palabras clave:** Puerto de Kingston, transplantes, corales, impactos, dragados.

## REFERENCES

Benayahu, Y. & Y. Loya. 1981. Competition for space among coral reef sessile organisms of Eilat (Red Sea). Bull. Mar. Sci. 31: 514-522.

Bouchon, C., J. Jaubert & Y. Bouchon-Navaro. 1981. Evolution of a semi artificial reef built by transplanting coral heads. Tethys 10: 173-176.

Chornesky, E.C. 1989. Repeated reversals during spatial competition between corals. Ecology 70: 843-855.

Chevannes-Creary, M. 2001. Caribbean Planning for Adaptation to Global Climate Change. Component 5: Coral Reef Monitoring for Climate Change Impacts. Benthic Features Manual – Jamaica.

Harriott, V.J. & D.A. Fisk. 1988. Coral transplantation as a reef management option. Proc. 6th Int. Coral Reef Symp. Australia 2: 375-379.

Jaap, W.C. 2000. Coral reef restoration. Ecol. Engin. 15: 345-364.

Lang, J.C. & E.C. Chornesky. 1990. Competition between scleractinian reef corals: a review of mechanisms and effects, p. 209-252. *In* Z. Dubinsky (ed.). Ecosystems of the World, Vol. 25 Coral Reefs. Elsevier, Amsterdam, Netherlands.

Rogers, C.S. 1990. Responses of coral reef and reef organisms to sedimentation. Mar. Ecol. Prog. Ser. 62: 185-202.

Schumacher, H. 1988. Development of coral communities on artificial reef types over 20 years. Proc. 6th Int. Coral Reef Symp. Townsville 2: 379-384.