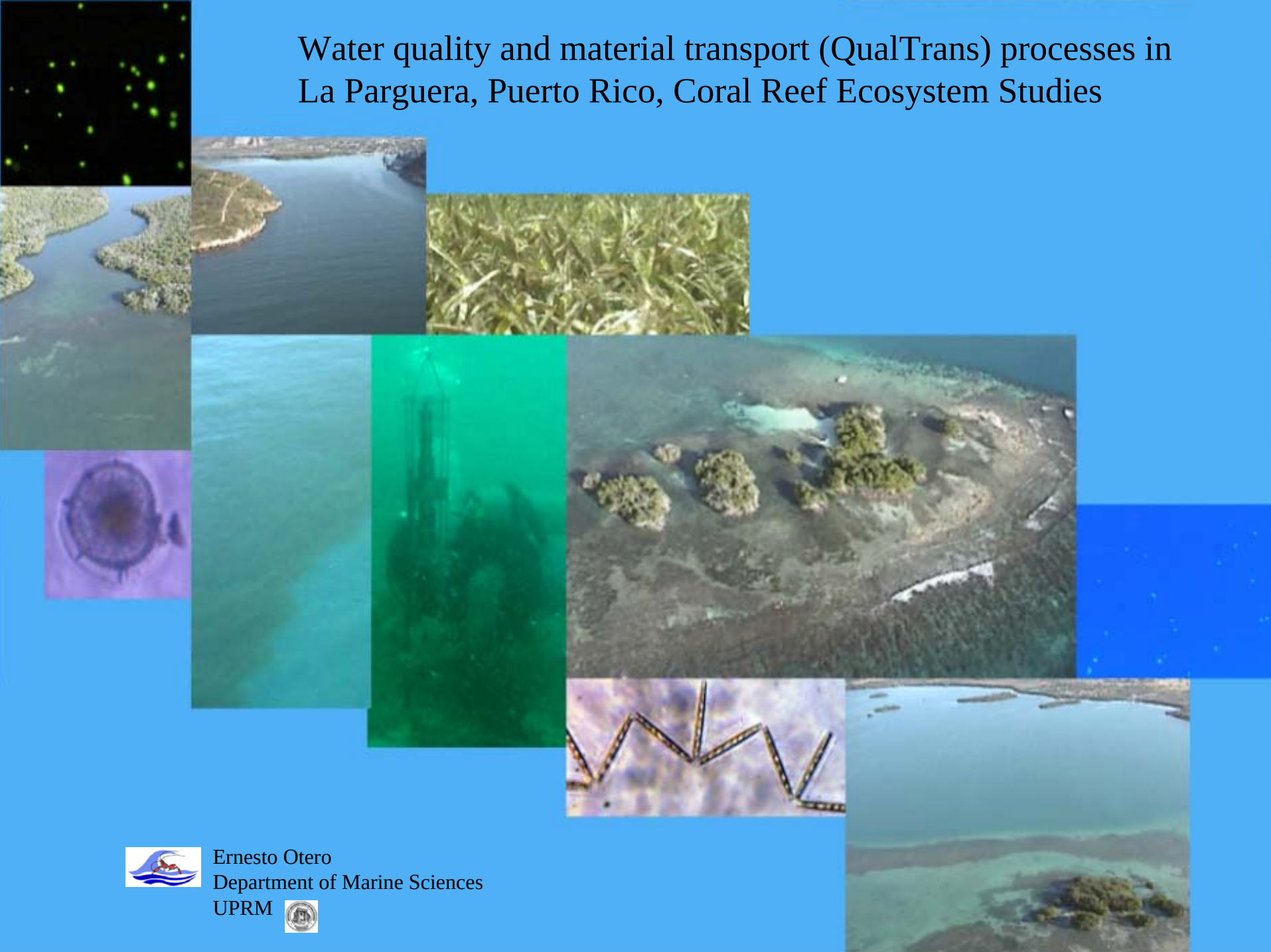
Water quality and material transport (QualTrans) processes in La Parguera, Puerto Rico, Coral Reef Ecosystem Studies



Ernesto Otero
Department of Marine Sciences
UPRM

Introduction

The coral reef ecosystem, far from being isolated, is adapted to external sources of materials supporting its biocomplexity through unclear connectivities. For example, salt water and soil salt concentration, soil types, hydrology, and rain patterns partially define the composition of mangroves in their watersheds. Similarly, watersheds, through rivers/creeks and estuaries, input materials to coastal waters that help define the state of coral reef ecosystems. Transported materials include, but are not limited to, nutrients, dissolved and particulate matter, and pollutants. These inputs are, in turn, affected by land-use and atmospheric patterns that impart spatial and temporal variability to coral reef ecosystems in this complex scheme. Other examples of coral reef ecosystem connectivities are fish grazing and migration, transport of larvae, and pathogen dispersal.

Objectives

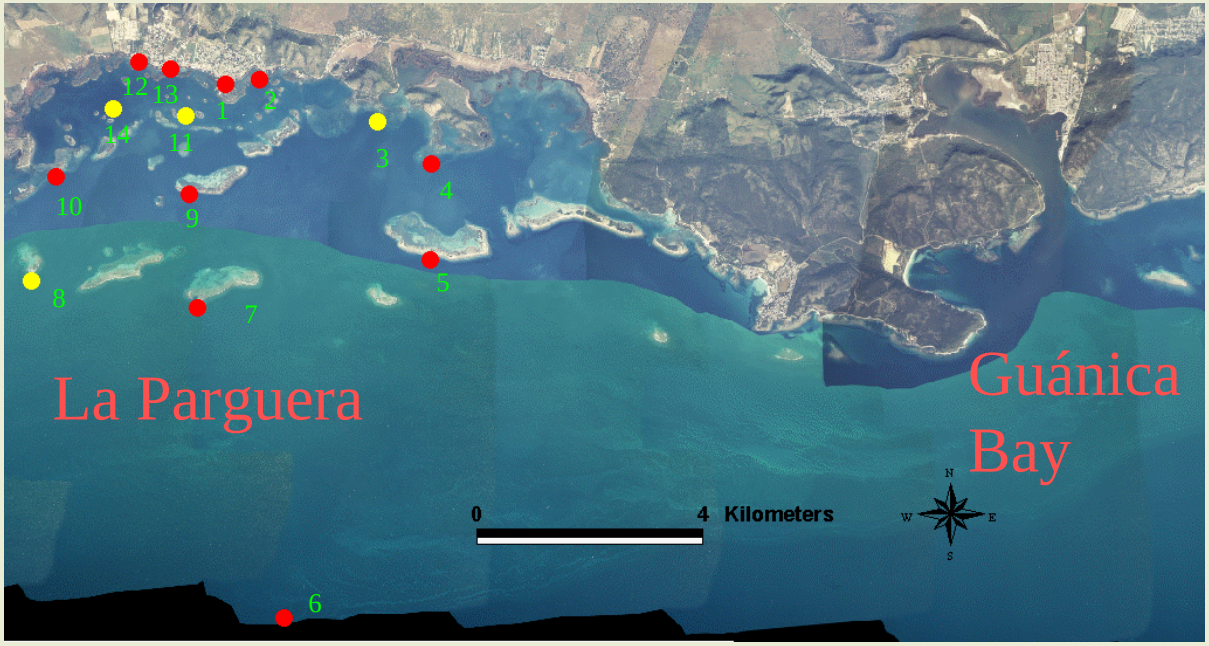
Studies of constituents present and processes occurring within the water column *habitat* of coral reef systems provide basic and important insights into the complex temporal and spatial interactions that significantly control productivity, stability, biodiversity, and health of coral reef systems. At present, there is a lack of concerted information in relation to the distribution of chemical and biologically significant components of the water column of the coral reef ecosystem of La Parguera Natural Reserve, one of NOAA's Coral Reef Ecosystem Study (NOAA-CRES) sites. This portion of the PR-CRES effort strives toward elucidating spatial and temporal patterns and variability in several water column parameters that result from environmental complexities such as inputs from terrestrial/coastal systems, redistribution of water constituents, and distribution and growth of microbiota. By assessing the spatial and temporal variations in water column components, this research will provide some of the knowledge base needed to understand the status of the biological assemblages found in the study area. In addition, this work will provide vital information related to the development of an integrated ecosystem approach to management of regional and local estuarine, coastal, and reef systems.

Methods

Location

Stations were selected to account for a large portion of the environmental variability in La Parguera. Consideration was given to land-ocean and longshore gradients (Fig. 1). Between 10 and 14 stations were sampled in this effort.

Fig. 1. Stations visited during water quality and material transport work. The predominant sources of materials are the local watershed of the town of La Parguera, mangroves, seagrasses, open ocean, and the nearby estuary of Guánica Bay.



Station Designation

1.Magueyes; 2. Náutico; 3. Bahía; 4. Matei; 5. Romero; 6. Veril; 7. Media Luna; 8. San Cristobal; 9. Enrique 10. Pelotas; 11. Caballo Blanco; 12. Varadero; 13. Ramp;14. Tres Marías.

- Serial-Semi-continuous Sampling and Single Time Multi-station Sampling
- Only Single Time Multi-station Sampling

Sampling Approach

Single Time Multi-station Sampling (SiTMusS): consists of collecting discrete water samples for a suite of analyses as well as *in situ* measurements at discrete stations over a short period of time (2-3 hours). These samples represent a quasi-synoptic view of the state of water column constituents and processes.

Serial Semi-continuous Sampling (SeConS): an *in situ* water quality monitoring system, anchored close to the bottom and moved to a different station every 48hrs. Chlorophyll *a* concentration data (phytoplankton biomass), turbidity, salinity, temperature, and depth (tidal stage) are collected.

Special Efforts (SE): sampling related to the expression of unpredictable atmospheric events on coral reef ecosystem water column constituents or other initiatives.

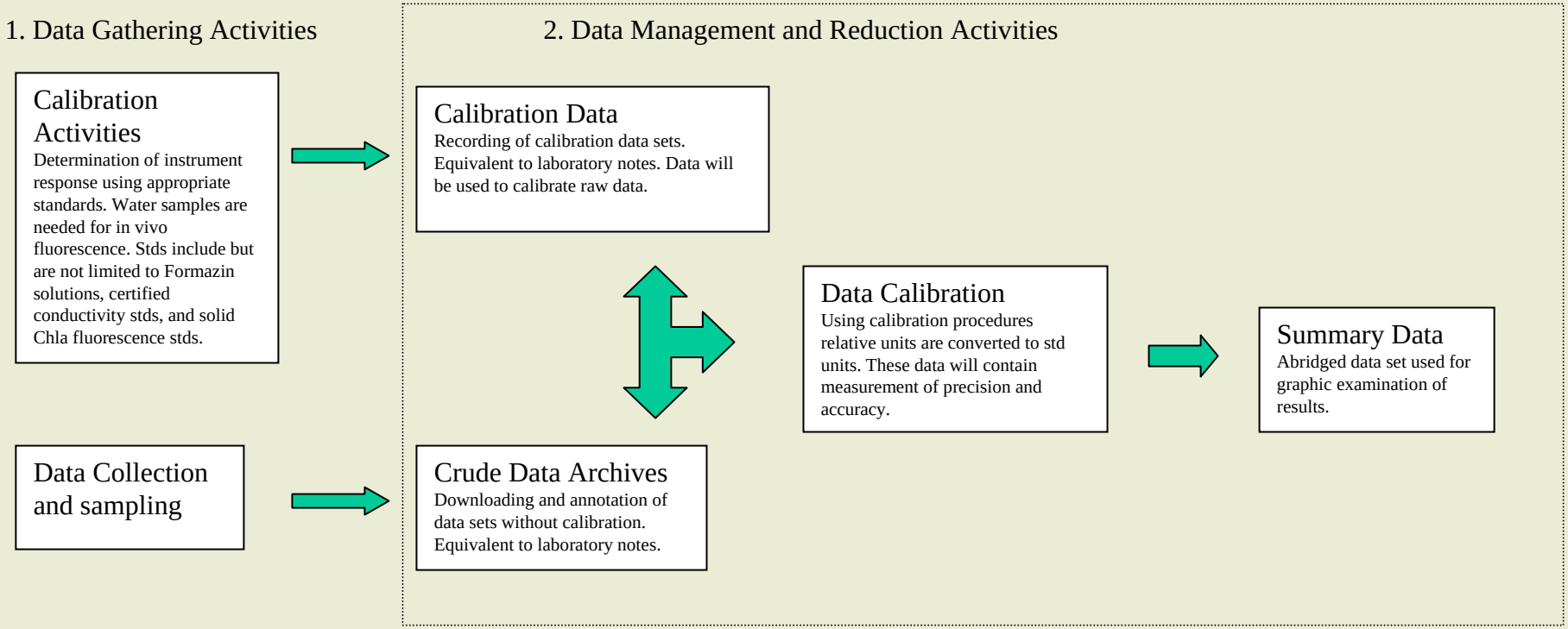
Table 1. Variables measured during each type of sampling. SE usually include only multiprobe data, suspended solids, and DOM fluorescence.

Type of Sampling	Analysis	Type of Analysis	Instrumentation
SiTMuSS	Salinity	Conductimetric	Multiprobe(Horiba AU22)
	Turbidity	Nephelometry	Multiprobe(Horiba AU22)
	Temperature	Termistor	Multiprobe(Horiba AU22)
	Chlorophyll a	Acetone Extraction Fluorometric	Spectrofluorometer (Hitachi SF2000)
	Bacterial counts	DAPI Epifluorescence	Olympus BX-41
	Unicellular Cyanobacteria	Autofluorescence	Olympus BX-41
	Total suspended solids	Dry weight Análisis	Analytical balance (4 dec places)
	Bacterial Production	Leucine Incorporation	Liquid Scintillation Counter (Beckman)
	Water Transparency	Attenuation of PAR	Cosine Par Collector (Licor)
	DOM Fluorescence	spectrofluorometric	Spectrofluorometer (Hitachi SF2000)
SeConS	In vivo Chlorophyll a fluorescence	In vivo fluorescence	SCUFA II (Turner Designs)
	Turbidity	Nephelometry	SCUFA II (Turner Designs)
	Temperature	Thermistor	DST-CTD (Star-Oddi)
	Salinity	Conductimetric	DST-CTD (Star-Oddi)
	Tidal Stage	Pressure	DST-CTD (Star-Oddi)

Data Collection and Processing

The data collection process is divided in various steps: instrument calibration, data collection and sampling, crude data archiving, management of data files and calibration, and development of summary data. This process is depicted in Fig 2.

Figure 2. Flowchart indicating activities and interaction between each step in the data collection and processing activities



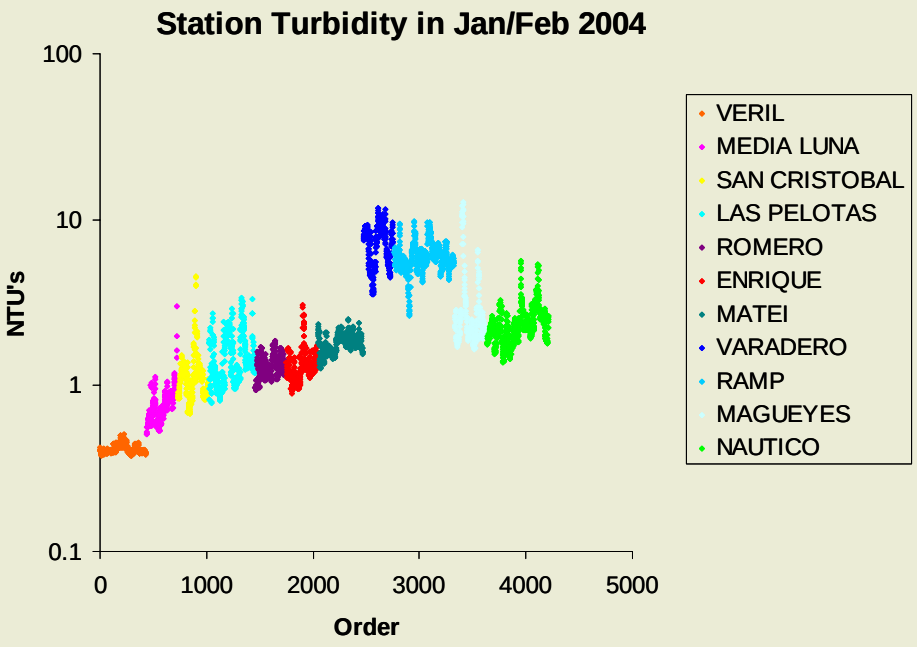
Summary of data collection activities from July 2003-2004

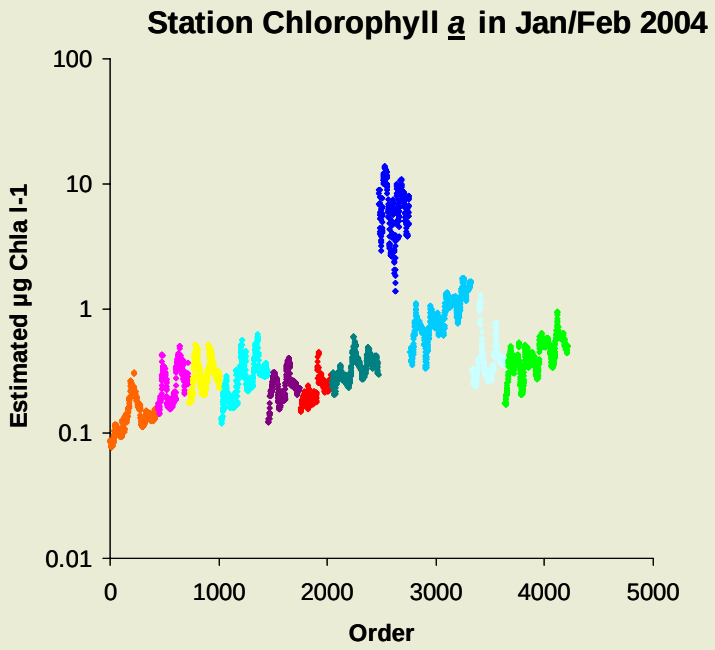
Date	Type of Sampling	Status of Data	Notes
July 2003	2	Final	No DST-CTD data
September 2003	3	Final	*Acropora cervicornis* regrowth assays
Sept-Oct 2003	1,2	Final	No CTD data
October 2003	3	Final	*Acropora cervicornis* regrowth assays
Nov Dec 2003	1,2	Final	
November 2003	3	Final	*Acropora cervicornis* regrowth assays; November rain events
December 2003	3	Final	*Acropora cervicornis* regrowth assays
Jan Feb 2004	1, 2	Final	
Apr May 2004	1,2	2nd revision	
July 2004	2	Raw	

1: SiTMusS; 2: SeConS; 3: SE

Data Product Examples

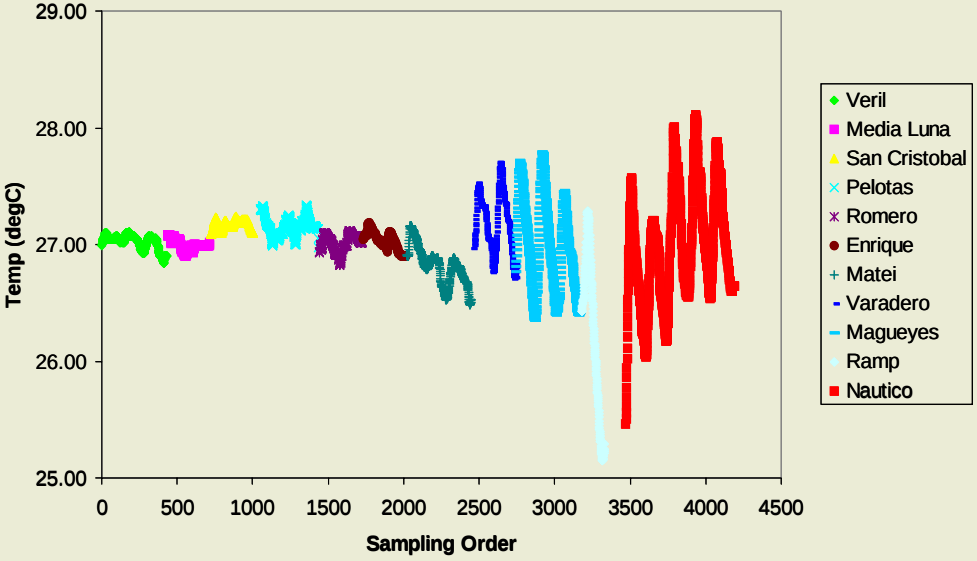
Turbidity and Chlorophyll at Different Stations. January and February 2004 Sampling (SeConSS data). Data interval is every 10 minutes starting January 23 – February 18, 2004. Notice daily variability in all stations for both parameters.



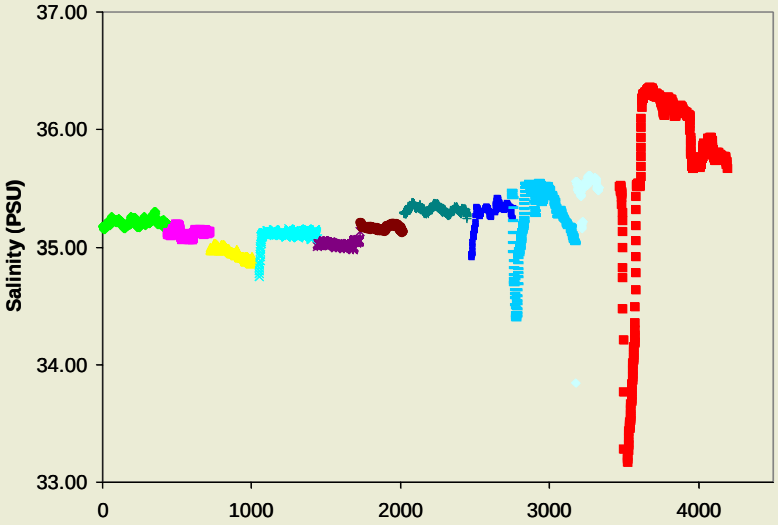


Temperature and Salinity at Different Stations. January and February 2004 Sampling (SeConSS data). Data interval is every 10 minutes starting on January 23 – February 18, 2004. Large fluctuations in temperature are associated with inner shelf stations. Larger fluctuations in salinity are due to rain events during this period, especially at inner shelf stations. These extreme salinity decreases can be associated with pollutant indicators such as fecal bacteria and nutrient enrichment.

Station Temperature during Jan/Feb 2004

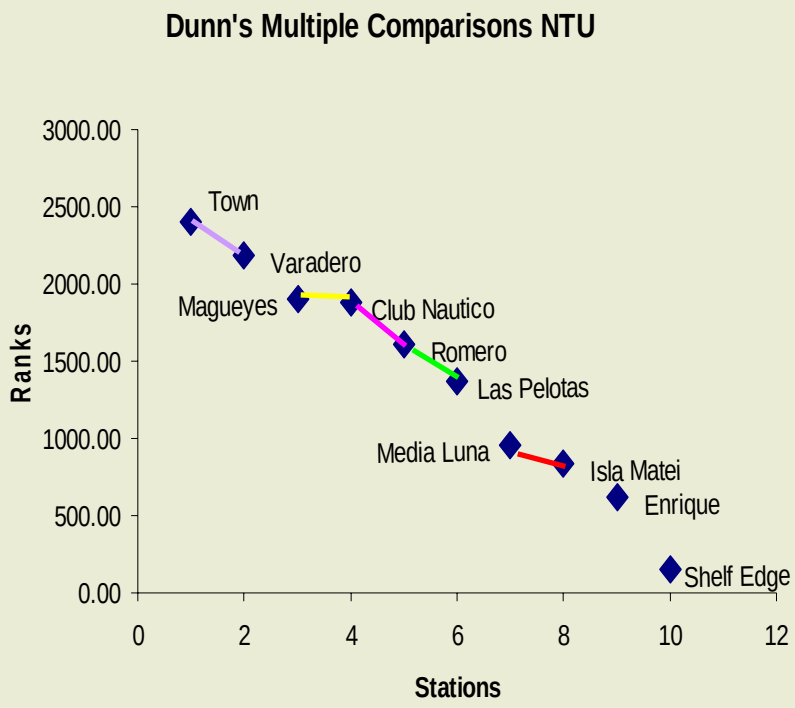


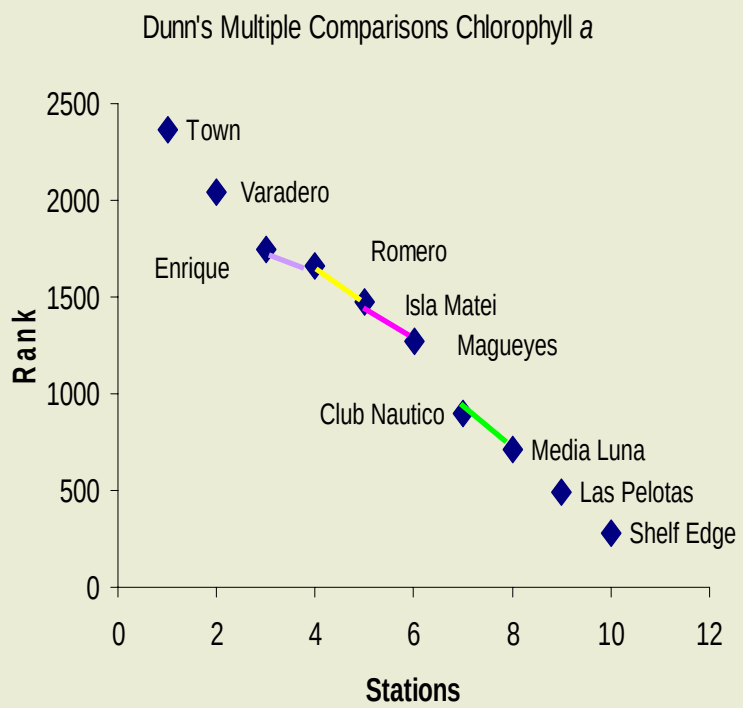
Station Salinity during Jan/Feb 2004



Similarity among Stations using Turbidity and Chlorophyll a data derived from SeConSS effort during July-August 2003 (Otero et al, 2003).

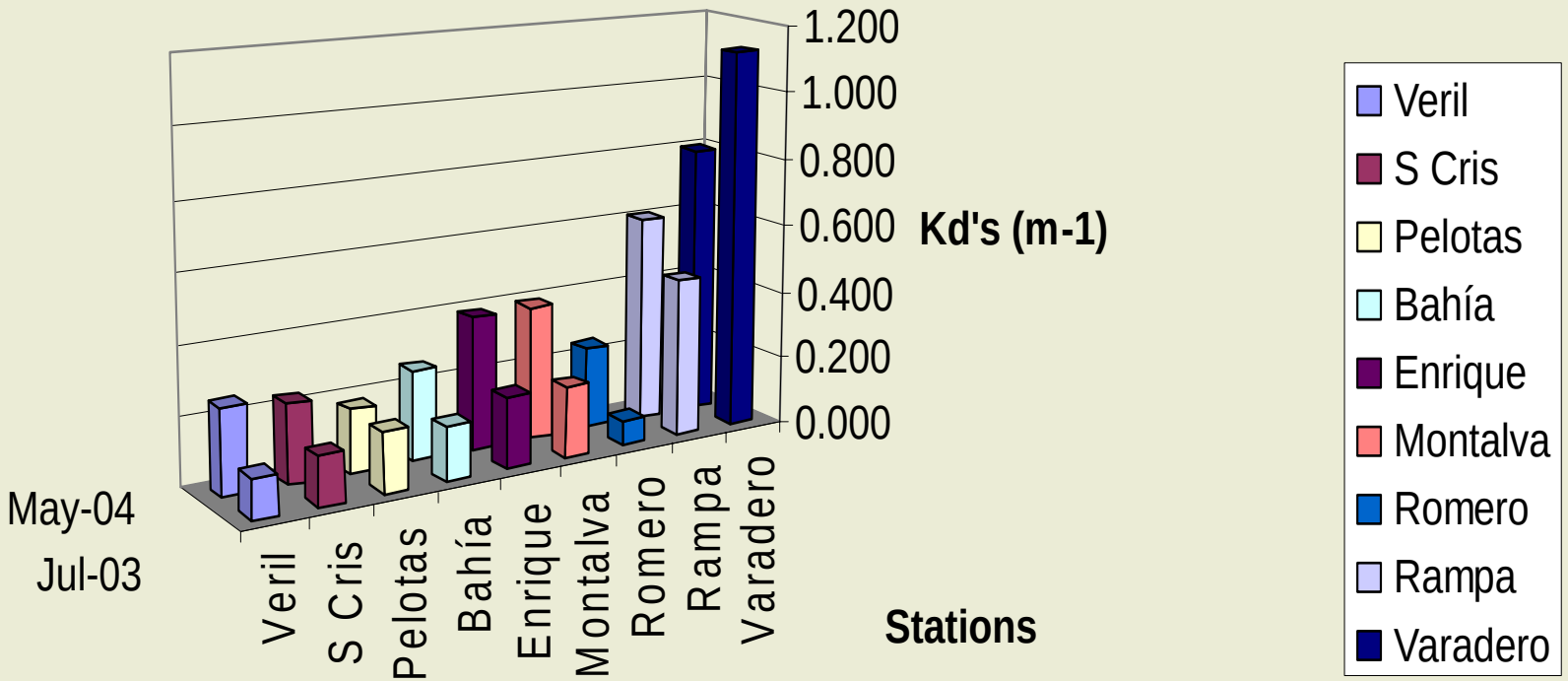
Analysis of similarity among different stations included diel variabilities within each station. Lines of different colors indicate stations that were not significantly different using Turbidity and Chlorophyll a analysis as indices. (The shelf-edge station = Veril in other graphs).



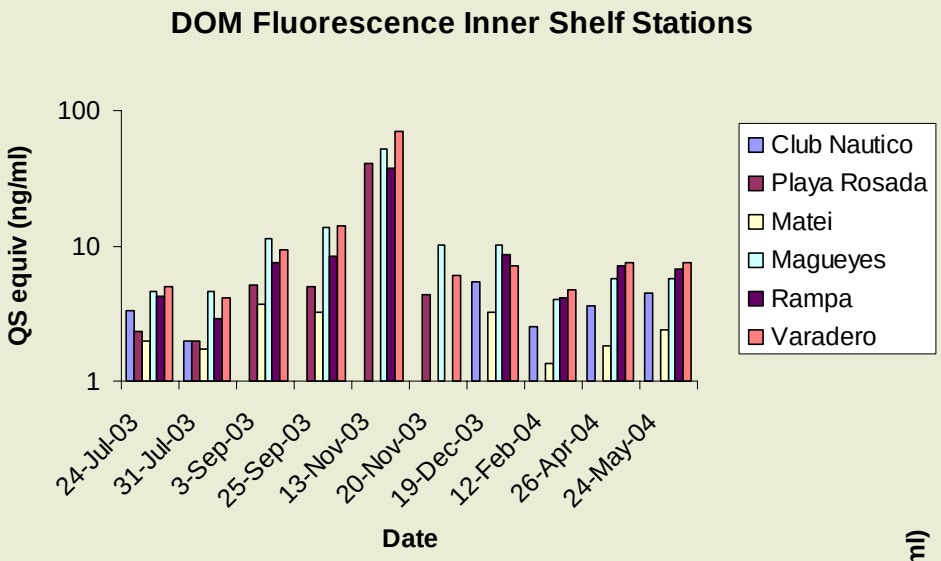


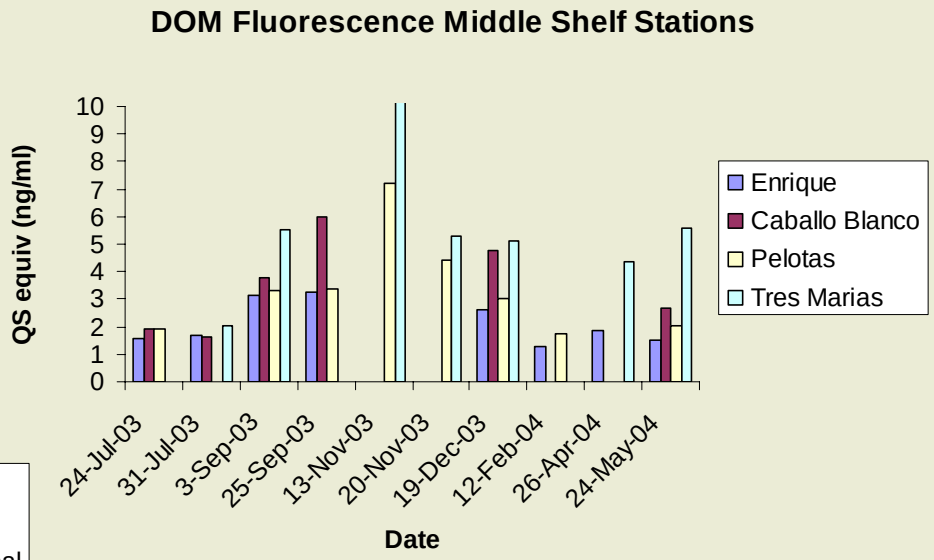
Apparent Attenuation Coefficients (Kd's) of Photosynthetically Active Radiation (PAR)

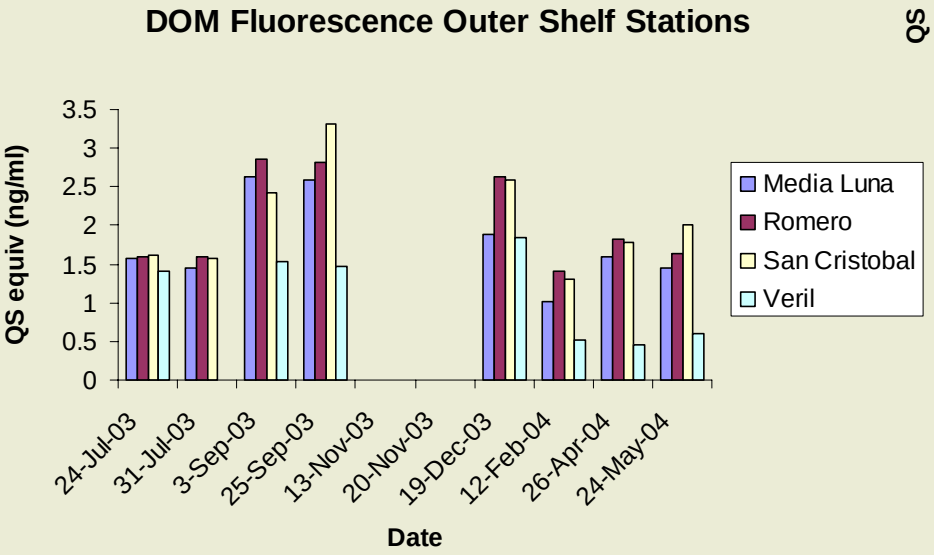
Variations in PAR attenuation at different stations in La Parguera control primary productivity and, therefore, affect corals and algae in coral reef systems. Estimates of Kd's during SiTMusS efforts allow the parameterization of such variations and further calculation of available light levels at different depths. For example, in July 2003 at the Veril station, 10% of below surface PAR reached 20 m depth while, in May 2004, it reached only 9 m.



Fluorescent dissolved organic matter (DOMFL) as quinine sulfate equivalents (QS equiv; ng/ml) from July 2003 to May 2004 at Inner, Mid and Outer Shelf Stations (SiTMusS and SE data)



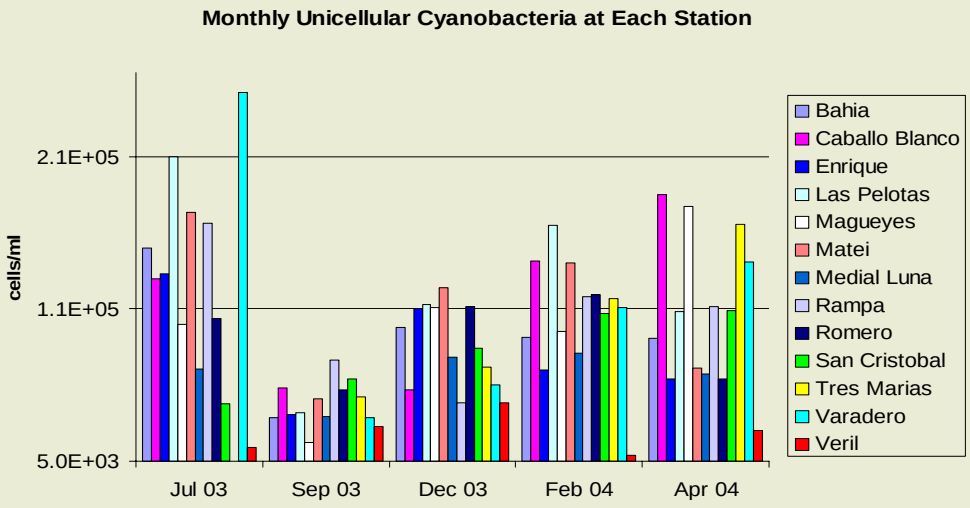


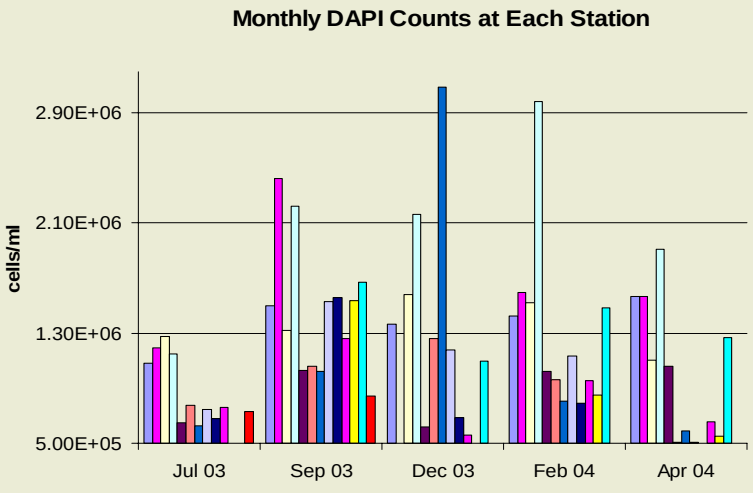


Inputs of organic matter from terrestrial/coastal systems can be traced by DOM FL measurements. There are significant variations in time and space suggesting different zones where terrestrial inputs are important. The maximum values of DOM FL are associated with November rain events.

Direct counts of microbial community components in water at La Parguera CRES sites.

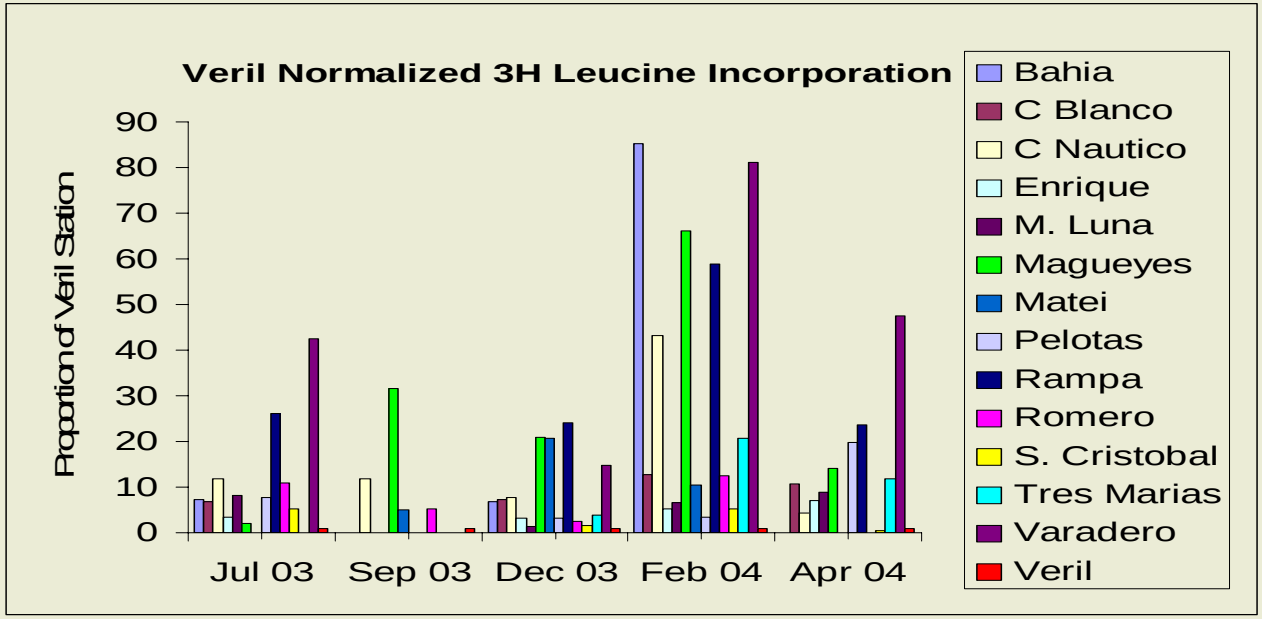
An important and abundant component of phytoplankton community, unicellular cyanobacteria (*Synnechococcus*-like) show significant temporal and spatial variations. Heterotrophic bacteria (DAPI counts) also show significant variations, independent of those of unicellular cyanobacteria. These communities respond to different environmental cues, including inorganic nutrients, organic substrates, and light regime.





Proportion of secondary production of heterotrophic bacteria at each station relative to that observed at Veril station

Temporal changes in bacterial growth in natural samples indicate changes in nutrient availability through the year. These changes may be produced by rain events or materials transported from other sources. Bacterial secondary production provides an index of bacterial activity in coral reef habitats. Differences were observed during the year. For example, bacterial growth was 12 times faster at the Bahia station and 3.5 times faster at the San Cristobal station during February 04 than during Dec 03.



Overall Results

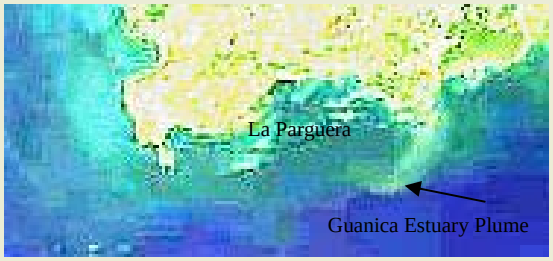
The Qual Trans effort of Puerto Rico CRES has established a series of time series measurements at 10-14 stations to help define the environmental regime in the local coral reef ecosystem in La Parguera.

All collected data show significant temporal and spatial variability in water constituents and processes that translate into complex dynamics in material transport.

Significant inputs of terrestrially derived matter are evidenced in inner and mid shelf stations during intense rain events such as during November 2003. These inputs persist for a few days after the events.

Preliminary data from Special Efforts coordinated during September through December 2003 demonstrated significant material inputs to outer shelf stations (such as Veril) from a system outside the PR CRES study area, probably Guánica Bay (García and Otero, 2004). Remote sensing imagery corroborates these findings. This is the first time such an *in situ* observation has demonstrated the presence of allochthonous inputs into La Parguera region. This approach will facilitate the quantification of this important connection between the systems of La Parguera and allochthonous material sources.

MODIS Image showing a plume of material moving in the direction of La Parguera days after intense rains. The expression of this plume in water constituents was observed during Qual Trans efforts. (Image Courtesy of Dr. Roy Armstrong)



Related Presentations

Otero, E., K. Carbery, L. Perez, and Y. Rivera. Chlorophyll *a* and turbidity patterns over coral reefs systems of La Parguera Reserve as derived from continuous water quality sampling. 31st AMLC Scientific Meeting 14-18 July 2003. Port of Spain, Trinidad.

Carbery, K., E. Otero-Morales and Y. Rivera-Torres. 2004. Spatial and temporal water quality monitoring among coral populations in La Parguera, Puerto Rico. XXIII Simposio Fauna y Flora del Caribe. 30 April, 2004. Humacao, PR.

Otero, E., K. Carbery and Y. Rivera. 2003. Monitoreo instrumental semi-continuo de calidad de agua de sistemas arrecifales de La Parguera, Puerto Rico. XXIII Simposio Fauna y Flora del Caribe. 30 April, 2004. Humacao, PR.

Rivera-Torres, Y., K. Carbery and E. Otero. 2004. Determination of Nutrient Limitation of Phytoplankton at La Parguera, Puerto Rico. XXIII Simposio Fauna y Flora del Caribe. 30 April, 2004. Humacao, PR.

Garcia-Urueña, R.d.P., and E. Otero. 2004. Natural short-term environmental changes, growth and survival of *Acropora cervicornis* as viewed through continued monitoring. 10th ICRS. 28 Jun-2 Jul 2004.