Biogeographic Analysis of Tortugas Ecological Reserve: Examining the Refuge Effect Following Reserve Designation

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Project Goals

The ultimate goal of this program is to provide a measurement of the refuge effect of the Tortugas Ecological Reserve (TER). To achieve such an assessment, we have focused our efforts on: 1) an extensive habitat characterization of the benthos in and around TER, 2) a multiple stable isotope analysis of the food web supporting fish production in TER, 3) an examination of the abundance and composition of reef fishes in TER, and 4) an examination of the effects of trawl exclusion on benthic habitats located in TER. Since 2000, a total of eight cruises, utilizing three different NOAA ships, have been conducted in support of this research (Table 1).

The need for detailed habitat characterization is inextricably linked with the question of where to establish a reserve. Biogeography simply focuses attention on what ecologists have implicitly known for many years, that the geographic context of the biota not only signals the organization of ecosystem processes, but in many instances acts to control or strongly modify those processes. In other words, to examine living organisms without regard to their spatial and temporal organization at multiple scales of organization, and in association with first order environmental factors will fail to elucidate vulnerability, susceptibility, and resilience of the ecosystem. Many reef fishes leave the structure of the reef at night to forage in adjacent sand, algal, and seagrass flats, thereby importing significant amounts of nutrients onto the reef environment, contributing to its high productivity (Meyer et al. 1983). This mass transfer also ultimately contributes to energy requirements of small grazers that cannot access the adjacent, non-coral reef resources. The importance of off-reef migration should be reflected in food web analyses. Multiple stable isotope analysis has been used to trace the sources of primary production contributing to the food web in a variety of marine environments (Fry et al. 1982; Peterson et al. 1985). In addition, stable isotopes can be used to track animal movements between habitats (Fry et al. 1999).

Methods

We chose to adopt a sampling protocol that focused on habitat interfaces (i.e., areas where coral reef meets seagrass/algal plain), using randomly selected, permanent transects. The area within and outside the Reserve was divided into three strata: 1) the existing Dry Tortugas National Park (DTNP, Park), 2) the Reserve (not falling within the existing jurisdiction of the DTNP), and 3) a 5 km buffer around the Reserve not within the DTNP (Out) for before/after comparisons (a Before-After Control Impact (BACI) sampling strategy (Underwood 1991). Lines were drawn through the longest axis of the Tortugas Bank and DTNP, normal to the prevailing northwest-southeast currents and bisecting these features into areas facing either upstream (North) or downstream (South; Fig. 1). In conjunction with the Reserve, Park, and Out strata, the interface zones along both of the large reef structures in Tortugas North (Tortugas Bank and DTNP) were designated as one of six categories: 1) Out North; 2) Out South; 3) Park North; 4) Park South; 5) Reserve North; and 6) Reserve South.

Table 1. Completed research cruises.

Cruise Name	Dates	Vessel	Sea Days	# Dives
FE-00-09-BL	7/10/00 - 8/4/00	NOAA Ship *FERREL*	20	164
OT-01-01	1/4/01 - 2/13/01	NOAA Ship *OREGON II*	8	0
FE-01-07-BL	4/8/01 - 4/20/01	NOAA Ship *FERREL*	12	55
FE-01-10-BL	6/17/01 - 7/1/01	NOAA Ship *FERREL*	13	111
FE-01-11-BL	7/8/01 - 7/21/01	NOAA Ship *FERREL*	13	86
GU-01-03	7/2/01- 7/3/01	NOAA Ship *GORDON GUNTER*	2	0
	5/11/02 - 5/13/02	*F/V Alexis M* (charter)	3	1
	5/27/02 - 5/30/02	*F/V Alexis M* (charter)	4	12
	6/6/02 - 6/12/02	*F/V Alexis M* (charter)	4	9
	6/23/02- 6/26/02	*F/V Alexis M* (charter)	4	10
FE-02-14-BL	6/17/02 - 7/12/02	NOAA Ship *FERREL*	24	184
FE-02-15-FK	7/15/02 - 7/19/02	NOAA Ship *FERREL*	5	49
	7/23/02 - 7/26/02	*F/V Alexis M* (charter)	4	13
	10/20/02 - 10/23/02	*F/V Alexis M* (charter)	4	8
TOTAL DAYS AT SEA			120	
TOTAL # DIVES				702

To choose five random transects from within each of the six categories, we used ESRI's ArcInfo® software and imposed a line at roughly the 10 fathom isobath around the perimeter of the two large coral features because this roughly approximated the location of the sand-coral interface. Each line was then broken down into the six categories and random distances, 50 m apart along each line type, were selected. It was estimated that 50 m would allow for visual isolation of potentially adjacent sites, an important factor for our fish visual census method. The selection of random locations along line type was continuous across the entire landscape, even though line types were segmented among the two large coral features, yielding true randomization. Random points were spaced 50 m along segments so that visual census methods would not overlap in the event two random numbers were adjacent to each other (which did not occur).

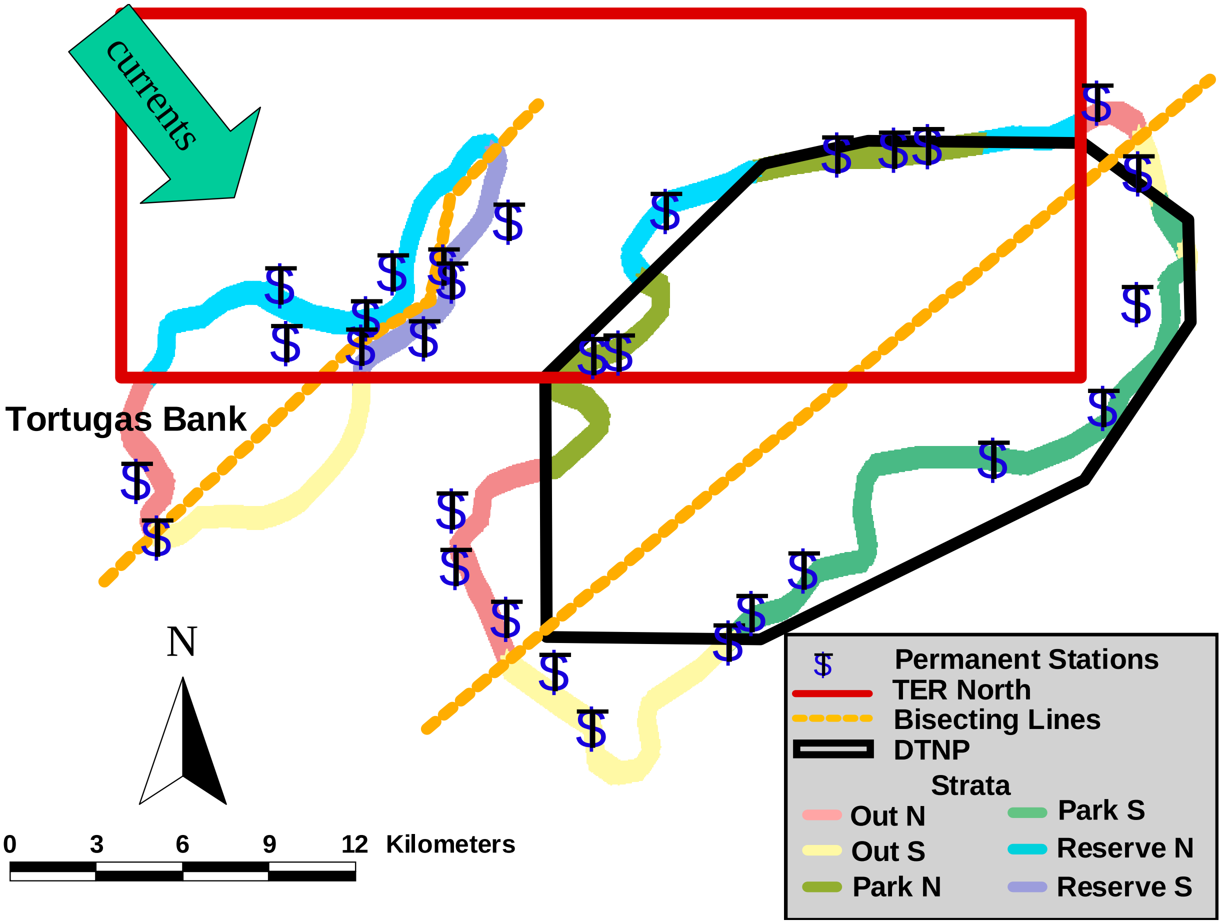

Figure 1. Location of interface strata and 30 permanent stations.

Habitat Characterization

Coarse-scale mapping of each station has been conducted using a variety of platforms over the years to address issues of scale. A MiniBAT® tow body housing a downward facing SeaViewer® color Sea-Drop camera was used to videotape the seafloor at ~ 10 cm resolution. Video was recorded onto either digital, SVHS, or VHS tapes and the exact time and location along each transect was stamped onto the video using the Horita® GPT-50 GPS video titler linked to a Trimble GPS Pathfinder Pro XR/XRS. Track lines were recorded using Trimble ASPEN® software. Beginning in 2002, we began mapping the stations using a sidescan sonar (Sport Scan®). On several occasions, the MiniBAT was run simultaneously with the Sport Scan as a means of video-calibrating the sonar images. A RoxAnn® Groundmaster seabed classification system was deployed and run simultaneously with the MiniBAT unit on occasion as well.

Fine-scale mapping by divers has taken place since 2001. Semi-permanent rebar stakes were established at the interface of each station by divers. Dive teams followed transect lines beginning from the permanent/temporary marker at the interface and running 30 m out in either direction, perpendicular to the interface (sand plain vs reef). A digital video camera (SONY DCR TRV900 MiniDV Handycam® camcorder) contained in an underwater housing, was used to record the substrate along the length of each transect at 40 cm above the substrate.

Food Web Analysis

We collected samples for use in a multiple stable isotope analysis of the food web supporting fish production in TER. Samples collected from within the permanent stations included primary producers (phytoplankton, benthic microalgae, benthic macroalgae, and seagrass) and secondary consumers (fish, crabs, and shrimp). Several methods of collection were employed including hook and line from the research vessel, divers armed with sling spears, beam trawls, hand collection by divers, and bucket/Niskin Bottle casts. This sampling targeted specific species from different levels of the food web in order to examine trophic relationships in the reef-interface zone.

Reef Fish

Paired band transect visual censuses were made by divers over the reef and soft bottom habitat along the 30 m transects as described above. Fish counts were made within 1 m on either side of the permanent transect.

Trawl Impact

Along the northern boundary of Tortugas North, pairs of randomly selected coordinates were chosen for beam trawl samples. The coordinates served as starting points for trawl tow paths. One coordinate of each pair was located ~ 2 km due south of the Tortugas North northern boundary (within the Reserve), and the other ~ 2 km due north of the boundary (outside the Reserve). One set of coordinates spanned the eastern boundary of Tortugas North. In this case, one coordinate was located ~ 2 km due west of Tortugas North’s eastern boundary (within the Reserve), and the other ~ 2 km due east of the boundary (outside the Reserve). We conducted three-minute tows at each coordinate using a modified 2 m beam trawl with a 3 mm mesh cod end.

Results to Date

Habitat Characterization

Track line files generated in ASPEN were exported to Microsoft® Excel. The times and coordinates displayed on the videos correspond to the chronologic records in the ASPEN-generated Excel spreadsheet. While the video was playing, CCFHR staff recorded a habitat code every five seconds based upon what was viewed in the video frame at that time. The track line spreadsheet, complete with habitat classification, was converted to a text file and imported into ESRI’s ArcView® software. In ArcView, the habitat codes were assigned unique color values. The color-coded track lines were then displayed on a chart of the Dry Tortugas, effectively creating a habitat map of the area. SportScan images will be calibrated with associated video transects as well. Analysis is on-going at CCFHR.

Food Web Analysis

The majority of fish analyzed so far exhibit a C isotope signature of -16 or less, consistent with a food web based on benthic primary producers (Fig. 2). Penaeid shrimp (Penaeidae), flounder

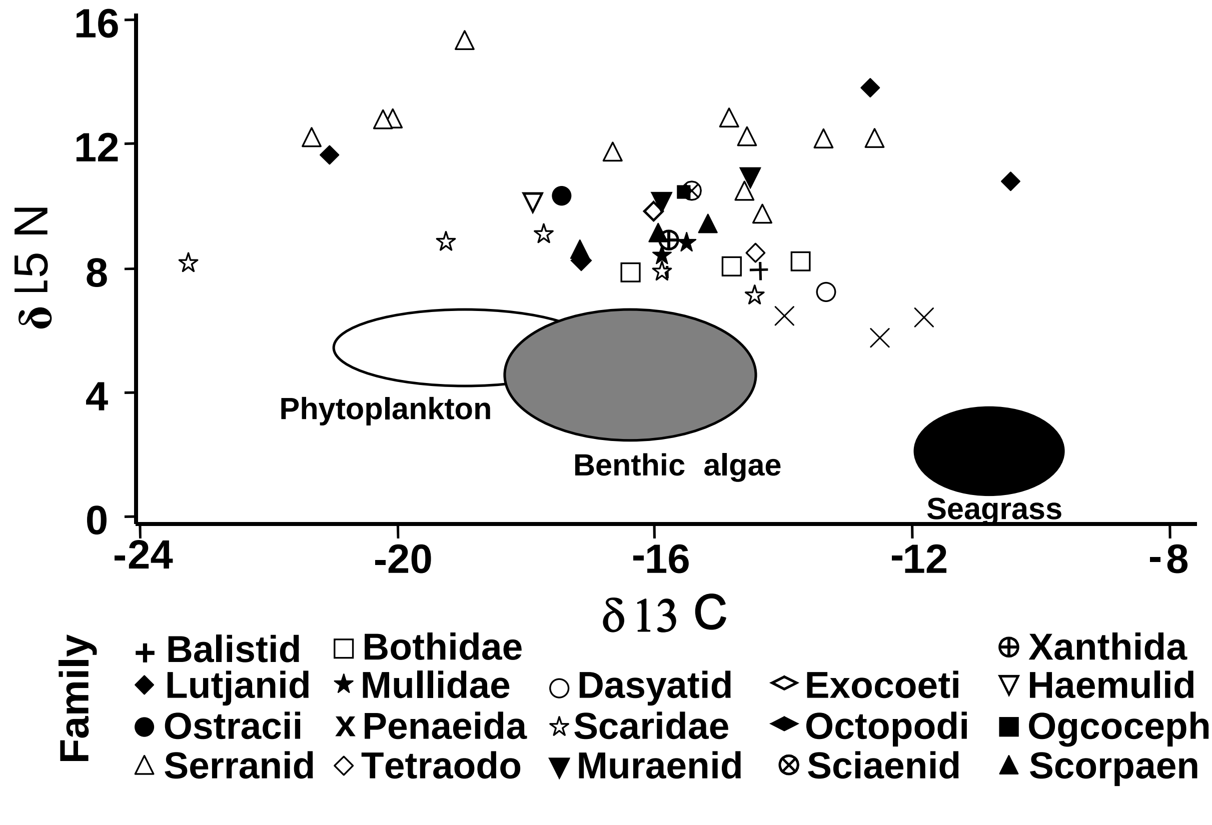

Figure 2. Carbon isotopic signatures for various fish families found in TER.

(Bothidae) and gray snapper (Lutjanidae) samples exhibited the most enriched C values, consistent with a food web based in part on seagrass carbon. Some fish, such as red grouper (family Serranidae) and parrotfish (Scaridae) exhibited a wide range in C isotope values. Additional results will help us to determine whether there is a significant geographic or reserve effect on the food webs utilized by these fish.

Nitrogen isotope values are helpful in determining ontogenetic changes in fish diets, and particularly in detecting increases in trophic level. This is because animals preferentially retain ^{15}N, so that there is an approximate 3 per mil increase in $d^{15}N$ per trophic level. This approach can be used to help determine whether ontogenetic diet changes include a switch from herbivory to carnivory (Cocheret de la Morineire et al. 2003). Figure 3 shows an increase in nearly two trophic levels as red grouper (Serranidae) increase in size from 25 to 70 cm. Parrotfish (Scaridae), however, exhibit little trophic change between 8 and 25 cm length (Fig. 3). These data can help to predict the potential ecosystem effects of changes in average fish size as the result of no-take regulations.

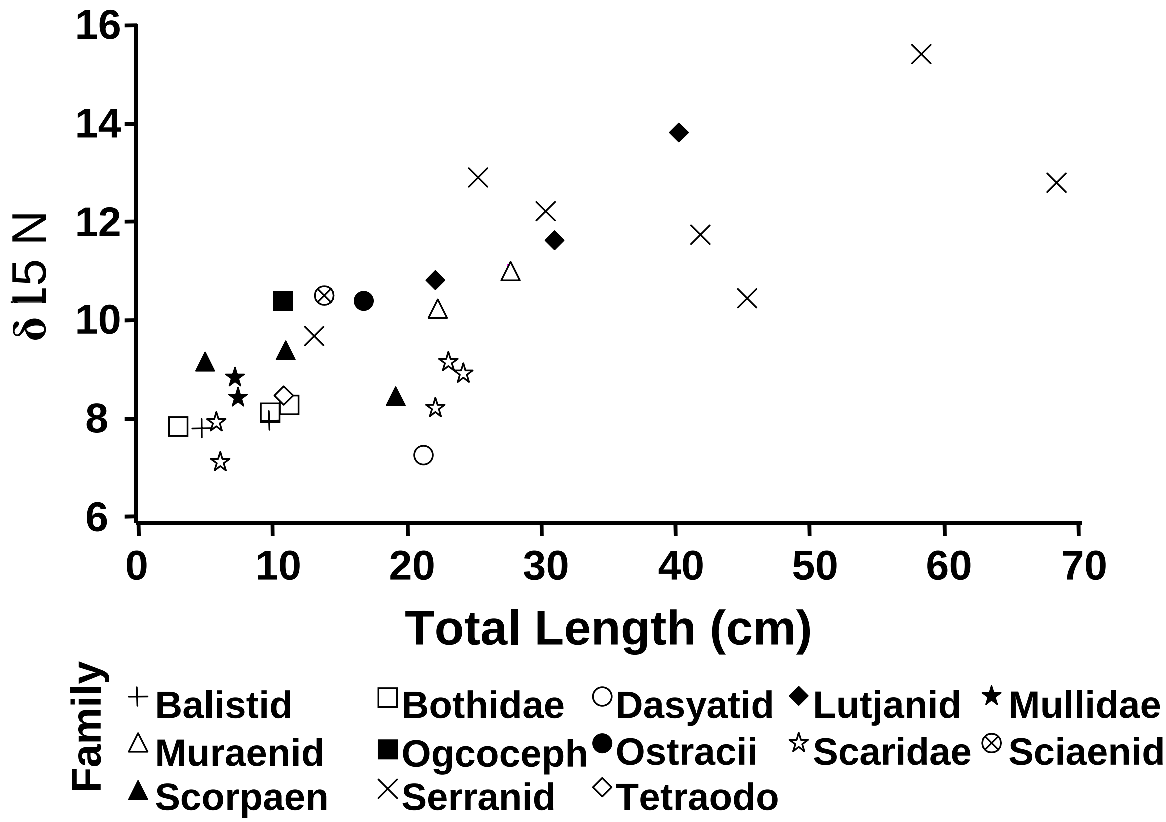

Figure 3. Nitrogen isotopic signatures by total length for various fish families found in TER.

Reef Fish

Although it is not possible to identify definitive changes in fish population dynamics after two years of protection, some interesting patterns have emerged. The numbers of fish > 20 cm total length appear to have increased in the new Reserve when compared to the Park and Open strata (Fig. 4). Six fish species (representing the most abundant species in each of six important reef fish families) show an increase in number and size within the Reserve when compared to the Park and Open strata (Fig. 5). In 2002, both large red and black grouper, on the order of five years old, were conspicuous parts of the fish assemblage at the reef soft bottom interface. In 2001, only large red grouper were abundant. The source of these differences could generally be attributed to the considerable natural variability of such systems, increasing grouper densities at interior reef sites, or movement with growth, of an exceptional year class of black grouper, to productive, though risky feeding habitat. The need for development of a longer-term data base is required to make effective comparisons among Use strata. Analysis of census data is ongoing at CCFHR.

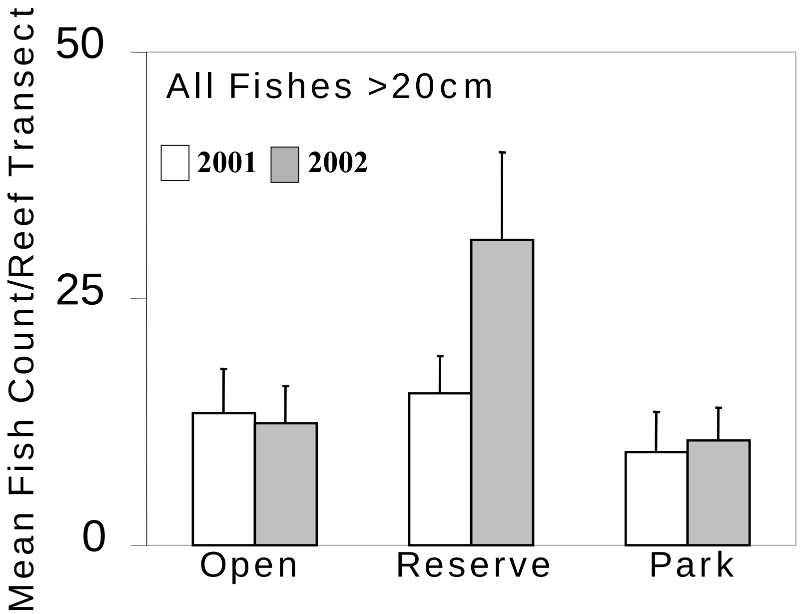

Figure 4. Mean number of fish (< 20cm) per transect, all species combined. N = 10 for each strata per year.

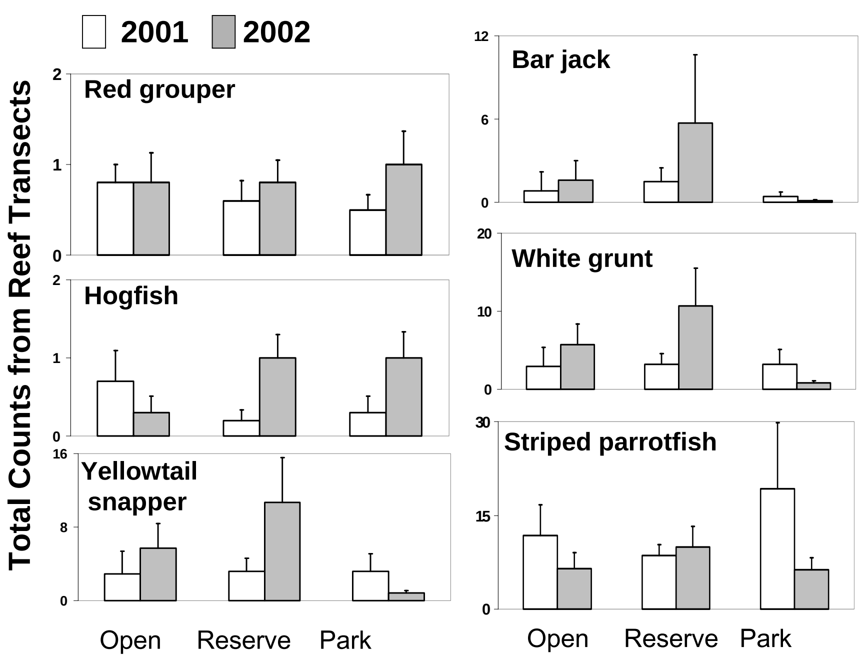

Figure 5. Total number of fish, by species, per transect for each strata per year.

Gear Impact

Our faunal collections from open and protected softbottom habitat near the northern boundary of Tortugas North strongly suggest that relaxation of trawling pressure has increased benthic biomass and diversity in this area of the TER. The Reserve may act as a refuge for large pink shrimp targeted by the fishery, and their density as well as biomass and diversity of smaller crustaceans was obviously higher in paired protected vs. open samples. Although not as obvious, differences in the fish and echinoderm assemblages between trawled and protected bottom are likely to become clear with the detailed analysis of our samples. It appears that these softbottom communities respond quickly to relaxation of the disturbance of trawling and we hypothesize that further changes will occur over time with development of a more stable assemblage of attached invertebrates that should develop in the more physically stable parts of the shelf. We believe that an increase in fishes and other benthic animals can be assumed to be occurring in protected habitats within the Reserve. However, we do not have replicate Ecological Reserves, and differences among samples taken within the TER versus those taken just out of the area may conceivably be an artifact of distance from reef structure. The final interpretation of these findings will, like other aspects of the study, rely on BACI design constraints. Moreover, whether or not the current reserve status of the TER is having a beneficial effect on the ecosystem in general and on targeted, long-lived reef predators will require continued assessment. Sample processing continues at CCFHR including new samples obtained in July 2003.

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