Comparison of Sedimentation in Bays and Reefs below Developed versus Undeveloped Watersheds on St. John, US Virgin Islands

Sarah C. Gray, Kimbrie L. Gobbi & Trish V. Narwold
Marine Science and Environmental Studies, University of San Diego
(sgray@sandiego.edu)

FIGURES & TEXT FROM POSTER PRESENTATION AT THE 11th INTERNATIONAL CORAL REEF SYMPOSIUM; FT. LAUDERDALE, FL, JULY 5TH-11, 2008.

PURPOSE

Coral stress response to sedimentation depends on the type and the quantity of sediment. Here we present preliminary data from an ongoing study to evaluate if development on St John, US Virgin Islands has impacted the quantity, quality, and spatial variability of sedimentation in four bays with fringing reefs—one below a developed watershed (Fish Bay; **Fig. 1D**) and three below undeveloped watersheds located within the VI National Park (Great Lameshur, Reef, and Hawksnest Bays; **Fig. 1 C, E, F, G**). We targeted our sampling to examine locations with monitored reefs and locations that were sampled 20 years ago by Hubbard et al. (1987). St. John, USVI is an ideal location to study the impacts of sedimentation on coral reefs because: a) there is a distinct delineation between developed and undeveloped watersheds due to the VINP; b) sediment originating from land (terrigenous & siliceous) is mineralogically distinct from marine (carbonate) due to the lack of terrestrial carbonate sources; and c) the fringing reefs on the island are well monitored.

RESEARCH QUESTIONS

1) What is the composition and quantity of suspended, settling (sediment trap), and accumulated (bay-floor bottom) sediments?
2) How does the sediment composition (mineralogy) and quantity:
   a. Vary spatially within each bay along pathways of sediment dispersal and among the bays?
   b. Vary temporally during the study period (August-November, 2007)?
   c. Compare to 20 years ago?

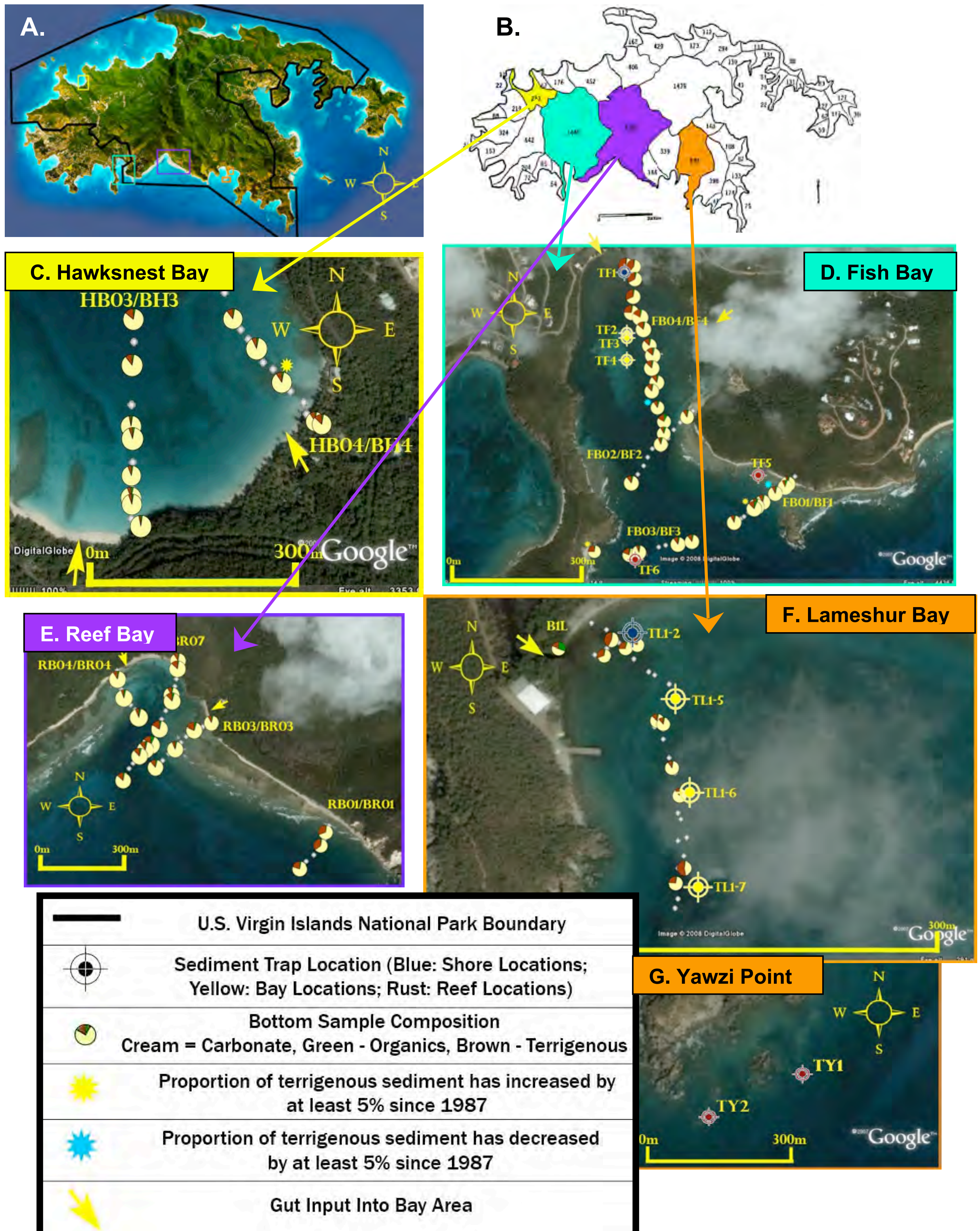


FIGURE 1. Location maps and sampling stations. A) Map of St. John showing the boundaries of the VI National Park (black) and the sampling locations (colored boxes). B) Watersheds draining into study areas: C) Hawksnest Bay; D) Fish Bay (Developed Bay); E) Reef Bay F) Great Lameshur Bay; G) Yawzi Point; and.

METHODS

Transects generally followed sediment runoff dispersal routes from guts (seasonal streams) into bays and across fringing reefs. Bottom sediment (upper 3 cm) transects closely replicated the sampling locations of Hubbard et al. (1987) in Fish, Reef and Hawksnest Bays. The variations in settling sediment (flux rates) were determined by deploying 14 sediment trap arrays (each with 4 exchangeable PVC tubes (length:diameter >4) attached to a metal stake 60 cm above the bay floor in Fish and Lameshur Bays **(Figs. 1 D, F, G)**. Sediment accumulation was monitored after 8 sampling periods ranging in duration from 7-23 days between August-December of 2007. Sediments from three PVC tubes were filtered, rinsed, dried and weighed to provide replicate measurements of the dry mass of sediment flux over the time deployed. Water samples were collected next to each sediment trap and filtered through a pre-combusted glass fiber filter (GF/F Whatman) to determine the total suspended sediment. The % organic matter and carbonate was determined by Loss on Ignition (LOI) at 550^{o}C and 950^{o} C, respectively. A subset of samples was sieved to determine the variation in mineral composition with grain size.

RESULTS

SEDIMENT FLUX & TOTAL SUSPENDED SEDIMENT (TSS): Unseived sediment flux rates ranged from less than 1 to 400 mg/cm^2/day **(Fig. 2)**. The greatest sediment flux rates occurred between 11/4/07-11/17/07 when rain and mean wind speeds were highest **(Fig. 2)**. Total mean sediment flux rates for the shore, bay, and reef stations were significantly higher in the developed (Fish) compared to the undeveloped bay (G. Lameshur Bay) **(Fig. 2)**. Compared to the flux rate at the undeveloped stations, mean sediment flux rates were up to 73, 16, and 94 times higher on the developed reef, bay and shore stations, respectively **(Table 1)**. Regression analysis showed that 72% of the variance in the sediment flux could be attributed to which bay (developed or undeveloped), rainfall, distance from gut, daily average wind speed, and trap depth. Sediment flux rates on reefs below the undeveloped watershed (Yawzi Reef) were consistent with rates recorded for reefs not subjected to human activities (<1-10 mg cm^{-2}d^{-1}: Rogers, 1990) and sediment flux rates on the reefs below the developed watershed were sometimes high enough to be considered dangerous to the corals (Riegl and Branch 1995, Philipp and Fabricius 2003) **(Fig. 2)**. Mean total suspended sediment for the season ranged from 0.004 to 0.02 g/L and was significantly higher at the developed compared to the undeveloped shore and bay stations.

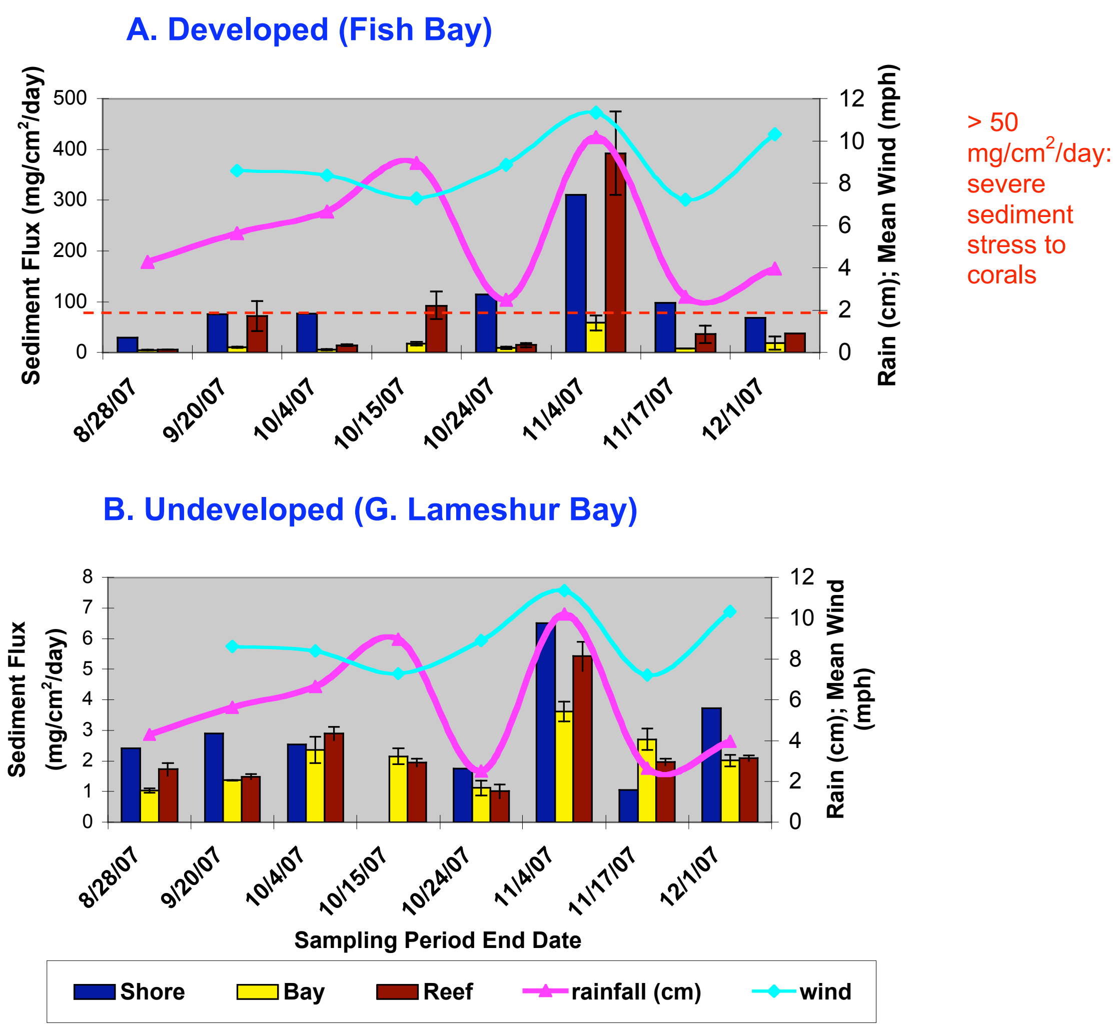
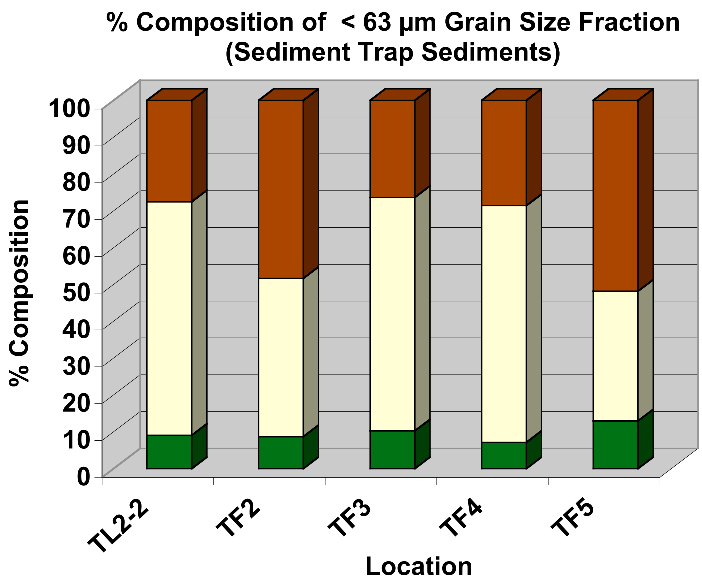


FIGURE 2. Variation in sediment flux with time (Fall 2007) and rain and mean wind speed in the A) developed and B) undeveloped watershed.

Table 1. Ratio of unsieved sediment flux below the developed watershed (Fish Bay) to unseived sediment flux below the undeveloped watershed (G. Lameshur Bay) for each sampling period.

Sampling Period	28-Aug	20-Sep	4-Oct	15-Oct	24-Oct	4-Nov	17-Nov	1-Dec
Shore	12	26	30		66	48	94	18
Bay	4	8	2	8	8	16	3	9
Reef	3	48	5	48	14	73	18	18
Whole bay	**6**	**25**	**8**	**18**	**24**	**45**	**15**	**12**



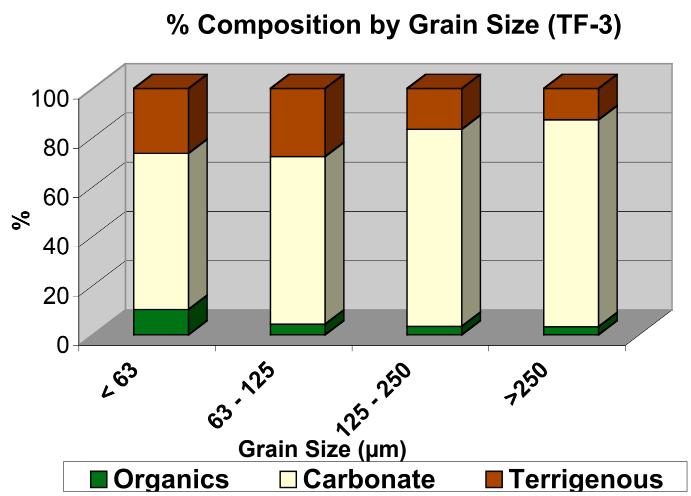


FIGURE 3. ABOVE) Mineralogic composition of the < 63 µm size fraction of select sediment trap samples. BELOW) Mineralogic composition of grain size fractions of a select sediment trap samples.

Table 2. Range of developed/undeveloped flux-rate ratios for each sampling period.

	Carbonate	Terrigenous	Organic
Bay	2 to 17	4 to 17	2 to 10
Shore	11 to 110	13 to 128	9 to 48
Reef	3 to 58	3 to 47	2 to 36

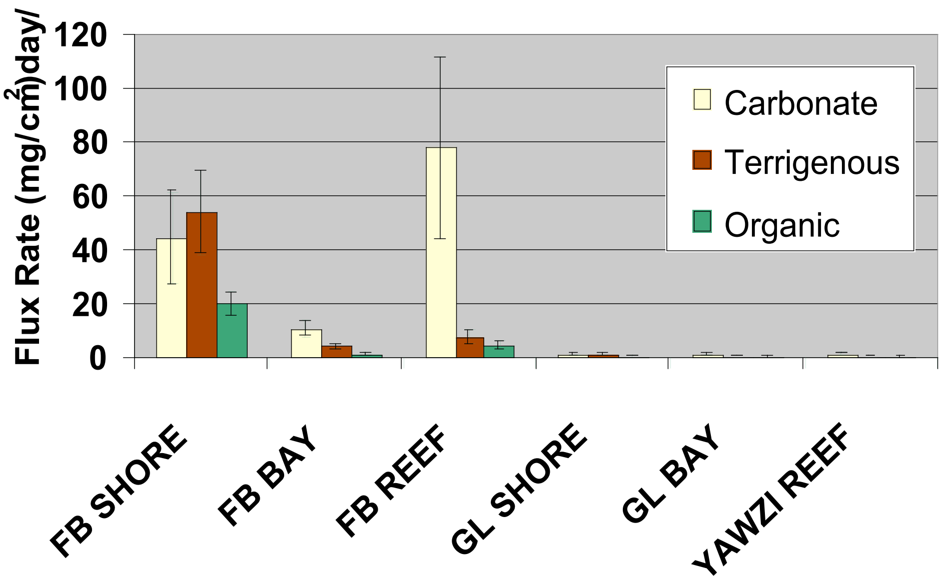


FIGURE 4 Mean seasonal flux rates for carbonate, terrigenous (siliceous) and organic matter. (FB: Fish Bay; GL: Great Lameshur).

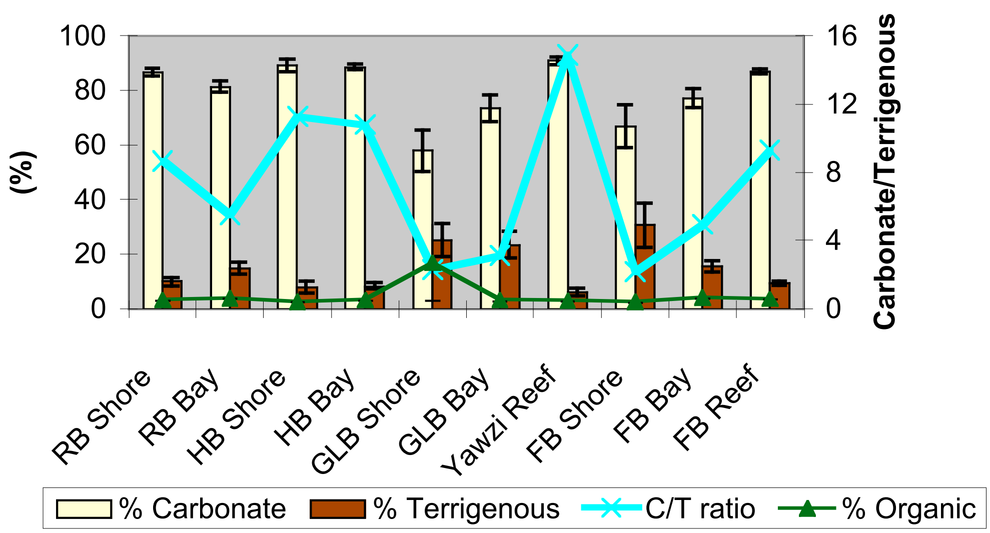


FIGURE 5. Mineral composition of the bottom samples and Carbonate/ Terrigenous ratios. (RB: Reef Bay; HB: Hawksnest Bay; GLB: Great Lameshur Bay; FB: Fish Bay).

RESULTS (CONT.)

SEDIMENT COMPOSITION (MINERALOGY): The mineralogic composition of the sediments did not appear to vary much between grain size fractions **(Fig. 3)**. Carbonate, terrigenous and organic matter was found in all grain size fractions suggesting that sieving is not an appropriate way to separate the terrigenous from the carbonate component. Carbonate was the most abundant constituent at all the bottom sediment and most sediment trap stations (except those nearest the shore) **(Figs. 1, 4 & 5)**. Mean carbonate, terrigenous, and organic flux rates were up to 110, 128 and 28 times higher, respectively at the stations below the developed compared to the undeveloped watershed **(Table 2)**. The % composition of organic and terrestrial material in the bottom sediments showed a significant decrease with distance from the shore/gut in Fish Bay, but not in the other bays. The ratio of carbonate to terrigenous material in the bottom sediments significantly increased with distance from the shore to the reef in both Fish & G. Lameshur Bays but not in Reef or Hawksnest Bays **(Fig. 5)**. The percentage organic matter differed between the three sediment reservoirs (suspended:36%-68%; trapped: 6%-23% and bottom: 2% to 4%) **(Fig. 6)** but was significantly higher in the sediments below the developed compared to the undeveloped watershed. Distinct compositional sediment flux ratios characterized sediments collected in each of the three environments (shore, bay, reef) **(Fig. 7)**. Although the compositional flux ratios from the developed and undeveloped stations overlap, the flux ratios from the developed bay (Fish Bay) show a much wider range of values than do those from the undeveloped bay (G. Lameshur Bay) **(Fig. 7)**.

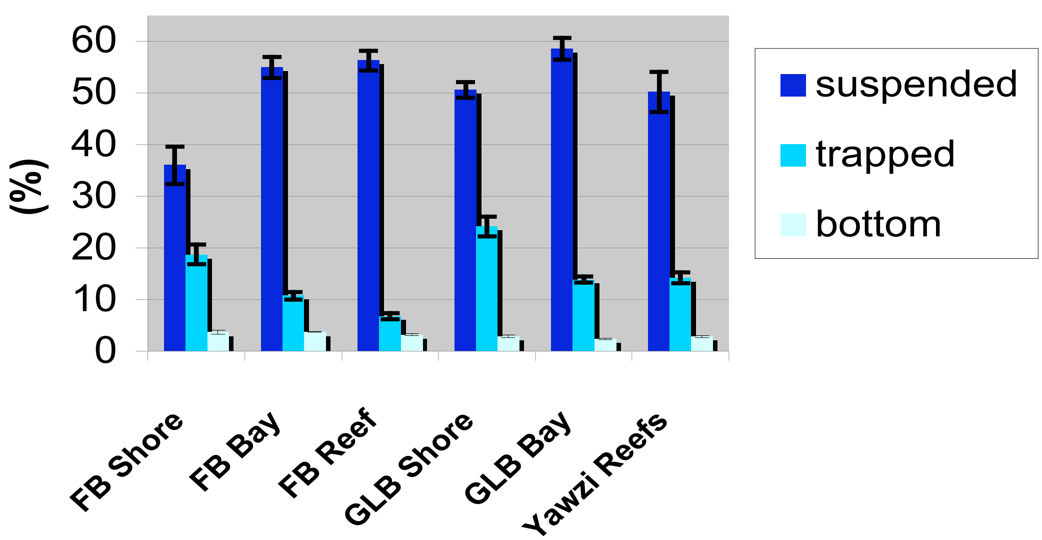


FIGURE 6. Mean % organic matter in three sediment reservoirs (suspended, trapped & bottom). (FB: Fish Bay; GLB: Great Lameshur Bay).

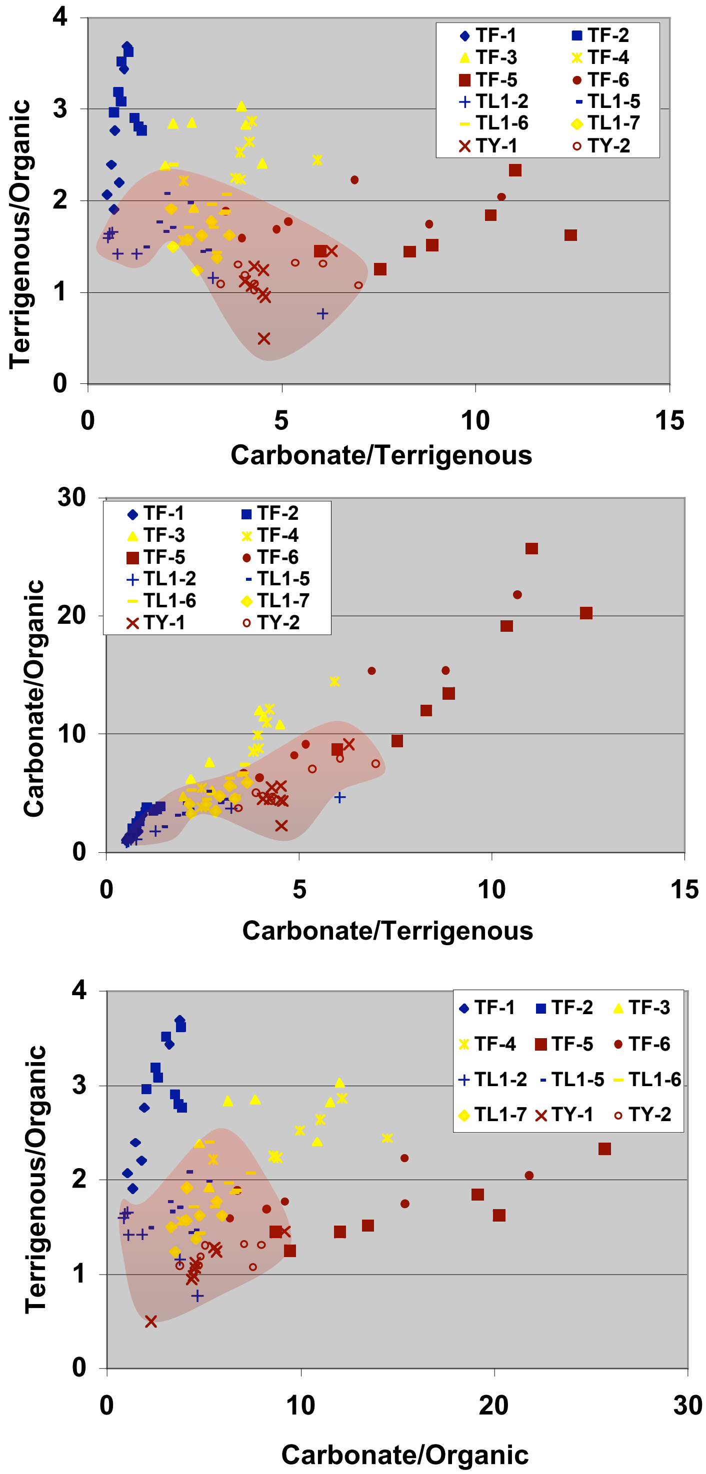


FIGURE 7. Distribution of compositional flux rate ratios for each sediment trap and sampling period. Blue points are shore stations, yellow are bay stations and rust are reef stations. The distribution shows distinct ratios for the reef (rust), bay (yellow) and shore (blue) environments, but a wider range of values for the developed compared to the undeveloped (shaded) stations.

RESULTS (CONT.)

CHANGES OVER 20 YEARS: Our preliminary comparisons show that the composition of bottom sediments has not systematically changed (within 5% relative %) since the Hubbard et al. (1987) sediment survey **(Fig. 1)**.

FUTURE RESEARCH

Continued analyses of the texture, mineralogy, organic matter, water chemistry and benthic substrate characteristics are underway for the 2007 data set. Sediment and storm water monitoring will continue through the rainy season of 2008.

ACKNOWLEDGEMENTS

Mike Fox, Kara Miller, Dr. Andrew Narwold, Jamie Irving, Virgin Islands Environmental Resource Station (VIERS). This project was supported by USD internal grants (University Professorship Grant; USD Summer Undergraduate Research Experience Grant; International Oportunities Grant) and the Project Aware Foundation.

REFERENCES

Hubbard, D. K., et al. 1987. Virgin Islands Resource Management Cooperative. Biosphere Reserve Research Report No. 21.
Philipp, E. and K. Fabricius. 2003. Journal of Experimental Marine Biology and Ecology 287: 57-78.
Riegl, B, and G.M. Branch. 1995. Journal of Experimental Marine Biology and Ecology 186: 259-275.
Rogers, C.S. 1990. Marine Ecology Progress Series 62: 185-202.