Baseline Characterization Of Bio-Optical Oceanographic Properties And Their Relation To The Diversity And Health Of Coral Reef Communities

Final Data Report

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1.0 Introduction

Measuring and monitoring the underwater light field is essential for coral reef habitat monitoring initiatives and to test the hypothesis that states that the health of these communities depend upon low transport of nutrients, sediments and other inanimate materials from the (1) land into the marine environment and (2) from nearshore to offshore areas within the marine realm. Significant changes in water optical parameters in coral reef areas can be due to: 1) sediment runoff or re-suspension of bottom sediments resulting from episodic events and 2) land-use changes in the drainage basins that affect coastal areas. Since land-use changes occur over decadal time scales and episodic events can be infrequent, long-term monitoring of water optical properties and sediment/nutrient loads are required to ascertain the impact of these factors in the community structure, diversity and health of coral reefs.

The use of remote sensing technology from aircraft and satellites has been proposed as a promising tool for monitoring coral reefs and assessing their health status. However, the limitations in spectral and spatial resolution of existing sensors and the confounding effects of variable water optical properties and bathymetry are significant obstacles for the implementation of this technology. Another way of inferring coral reef community structure and "health status" is through the characterization of surrounding water optical properties. I propose that before we attempt to use remote sensing as a monitoring tool for coral reefs, we must establish the relationship between *in situ* apparent and inherent optical properties and the coral reef parameters of interest.

The main objectives of this first year baseline research are:

1) Measure spectral reflectance properties of scleractinian corals.
2) Determine variability of apparent and inherent optical properties over coral reef areas.
3) Determine the community structure at these coral reef sites.
4) Correlate the attenuation coefficient of PAR ($Kd_{(PAR)}$) to the diversity and percent cover of living corals.
5) Establish relationships between light penetration, chlorophyll-a concentrations and phytoplankton-zooplankton taxonomic structure and abundance from coral reef systems in Puerto Rico.
6) Provide a general taxonomic survey of zooplankton and ichthyoplankton as an additional characterization of the biodiversity features of each reef system.

2.0 Methods

2.1 Bio-Optical Measurements

An optical package with the instruments described below was used to measure profiles of the apparent and inherent water optical properties. A CTD (Seabird SBE-19 with pump) measured temperature, salinity and depth. A WetStar fluorometer (from Wet Labs) measured chlorophyll fluorescence. The beam attenuation coefficient, c (λ), and

absorption coefficient, a (λ), was measured over nine wavelengths with an AC-9 meter (from Wet Labs). The backscattering coefficient, $b_b(\lambda)$, at six wavelengths was measured with a HydroScat-6 (from Hobi Labs). Profiles of downwelling irradiance of photosynthetically active radiation ($E_{d\ PAR}$) was obtained using a submersible radiometer (Model LI-1400 from Licor). These measurements were used to calculate the diffuse attenuation coefficient (Kd_{PAR}). Water-leaving radiance, $L_w(\lambda)$, and the above-surface downwelling irradiance, $E_d(0^+,\lambda)$, was measured using a GER 1500 portable spectroradiometer. Remote sensing reflectance (R_{rs}) was calculated from the ratio between $L_w(\lambda)$ and $E_d(0^+, \lambda)$.

Water samples were collected at several depths. Concentration of phytoplankton chlorophyll-a was obtained using the standard fluorometric method (Yentsch and Menzel, 1963). Total particulate absorption spectra, $a_p(\lambda)$, for samples collected on Whatman GF/F glass-fiber filters were measured with an integrating sphere attached to a GER 1500 portable spectroradiometer using the method developed by Mitchell and Kiefer (1984) and the optical-path elongation factor from Bricaud and Stramski (1990). Methanol-extractable pigments were removed by slowly passing hot methanol through the filter pad (Roesler et al., 1989). The absorption spectrum of this pad was measured to determine the detritus absorption coefficient, $a_d(\lambda)$. The difference between the particulate and detritus spectra, before and after the methanol extraction, is considered to be the *in vivo* phytoplankton absorption, $a_{ph}(\lambda)$. Optical absorption spectra of the colored dissolved organic matter (CDOM), $a_g(\lambda)$, was determined with a Perkin Elmer double-beam spectrophotometer following the method described by Bricaud et al. (1981).

Individula coral spectral reflectance measurements were obtained in aquaria using a GER-1500 spectroradiometer and a fiber optic probe. The probe was placed about 2 cm from the coral colony and the average of three spectral scans was used. This was divided by a reference scan from a Spectralon reflectance standard which was placed next to each coral colony in order to compute the reflectance factor of each coral colony.

2.2 Plankton Studies

Three stations, or reef areas were sampled from each site using a bongo net sampling system with integrated flowmeters and 308 μm mesh nets. At each station, or reef, three replicate samples were collected. The amount of filtered water on each tow was approximately 350 m^3. A total of 54 samples were collected during the cruise. Each sample was completely sorted for larval fishes and larval lobsters and each of the sorted larvae was identified to the lowest possible taxon. Zooplankton samples were also processed to determine the abundance and taxonomic composition of holoplankton and meroplankton. Two aliquotes of each sample were analyzed under a dissection microscope and averaged for determinations of abundance for each taxa. Aliquotes were adjusted to count at least 200 individuals of the most abundant taxa. Samples were fixed in 5 % formalin and sorted larval fishes will be kept in 95 % ETOH after fixation.

Taxonomic references for ichthyoplankton and larval lobsters can be found in Ramirez and García (1997) and Sabater and García (1997).

3.0 Oceanographic cruises

3.1 December 13-15, 2000 Cruise

An initial oceanographic cruise aboard the R/V Chapman was performed during December 13-15, 2000 to characterize bio-optical properties and plankton community structure at three coral reef systems located off western Puerto Rico. These were Mayaguez Bay, La Parguera and Desecheo Island. Three reefs were studied per site, for a total of nine reef stations occupied during this cruise.

CTD profiles of the entire water column were taken at each reef, except at North Reef in Desecheo Island, where conditions were inappropriate. Geographic coordinates and other supporting information for plankton samplings and CTD casts taken are presented in Table 1. Three replicate oblique plankton tows were taken using a bongo net system fitted with 308 um mesh nets. All plankton samples have already been sorted for fish larvae. One sample from each reef has been analyzed for larval fish composition and abundance. A total of 45 families of reef fishes have been identified so far from the samples analyzed from the nine reefs.

Profiles of inherent and apparent water optical properties, using the instruments described above, were obtained at each site. Profiles of downwelling irradiance were used to derive the attenuation coefficient of PAR (Kd_{PAR}) at each station.

Table 1. Sampling station data for the December 13-15, 2000 cruise.

Station	Depth (m)	Tow Duration In	Tow Duration Out	Flow Meter In	Flow Meter Out	Wire Angle	GPS Position Position In	GPS Position Position Out	CTD	Secchi (m)	Optics Cast Position
Mayagüez											
Media Luna	23										
23-12-surface									10:40	17 m	
R-1	23	11:24	11:27	1500	10328	55°	18°05.632 N 67°18.440 W	18°05.719 N 67°18.573 W			
R-2	23	11:27	11:33	870742	881798	60°	18°05.632 N 67°18.440 W	18°05.719 N 67°18.573 W			
R-3	23	11:33	11:38	361849	370570	50°	18°05.632 N 67°18.440 W	18°05.719 N 67°18.573 W			
Las Coronas	23								10:00	15 m	18°05.579 N 67°17.679 W
23-12-surface											
R-1	23	11:58	12:02	10328	20397	50°	18°05.527 N 67°17.456 W	18°05.780 N 67°17.439 W			
R-2	20	12:02	12:07	881798	891939	45°	18°05.527 N 67°17.456 W	18°05.780 N 67°17.439 W			
R-3	17	12:08	12:12	370570	377557	40°	18°05.527 N 67°17.456 W	18°05.780 N 67°17.439 W			

Tourmaline	42										
26-12-surface											
R-1	40	23:54	23:59	410567	422403	50°	18°10.254 N	18°10.250 N			
							67°17.008 W	67°17.143 W			
R-2	45	0:06	0:08	422403	431107	55°	18°10.238 N	18°10.248 N	14:25	22m	18°10.100 N
							67°16.446 W	67°16.590 W		14:30	67°16.921 W
R-3	45	0:17	0:21	431107	438938	50°	18°12.787 N	18°12.716 N			
							67°14.491 W	67°14.605 W			
Desecheo											
North Reef	30										
30-15-surface											
R-1	30	8:24	8:30	245558	267790	60°	18°23.664 N	18°23.747 N			
							67°29.449 W	67°29.711 W			
R-2	35	8:38	8:43	267790	275799	40°	18°23.730 N	18°23.627 N			
							67°29.493 W	67°29.495 W			
R-3	33	8:24	8:30	275799	284816	50°	18°23.457 N	18°23.369 N			
							67°29.568 W	67°29.648 W			

Station	Depth (m)	Tow Duration		Flow Meter		Wire Angle	GPS Position		CTD	Secchi (m)	Optics Cast Position
		In	Out	In	Out		Position In	Position Out			
Puerto Canoas	30								10:50	30m	18°22.808
25-12-surface											67°29.327
R-1	27	9:03	9:08	302234	309635	50°	18°23.055 N	18°23.009 N			
							67°29.629 W	67°29.740 W			
R-2	37	9:18	9:23	294593	302234	50°	18°23.097 N	18°23.645 N			
							67°29.634 W	67°29.693 W			
R-3	30	9:30	9:34	284816	294593	55°	18°23.044 N	18°22.978 N			
							67°29.569 W	67°29.627 W			
Puerto Botes	40								11:39	40m	18°22.792 N
25-12-surface											67°29.165 W
R-1	40	9:44	9:47	309635	317173	55°	18°22.708 N	18°22.629 N			
							67°29.361 W	67°29.382 W			
R-2	33	9:53	9:58	317173	324832	45°	18°22.840 N	18°22.746 N			
							67°29.384 W	67°29.415 W			
R-3	30	10:05	10:10	324832	332575	45°	18°22.796 N	18°22.691 N			
							67°22.691 W	67°29.424 W			
La Parguera											
Margarita Reef	24								9:52	24m	17°52.052 N
12-6-surface											67°06.022 W
R-1	24	9:15	9:18	438936	445812	45°	17°52.000 N	17°51.952 N			
							67°05.819 W	67°05.919 W			
R-2	15	9:22	9:26	445812	452632	55°	17°51.992 N	17°51.979 N			
R-3	5	9:30	9:35	452632	462366	40°	17°52.045 N	17°51.928 N			
							67°05.600 W	67°05.514 W			
	23								11:06	20m	17°53.314 N

Shelf edge											
15-8-surface											66°59.877 W
R-1	22	11:22	11:26	462361	469673	35°	17°53.231 N	17°53.176 N			
							67°00.180 W	67°00.055 W			
R-2	19	11:31	11:35	469673	479634	50°	17°53.277 N	17°53.245 N			
							66°59.946 W	66°59.828 W			
R-3	16	11:40	11:44	479634	487045	50°	17°53.530 N	17°53.228 N			
							66°59.676 W	66°59.599 W			
Cayo Laurel	16								12:42	16m	17°53.988 N
12-6-surface											67°01.119 W
R-1	16	12:00	12:04	487045	494324	55°	17°53.967 N	17°53.866 N			
							67°00.845 W	67°00.966 W			
R-2	16	12:07	12:13	494324	503779	55°	17°53.816 N	17°53.787 N			
R-3	16	12:17	12:20	503779	511127	60°	17°53.840 N	17°53.895 N			
							67°01.354 W	67°01.341 W			

3.2 July 3, 2001 Cruise to Mayaguez Bay

A one-day cruise to Mayaguez Bay took place on July 3, 2001. The purpose of this cruise was to sample various stations throughout Mayaguez Bay in order to evaluate the variability of water optical properties in the transitional period between the dry and wet seasons. Plankton tows and optical profiles were obtained from Manchas Reef, Oceanica, Atuneras, Añasco, and the Triple A Stations.

Table 2: Sampling Station data for the July 2001 cruise.

	Depth	Tow Duration		Flow Meter		Wire	GPS Position		CTD	Secchi
Station	**(m)**	**In**	**Out**	**In**	**Out**	**Angle**	**Position In**	**Position Out**		**(m)**
Oceánica	197								9:40	25m
60-30-surface										
R-1	197	9:57	10:06	020417	033628	45°	18°12.755 N	18°12.739 N		
							67°14.298 W	67°14.255 W		
R-2	197	10:10	10:18	033628	047055	40°	18°12.751 N	18°12.835 N		
							67°14.292 W	67°14.430 W		
R-3	197	10:20	10:24	047055	057317	45°	18°12.787 N	18°12.716 N		
							67°14.491 W	67°14.605 W		
Manchas	20								11:24	12m
15-surface										
R-1	20	10:48	10:53	057317	067995	55°	18°13.181 N	18°13.240 N		
							67°10.819 W	67°10.911 W		
R-2	20	11:00	11:04	067995	081848	55°	18°13.188 N	18°13.165 N		
							67°11.093 W	67°11.212 W		
R-3	20	11:11	11:15	081848	093031	55°	18°13.171 N	18°13.181 N		
							67°11.311 W	67°11.434 W		

Atunera									11:37	3.6m
10-surface										
R-1	12	11:45	11:47	093031	101657	55°	18°13.172N 67°10.222W	18°13.227 N 67°10.285 W		
R-2	12	11:54	11:59	101657	111647	55°	18°13.186 N 67°10.282 W	18°13.082 N 67°10.253 W		
R-3	12	12:07	12:13	111647	121944	55°	18°13.161 N 67°10.069 W	18°13.218 N 67°10.140 W		
Añasco									13:12	3m
10-surface										
R-1	11	12:38	12:43	121944	130822	55°	18°15.629 N 67°11.968 W	18°15.629 N 67°11.968 W		
R-2	11	12:53	12:57	130822	138183	55°	18°15.629 N 67°11.968 W	18°15.629 N 67°11.968 W		
R-3	11	13:03	13:06	138183	145384	55°	18°15.629 N 67°11.968 W	18°15.629 N 67°11.968 W		
Triple A	12								13:29	9m
10-surface										
R-1	12	13:42	13:46	145384	155427	55°	18°14.406 N 67°11.433 W	18°14.406 N 67°11.433 W		
R-2	12	13:51	13:56	155427	164618	55°	18°14.406 N 67°11.433 W	18°14.406 N 67°11.433 W		
R-3	12	14:01	14:06	164618	174183	55°	18°14.406 N 67°11.433 W	18°14.406 N 67°11.433 W		

3.3 August 2001 Cruise to Guanica and Guayanilla Bays

The purpose of this cruise was to sample two areas that include reefs that for many years have been subjected to sediment stress. Three reefs were sampled from each bay. These included Caña Gorda (Ballena) Reef, Cayo Coral, and Punta Ventana Reef from the Guanica Bay area and Tallaboa Reef, Maria Langa, and Shelf Edge (Beril) Reef from the Guayanilla Bay area.

Table 3: Sampling station data for the August 2001 cruise.

Station	Depth (m)	Tow Duration In	Tow Duration Out	Flow Meter In	Flow Meter Out	Wire Angle	GPS Position Position In	GPS Position Position Out	CTD
Cayo Coral	25								11:50
10 - surface									
R-1	25	11:13	11:16	180106	204659	45°	17°56.173N	17°56.173N	
							66°53.303W	66°53.303W	
R-2	25	11:17	11:20	190177	215128	45°	17°56.173N	17°56.173N	
							66°53.303W	66°53.303W	
R-3	25	11:22	11:25	022894	041997	45°	17°56.173N	17°56.173N	
							66°53.303W	66°53.303W	
Ventana	70								13:01
15-surface									
R-1	70	13:10	13:14	204659	217435	45°	17°56.221N	17°56.221N	
							66°49.230W	66°49.230W	
R-2	70	13:16	13:19	215128	234058	45°	17°56.221N	17°56.221N	
							66°49.230W	66°49.230W	
R-3	70	13:22	13:26	041997	054505	45°	17°56.221N	17°56.221N	
							66°49.230W	66°49.230W	
									16:16
Tallaboa	10	15:56							
5-surface									
R-1	10	15:56	15:59	277454	307166	45°	17°56.767N	17°56.767N	
							66°43.480W	66°43.480W	
R-2	10	16:00	16:03	256472	265910	45°	17°56.767N	17°56.767N	
							66°43.480W	66°43.480W	
R-3	10	16:04	16:07	081255	096135	45°	17°56.767N	17°56.767N	
							66°43.480W	66°43.480W	
Shelf edge	20								
10-surface									
R-1	20	15:13	15:18	252128	277454	45°	17°57.563 N	17°57.563 N	16:46
							66°45.254 W	66°45.254 W	
R-2	20	15:20	15:24	245475	256472	45°	17°57.563 N	17°57.563 N	
							66°45.254 W	66°45.254 W	
R-3	20	15:24	15:29	066332	061255	45°	17°57.563 N	17°57.563 N	
							66°45.254 W	66°45.254 W	
Maria Langa	10								16:58
10 - surface									
R-1	10	16:24	16:30	217435	252128	45°	17°57.630N	17°57.630N	
							66°45.256W	66°45.256W	
R-2	10	16:33	16:37	234058	245475	45°	17°57.630N	17°57.630N	
							66°45.256W	66°45.256W	
R-3	10	16:40	16:45	054505	066332	45°	17°57.630N	17°57.630N	
							66°45.256W	66°45.256W	

4.0 Characterization of Coral Optical Properties

The spectral reflectance properties of the nine scleractinian species sampled were very similar (Figure 1). The implication of this in terms of using remote sensing for coral reef studies is that species discrimination even by using hyperspectral sensors will be very difficult. A higher albedo in the reflectance spectrum of *Porites porites* is due to the light grey coloration characteristic of this species.

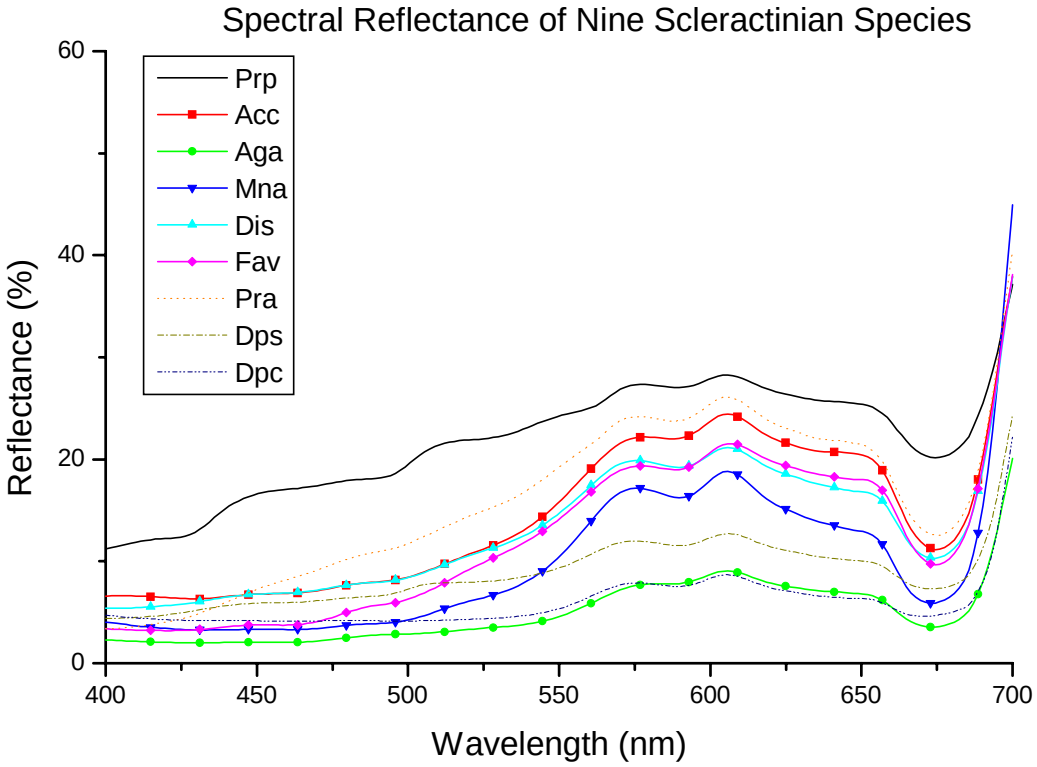

Figure 1. Reflectance spectra of nine Scleractinian species.

Coral bleaching is easier to detect due to increases in albedo from non-bleached colonies (Figure 2). Notice, however, that the most pronounced differences in albedo are in longer wavelengths where water attenuation is highest.

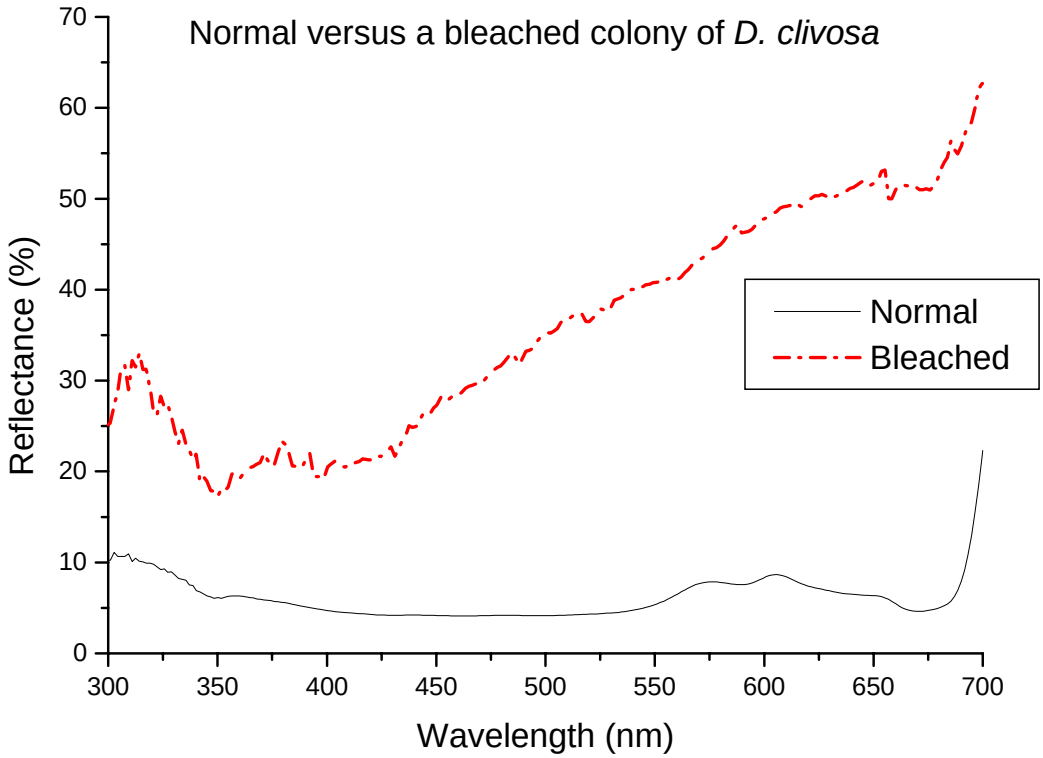

Figure 2. Spectral reflectance of normal versus a bleached colony of *Diploria strigosa*.

5.0 Reef Descriptions

5.1 Tourmaline Reef Natural Reserve – Mayaguez Bay

Tourmaline Reef, located due west of Bahía Bramadero, Cabo Rojo, was designated as Natural Reserve in 1996 in recognition of its ecological value as the most important coral reef system of the west coast of Puerto Rico. The total extension of the Natural Reserve is 19.43 square nautical miles. The reef sits at the northern section of the Cabo Rojo platform, approximately five miles away from the coastline (Figure 3).

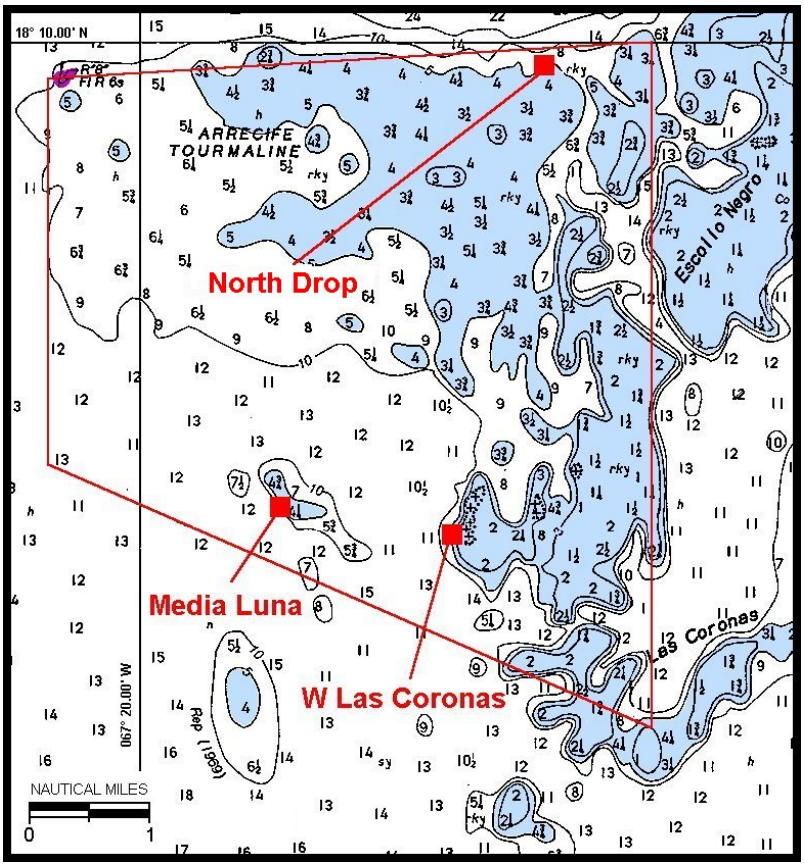

Figure 3. Tourmaline Natural Reserve in Mayaguez Bay showing general location of reef survey sites

Most of the reef lies submerged, surrounded by waters of 20-25 meters in depth. The reef is largely an extensive hard-ground platform with areas of discontinuous steep promontories that reach up to 3-4 meters from the surface. Emergent reef structures include Las Coronas, on the southeast corner of the Reserve and Escollo Media Luna, located due west of Las Coronas. At the northern boundary of the reserve lies an extensive "spur and groove" coral reef formation that begins at a depth of 10 meters and extends north toward the shelf-edge to a depth of 30 meters. This shelf-edge reef is undoubtedly, one of the best coral reefs in Puerto Rico. El Tourmaline Reef is known to be a spawning site of the Red Hind, *Epinephelus guttatus*, a commercially exploited grouper species. A general description of marine habitats and taxonomic account of

species present was prepared by Vicente (1996) as part of the background studies for designation of Tourmaline Reef as a Natural Reserve. The geographic boundaries that delimit El Tourmaline Natural Reserve are the following:

Northeast : 18° 10' N; 67 ° 15.5' W
Northwest : 18° 10' N; 67 ° 20.1' W
Southeast : 18° 04.6' N; 67 ° 15.5' W
Southwest : 18° 06.5' N; 67 ° 20.1' W

Our survey of coral reefs in Mayaguez Bay included the Tourmaline North Drop, Media Luna and Las Coronas.

Location of permanent transect locations at reefs studied within the Tourmaline Natural Reserve, Mayaguez Bay.

Reef Name	*Survey Date*	*Depth (m)*	*Latitude (N)*	*Longitude (W)*
North Drop	23-June-99	10.6	18 ° 09.794'	067 ° 16.418'
Las Coronas	25-June-99	10.0	18 ° 05.836'	067 ° 17.225'
Media Luna	28-June-99	10.6	18 ° 06.079'	067 ° 18.731'

5.1.1 North Drop Reef

The North Drop Reef is a well-developed "spur and groove" coral reef formation associated with the shelf-edge at the northern section of Mayaguez Bay (Figure 3). The reef runs perpendicular to the shelf-edge from a depth of 10 meters and extends down towards the shelf-break at a depth of approximately 25 meters. The spurs range in height at about 2-3 meters and are separated by white sandy sediments accumulated at the grooves. The edge of the shelf is highly irregular with a series of terraces and large crevices in the vertical walls. Stony corals grow on top of the spurs and along the walls in massive, branching and encrusting colonies. Soft corals are also very prominent and combined with stony corals represent the visually dominant feature of this reef.

Line transects were established longitudinally on top of the spurs at a depth of approximately 10 meters in sections of optimum coral growth. Horizontal underwater visibility was estimated at approximately 20 meters during our survey.

5.1.2 Las Coronas Reef

Las Coronas Reef is one of the few emergent reef platforms within the Tourmaline Natural Reserve in Mayaguez Bay. This reef is located on the southern border of the reserve, at about four nautical miles from the shoreline. The reef emerges from a platform at 12 meters with a rather steep slope. There is a fairly extensive reef flat at two

meters where corals grow as dispersed colonies. Most of the coral development occurs along the fore reef slope. Our survey was conducted on the fore reef slope located on the west section of the reef. Transects were aligned along a north-south axis, following the 10 meter depth contour.

5.1.3 Media Luna Reef

Media Luna Reef is a submerged patch reef located on the southern boundary of El Tourmaline Natural Reserve, at about one nautical mile west of Las Coronas Reef and approximately 5.5 nautical miles from the coastline due west off Puerto Real, Cabo Rojo. Media Luna sits in the same hard-ground platform as Las Coronas, with the base of the reef at a depth of 13 meters. The reef comes up to a depth of about 4 meters. The reef is elongated and measures approximately one nautical mile along its northwest – southeast axis. Transects were established on a narrow terrace following the 10 meter depth contour.

5.1.4 CTD Profiles – Tourmaline Reef System

Conductivity, temperature and chlorophyll profiles for the three sites sampled within the Tourmaline Reef System (North Drop, Media Luna, Las Coronas – West) are presented in Figures 4-6. Temperature, salinity, and density profiles are very similar in magnitude and depict a vertical homogeneous water mass. In fact, these physical properties, within the first 20 meters, are nearly identical to an offshore site in deep water (Oceanica Station, Figure 7). Surface chlorophyll amount is nearly identical throughout these sites with a slight increase at intermediate depths.

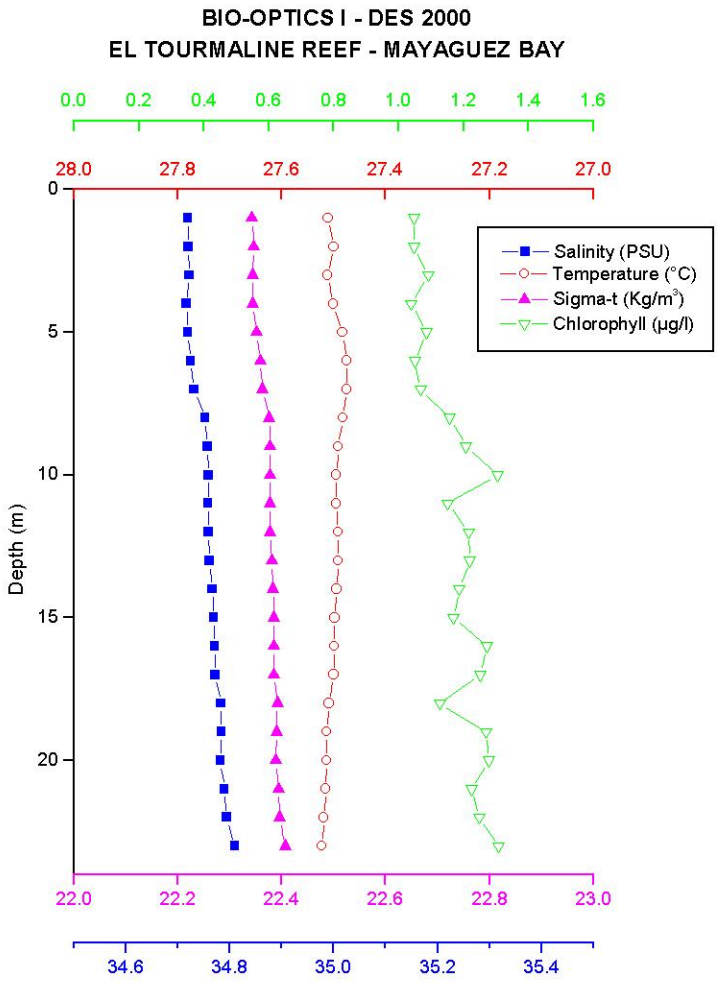

Figure 4: CTD Profile - North Drop Reef, Tourmaline

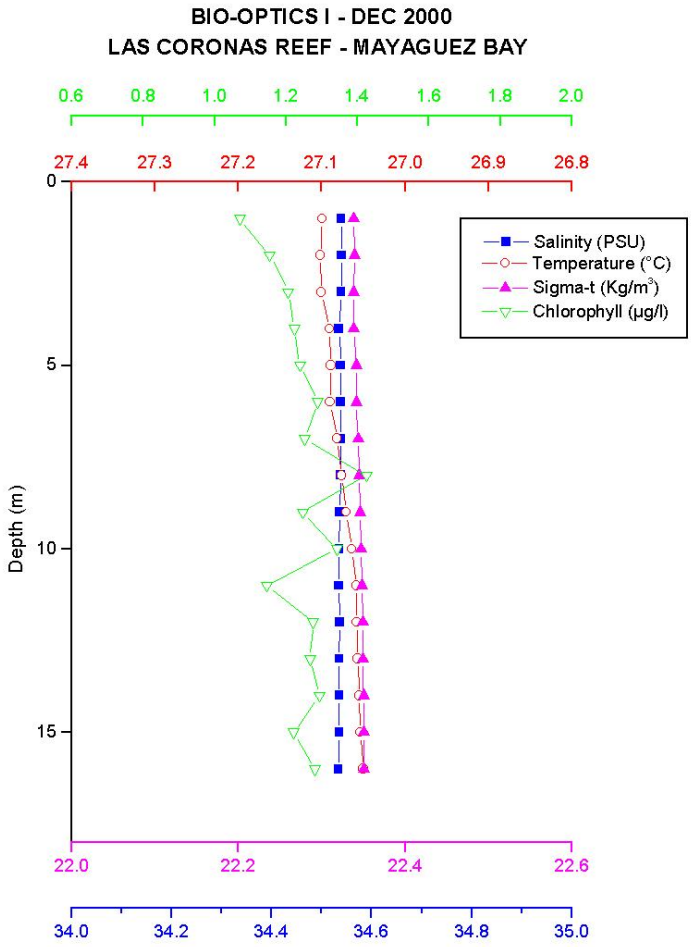

Figure 5: CTD Profile – Las Coronas Reef, Tourmaline.

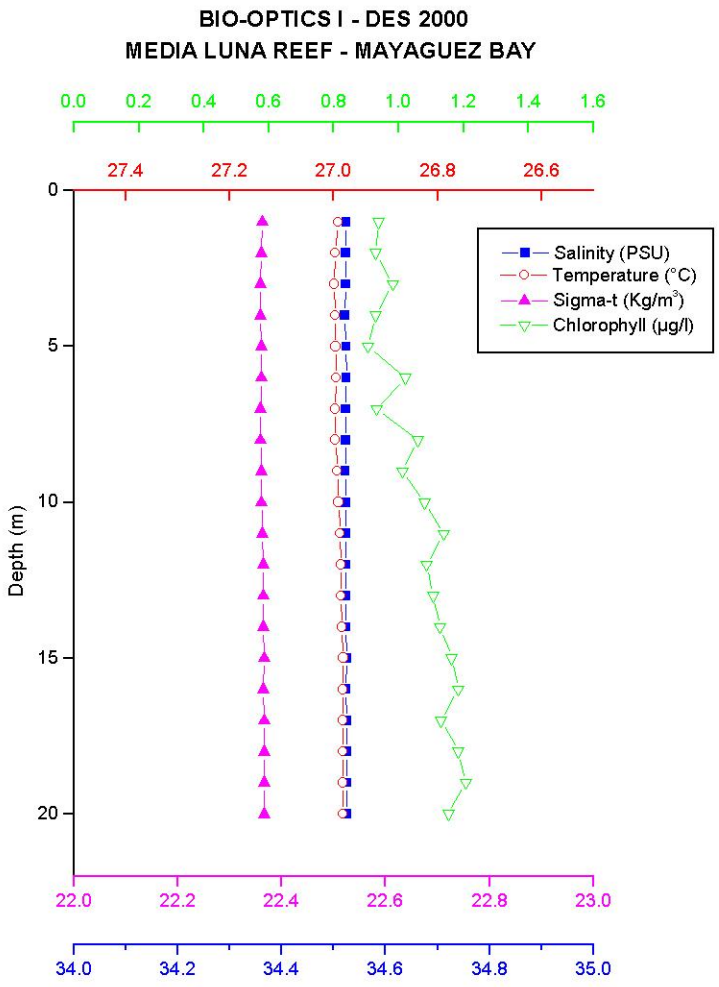

Figure 6: CTD Profile – Media Luna Reef, Tourmaline

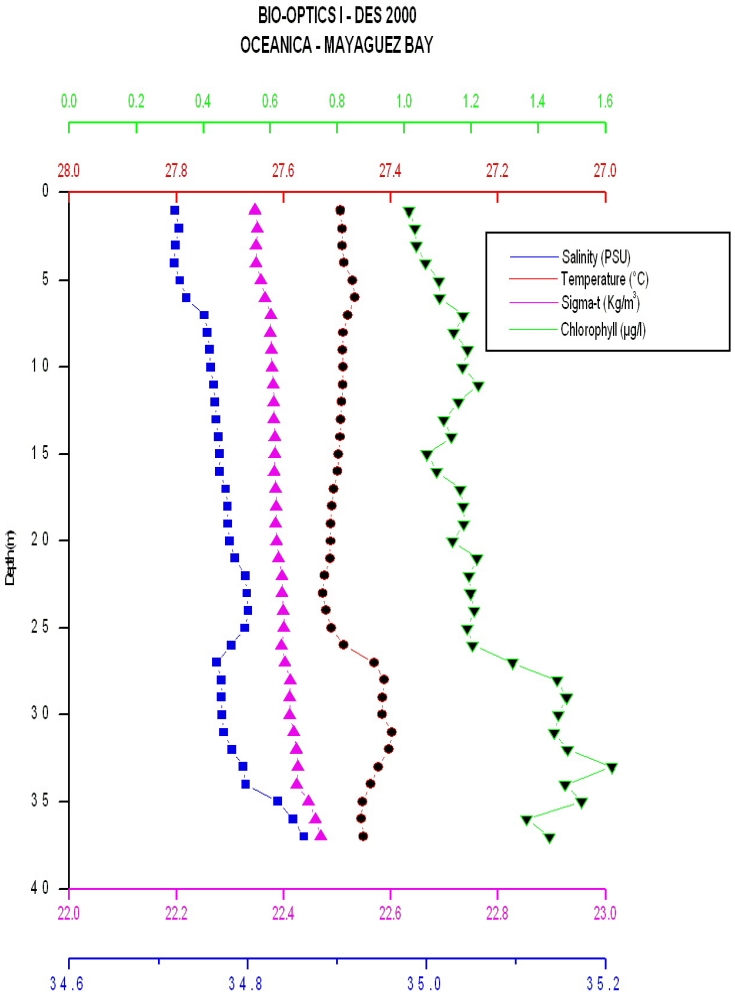

Figure 7. CTD Profile– Oceanic Station

5.2 Isla Desecheo Natural Reserve

Isla Desecheo is an oceanic island in the Mona Passage, located approximately nine nautical miles off Rincon, north west coast of Puerto Rico. The island, which used to be a U.S. Navy shooting range, was designated as a Natural Reserve in 1999. Marine communities at Desecheo are influenced by clear waters, strong currents and seasonally high wave action from North-Atlantic winter swells. Coral reefs are established on the west and northwest sections of the insular shelf at depths between 10 - 30 meters. Coral community surveys were performed at North Reef, Puerto Botes Reef and Puerto Canoas Reef (Figure 8). Locations and depths of reef surveys at Isla Desecheo are presented in Table 4.

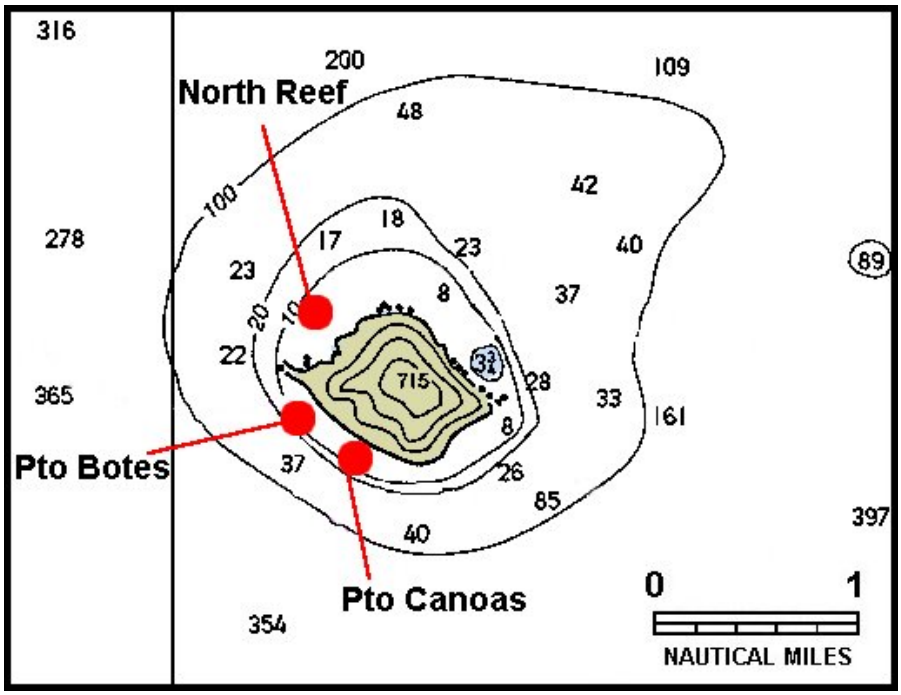

Figure 8. Location of reefs surveyed at Isla Desecheo Natural Reserve.

TABLE 4. GEOGRAPHIC COORDINATES AND DEPTH OF REEFS STUDIED AT ISLA DESECHEO NATURAL RESERVE, JUNE, 2000

Reef Name	*Survey Date*	*Depth (m)*	*Latitude*	*Longitude*
North Reef	20-June-00	10.6	18 º 23.416' N	067 º 29.229' W
Puerto Canoas Reef	21-June-00	17.6	18 º 22.699' N	067 º 29.026' W
Puerto Botes Reef	22-June-00	17.0	18 º 22.895' N	067 º 29.316' W

5.2.1 North Reef

North Reef, on the northwest corner of the island, is formed by a series of massive lava rock promontories, some of which appear to have been displaced from the main island shelf. Due north of the island there is an isolated pinnacle known as "Yellow Reef" that rises from the base of the reef platform at a depth of 60 meters to about 6 meters from the surface. Our survey at North Reef was performed at the upper terrace of one of the shelf promontories close to the shoreline at depths between 10-12 meters. Transects were established north-south at two adjacent promontories separated from each other by a sandy channel with its base at a depth of 18 meters.

5.2.2 Puerto Canoas Reef

Puerto Canoas is located on the western section of Isla Desecheo. This is the leeward, or protected side of the island where the most extensive coral reef system is found. The insular shelf is narrow (< 0.25 nautical miles) and slopes from the shoreline to a relatively flat terrace at a depth of 15 meters. The terrace extends to a depth of approximately 23 meters. It is across this fringe where most of the coral reef system has developed. Beyond 23 meters, the shelf slopes down to a deeper terrace at depths of 50 – 60 meters, before dropping down the insular slope to depths of more than 600 meters. The coral reef system at Puerto Canoas is exuberant, with huge stony coral colonies growing close together and forming large coral promontories that provide very high topographic relief. At some points, sand channels cut through the reef towards the shelf-edge. Permanent transects were aligned east-west at a depth of 17.6 meters.

5.2.3 Puerto Botes Reef

Puerto Botes Reef is located to the north of Puerto Canoas, on the northwestern shelf section of Isla Desecheo. It is part of a discontinuous fringing reef formation established at depths between 15 – 23 meters throughout most of the western island shelf. Coralline sand patches cut the reef in large sections. Permanent transects were aligned east-west, using large coral heads as anchor points for steel rod transect markers.

5.2.4 CTD Profiles – Isla Desecheo

Conductivity, temperature and chlorophyll profiles where obtained for two of the three sites sampled within the Isla Desecheo Reef System (Figures 9-10) A CTD cast for North Reef could not be obtained due to rough sea conditions. Notice how temperature, salinity, and density profiles are very similar in magnitude and depict a vertical homogeneous water mass at Puerto Botes and Puerto Canoas. It is reasonable to assume that the physical conditions at North Reef were also very similar since Isla Desecheo is an oceanic island surrounded by oligotrophic waters year-round.

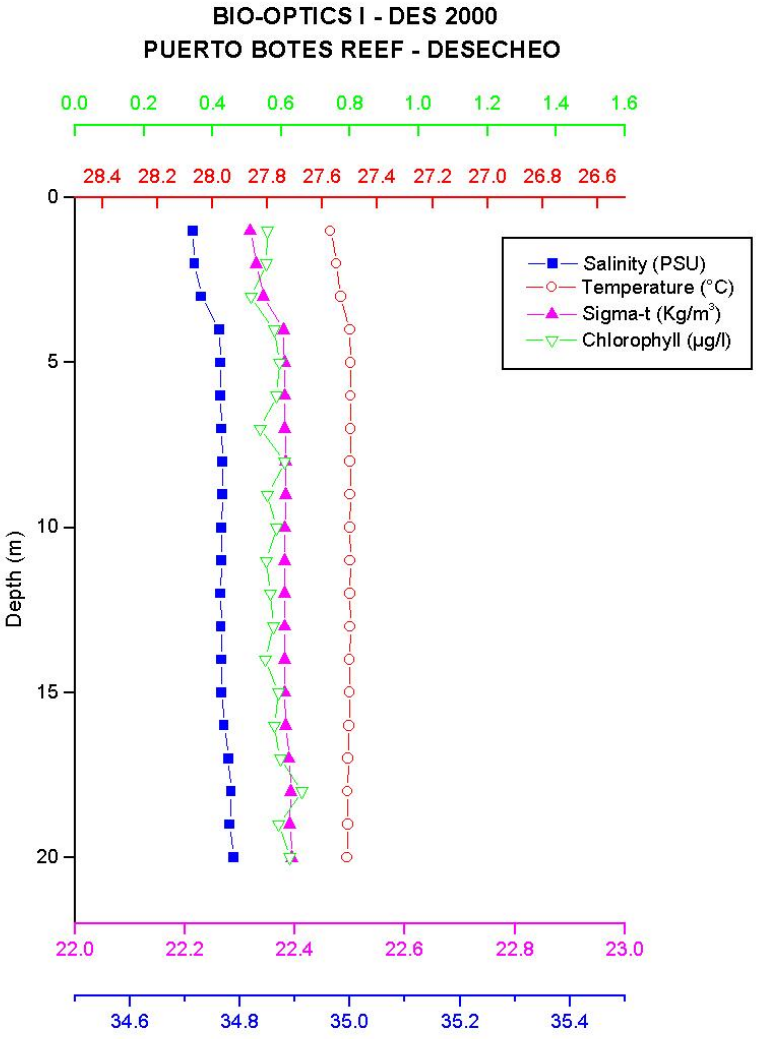

Figure 9: CTD cast – Puerto Botes Reef

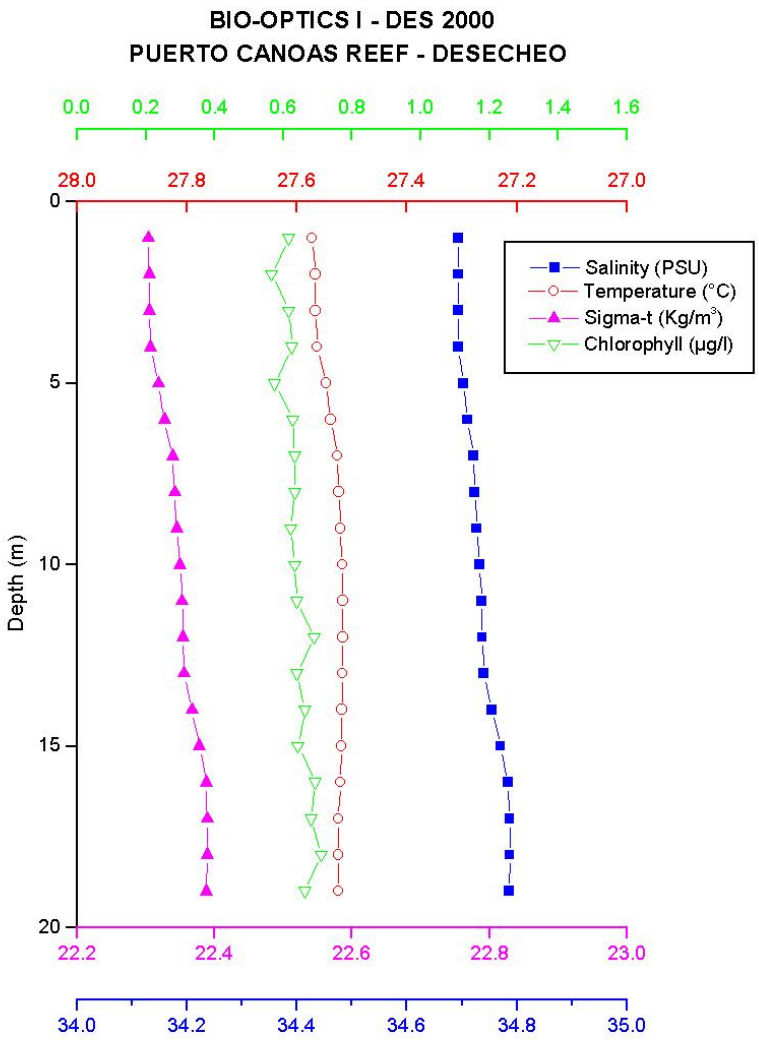

Figure 10: CTD cast – Puerto Canoas Reef

5.3 La Parguera Natural Reserve

La Parguera Natural Reserve was designated in 1979 and amended in 1998 to expand its marine boundaries. It is located due east of Cabo Rojo on the southwest section of the island. La Parguera is internationally famous for its bioluminescent bays (Bahia Fosforescente, Laguna Monsio José), but also presents some of the largest and best developed coral reefs in Puerto Rico. Coral reefs, seagrass beds and mangrove habitats coexist in La Parguera to form a marine ecosystem of unsurpassed biodiversity in Puerto Rico. The submerged shelf-edge reef of La Parguera is the most extensive and perhaps, one of the oldest coral reefs in Puerto Rico. A series of submerged patch reefs and fringing coral reefs associated with more than twenty emergent islands or keys add to the collection of coral reefs found within La Parguera Natural Reserve.

In this study, coral reef community surveys were performed at La Boya, a section of the shelf-edge reef in the outer shelf, at a hard-ground platform south off Margarita Reef, and at a submerged spur and groove reef formation located south of Turrumote (Figure 11). Location and depths of reef surveys at La Parguera are presented in Table 5.

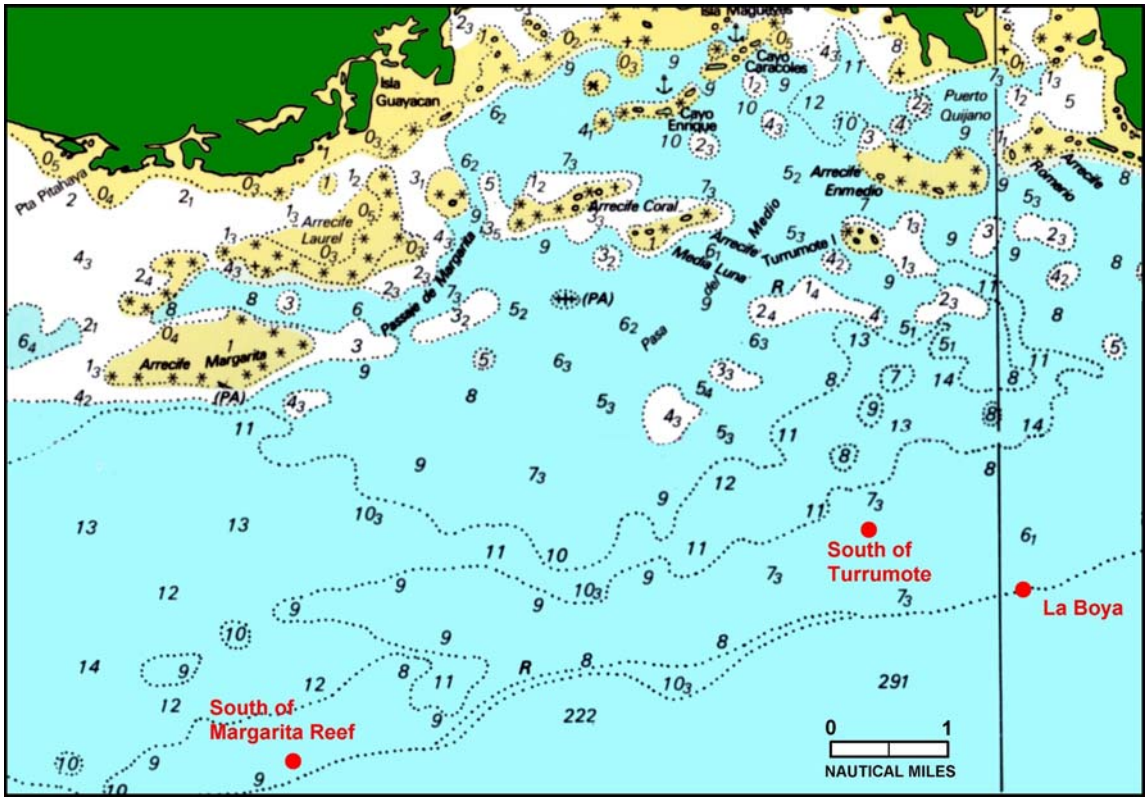

Figure 11. Location of reefs surveyed at La Parguera Natural Reserve.

TABLE 5. GEOGRAPHIC COORDINATES OF REEFS STUDIED AT LA PARGUERA NATURAL RESERVE, LAJAS.

Reef Name	*Survey Date*	*Depth (m)*	*Latitude*	*Longitude*
Shelf Edge Reef	17-May-00	18.1	18 ^{o} 00.299' N	067 ^{o} 19.785' W
South of Margarita Reef	24-May-00	14.0	17 ^{o} 59.470' N	067 ^{o} 13.987' W
South of Turrumote Reef	17-July-00	15.0	18 ^{o} 00.034' N	067 ^{o} 12.670' W

5.3.1 Shelf Edge (La Boya) Reef – La Parguera

La Boya Reef is part of an extensive coral reef system associated with the shelf-edge that extends from Punta Verrraco to Cabo Rojo on the southwestern tip of Puerto Rico. Off from La Parguera, Lajas, La Boya Reef is approximately six nautical miles away from the coastline. The reef is a "spur and groove" formation that runs north-south, perpendicular to the shelf-edge and to the coastline. The reef starts at a depth of 17 meters, as the spurs rise from a coralline sandy bottom and ends at the shelf-edge at a depth of 22 meters. Down the shelf-edge, scattered and mostly encrusting stony coral colonies are found. Coral spurs rise up 4 - 5 meters in many sections of La Boya, separated by grooves where coralline sands are transported down the insular slope. The water is generally clear at La Boya, with horizontal underwater visibility normally exceeding 20 meters. Line transects were established on top of consecutive spurs, close to the shelf edge at a depth of 18 meters.

5.3.2 South of Margarita Reef – La Parguera

At approximately three nautical miles due south from Margarita Reef there is an extensive hard ground reef that comes up as a ridge from a sandy bottom at a depth of 22 meters to a mostly flat platform at a depth of 14 meters. The hard ground platform leads to the shelf-edge. There were no "spur and groove" or patch reef formations within the hard ground. Most of the stony coral development was concentrated along the walls at the base of the ridge. Our survey was performed on top of the ridge at a depth of 14 meters. Transects were installed on a north–south axis, perpendicular to the shelf edge.

5.3.3 South of Turrumote Reef – La Parguera

At about two nautical miles south of Cayo Turrumote a "spur and groove" reef formation lies submerged at a depth of 15 meters. The spurs of the reef, where most of the coral growth is concentrated are aligned north-south, perpendicular to the shoreline. The reef extends over one nautical mile towards the shelf-edge as a series of discontinuous spurs, locally known as "canjilones". Reef spurs are separated from each other by coralline sand channels. The spurs range in height from 2 – 4 meters in reef sections surveyed. Water transparency was at least 20 meters during our survey.

5.3.4 CTD Profiles – La Parguera

Conductivity, temperature and chlorophyll profiles where obtained for the three sites sampled within the La Parguera Natural Reserve System (Figures 12-14). Temperature, salinity, and density profiles are very similar in magnitude and depict a vertical homogeneous water mass at these offshore reef sites. The only difference was a slight higher chlorophyll value (around 1.0 µg/l) in the water column at the South of Turrumote Reef. This submerged reef is closer to land than the other two reefs.

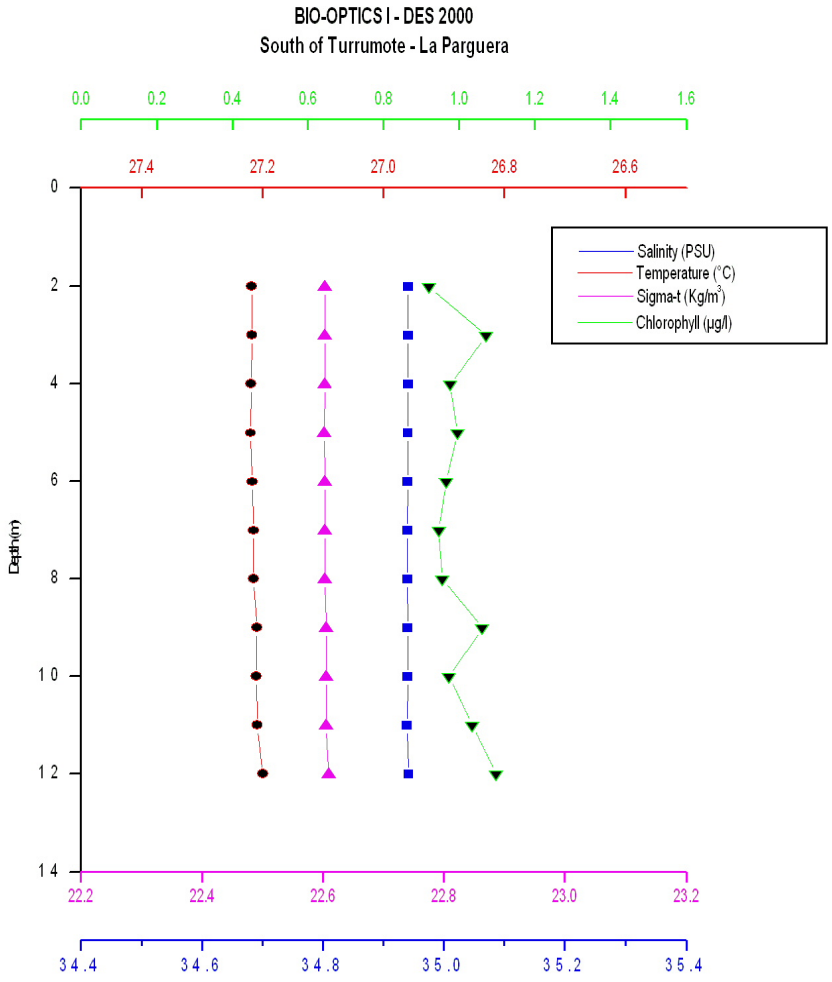

Figure 12: CTD cast – South of Turrumote Reef

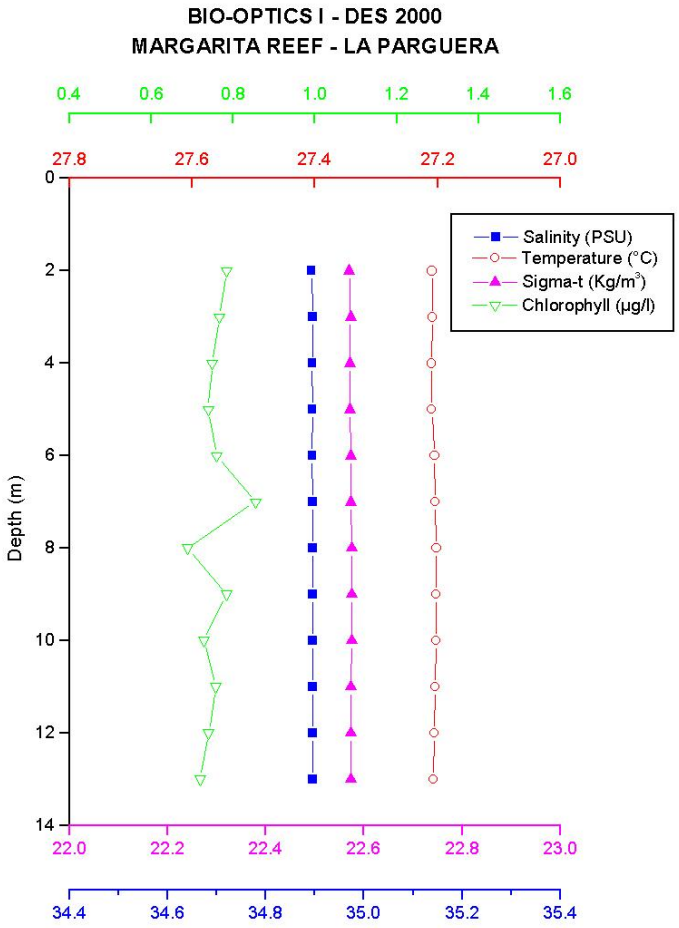

Figure 13: CTD cast – South of Margarita Reef

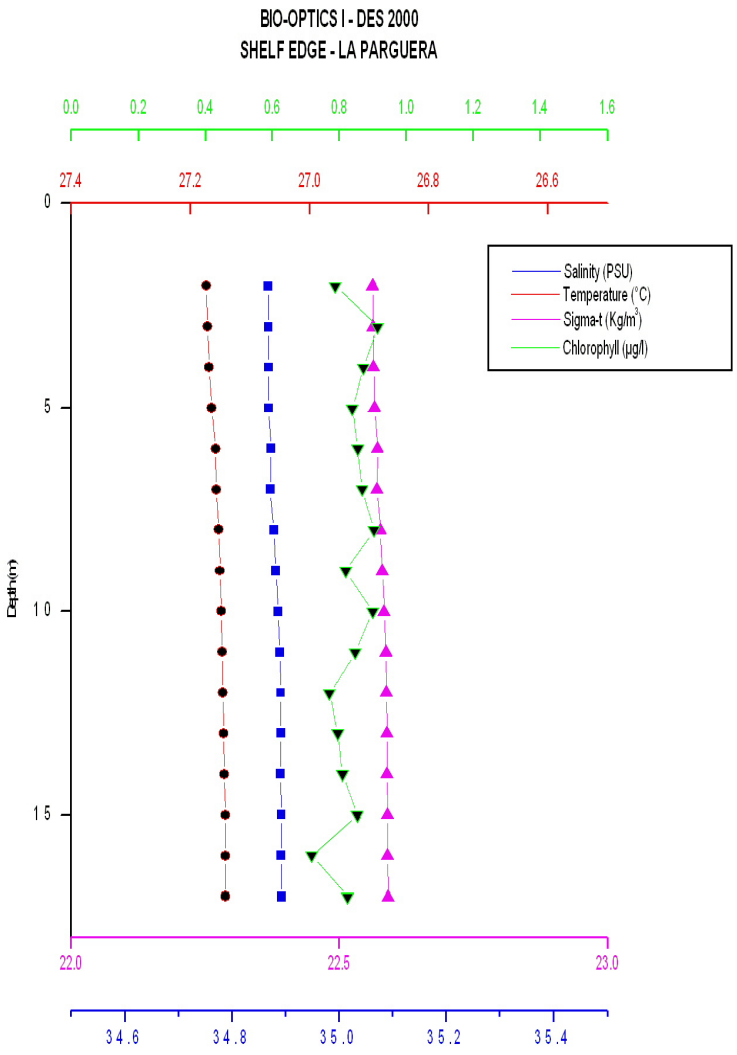

Figure 14: CTD cast – Shelf Edge (La Boya) Reef

6.0 Bio-Optical Oceanographic Data

6.1 December 2000 Cruise

Profiles of inherent and apparent water optical properties, using the instruments described above, were obtained during the December 2000 cruise. The inherent optical properties (IOP's) measured include the absorption coefficient of particles (ap), detritus (ad), and phytoplankton (aph). Profiles of downwelling irradiance were used to derive the attenuation coefficient of PAR (Kd $_{PAR}$) at each station.

6.1.1 Inherent Optical Properties

The spectral absorption coefficient of particles (ap) was highest for the Mayaguez Bay stations and lowest for Desecheo Island (Figure 15). Absorption by detritus (ad) plays a dominant role in the total absorption coefficients for Mayaguez Bay (Figure 16).
The absorption coefficient of phytoplankton was lowest for the Desecheo reefs and Margarita Station in La Parguera (Figure 17). Similarly, chlorophyll-a concentration was lowest for Desecheo, Margarita, and Oceanica Stations (Figure 18).

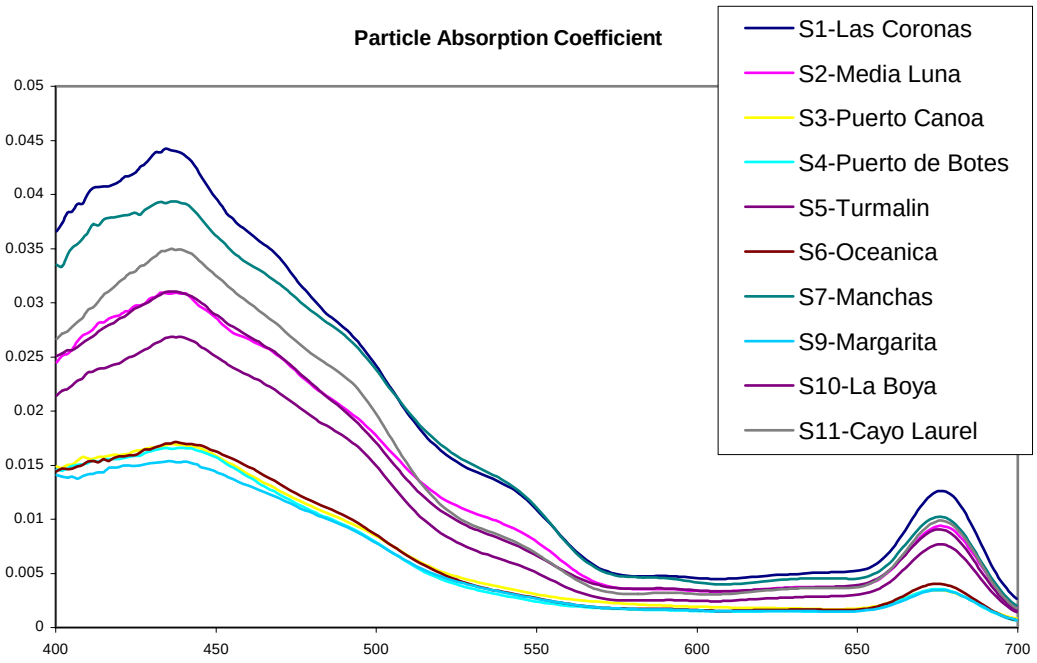

Figure 15: Particle absorption coefficient for stations sampled during December 2000.

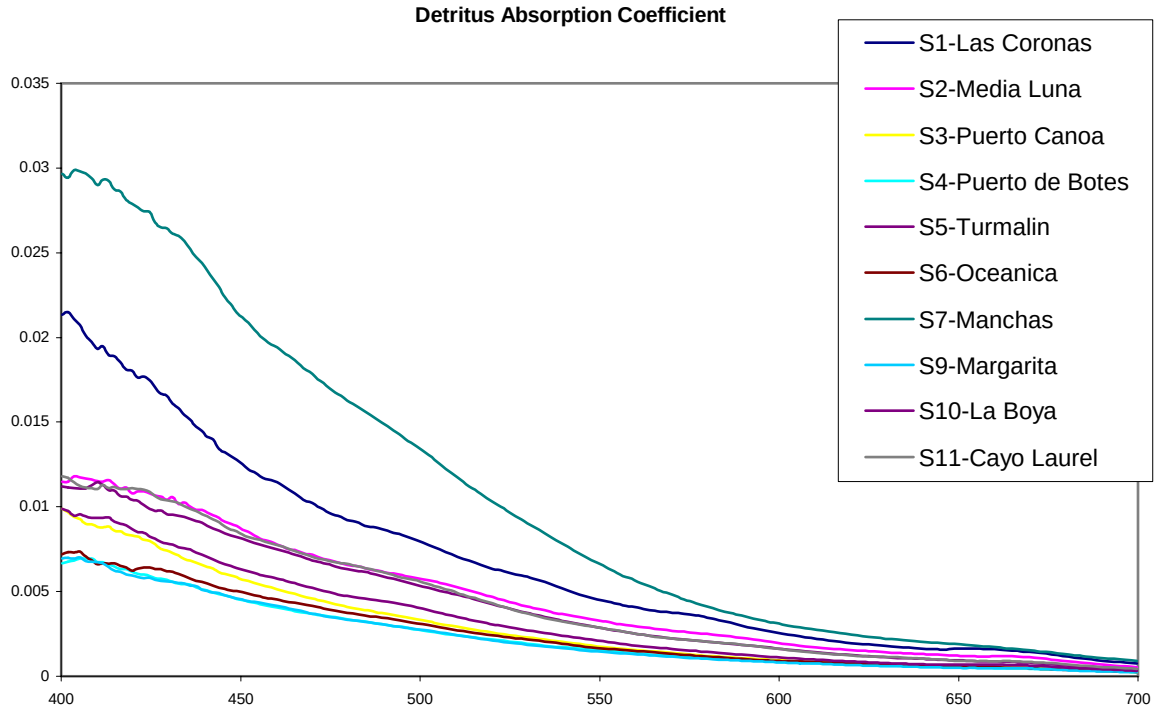

Figure 16: Detritus absorption coefficient for stations sampled during December 2000.

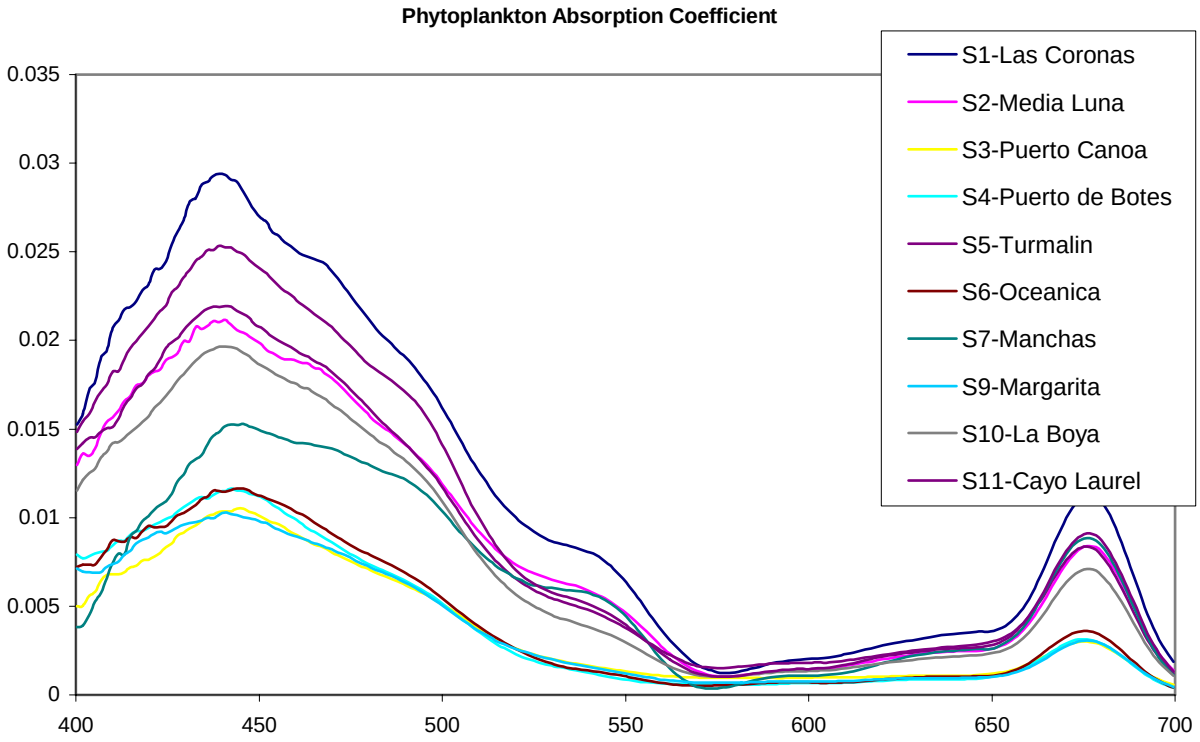

Figure 17: Phytoplankton absorption coefficient for stations sampled during December 2000.

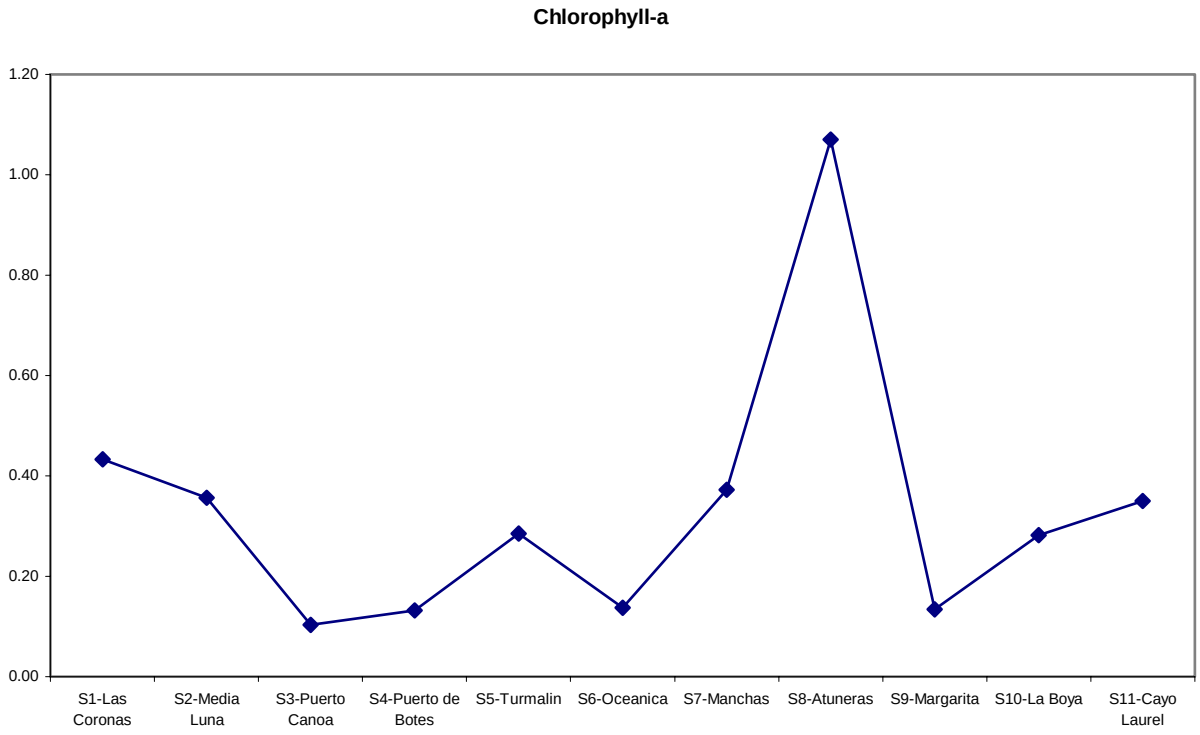

Figure 18: Measured chlorophyll-a concentration at stations sampled during December 2000.

6.1.2 Apparent Optical Properties

The apparent optical property measured was the downwelling irradiance of photosynthetically active radiation (Ed $_{PAR}$). Profiles of Ed (Figure 19) were used to calculate the attenuation coefficient of PAR (Kd $_{PAR}$) at each station. Figures 20 through 27 show the individual Ed profiles for each station sampled during the December 2000 cruise and the corresponding Kd value.

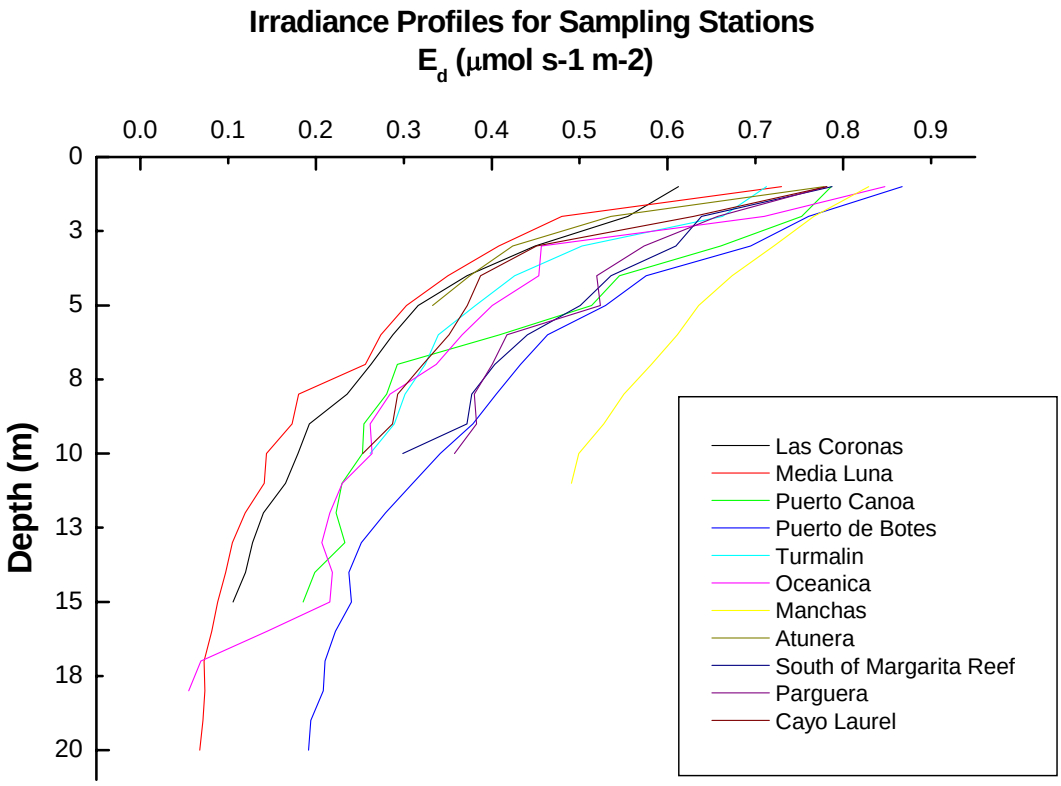

Figure 19: Downwelling irradiance profiles for stations sampled during December 2000.

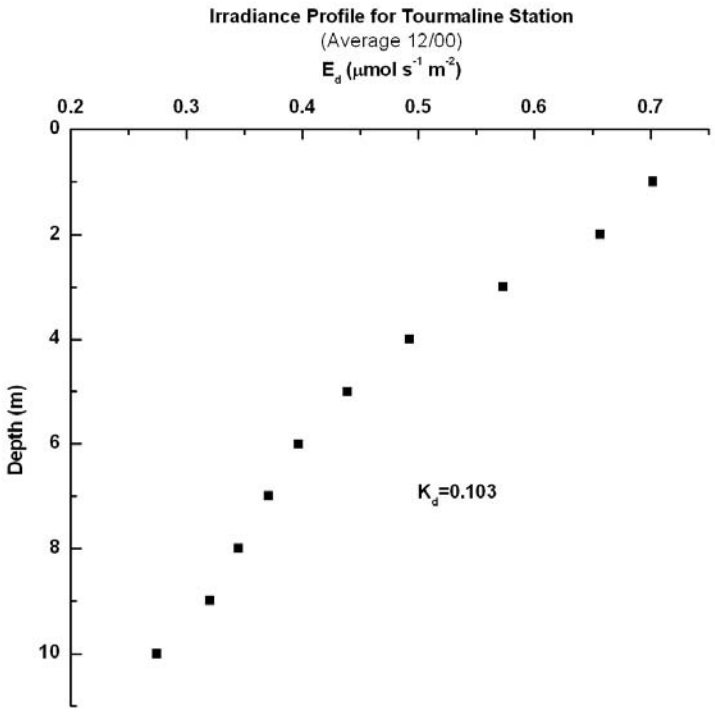

Figure 20: Downwelling Irradiance (Ed) profile at North Drop, Tourmaline.

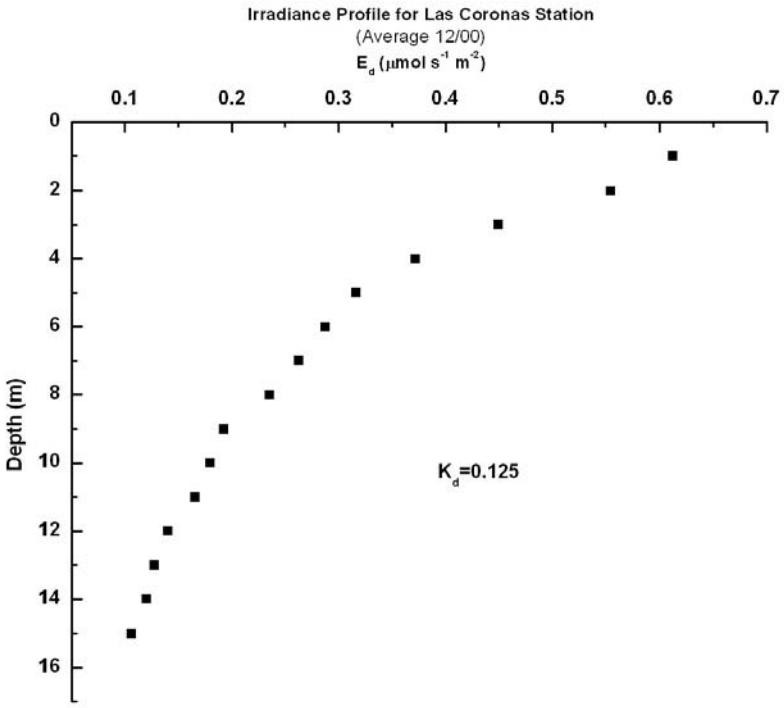

Figure 21: Downwelling Irradiance (Ed) profile at Las Coronas, Tourmaline.

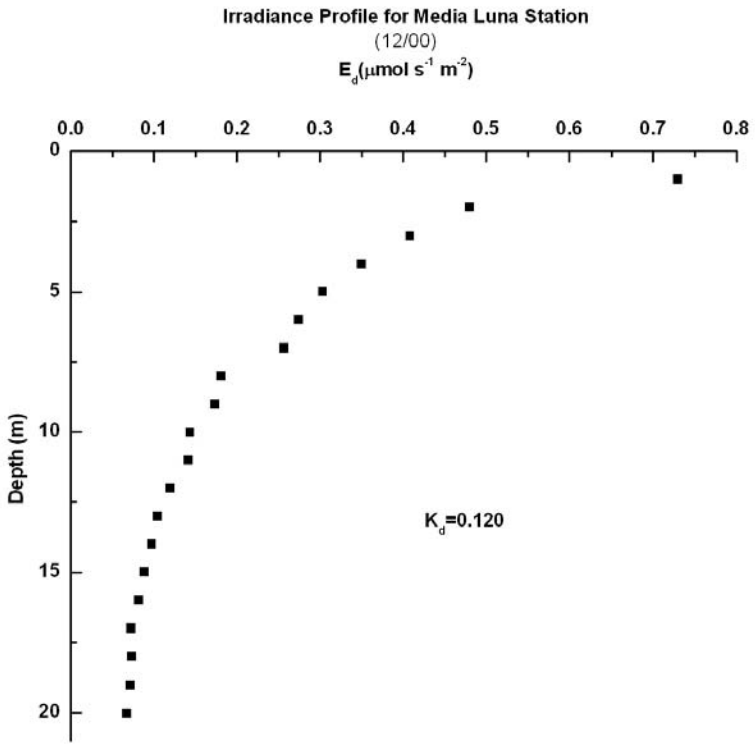

Figure 22: Downwelling Irradiance (Ed) profile at Media Luna, Tourmaline.

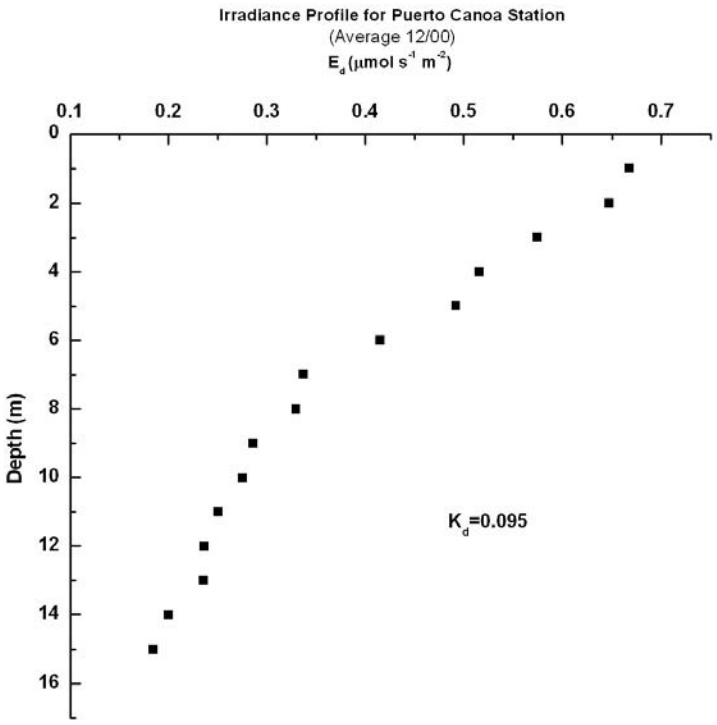

Figure 23: Downwelling Irradiance (Ed) profile at Puerto Canoa, Desecheo.

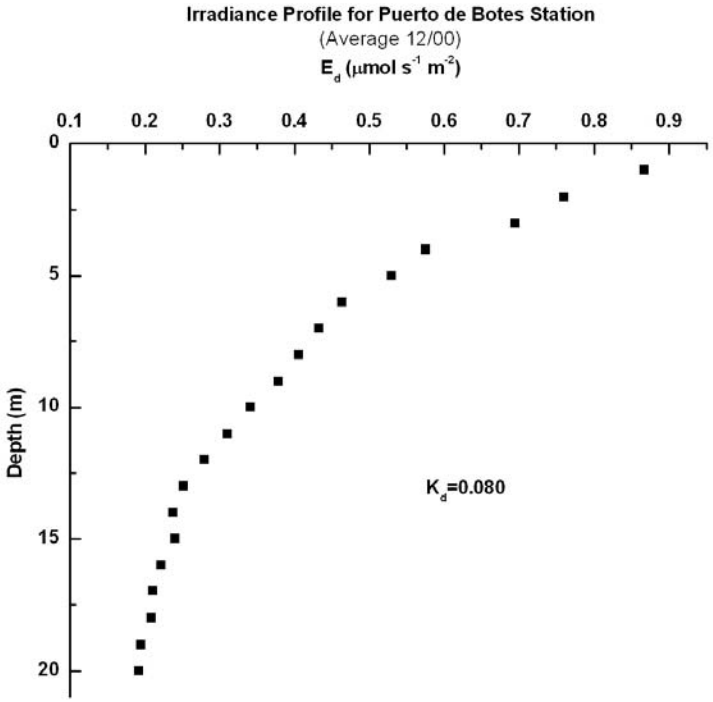

Figure 24: Downwelling Irradiance (Ed) profile at Puerto Botes, Desecheo.

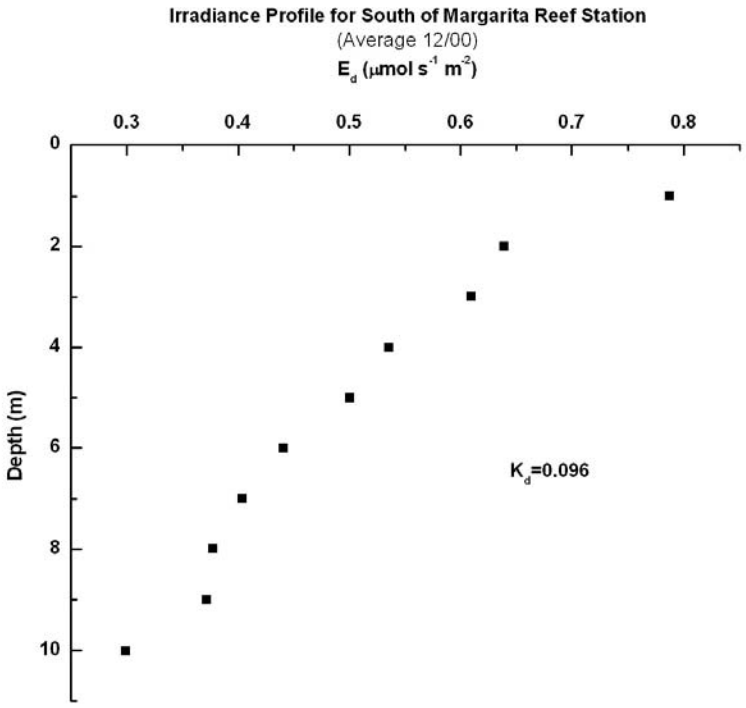

Figure 25: Downwelling Irradiance (Ed) profile at South of Margarita Station, La Parguera.

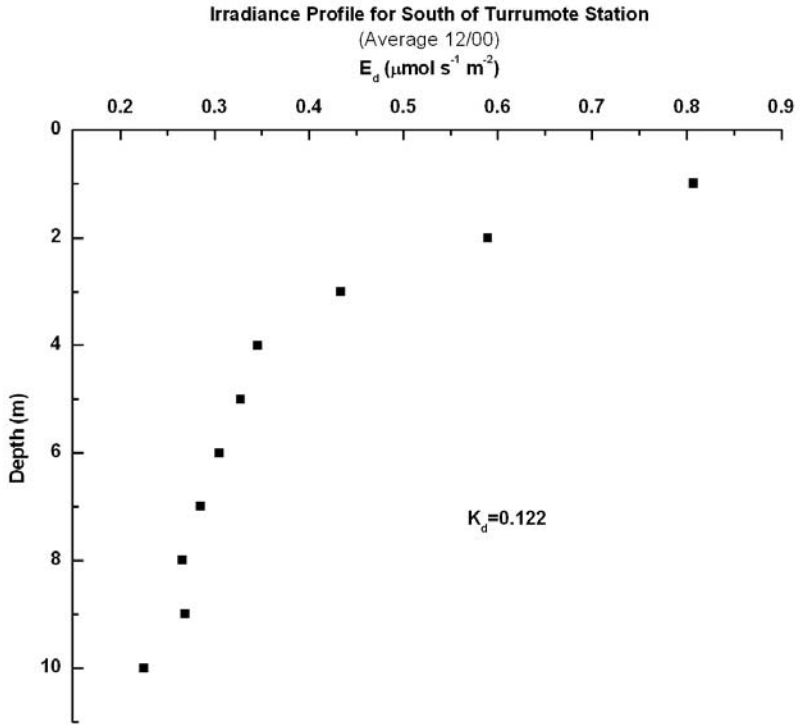

Figure 26: Downwelling Irradiance (Ed) profile at South of Turrumote Station, La Parguera.

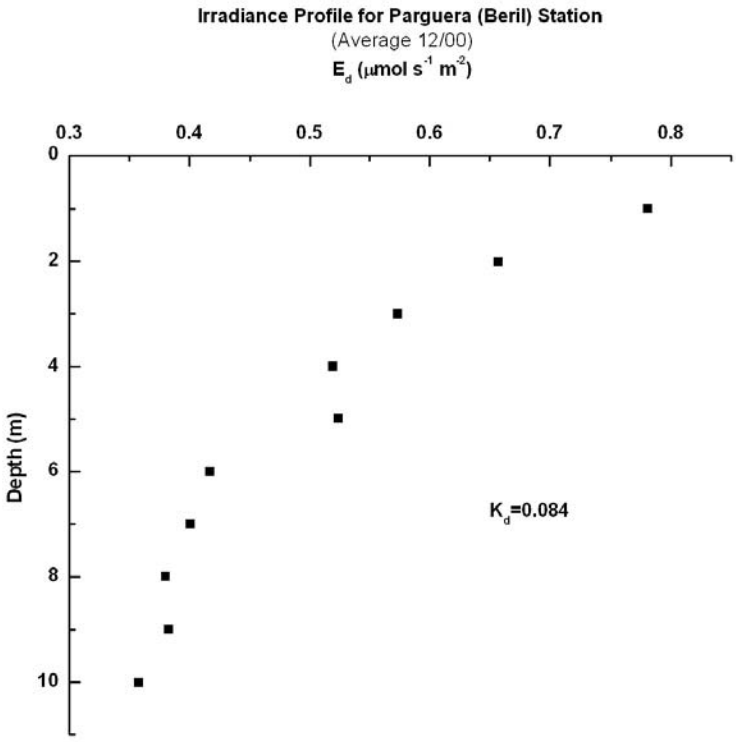

Figure 27: Downwelling Irradiance (Ed) profile at the Shelf Edge (Beril) Station, La Parguera.

6.2 July 2001 Cruise – Optical Properties

A one-day cruise to Mayaguez Bay took place on July 3, 2001 to characterize the variability in water optical properties at several stations during the transitional period between the dry and wet seasons. The stations sampled included Oceanica (an oceanic clear water station), Manchas (a coral reef site at 15 m depth), Atuneras (anm inner bay site in the port of Mayaguez), Añasco (the outfall of the Añasco River), and Triple A (the ocean outfall of a sewage treatment plant).

Downwelling irradiance (Ed) profiles and the corresponding Kd values are presented in Figures 28 through 32. Notice the high attenuation (Kd = 0.5) at the Añasco River plume station.

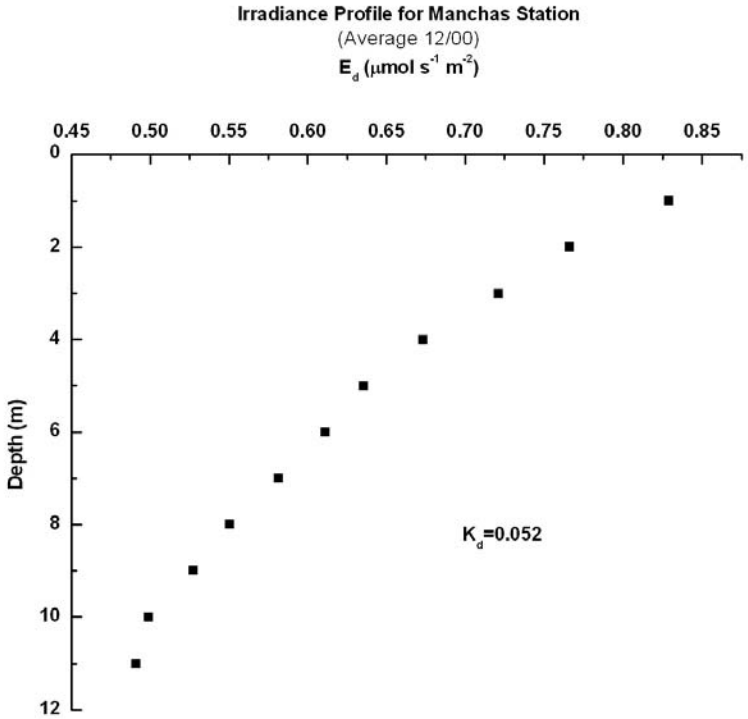

Figure 28: Downwelling irradiance profile at Manchas Station.

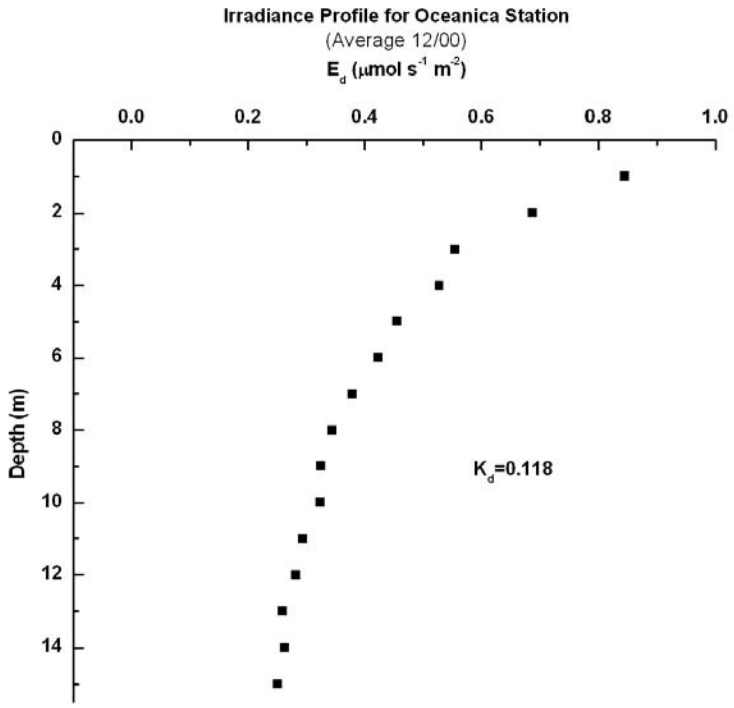

Figure 29: Downwelling irradiance profile at Oceanica Station.

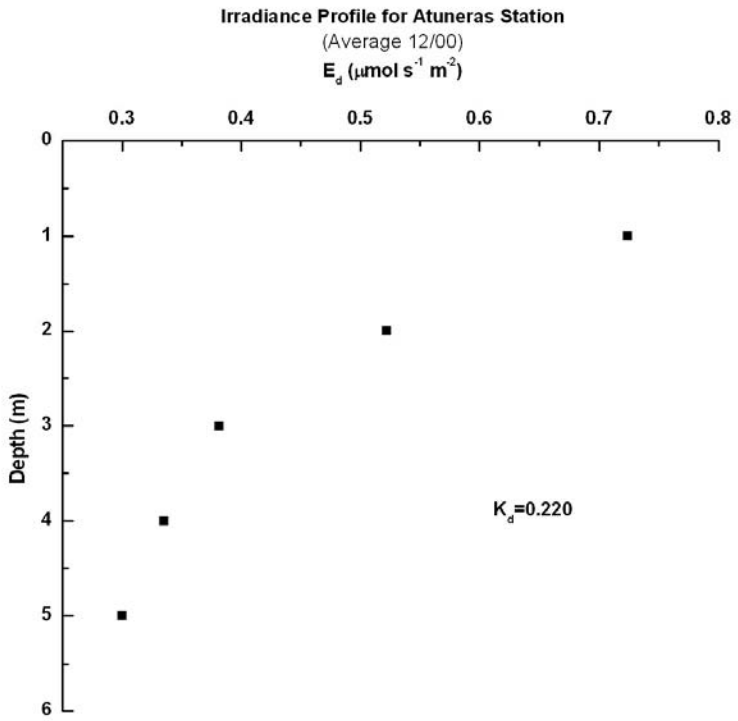

Figure 30: Downwelling irradiance profile at Atuneras Station.

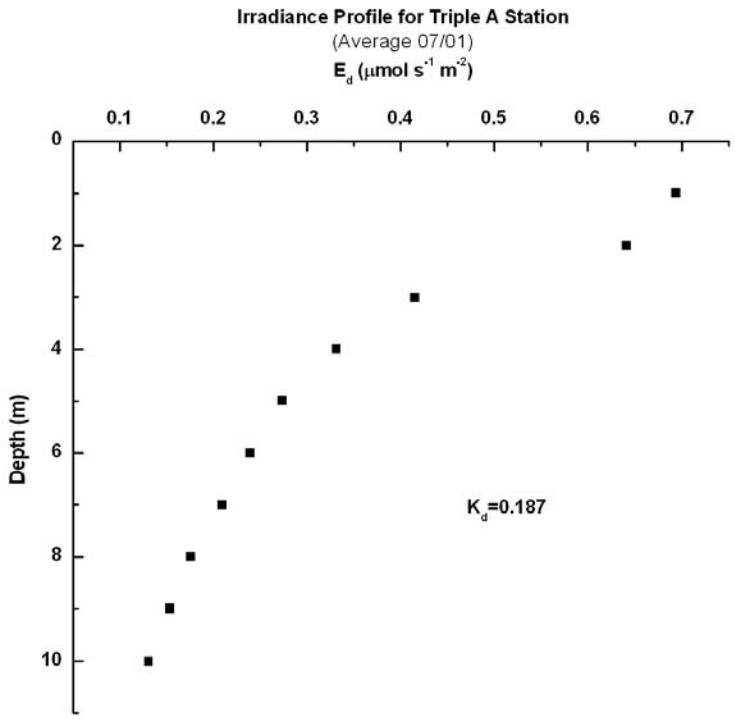

Figure 31: Downwelling irradiance profile at Triple-A Station.

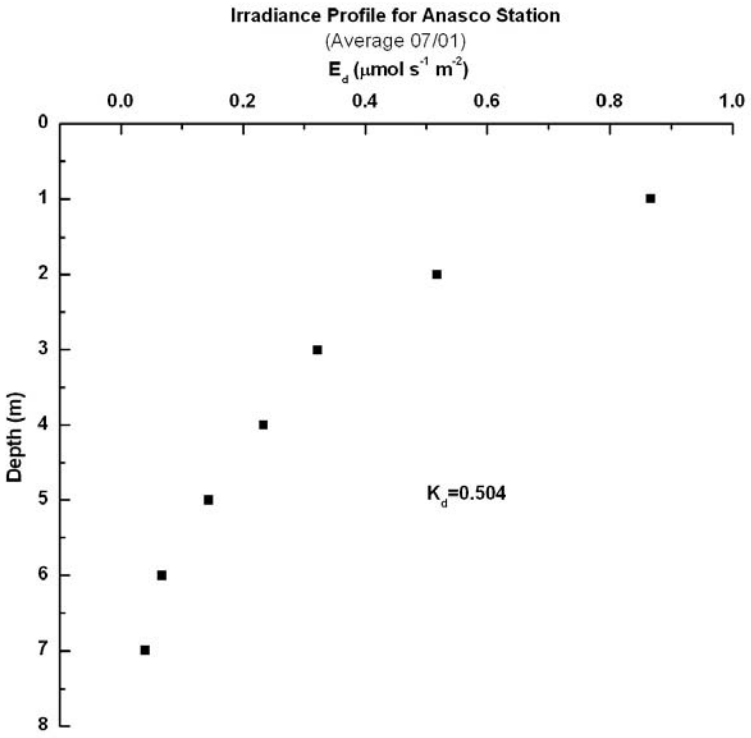

Figure 32: Downwelling irradiance profile at Añasco Station.

6.3 August 2001 Cruise

6.3.1 CTD Profiles

A cruise to Guanica and Guayanilla Bays took place during August 28, 2001. Six coral reef sites were sampled for physical properties (conductivity and temperature) using a CTD. CTD profiles are shown in Figures 33 through 38. Notice how some of these stations are relatively stratified and show some of the highest chlorophyll values encountered in this study.

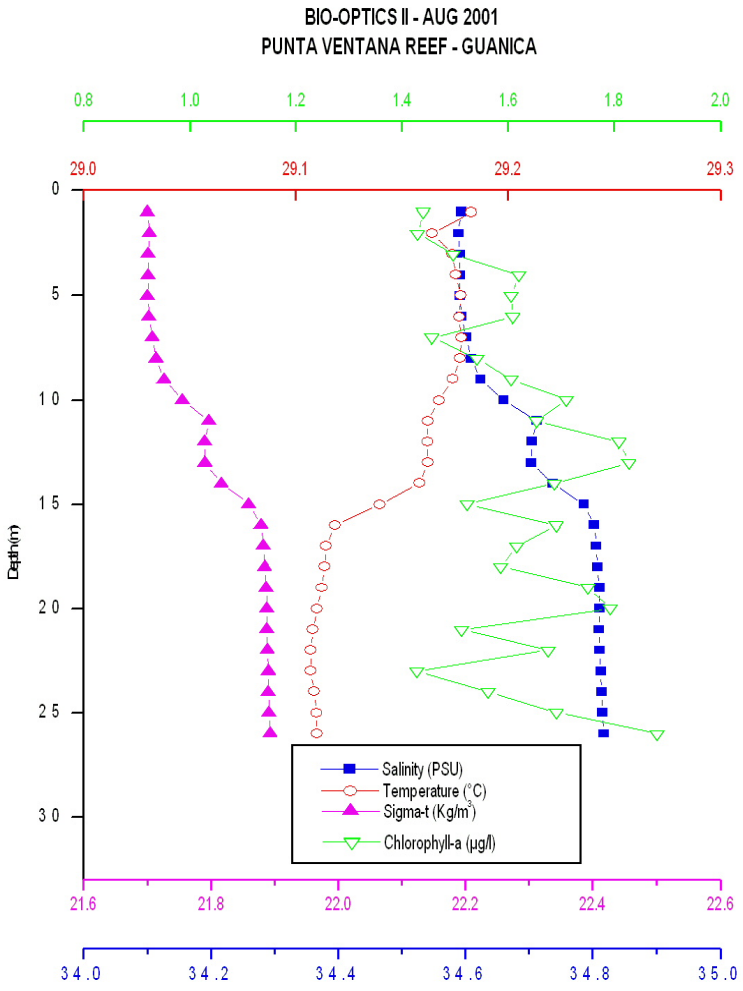

Figure 33: CTD profile for Punta Ventana, Guanica.

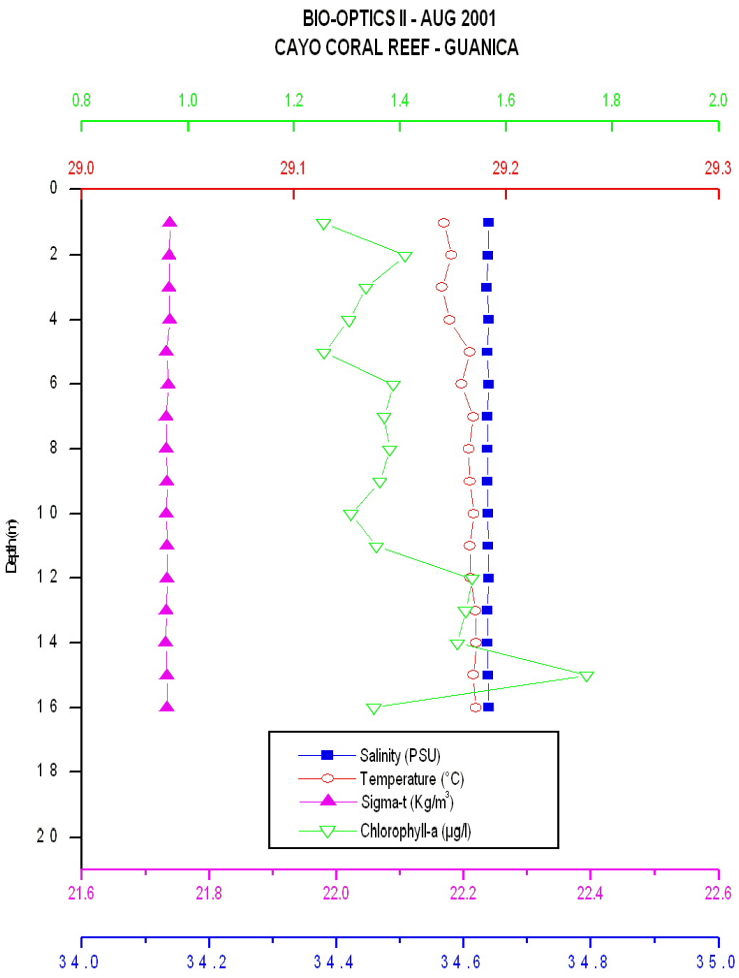

Figure 34: CTD profile for Cayo Coral, Guanica.

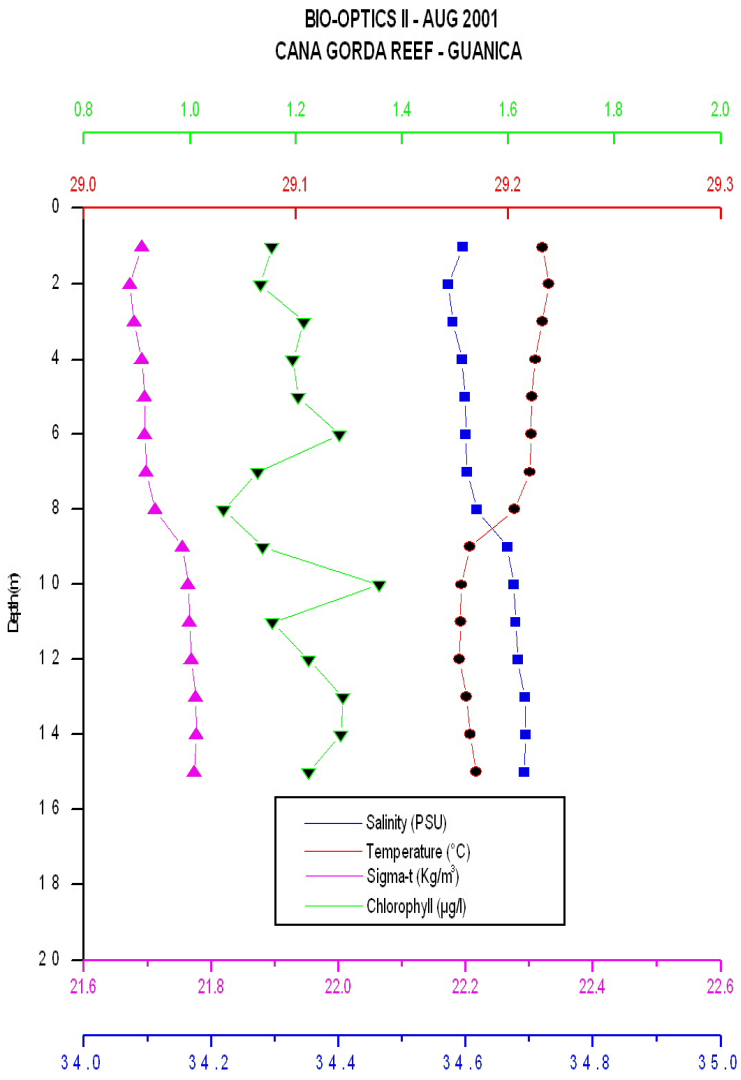

Figure 35: CTD profile for Caña Gorda, Guanica.

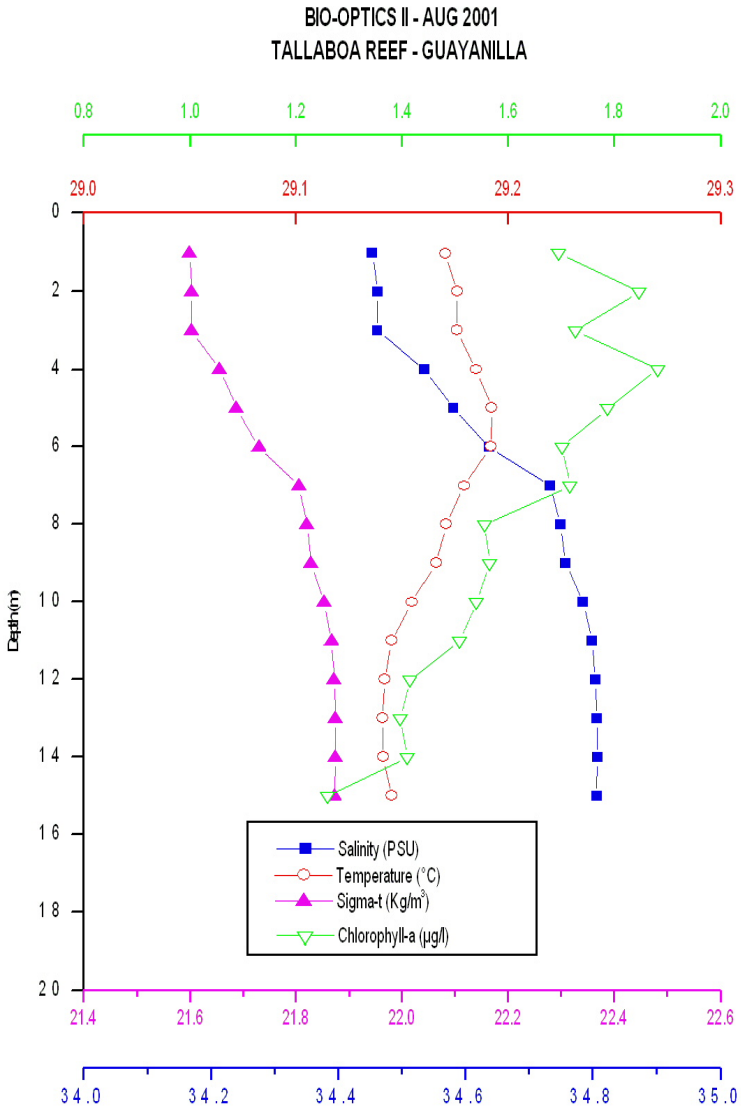

Figure 36: CTD profile for Tallaboa Reef, Guayanilla.

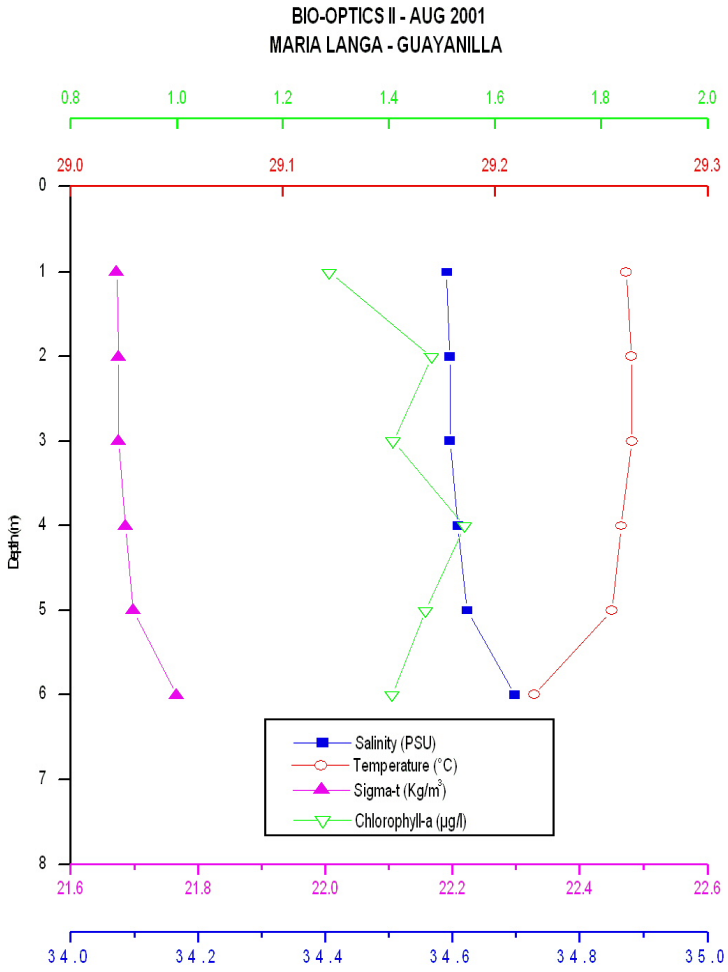

Figure 37: CTD profile for Maria Langa Reef, Guayanilla.

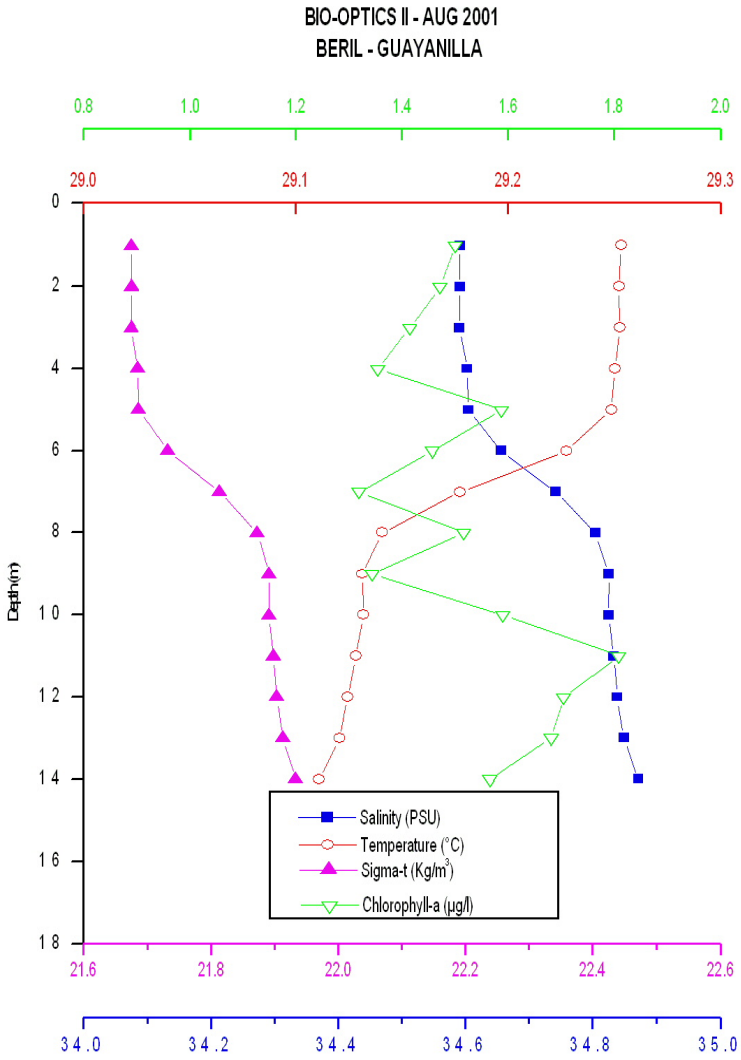

Figure 38: CTD profile for Beril Reef, Guayanilla.

6.3.2 Optical Properties

Downwelling irradiance (Ed) profiles and the corresponding Kd values are shown in Figures 39 through 44.

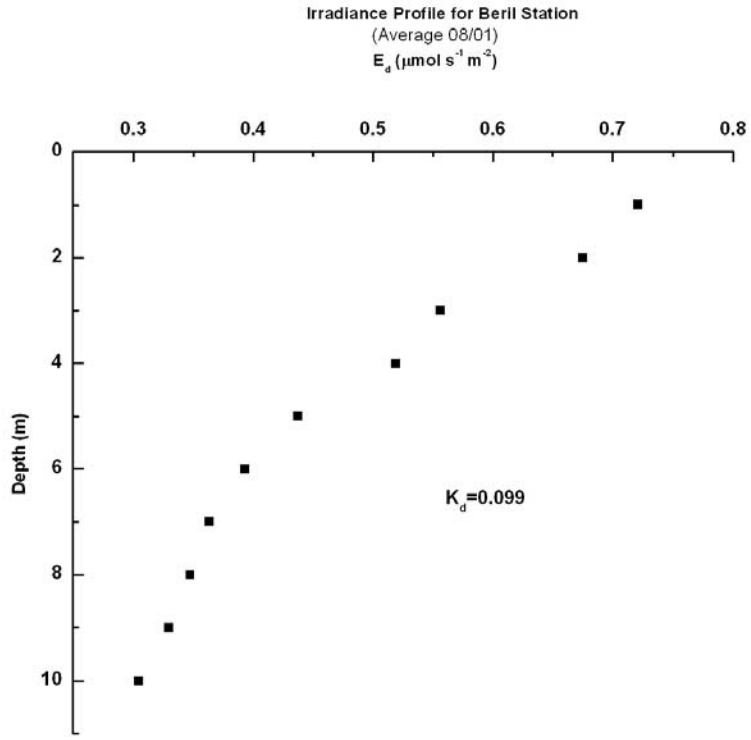

Figure 39: Ed profile and corresponding Kd value for Beril Station, Guayanilla.

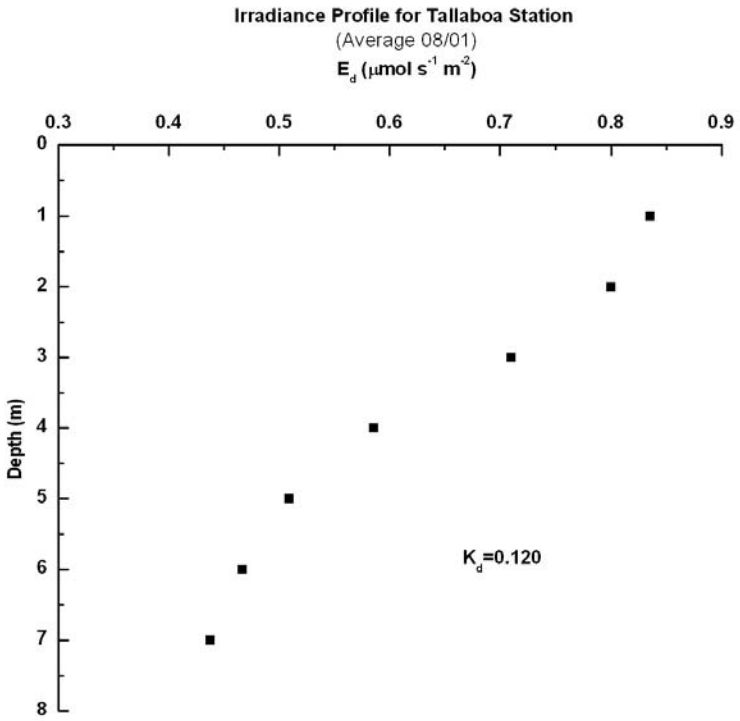

Figure 40: Ed profile and corresponding Kd value for Tallaboa Station, Guayanilla.

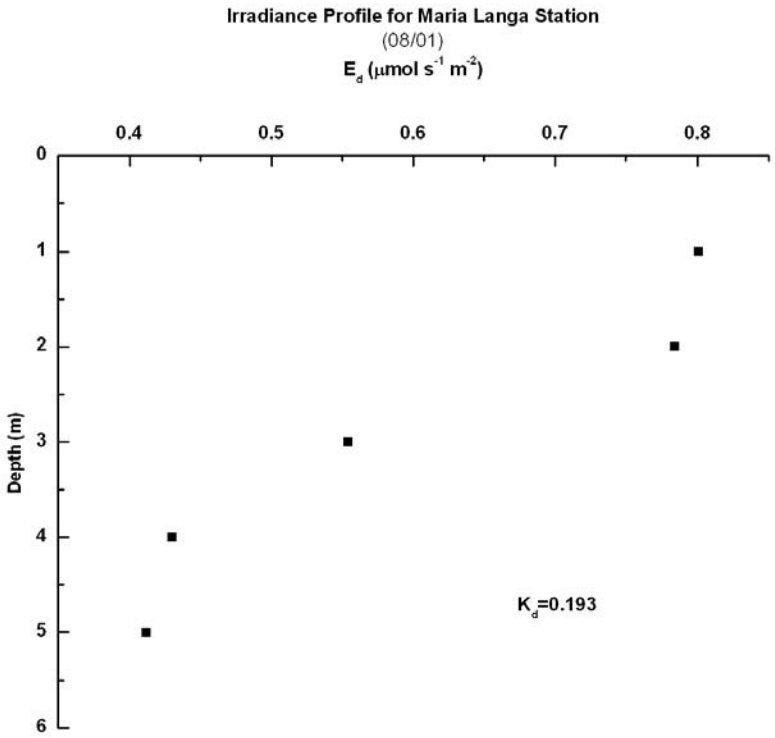

Figure 41: Ed profile and corresponding Kd value for Maria Langa, Guayanilla.

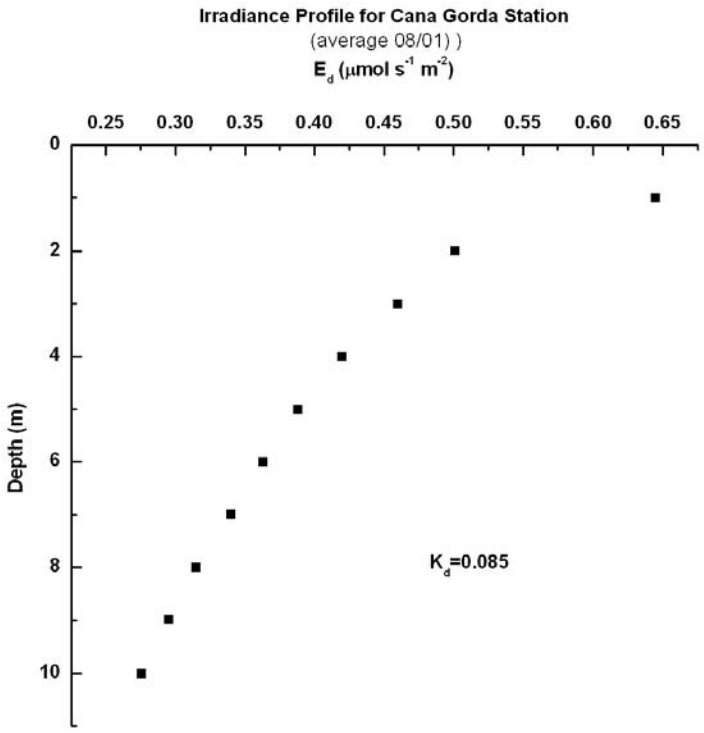

Figure 42: Ed profile and corresponding Kd value for Caña Gorda, Guanica.

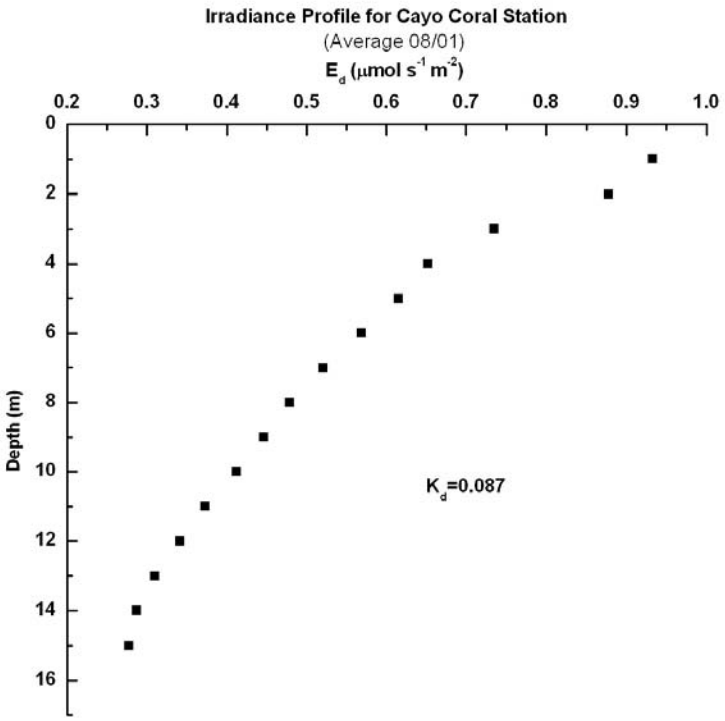

Figure 43: Ed profile and corresponding Kd value for Cayo Coral, Guanica.

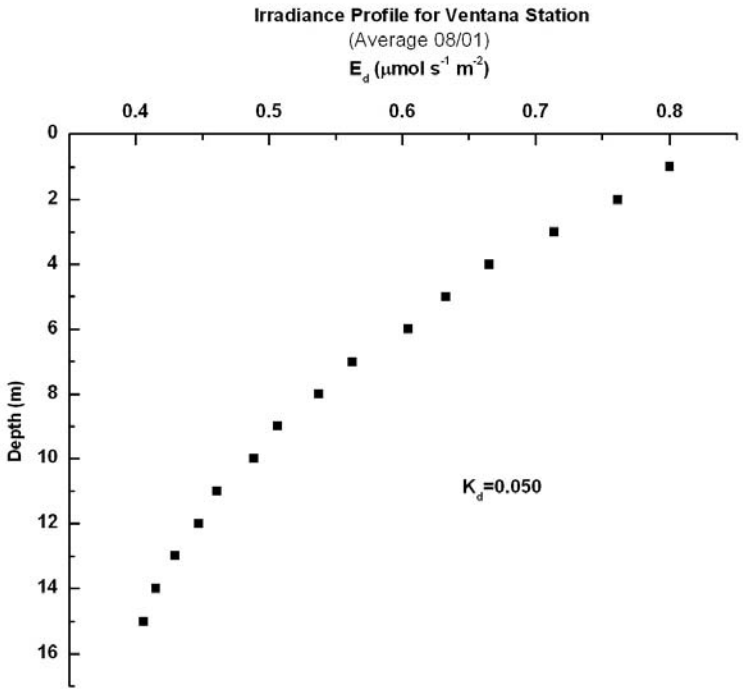

Figure 44: Ed profile and corresponding Kd value for Ventana Station, Guanica.

7.0 Larval Fish and Fish Species Diversity Data

Table 5: Taxonomic composition and relative abundance (%) of larval fishes - December/2000

TAXON	PARGUERA		DESECHEO		MAYAGUEZ		GUAYANILLA		GUANICA	
	Ind/100m3	%	Ind/100m3	%	Ind/100m3	%	Ind/100m3	%	Ind/100m3	%
Leptocephali Larvae							2.17	1.90		
Clupeiformes	1.9	1.4	7.6	3.4	39.1	13.3	53.00	46.43	22.33	41.54
Clupeidae									0.61	1.13
Myctophidae	2.7	2.1	46.7	20.6	14.8	5.0	1.58	1.38	3.25	6.04
Photichthyidae			4.3	1.9						
Holocentridae			2.5	1.1						
Scorpaenidae			2.3	1.0						
Hemiramphidae	1.6	1.2								
Exocoetidae	4.7	3.5								
Ophidiidae	6.3	4.8								
Perciformes							4.19	3.67	2.03	3.78
Apogonidae					3.6	1.2	8.03	7.03		
Carangidae	8.9	6.8	9.2	4.1	8.1	2.8	3.18	2.79	5.21	9.70
Lutjanidae	1.3	1.0	15.4	6.8	7.7	2.6	9.41	8.24	5.54	10.30
Gerreidae	9.6	7.3			3.9	1.3	3.78	3.31	1.25	2.33
Haemulidae	1.7	1.3			51.9	17.7	2.37	2.07	1.40	2.60
Mullidae	26.1	19.8	3.2	1.4						
Labridae	3.7	2.8	5.4	2.4						
Scaridae			56.7	25.0	20.3	6.9	1.40	1.22		
Pomacentridae	7.1	5.4			6.7	2.3			0.66	1.22
Pomacanthidae	2.9	2.2							0.97	1.79
Labriosomidae	28.0	21.2	12.1	5.3						
Opistognathidae	1.5	1.2	4.5	2.0	4.6	1.6			1.23	2.29
Sphyraenidae	2.4	1.8								
Microdesmidae					16.6	5.7	3.34	2.93		
Gobiidae	5.5	4.2	4.9	2.2	57.4	19.6	11.68	10.23	3.88	7.22
Tripterygiidae			7.7	3.4						
Callionymidae					3.0	1.0				
Blenniidae	4.0	3.0	2.5	1.1	14.1	4.8				
Acanthuridae			4.8	2.1						
Scombridae			6.2	2.7					1.01	1.87
Bothidae			6.5	2.8						
Monacanthidae					6.5	2.2				
	120.1		202.6		258.3		114.15	91.22	49.36	91.80
Others	12.0	9.1	24.5	10.8	35.3	12.0	20.85	8.78	15.95	8.20
Total Abundace	132.1	100.0	227.1	100.0	293.6	100.0	135.00	100.00	65.31	100.00

Table 6: Fish Species Diversity: December 2000- August 2001

Station	No. of Family (S)	Total Abundance (N)	Species Diversity (H')	Species Richness (d1)	Species Evenness (J')
DESECHEO					
NORTH REEF	17	34.5	2.01	4.52	0.71
PUERTO BOTES	28	66.2	2.34	6.44	0.71
PUERTO CANOAS	34	125.9	2.47	6.82	0.7
MAYAGUEZ					
MEDIA LUNA	29	117	2.53	5.88	0.75
LAS CORONAS	26	90.5	2.34	5.55	0.72
TOURMALINE	36	85	2.82	7.88	0.79
PARGUERA					
SHELF EDGE	22	57.77	2.62	5.18	0.85
LAUREL	20	41.12	2.10	5.11	0.70
MARGARITA	17	33.26	1.94	4.57	0.68
GUAYANILLA					
MARIA LANGA	30	164.1	1.73	5.69	0.51
VERIL	27	112.5	2.31	5.51	0.70
TALLABOA	26	65.92	2.30	5.97	0.71
GUANICA					
CAÑA GORDA	20	26.5	2.42	5.8	0.81
VENTANA REEF	26	82.4	2.19	5.67	0.67
CAYO CORAL	22	52.4	1.96	5.3	0.64

8.0 Sessile-Benthic Reef Community and Taxonomic Composition and Fish Abundance Data.

Table 7: Percent Linear Cover By Sessil-Benthic Categories At North Drop Reef Tourmaline Reserve, Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.71	3.31	4.00	4.38	3.56	**3.79**
SUBSTRATE CATEGORIES						
Live Coral	41.26	67.38	50.94	41.31	44.82	**49.1**
Turf Algae	24.8	19.91	31.64	39.29	42.18	**31. 6**
Reef Overhangs	6.71	4.58	5.57	6.54	3.24	**5.3**
Gorgonian Bases	2.63	1.8	4.36	7.58	7.15	**4.7**
Coral Rubble	15.97	2.03	3.64			**4.3**
Sponges	3.21	1.35	2.14	1.95	1.03	**1.9**
Fleshy Algae	0.88	2.93	0.93	1.67	1.18	**1.5**
Zoanthids	2.99		0.71	1.67		**1.1**
Hydrocorals	1.53		0.21		0.44	**0.4**
Gorgonian Colonies	22	23	12	21	25	**21**

Table 8: Taxonomic Composition And Linear Cover Of Coral Species At North Drop Reef Tourmaline Reserve, Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
CORAL SPECIES						
Montastrea annularis	8.32	23.52	18.00	12.24	15.04	**15.42**
Porites astreoides	6.27	7.21	10.36	3.62	7.52	**7.00**
Madracis mirabilis		27.42				**5.48**
Porites porites	4.45	1.35	4.14	5.77	10.62	**5.27**
Dendrogyra cylindrus	11.01			7.75		**3.75**
Agaricia sp.	4.01	4.58	2.00	2.57	1.25	**2.88**
Colpophyllia natans	5.47		8.57			**2.81**
Montastrea cavernosa			4.14	1.6	4.87	**2.12**
Agaricia agaricites		0.75	0.4	4.59	3.02	**1.75**
Meandrina meandrites	1.31	0.74	2.52	1.67	0.42	**1.33**
Diploria labirynthiformis		1.8			1.25	**0.61**

Mycetophyllia sp.			0.98		**0.20**
Diploria strigosa				0.83	**0.17**
Acropora cervicornis	0.44	0.2			**0.13**
Eusmilia fastigiata		0.6			**0.12**
Siderastrea siderea			0.49		**0.10**

Outside transects:

Dichocoenia stokesii
Madracis decactis
Manicina areolata
Millepora alcicornis
Millepora squarrosa
Mycetophyllia aliciae

Mycetophyllia lamarckiana
Porites furcata
Scolymia sp.
Stephanocoenia michilini
Stylaster roseus

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Table 9: Taxonomic Composition And Abundance Of Fishes At North Drop Reef Tourmaline Reserve. Mayaguez.

Location (D-GPS):
18° 09.794' N; 067° 16.418' W

		BELT-TRANSECTS					
		1	2	3	4	5	
	Depth (m) :	10.6	10.6	10.6	10.6	10.6	
FISH SPECIES	**COMMON NAME**	**(Individuals/30 m2)**					**MEAN**
Chromis cyanea	Blue chromis	38	28	8	17	14	21.00
Stegastes partitus	Bicolor damselfish	9	25	22	11	13	16.00
Clepticus parrae	Creole wrasse	32	6	17		5	12.00
Scarus iserti	Striped parrotfish	8	11	7	4	10	8.00
Thalassoma bifasciatum	Yellowhead wrasse	12	14	10			7.20
Haemulon flavolineatum	French grunt	1	1	4	7		2.60
Sparisoma aurofrenatum	Redband parrotfish	3	4		3	3	2.60
Halichoeres garnoti	Yellowhead wrasse	5	1	1	3	2	2.40
Sparisoma viride	Stoplight parrotfish	5	2	3	2		2.40
Stegastes leucostictus	Beaugregory	2	3	1	2	2	2.00
Stegastes planifrons	Yellow eye	2	2	3	2		1.80

	damselfish						
Haemulon chrysargyreum	Smallmouth grunt			1	6		1.40
Adioryx sp.	Squirrelfish		2	1	2	1	1.20
Myripristis jacobus	Blackbar soldierfish				4	2	1.20
Acanthurus bahianus	Ocean surgeon	1	1	1		2	1.00
Acanthurus chirurgus	Doctorfish	1	2	1	1		1.00
Chaetodon capistratus	Four eye buterflyfish			2	1	2	1.00
Coryphopterus personatus	Masked goby		5				1.00
Serranus tigrinus	Harlequin bass	1		1		3	1.00
Cephalopolis cruentatus	Graysby	2	1		1		0.80
Chromis multilineata	Brown chromis	2		1	3		0.80
Lutjanus apodus	Schoolmaster			2	2		0.80
Scarus vetula	Queen parrotfish			1	2	1	0.80
Acanthurus coeruleus	Blue tang	2	1				0.60
Aulostomus maculatus	Trumpetfish	1	1			1	0.60
Canthigaster rostrata	Caribbean puffer			1	1	1	0.60
Gramma loreto	Royal gramma		3				0.60
Hypoplectrus puella	Barred hamlet	1		1		1	0.60
Hypoplectrus unicolor	Butter hamlet			3			0.60
Holocentrus rufus	Squirrelfish		1		1		0.40
Amblycirrhitus pinos	Redspotted hawkfish	1					0.20
Bodianus rufus	Spanish hogfish				1		0.20
Chaetodon ocellatus	Spotfin butterflyfish				1		0.20
Epinephelus guttatus	Red hind		1				0.20
Holacanthus tricolor	Rock beauty	1					0.20
Hypoplectrus guttavarius	Shy hamlet	1					0.20
Microspathodon chrysurus	Yellowtail damselfish				1		0.20
Odontoscion dentex	Reef croaker		1				0.20
Priacanthus cruentatus	Glasseye					1	0.20
Scomberomorus regalis	Cero	1					0.20
Sphaeroides sp.	Puffer					1	0.20
Stegastes dorsopunicans	Dusky damselfish	1					0.20
	TOTAL INDIVIDUALS	**133**	**116**	**92**	**78**	**65**	**96.8**
	TOTAL SPECIES	**24**	**22**	**23**	**23**	**18**	**22**

Outside Transects :

Lutjanus mahogany	Mahogany snapper
Anisotremus virginicus	Porgy
Carangoides ruber	Bar jack

Halichoeres radiatus	Puddingwife
Holacanthus ciliaris	Queen angelfish
Mulloides martinicus	Yellowtail goatfish
Pomacanthus arcuatus	Gray angelfish
Prognathodes aculeatus	Longsnout butterflyfish
Scomberomorus cavalla	King mackerel
Spyraena barracuda	Great barracuda

Table 10: Percent Linear Cover By Sessil-Benthic Categories At Las Coronas Reef Tourmaline Reserve, Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	3.42	1.63	3.87	4.23	1.99	**3.03**
SUBSTRATE CATEGORIES						
Turf Algae	44.93	40.15	34.68	50.60	60.13	**46.10**
Live Coral	33.00	18.09	37.46	26.39	31.71	**29.33**
Fleshy Algae	1.19	31.56	5.98			**7.75**
Gorgonian Bases	9.61	1.46	11.32	9.08	4.00	**7.09**
Reef Overhangs	5.89	7.65	8.15	7.68	1.42	**6.16**
Sponges	1.34	2.06	1.01	5.73	2.67	**2.56**
Coral Rubble	3.87					**0.77**
Zoanthids	0.22		1.51	0.49		**0.44**
Gorgonian Colonies	22	13	23	19	31	**22**

Table 11: Taxonomic Composition And Linear Cover Of Coral Species At Las Coronas Reef Tourmaline Reserve. Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
CORAL SPECIES						
Montastrea annularis	11.70	10.92	12.62	13.27	12.43	**12.19**
Agaricia sp.	2.61	0.73	12.18	5.31	6.67	**5.50**
Montastrea cavernosa	9.99	2.41	3.39		4.50	**4.06**
Porites astreoides	2.61	1.98	0.41	0.69	3.25	**1.79**
Siderastrea siderea			1.95	1.89	4.50	**1.67**
Porites porites	0.11	0.12	1.80	3.56	0.35	**1.19**
Diploria strigosa	1.58		2.44			**0.80**
Colpophyllia natans		1.94	1.66			**0.72**
Madracis decactis	2.83					**0.57**

Mycetophyllia sp.			1.67	**0.33**
Mycetophyllia aliciae	1.05			**0.21**
Diploria labyrinthiformis		1.02		**0.20**
Leptoseris cucullata	0.52			**0.10**

Outside transects:

Agaricia agaricites
Dendrogyra cylindrus
Isophyllia sinuosa
Leptoseris cucullata
Manicina areolata

Meandrina meandrites
Millepora alcicornis
Mycetophyllia aliciae
Mycetophyllia ferox
Mycetophyllia lamarckiana
Scolymia sp.
Stephanocoenia michilini

Table 12: Taxonomic Composition And Abundance Of Fishes At Las Coronas Reef Tourmaline Reserve. Mayaguez.

Location (D-GPS): 18° 05.836'; 067° 17.225'

		BELT-TRANSECTS					
		1	2	3	4	5	
	Depth (m) :	10.0	10.0	10.0	10.0	10.0	
FISH SPECIES	**COMMON NAME**	**(Individuals/30 m2)**					**MEAN**
Scarus iserti	Striped parrotfish		12	4	6	5	5.40
Stegastes partitus	Bicolor damselfish	2	5	2	8	3	4.00
Chromis cyanea	Blue chromis	8	2	6	3		3.80
Stegastes leucostictus	Beaugregory	2	3	4	2	4	3.00
Stegastes planifrons	Yellow eye damselfish	2	1	3	4	3	2.20
Halichoeres garnoti	Yellowhead wrasse		4	1	3	2	2.00
Sparisoma aurofrenatum	Redband parrotfish	3	2		1	3	1.80
Sparisoma viride	Stoplight parrotfish	1	2	2	2	2	1.80
Holocentrus rufus	Squirrelfish	1	2	2	1		1.20
Sparisoma radians	Bucktooth parrotfish		2	2	2		1.20

Thalassoma bifasciatum	Yellohead wrasse	1	1	4		1	1.20
Chaetodon capistratus	Four eye butterflyfish		2	1		2	1.00
Canthigaster rostrata	Caribbean puffer	1	1		1	1	0.80
Gobiosoma evelynae	Sharknose goby				4		0.80
Ocyurus chrysurus	Yellowtail snapper		1	1		1	0.60
Stegastes dorsopunicans	Dusky damselfish	1				2	0.60
Acanthurus bahianus	Ocean surgeon					1	0.20
Acanthurus chirurgus	Doctorfish	1					0.20
Amblycirrhitus pinos	Redspotted hawkfish					1	0.20
Aulostomus maculatus	Trumpetfish		1				0.20
Hypoplectrus chlorurus	Yellowtail hamlet	1					0.20
Hypoplectrus guttavarius	Shy hamlet					1	0.20
Hypoplectrus puella	Barred hamlet				1		0.20
Hypoplectrus sp.	Hamlet				1		0.20
Hypoplectrus unicolor	Butter hamlet				1		0.20
Myripristis jacobu	Blackbar soldierfish				1		0.20
Priacanthus cruentatus	Glasseye				1		0.20
Pseudupeneus maculatus	Spotted goatfish					1	0.20
Scarus taeniopterus	Princess parrotfish				1		0.20
Scarus vetula	Queen parrotfish	1					0.20
	TOTAL INDIVIDUALS	**25**	**41**	**32**	**43**	**33**	**34.80**
	TOTAL SPECIES	**13**	**15**	**12**	**18**	**16**	**15**

Outside Transects :

Acanthurus coeruleus	Blue tang
Cephalopholis fulva	Coney
Chromis multilineata	Brown chromis
Coryphopterus sp.	Goby
Ephinephelus guttatus	Red hind
Gramma loreto	Royal gramma
Haemulon aurolineatum	Tomtate
Halichoeres maculipinna	Clown wrasse
Holacanthus ciliaris	Queen angelfish
Holacanthus tricolor	Rock beauty
Hypoplectrus chlorurus	Yellowtail hamlet
Hypoplectrus nigricans	Black hamlet
Lachnolaimus maximus	Hogfish

Lactophrys triqueter	Smooth trunkfish
Lutjanus synagris	Lane snapper
Pomacanthus ciliaris	French angelfish
Pempheris poeyi	Shortfin sleeper
Pomacanthus arcuatus	Gray angelfish
Scomberomorus regalis	Cero

Table 13: Taxonomic Composition And Abundance Of Motile Megabenthic Invertebrates At Las Coronas Reef, Tourmaline Reserve. Mayaguez.

		BELT-TRANSECTS					
		1	**2**	**3**	**4**	**5**	**MEAN ABUNDANCE**
SPECIES	**COMMON NAME**						**(IND/30 m2)**
Panulirus guttatus	Rock Lobster	0	0	1	0	0	0.2
Carpilius corallinus	Coral Crab	0	0	1	0	0	0.2
	TOTALS	**0**	**0**	**2**	**0**	**0**	**0.4**

Table 14: Percent Linear Cover By Sessil-Benthic Categories At Media Luna Reef Tourmaline Reserve, Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
Rugosity (m)	1.82	1.38	1.62	1.76	1.87	**1.69**
SUBSTRATE CATEGORIES						
Turf Algae	73.60	78.03	76.94	74.23	75.57	**75.7**
Sponges	10.41	11.25	12.99	8.16	10.45	**10.6**
Live Coral	10.83	4.61	6.54	17.17	10.95	**10.0**
Gorgonian Bases	2.71	5.36	3.18	0.51	1.35	**2.6**
Reef Overhangs	1.95		0.34		1.77	**0.8**
Zoanthids		0.53				**0.1**
Ascidians	0.51					**0.1**
Fleshy Algae		0.26				**0.05**

Gorgonian Colonies	61	52	47	52	49	**52**

Table 15: Taxonomic Composition And Linear Cover Of Coral Species At Media Luna Reef Tourmaline Reserve. Mayaguez.

	TRANSECTS					
	1	**2**	**3**	**4**	**5**	**MEAN**
CORAL SPECIES						
Diploria strigosa	2.12	2.72	0.73	5.87	1.43	**2.57**
Montastrea cavernosa	1.19	1.14	1.55	6.04	2.36	**2.46**
Siderastrea siderea	5.13		0.24	1.45		**1.36**
Meandrina meandrites			0.85	1.44	2.86	**1.03**
Dendrogyra cylindrus					4.30	**0.86**
Porites porites	1.19	0.12	1.21			**0.50**
Agaricia agaricites	0.36	0.25	1.21	0.60		**0.48**
Diploria labyrinthiformis				1.79		**0.36**
Stephanocoenia michilini			0.73			**0.15**
Porites astreoides	0.72					**0.14**
Meandrina brasiliensis		0.37				**0.07**
Mycetophyllia aliciae	0.12					**0.02**
Outside transects:						
Acropora cervicornis						
Colpophyllia natans						
Dichocoenia stokesii						
Madracis decactis						
Manicina areolata						
Millepora alcicornis						
Stephanocoenia michilini						

Table 16: Taxonomic Composition And Abundance Of Fishes At Media Luna Reef Tourmaline Reserve. Mayaguez.

Location (D-GPS): 18° 06.079'; 067° 18.731'

		BELT-TRANSECTS					
		1	2	3	4	5	
	Depth (m) :	10.0	10.0	10.0	10.0	10.0	
FISH SPECIES	**COMMON NAME**	**(Individuals/30 m2)**					**MEAN**
Halichoeres garnoti	Yellowhead wrasse	13	11	12	7	16	11.80
Stegastes partitus	Bicolor damselfish	9	10	8	1	3	6.20

Sparisoma aurofrenatum	Redband parrotfish	4	5	6	9	1	5.00
Scarus iserti	Striped parrotfish	2	5	10	5	1	4.60
Chromis cyanea	Blue chromis	4	1			7	2.40
Sparisoma radians	Bucktooth parrotfish	3	4	3		3	2.00
Chaetodon capistratus	Four eye butterflyfish	2	2	3	2		1.80
Acanthurus bahianus	Ocean surgeon	3		3	1	1	1.60
Canthigaster rostrata	Caribbean puffer	1	2	1	2	2	1.60
Sparisoma viride	Stoplight parrotfish	2	1		1		0.80
Stegastes planifrons	Yellow eye damselfish	2				1	0.60
Acanthurus chirurgus	Doctorfish		1	1			0.40
Hypoplectrus unicolor	Butter hamlet				1	1	0.40
Malacoctenus triangulatus	Saddled blenny	1		1			0.40
Pseudupeneus maculatus	Spotted goatfish				1	1	0.40
Scarus vetula	Queen parrotfish			1	1		0.40
Synodus intermedius	Lizardfish		1	1			0.40
Aulostomus maculatus	Trumpetfish	1					0.20
Bodianus rufus	Spanish hogfish				1		0.20
Cantherhines pullus	Tail ligth filefish		1				0.20
Epinephelus guttatus	Red hind				1		0.20
Holocentrus rufus	Squirrelfish	1					0.20
Ocyurus chrysurus	Yellowtail snapper	1					0.20
Scarus taeniopterus	Princess parotfish		1				0.20
Serranus tigrinus	Harlequin bass		1				0.20
Stegastes leucostictus	Beaugregory					1	0.20
	TOTAL INDIVIDUALS	**49**	**46**	**50**	**33**	**38**	**43.20**
	TOTAL SPECIES	**15**	**14**	**12**	**13**	**12**	**13**

Outside Transects :

Dasyatis americana	Southern stingray
Anisotremus surinamensis	Black margate
Acanthurus coeruleus	Blue tang
Balistes vetula	Queen triggerfish
Cephalopolis fulva	Coney
Chaetodon ocellatus	Spotfin butterflyfish
Chaetodon striatus	Banded butterflyfish
Gobiosoma elvelynae	Sharknose goby
Gramma loreto	Royal gramma
Haemulon aurolineatum	Tomtate
Haemulon flavolineatum	French grunt
Haemulon sciurus	Bluestripped grunt
Hemiramphus ballyhoo	Ballyhoo
Holacanthus ciliaris	Queen angelfish

Hypoplectrus puella	Barred hamlet
Lactophrys bicaudalis	Spotted trunkfish
Lactophrys triqueter	Smooth trunkfish
Lutjanus apodus	Schoolmaster
Lutjanus synagris	Lane snapper
Microspathodon chrysurus	Yellowtail damselfish
Thalassoma bifasciatum	Yellowhead wrasse
Tylosurus crocodrilus	Houndfish

9.0 Literature Cited

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