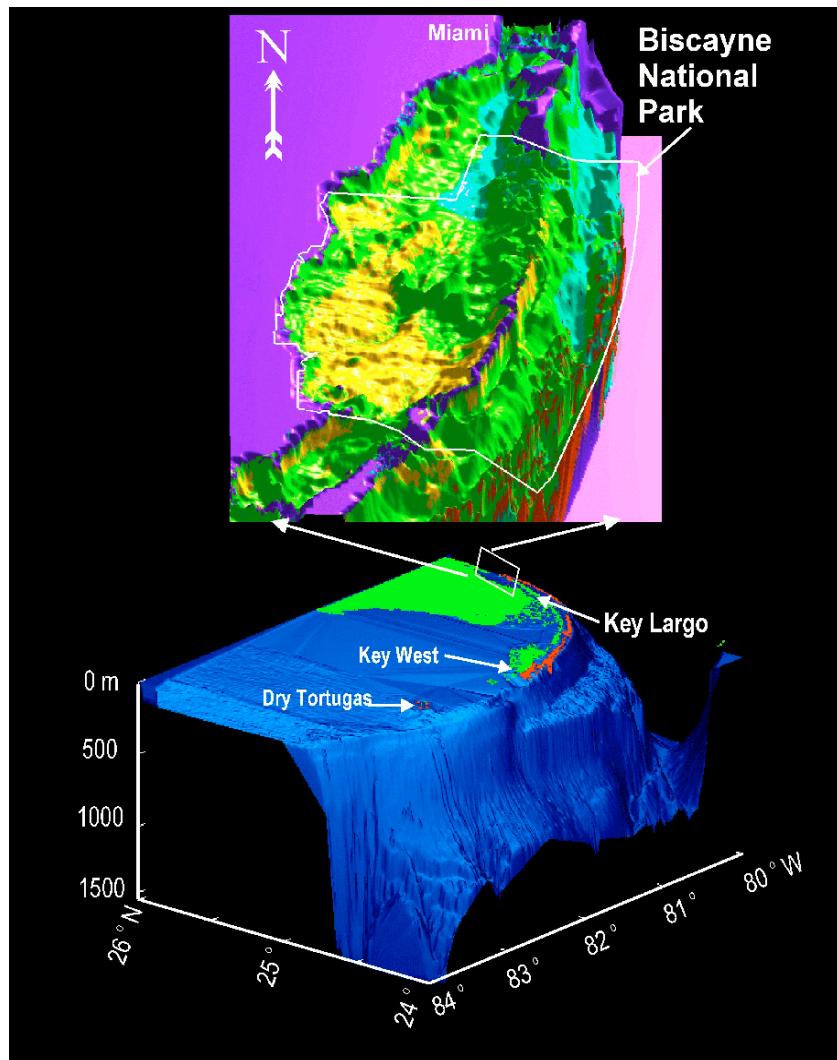




## Site Characterization for Biscayne National Park: Assessment of Fisheries Resources and Habitats

Jerald S. Ault, Steven G. Smith, Geoffrey A. Meester, Jiangang Luo, and James A. Bohnsack



U.S. Department of Commerce  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Southeast Fisheries Science Center  
75 Virginia Beach Drive  
Miami, Florida 33149

October 2001





## Site Characterization for Biscayne National Park: Assessment of Fisheries Resources and Habitats

Jerald S. Ault <sup>1</sup>, Steven G. Smith <sup>1</sup>, Geoffrey A. Meester <sup>1</sup>, Jiangang Luo <sup>1</sup>, and James A. Bohnsack <sup>2</sup>

U.S. DEPARTMENT OF COMMERCE  
Donald L. Evans, Secretary

National Oceanic and Atmospheric Administration  
Scott B. Gudes, Acting Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service  
William T. Hogarth, Assistant Administrator for Fisheries

October 2001

This technical memorandum series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. Although the memoranda are not subject to complete formal review, editorial control, or detailed editing, they are expected to reflect sound professional work.

<sup>1</sup> University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, Miami, FL

<sup>2</sup> NOAA/NMFS Southeast Fisheries Science Center, Miami, FL

## **NOTICE**

The National Marine Fisheries Service (NMFS) does not approve, recommend, or endorse any proprietary product or material mentioned in this publication. No reference shall be made to the NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein or which has as its purpose any intent to cause directly or indirectly the advertised product to be used or purchased because of NMFS publication.

This report should be cited as follows:

Ault, J.S., S.G. Smith, G.A. Meester, J. Juo, and J.A. Bohnsack. 2001. Site Characterization for Biscayne National Park: Assessment of Fisheries Resources and Habitats. NOAA Technical Memorandum NMFS-SEFSC-468. 156 pp.

This report will be posted on the NMFS Southeast Fisheries Science Center website at URL – <http://www.sefsc.noaa.gov/>

Copies may be obtained by writing:

National Marine Fisheries Service  
Southeast Fisheries Science Center  
75 Virginia Beach Drive  
Miami, Florida 33149

or

National Technical Information Service  
5258 Port Royal Road  
Springfield, Virginia 22161  
(800) 553-6847 or (703) 605-6000  
<http://www.ntis.gov/numbers.htm>

## **Executive Summary**

Biscayne National Park (BNP) in southeastern Florida is a unique tropical marine environment of national significance, renown for its productive coral reef ecosystem, diverse natural resources, important fishing opportunities, and spectacular scenic beauty. BNP's coastal bay and coral reef habitats play a critical role in the function and dynamics of the larger Florida Keys coral reef ecosystem and contribute substantially to the multibillion dollar tourism and fishing industry. Park waters provide critical nursery habitats and food web links for many important commercial and recreational fishery resources including: bonefish, snook, tarpon, permit, pink shrimp, spotted seatrout, oysters, clams, blue crabs and stone crabs, baitfishes; and, numerous coral reef fishes that include snappers, groupers, grunts, barracuda, spadefish, spiny lobster, parrotfish, surgeonfish and triggerfish. The production dynamics of these valuable natural resources are inextricably linked not only to fishing and rates of exploitation but also to the spatial distribution and quality of bay waters and habitats, themselves greatly affected by growing human uses and management practices. Since BNP's natural resources are intimately related to the broader regional ecosystem through water movements and animal migrations, any Park degradation will have consequences well beyond its boundaries.

Fishery management strategies now being proposed for BNP require precise spatial data and estimates of resource distribution and status prior to implementation of any spatial management policy. These data will facilitate concise and unambiguous baseline estimation of the Park resource status, provide critical inputs for models used to forecast potential impacts of policy changes, and enable design of an efficient sampling program to monitor future performance of a given management policy.

In a proactive movement towards development of strategic planning, this report takes the first steps in establishing the quantitative characterization and assessment of fisheries resources and habitats in BNP. The site characterization was based on an extensive overview and analysis of pertinent scientific and technical literature and biological, fishery, and physical databases relevant to the status and dynamics of fishery resources in Biscayne National Park, Florida. The estimation and simulation modeling “process” involved database assimilation, visualization and mapping of fish-habitat linkages, and multispecies assessments. In the process, we developed a new approach to stock assessment of multispecies coral reef fisheries that compare status of stocks relative to Federal fishery management guidelines. Our assessment research focused on 3 data sets containing more than 25 years of fishery-dependent (1976-1999 via BNP recreational creel survey) and fishery-independent (1979-2000 via SCUBA diver visual census and rollerframe trawls) survey sampling in BNP. Digital maps were created for a variety of spatial “habitats” including bathymetry, benthic substrates, salinity and other water quality parameters that relate to fishery resource distributions and abundances. Biological data were separated into 4 life-stage phases in terms of length for analysis: juveniles; pre-exploited; mature; and, exploited. Habitat data were co-plotted with species life-stage abundance and community diversity distributions to assess the spatial distribution and dynamics of fisheries and their dependence on habitats found in BNP. We noted:

- C Biscayne Bay plays an important role as primary nursery area for many coastal bay and coral reef fishes and macroinvertebrates (i.e., gray, mutton, lane, schoolmaster and yellowtail snappers; bonefish, tarpon, permit, sharks, molluscs, sponges, snook, seatrout, and pink shrimp, blue crabs, and spiny lobsters). Therefore, we conducted our analyses with respect to the relevant life stages of each species partitioned into four phases:

juvenile (from length of recruitment to size of sexual maturity); pre-exploited (recruitment length to minimum legal harvest size); mature (length of sexual maturity to maximum size); and, exploited (minimum legal to maximum size). We found that thirty-five (35) species of fish (about 11% of total BNP fishes) were present in all three survey types (TRAWL, CREEL, RVC), suggesting that there is use of habitats amongst lifestage phases. Fish diversity was lowest on the western fringe of Biscayne Bay (particularly at areas proximal to SFWMD canal outfalls and attendant freshwater influxes), increased moving seaward, and was highest in eastern BNP (areas on the barrier coral reef system open towards the Straits of Florida). The diverse spatial patterning of many species distributions reflects specialized ontogenetic use of certain habitats across the seascape. This suggests that a critical mosaic of interconnected habitats may be essential for sustaining fishery resources and ecosystem productivity.

We used a systems science approach to conduct a new multispecies assessment on exploited fishery resources found in BNP. The analyses used both fishery-independent and fishery-dependent data sources. We also acquired extensive biological and fishery information on population dynamics including age-growth, age (size) class distribution, and natural mortality rates. We estimated new fishery indicator variables developed from fishery-independent diver visual census data and fishery-dependent creel survey for 91 exploited species to assess the current status of the stocks. However, the reliability of population dynamic parameter datasets for a number of these species were suspect, or unavailable. As a result, this study focused on 35 important reef fish species that reflected the predominance of species and reliable population dynamics data. Commercial fisheries data were also acquired, but were deemed generally unreliable. Combining population-dynamic parameters and estimates of fisheries indices with the LBAR and REEFS assessment models facilitated evaluation of a series of fishery management benchmarks and estimated exploitation levels. We compared these estimates of current stock biomass and fishing mortality levels to the Federal standards. The following points summarize our findings:

- C For all of the harvested species analyzed, the average sized fish within the exploited phase of these populations for the last 25 years has remained relatively constant and is very close to minimum harvest sizes, not natural historical unfished population size. Many species with extremely low average length in the past have had very little change in average length even though new minimum size limits were imposed. The average size of black grouper is now 40% of what it was in 1940 and the spawning stock is now less than 5% of its historical unfished maximum.
- C Overall, 77% of the 35 individual stocks that could be analyzed are overfished. An analysis of the Spawning Potential Ratios (SPR) of exploited reef fish shows that 13 of 16 grouper species, 11 of 13 snapper species, barracuda, and 2 of 5 grunt species for which there are reliable population dynamics data are below the SPR that constitutes overfishing by Federal definitions (Magnuson-Stevens Fishery Management Conservation Act).
- C Stock biomass is critically low for most of the key targeted species within the recreational fishery. For example, the current level of fishing mortality for grouper stocks range from 3 to 10 times the exploitation level that would achieve Maximum Sustainable Yield (MSY). Some stocks appear to have been chronically overfished since at least the late 1970's.

- C Exceptionally high and sustained exploitation pressures have precipitated “serial overfishing” of key fishery resources. Smaller and less desirable species have consistently increased in the catch as larger more vulnerable species are eliminated.
- C The recreational fishing fleet in South Florida has grown at a near exponential rate since 1964 (a 444% increase in recreational boats from 1964 to 1998) with no limits on the number of boats allowed to fish. The relative effective vessel “fishing power” of the recreational fleet has quadrupled due to depth indicators and fish finders, global positioning systems, improved vessel designs, larger motors, and two-way radio communications.
- C A proportion of the fish in catches observed at the Biscayne NP boat ramps during creel surveys are **smaller** than the minimum size limit for legal harvest. This is as high as 70% for yellowtail and mutton snapper! Inadequate enforcement and knowledge of fishery regulations (reflected in preponderance of undersized “illegal” fish seen in creel catch size frequency distributions) and the extremely poor status of reef fish resources (BNP is the worst situation in the entire Keys) signals eminent resource collapses. Enforcement needs to be stronger to discourage poachers.
- C In fact, we also found that 13 of 35 species we analyzed have their minimum size of legal harvest set lower than the minimum size of sexual maturity, that is, these fishes are being captured before they have ever had a chance to spawn.
- C Little is known about a number of highly-prized species like bonefish, tarpon and permit, despite the fact that they are the focus of extremely important recreational fisheries. For example, bonefish have undoubtedly been under sampled, as only seven (7) fish have been reported in 23 years of BNP creel sampling, despite the fact that bonefish support an enormous regional recreational fishery. There are no monitoring programs for pink shrimp despite the large inshore biomass of juvenile shrimp that fed a broad range of juvenile and adult fishes in the BNP ecosystem, but is also under heavy exploitation pressures from an intensive commercial bait-shrimp and recreational wing-net fishery. In addition, economically-important spiny lobster, blue crabs and stone crabs lack monitoring in BNP.

The history of fishery management actions by the State and Federal Fishery Management Council for Biscayne NP waters clearly reflects the characteristics of trying to manage fisheries under increasing stress with conventional approaches. Actions have been taken only after declines have already occurred and were finally acknowledged. Actions are then usually only minimal and not at a level that ensures recovery will take place. (The history of increasingly more restrictive size limits placed on several grouper species until the fishery for some was eventually closed is a prime example of failure in conventional management approaches). Fisheries are not sustainable in BNP under the present levels of exploitation affecting stock status and habitat quality. We make the following recommendations:

- C We believe that a broader, more integrated strategy of monitoring, assessment and modeling is needed for effective fishery management in BNP. This comprehensive strategy must consider sampling of Bay, mangrove, coral reef, and pelagic fishery environments, and some consideration of new or enhanced use of data and technologies

(e.g., recreational creel and commercial catches, visual census, trawls and other nets, acoustics, LIDAR, etc.). There are severe limitations to the use of a single survey gear-type to conduct a meaningful synoptic study of fish and shellfish. The current, somewhat piecemeal, monitoring program must be reconfigured to meet assessment data demands. Monitoring efforts need to be integrated into a overarching design to facilitate short term fishery and “habitat” surveys. The analysis of a cost-effective composite design for  $n$  key target species is needed. In the course of the design, some special attention must be given to the barrier islands, mangrove fringe, and patch reef environments of the Park which have been sparsely sampled to date.

- C Envisaged ecosystem modeling and management endeavors must rely on a precise and cost-effective mechanism to understand and manage these valuable and essential fishery resources. Advanced monitoring efforts will also require refined resolution and precision of existing base habitat maps, including directed efforts to fill in data gaps. An experimental design to assess water quality effects of Everglades restoration on fishes in the “tide” will be important to develop. Monitoring activities should be designed at a time frequency dependent on key process rates, and such these integrated data will be critical for monitoring the efficacy of proposed management alternatives, ultimately leading to design of a longer-term program of optimal sampling, monitoring and assessment of the coral reef fish community and associated habitats in BNP.
- C Many of BNP’s most important fishery resources have received little attention (e.g., shellfish, bonefish, tarpon, snook, etc.). There is great need to develop additional population dynamics models and conduct fishery-independent surveys for these resources. This will require an improved capacity at BNP to monitor fishery resources across the breadth of environments. Little to no information was available for bonefish-tarpon, two mainstays of the highly valuable inshore recreational fishery, and broad knowledge gaps exist. There is an obvious need to protect “flats” environments from excessive use and degradation, and to develop a quantitative reef and coastal fish community index which may help in determining how close the “real” situation approximates “ideal” community structure.

The qualities that make BNP and the Florida Keys such venerable tourism and fishing destinations are eroding. Clearly, without some type of immediate proactive fishery management in BNP, collapse of many important fisheries resources is imminent. A multistock recovery strategy to sustainable target levels is needed. This strategy must address the great fleet fishing capacity and develop strategies to buffer exploitation in productive regions and reduce stress on key habitats. The obvious system connectivity that links BNP with the rest of the Florida Keys coral reef ecosystem means that long-term planning efforts for BNP should also include close integration of efforts with FKNMS, DTNP and the State of Florida. Marine protected areas and research natural areas are being implemented regionally; these may be a necessary step to build sustainable fisheries and to conserve marine biodiversity. To facilitate recovery of the region’s precious natural resources, it is clearly in the best interests of BNP to strongly support marine reserve development and implementation in the Dry Tortugas and other suitable upstream candidate sites.

## TABLE OF CONTENTS

### **BNP Site Characterization: Fisheries Resources and Habitats**

J.S. Ault, S.G. Smith, G.A. Meester, J. Luo, and J.A. Bohnsack

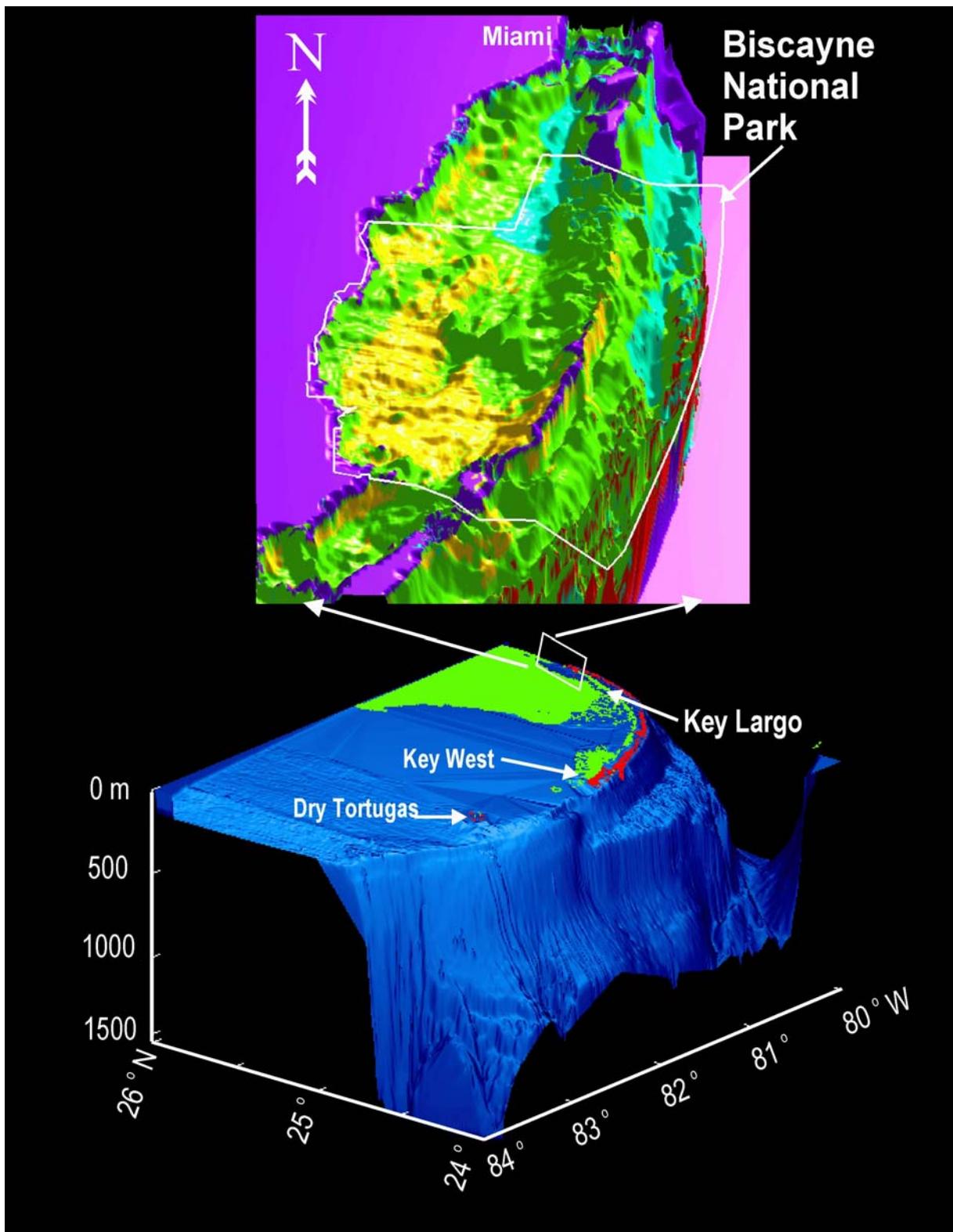
<b>Executive Summary.....</b>	iii
<b>Table of Contents.....</b>	vii
<b>1.0 Introduction.....</b>	1
<b>2.0 Databases for Resource Assessment and Analysis.....</b>	6
2.1 Reef fish visual census (RVC).....	6
2.2 Roller-frame trawl survey (TRAWL).....	7
2.3 Recreational fishery creel census (CREEL).....	8
2.4 Supplemental fishery-dependent databases.....	8
2.5 Biological and physical “habitat” databases.....	8
2.5.1 Benthic habitats and bathymetry.....	9
2.5.2 Water currents and salinity dynamics.....	9
<b>3.0 Overview of Species and Habitats.....</b>	10
3.1 BNP fishery ecosystem.....	10
3.2 Species inventory and fishes at risk.....	10
3.3 Fish habitats and community diversity.....	13
3.4 Water currents and juvenile recruitment pathways.....	19
3.5 Size distributions and spatial ontogeny for exploited species.....	21
3.6 Quantitative assessment of habitat use.....	37
<b>4.0 Fishery Overview and Estimation of Stock Status Indices.....</b>	42
4.1 Fishing effort and regional human population growth.....	42
4.2 Commercial landings.....	42
4.3 Size at first capture restrictions.....	47
4.4 Indicator variables of population status.....	49
4.4.1 Catch-per-unit-effort (CPUE).....	49
4.4.2 Average size in exploited phase.....	53
4.5 Non-compliance with fishery minimum size regulations.....	57
<b>5.0 Multispecies Fishery Stock Assessments.....</b>	60
5.1 Synthesis of population dynamics parameters.....	60
5.2 Estimation of total mortality rate from ‘average size’ statistics.....	60
5.3 Management benchmarks analyses.....	66
5.3.1 Fishery yields and YPR.....	68
5.3.2 Spawning potential ratios SPR.....	68
5.3.3 Limit control rules.....	70
5.4 Baseline status of BNP exploited fish stocks.....	73
<b>6.0 Conclusions and Recommendations.....</b>	78
<b>7.0 Literature Cited.....</b>	83
<b>8.0 Appendices.....</b>	87

## 1.0 Introduction

Biscayne National Park (BNP), encompassing approximately 728 km<sup>2</sup> in southeastern Florida (**Figure 1**), is a unique tropical marine environment of national significance, renown for its productive coral reef ecosystem, diverse natural resources, broad fishing opportunities, and spectacular scenic beauty. Explosive regional population growth and documented resource declines have raised concerns about the future of these resources. The NPS requires general management plans (GMP) for each national park unit. The GMP framework sets forth the management philosophy for decision making and problem solving in National Parks for the next 15 to 20 years to meet current and future conservation objectives and resource uses, while enhancing visitor experiences. In an effort consistent with the GMP framework and as an initial step leading towards development of a comprehensive fishery management plan for the Park, this report characterizes the current status of BNP's fisheries resources and associated habitats.

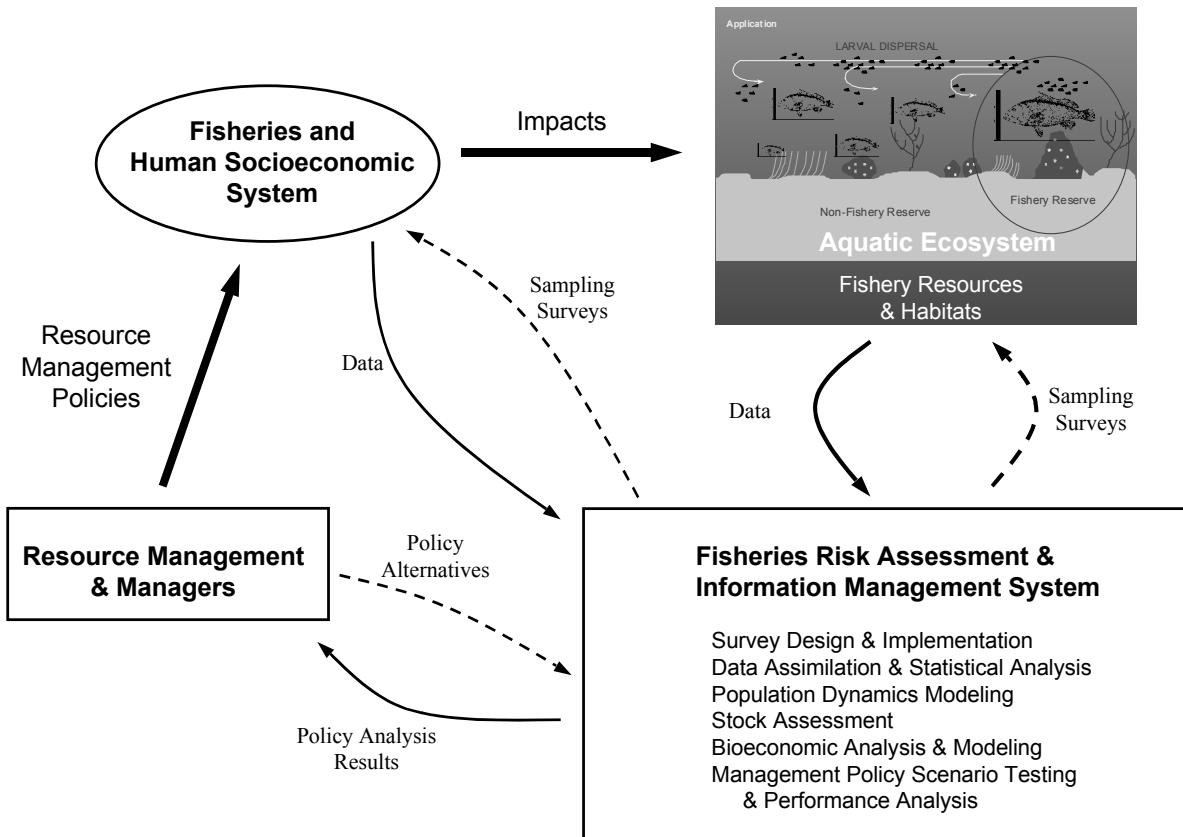
We view fisheries assessment and management from a systems science perspective (Ault 1996, Bohnsack and Ault 1996, Rothschild et al. 1996, Ault et al. 1998, Ault and Luo 1998, Bohnsack et al. 1999, Lindeman et al. 2000, Ault et al. 2000b), illustrated in **Figure 2**. In this approach, the fisheries assessment and management "system" is an organized set of scientific protocols and methods designed to achieve three main goals: (1) to understand fisheries resources and habitats within the context of the aquatic ecosystem; (2) to assess the impacts of human activities and economic drivers on these resources; and (3) to analyze and evaluate the degree of success of proposed and implemented management policies in mitigating human impacts on fisheries resources. A systems science overview of BNP fisheries resources is as follows. Located just south of Miami at the northernmost end of the Florida Keys, BNP's coastal bay and coral reef habitats play a critical role in the function and dynamics of the larger Florida Keys coral reef ecosystem. The inshore waters of Biscayne Bay serve as a nursery area for larvae and juveniles of a wide variety of fish and shellfish. Many of these live and reproduce in barrier coral reef and other offshore habitats as adults. The coastal bay environment also provides habitats for a number of highly prized gamefishes, such as bonefish, tarpon and snook. Fish and shellfish populations in the Florida Keys region currently support a multibillion dollar tourist and fishing economy. Over the past several decades, public use of and conflicts over fishery resources have increased sharply, while some fishery catches from historically productive snapper and grouper stocks have declined (Bohnack et al. 1994). A recent quantitative retrospective assessment of the Florida Keys multispecies reef fish community showed that fishing mortality levels are very intense, that many stocks are "overfished", and that signs of overfishing have been evident since the late 1970's (Ault et al. 1997a, 1998). A series of management actions, begun in the early- to mid-1980s, included establishing size, season, and bag limits on a number of species. Several species have been closed to harvest altogether.

Habitats of fish and shellfish in the Florida Keys ecosystem, particularly those located in nearshore areas, have also been impacted and compromised by human activities. Over the last eight decades, the Florida Keys, Florida Bay and Biscayne Bay have undergone dramatic changes in environmental conditions due to human alteration of the natural hydrology in southern Florida. These changes are now the focus of an intensive effort to restore the ecosystem by returning the hydrology to more natural conditions (Harwell et al. 1998, RESTUDY [www.acoe.jax.mil](http://www.acoe.jax.mil)). Coastal bay nursery grounds will likely bear the brunt of the proposed changes in freshwater outflows to estuarine and marine environments. The combination of rapidly growing human populations, overfishing, habitat degradation, pollution and changes in regional water quality from Everglades "restoration" make the Keys region an "ecosystem-at-risk" as one of the nation's most significant,



**Figure 1.-** Three-dimensional map of the Florida Keys coral reef ecosystem showing south Florida and the coral reef tract (red) stretching 380 km from Miami to the Dry Tortugas; and, Biscayne National Park habitats and fish sampling where the relative size of the blue balls inside Biscayne NP shows fish diversity as measured at trawl and visual sampling stations.

**Figure 2:** Conceptual overview of a systems science approach to fisheries assessment and management.



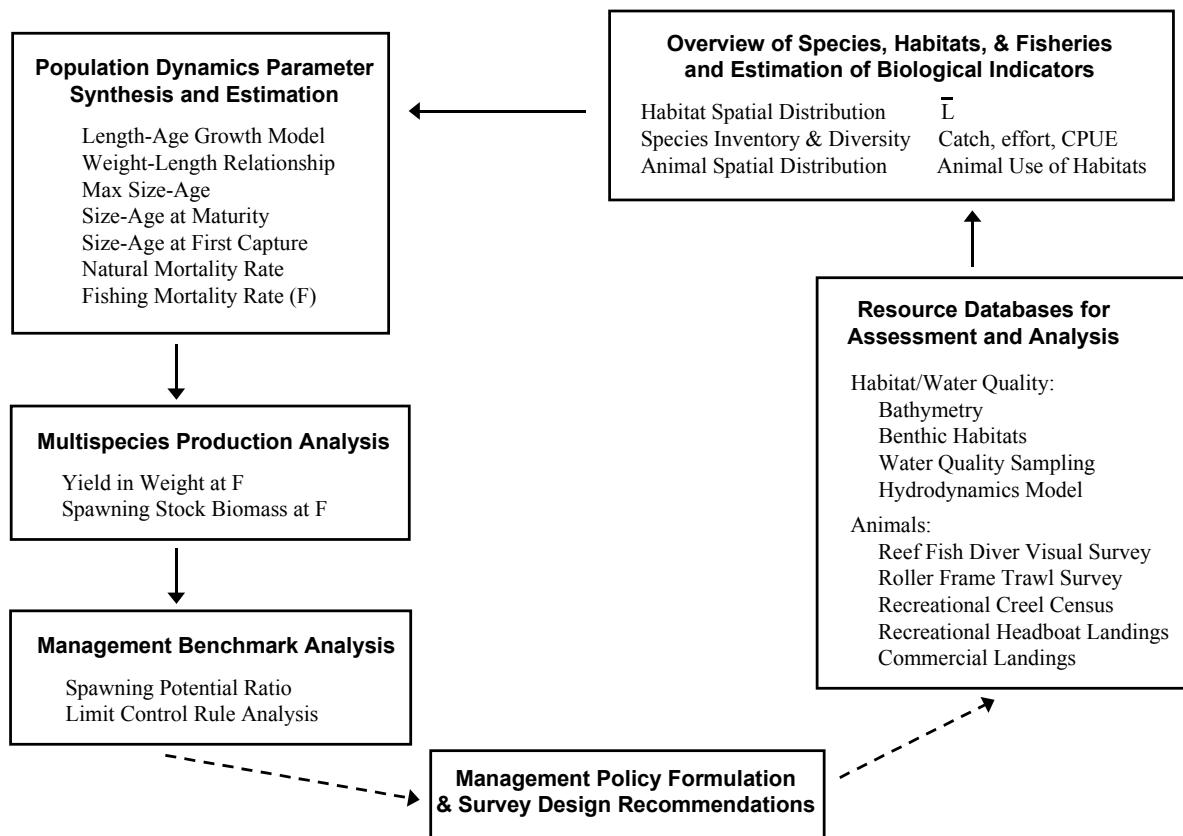
yet most stressed, marine resource regions under management of NOAA, the State of Florida, and the National Park Service (Ault et al. 1997a, 1998, 2000ab; Schmidt et al. 1999).

The goal of this report is to formally employ the systems science approach to assess the baseline status of multispecies fishery resources in BNP *circa* 2000 (**Figure 3**). The approach links the acquisition and assimilation of physical, biological and fishery databases to advanced statistical and modeling procedures to conduct multispecies stock assessments. Therefore, the objectives of this report are:

- To assimilate BNP regional resource databases and overview both species and habitats.
- To estimate biological indicators of stock status from several sources of fishery-independent and fishery-dependent survey data (i.e., creel census, coral reef visual census, and rollerframe trawl survey).
- To synthesize and estimate a suite of population dynamics parameters for assessment model building.
- To conduct length-based multispecies stock assessments for key exploited fishery resources in BNP waters using our new methods, to compare current estimates of exploitation to state-of-the-art fishery management benchmarks for fisheries sustainability, and to conduct a preliminary risk assessment of fishery management strategies for overfished stocks consistent with the Magnuson-Stevens Fishery Management Conservation Act.

The results of the analyses presented in this report provide guidance and identify priorities for developing comprehensive General Management and Fishery Management Plans for Biscayne National Park. In addition, these results will facilitate strategic formulation of policy alternatives that optimize conservation and use of Park fishery resources, and the design of high precision information systems that enable evaluation of the likelihood of success of a given policy in achieving Park natural resource management goals.

**Figure 3.-** Flow diagram of the systems science approach employed to assess Dry Tortugas region coral reef fishery resources. Solid lines depict analyses flow of this report, while dashed lines indicate future steps in fishery management plan development.



## **2.0 Databases for Resource Assessment and Analysis**

We assimilated, analyzed and visualized a number of fishery-independent and fishery-dependent survey databases on fishes and macroinvertebrates in Biscayne National Park. Databases of physical and biological “habitat” features of BNP were also integrated into these analyses. In addition to the following descriptions, a brief summary of each database is provided in **Appendix A**.

### **2.1 Reef Fish Visual Census (RVC)**

Biological data from Biscayne National Park were collected as part of a Florida Keys-wide fishery-independent sampling survey for reef fish conducted by NOAA Fisheries and University of Miami RSMAS scientists. The RVC (reef-fish visual census) survey database for BNP, extracted from the Keys-wide survey database, covered the years 1983 to 1992 and 1995 to 1999 for a total of 13 years. Data were collected by standard, non-destructive, *in situ* visual monitoring methods by highly trained and experienced divers using open circuit SCUBA (Bohnsack et al. 1999). Visual methods are ideal for assessing reef fishes in the Florida Keys because of prevailing good visibility and management concerns requiring the use of low impact assessment methods. The method provides reliable quantitative estimates of species composition, abundance (density per plot), frequency-of-occurrence, and individual size composition for the reef fish community. Data are collected by a stationary diver centered in a randomly selected circular plot (Bohnsack and Bannerot 1986, Ault et al. 1998). Divers sample 7.5 m radius circular plots for 5 minutes attempting to count all fish observed within each imaginary cylinder extending from the bottom to the limits of vertical visibility (usually the surface). Divers begin each sample by facing in one direction and listing all species within the field of view. When no new species are noted, new sectors are scanned sequentially by rotating in one direction for the 5 min period. Several complete rotations were usually made for each plot. After the initial 5 min, data are then recorded on abundance and minimum, mean, and maximum lengths for each species listed. Depth, bottom composition, estimated percentage cover, and maximum relief are recorded for each plot from the polar perspective of the centrally located observer. A calibration ruler held out perpendicularly at the end of a meter stick was used to reduce apparent magnification errors in size estimates. Divers periodically calibrate their sample radius estimates with either a meter stick or fiberglass tape. Species with few individuals (e.g. angelfish, barracuda, hogfish) are counted and their size estimated immediately. Highly mobile species that are unlikely to remain in the area (e.g. sharks, carangids) are tabulated when first observed and then ignored. For common species (e.g. damselfish, wrasses, etc.) one 360° rotation is made for each species by working back up the list in reverse order of recording to reduce potential bias by avoiding counting a species when they were particularly abundant or obvious. The time required to record each sample averages 15-20 min (range 5-30), depending on the habitat.

We used a two stage stratified random survey design to optimize sampling effort and choose sampling locations (Cochran 1977). Bottom features are first classified into habitat strata and mapped based on bottom structure and location. The Florida Keys sampling domain was partitioned into strata based on geographical location and habitat characteristics. The Florida Keys domain is overlain in a Geographical Information System (GIS) with a grid of 1 km<sup>2</sup> cells. Each cell contains 25 blocks of 200 x 200 m which are the primary sample units. Block size was chosen such that divers can easily swim from a moored vessel to any location within the boundaries. Second stage sample stations are randomly positioned in each block. There are 226 non-overlapping possible 7.5

m radius fish sampling stations within each block. Because of concerns about autocorrelation and safe diving practices, each fish sampling station consists of the average of combined stationary point estimates from two individual divers (i.e., a “buddy pair”). From 1983 through 1999, a total of 863 diver stations were sampled in BNP. Annual and total sample sizes are given in **Table 1**.

**Table 1.**- Sample size summary of fish sampling for Biscayne National Park for fishery-independent stratified random trawl (TRAWL) surveys, two-stage stratified random visual census (RVC), and fishery-dependent BNP dock-intercept recreational creel (CREEL) surveys from 1976 to 1999.

Biscayne Bay <u>Stratified Random Trawl Survey</u>		Biscayne National Park <u>Reef Fish Visual Census &amp; Recreational Creel Census</u>		
Month-Year	TRAWL	Year	RVC	CREEL
		<b>1976</b>		1388
		<b>1977</b>		2373
		<b>1978</b>		2845
		<b>1979</b>		2699
		<b>1980</b>		2326
		<b>1981</b>		2098
		<b>1982</b>		3161
		<b>1983</b>	18	2686
		<b>1984</b>	2	535
		<b>1985</b>	3	1191
		<b>1986</b>	4	1146
		<b>1987</b>	19	927
		<b>1988</b>	114	609
		<b>1989</b>	159	635
		<b>1990</b>	141	737
		<b>1991</b>	41	697
		<b>1992</b>	63	703
April - May <b>1996</b>	118	<b>1993</b>		620
August 1996	93	<b>1994</b>		844
Nov-Dec 1996	150	<b>1995</b>	68	366
March <b>1997</b>	122	<b>1996</b>	36	541
September 1997	151	<b>1997</b>	79	417
November 1997	120	<b>1998</b>	79	396
Oct-Nov <b>1999</b>	119	<b>1999</b>	37	
Feb-March <b>2000</b>	<u>110</u>			
<b>Totals</b>	<b>983</b>		<b>863</b>	<b>29,940</b>

## 2.2 Roller-Frame Trawl Survey (TRAWL)

Trawl sampling was conducted in Biscayne Bay from Rickenbacker Causeway to Long Arsenicker Key in Biscayne Bay, FL, at depths greater than 1 m, using a habitat-based stratified random survey design (see Ault et al. 1999a for details). Sampling was carried out exclusively at night to maximize the capture probability of shrimps, but captured about 120 finfish species. The survey employed a standard roller frame trawl used in the South Florida commercial live bait shrimp

fishery (cf., Serafy et al. 1997a). The trawl consists of a 10 mm square mesh net attached to a 3 m wide by 0.5 m high metal frame outfitted with a slotted roller along the lower portion. At a given sampling station, two nets were towed simultaneously on either side of the sampling vessel. A station tow distance of 200 m yielded a tow area of 600 m<sup>2</sup> for each trawl net. Upon completion of a tow, captured fish and shrimp were processed separately for each trawl net. Pink shrimp were sorted from the total catch of fishes and other macroinvertebrates and brought back to the laboratory, where each individual was sexed and carapace length (CL) recorded as the distance from the postorbital margin to the posterior margin of the carapace (Diaz et al. 2001). Individual fish were immediately identified and sized (to nearest mm total length TL) onboard, and then released back into the water. Water temperature, salinity, dissolved oxygen, and depth were measured at each sampling station. Sampling strata were delineated into distinct “habitats” based on a combination of depth, bottom substrate, and salinity zone. Eight “snapshot” surveys (2-3 weeks in duration) were performed in different seasons over the period from spring 1996 to winter 2000. Trawl station locations were randomly selected within each strata for each survey. The TRAWL survey database contains a total of 983 randomized trawl stations. Sample sizes for each seasonal survey are listed in **Table 1**.

### **2.3 Recreational Fishery Creel Census (CREEL)**

Creel census interviews of recreational fishers at public launch ramps have been conducted by BNP personnel and volunteers using standardized data collection procedures since 1976 (Davis and Thue 1979, Harper et al. 2000). Data collection included a fishing party interview and biological sampling of landings conducted at the conclusion of each recreational fishing trip. Information on angler effort and catches were distributed among areal partitions of BNP and detailed data collected included: date of trip, trip duration, number of anglers per vessel, hours fished, species, numbers and sizes of fish captured, numbers and species of fish released, targeted species, angler residence, trip origin, and party composition. Biological sampling consisted of recording fish lengths and numbers by species. The BNP CREEL census database from 1976 to 1998 covers 23 years of information obtained from a total of 29,940 interviews of sportfishers (**Table 1**) who fished either inside the Park boundaries or in the pelagic zone adjacent to the eastern Park boundary. Interviews of sportfishers who primarily fished in other areas outside the Park were not considered in our analysis.

### **2.4 Supplemental Fishery-Dependent Databases**

Other fishery dependent databases were used to supplement the three primary biological databases described above. The 1981-1995 NMFS headboat landings database (Bohnsack et al., 1994; Dixon and Huntsman, 1992) provided information on multispecies stock status in the greater Florida Keys-Dry Tortugas coral reef ecosystem, including but not limited to the BNP region. We also obtained commercial fishery landings reported for the statistical area covering Biscayne Bay, Barnes Sound, and Card Sound for 1986-1998. These were extracted from the NMFS general canvas landings database for the south Florida region (P. Eyo, NOAA SEFSC).

### **2.5 Biological and Physical “Habitat” Databases**

The principal physical and biological “habitat” data used in our analyses involved benthic substrate types, bathymetry, water quality, and hydrodynamics.

### **2.5.1 Benthic Habitats and Bathymetry**

Geographical information system (GIS) layers of bottom substrate classifications interpreted from aerial photographic surveys were provided by the Florida Marine Research Institute and Miami-Dade County Department of Environmental Resources Management. Data for the Biscayne National Park region were extracted from the Florida Keys-wide database. Bottom types included multiple categories of coral reef, seagrass, hardbottom, and sand/rock substrates. Data layer coverages pertaining to land and shoreline delineations were also included.

We acquired the National Ocean Service Hydrographic Survey database of depth soundings for the Florida Coast (NOAA, Silver Spring, MD; NOS, Boulder, CO). Water depths at latitude-longitude point locations were extracted for the BNP region and gridded into GIS layers.

### **2.5.2 Water Currents and Salinity Dynamics**

Water current and salinity dynamics were described for the BNP region using a 2D finite element numerical hydrodynamic model (Wang et al. 1988). Model inputs include empirical information on winds, tides, water currents, canal discharges, salinities, rainfall, evaporation, overland water flow, and groundwater flow collected at various times and locations within the region for approximately 25 years of observations (Wang et al. 2001). The model was developed to describe the currents, residence times, salinity patterns, and larval transport in the Biscayne Bay lagoonal system. The principal model outputs are water current vectors and salinity values along a horizontal spatial grid of resolution between 150 and 1000 m depending on the specific location in the model domain. The model was validated using point samples of surface, mid-water and bottom water quality parameters extracted from the DBHYDRO database provided by the South Florida Water Quality Management District. Data were utilized from 54 stations sampled within southern Biscayne Bay at 2-8 week time intervals during the period 1995-1998.

### **3.0 Overview of Species and Habitats**

The databases described in Section 2 were assimilated and analyzed to characterize the species and habitats of fish and shellfish (macroinvertebrate) community in Biscayne National Park. In our assessments, we begin by documenting the community structure in BNP, and then discuss and quantify the spatial and temporal relationships between fishery resources and habitats.

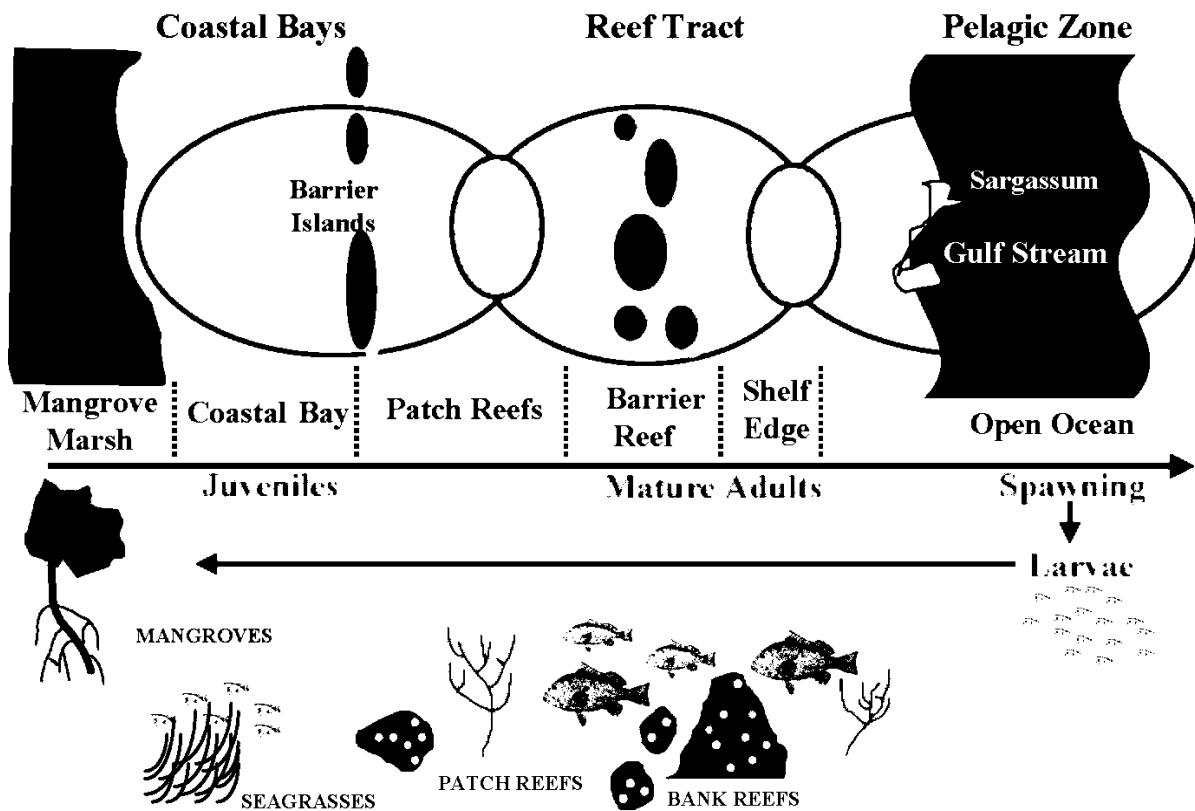
#### **3.1 BNP Fishery Ecosystem**

Coastal fishes, particularly reef fishes and shellfish, are ideal indicators of environmental stress (e.g., fishing, habitat changes, etc.) because they are tightly linked to the southern Florida coastal ecosystem. Many important reef species directly use Biscayne Bay and inshore habitats as nursery and juvenile forage areas before migrating offshore to the coral reefs (**Figure 4A**). They are likely to be directly and indirectly impacted by the Everglades restoration efforts. Mature animals spawn at the deep edge of the bank reefs, and then their larvae are advected coastward where juveniles settle in lagoons and seagrass beds on barrier islands. Obvious examples include pink shrimp (*Farfantepenaeus duorarum*) spiny lobster (*Panulirus argus*), barracuda (*Sphyraena barracuda*), hogfish (*Lachnolaimus maximus*), Goliath grouper (*Epinephelus itajara*), gray snapper (*Lutjanus griseus*), as well as several other snappers (Lutjanidae), groupers (Serranidae), grunts (Haemulidae), spadefish (Ephippidae), surgeonfish (Acanthuridae), triggerfish (Balistidae), parrotfish (Scaridae) and jacks (Carangidae). Even tarpon and snook are closely tied to Biscayne Bay as they extensively utilize reef habitats as adults. In most cases, however, the relative importance of different habitats in Biscayne Bay and offshore of the Keys has rarely been quantified for different reef or coastal species.

Key aspects of the south Florida fishery ecosystem pertaining to BNP are diagrammed in **Figure 4B**. Progressing from west to east, there are a wide variety of aquatic habitats spread over a relatively short distance. The western edge of BNP is lined with marsh and mangrove habitats which serve as the entry point for freshwater inflow to the Biscayne Bay environment via an extensive network of drainage canals. The Park's eastern boundary is characterized by an oceanic pelagic zone dominated by the Gulf Stream ocean current. A subtropical coastal bay environment, leeward barrier islands, and an offshore coral reef system are situated in between these boundaries along a west-to-east gradient of increasing salinity. Animal surveys, described above, targeted three principal habitats, the coastal bay (TRAWL and CREEL), coral reef tract (RVC and CREEL), and near-shore pelagic (CREEL) zones.

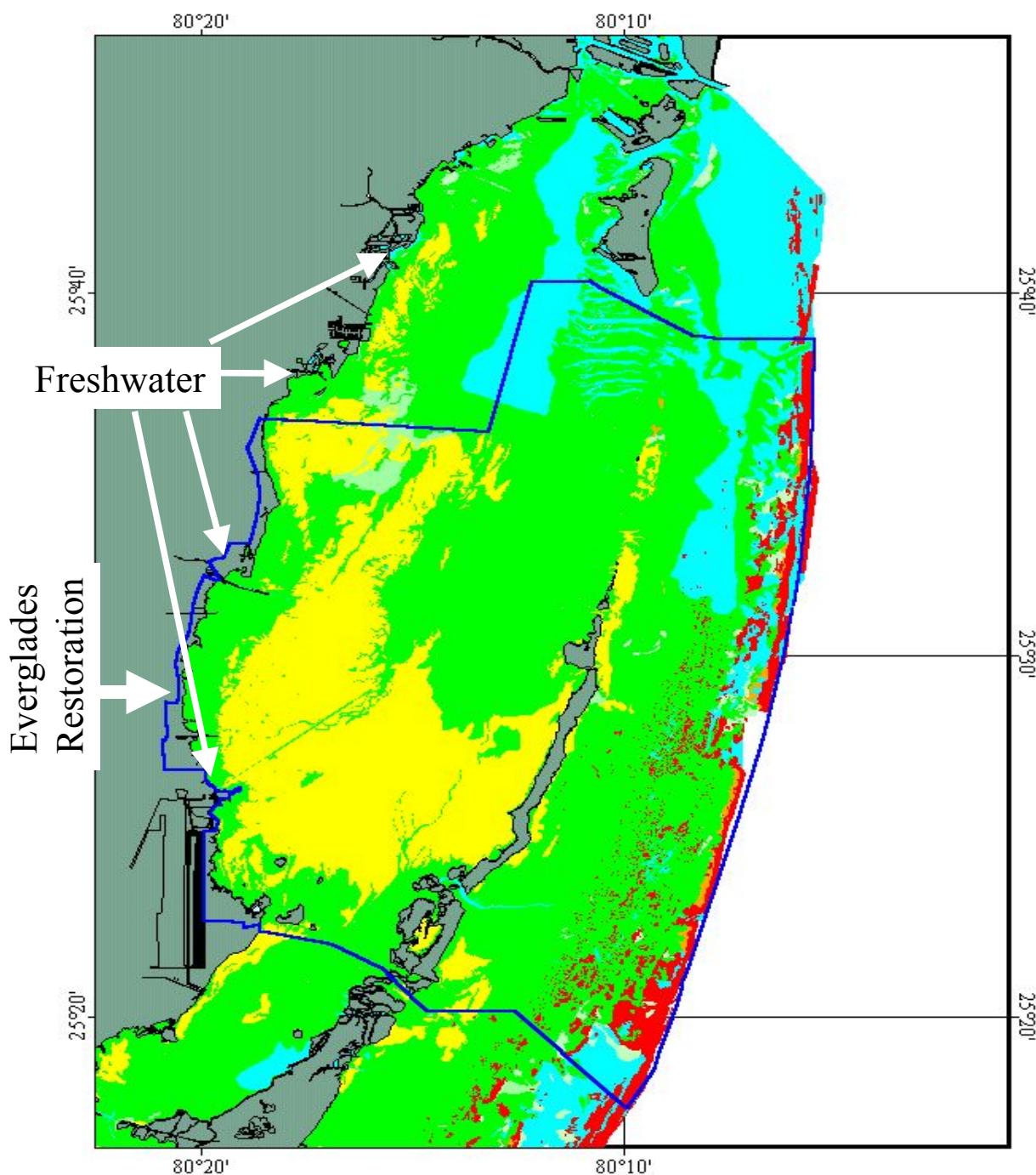
#### **3.2 Species Inventory and Fishes at Risk**

An overall species inventory for BNP was compiled by combining the following information from animal survey databases: (i) animals observed in the RVC survey that were identified to genus and species by NOAA and RSMAS divers; (ii) animals captured in the TRAWL survey that were identified to genus and species by RSMAS scientists; and (iii) animals captured and kept by sportfishers that were identified to genus and species by BNP scientists conducting the CREEL census. For the CREEL database, animals captured and released by sportfishers, and thus not positively identified by BNP scientists, were not included in the compilation because of the questionable reliability of these data. The overall compiled species inventory is provided in **Appendix B**. The three BNP animal survey databases contained 325 species of fishes and macroinvertebrates representing 77 different families (**Table 2**).



**Figure 4a.** - Conceptual organization of the south Florida ecosystem and key attributes of “bay to reef” ontogeny for many important coastal fishes and shellfishes. (A) Linkages between animal life stages and coastal habitat environments extending from freshwater and mangrove marshes on the western fringe to deep reef - pelagic environments in the east. (B) Actual distribution of habitats in Biscayne National Park.

**Figure 4b.- Biscayne National Park Fishery Ecosystem**



**Table 2.-** Number of species, families, and species unique to survey type within each dataset from three BNP fishery-independent (RVC, TRAWL) and fishery-dependent (CREEL) surveys.

	RVC	TRAWL	CREEL	Total
<b>Species</b>	182	155	143	325
<b>Families</b>	47	45	45	77
<b>Unique Species</b>	67	78	57	

In addition, each survey database contained a substantial number of species not seen or captured in other surveys (**Table 2**), reflecting differing survey targets with respect to habitats and species life stages. The TRAWL survey targets juvenile and subadult pink shrimp, as well as smaller pre-exploited life stages of fishes, in the coastal bay environment. The RVC survey targets all life stages of fishes in coral reef habitats within the offshore reef system. The CREEL census targets exploited life stages of animals in the coastal bay, offshore reef, and pelagic environments.

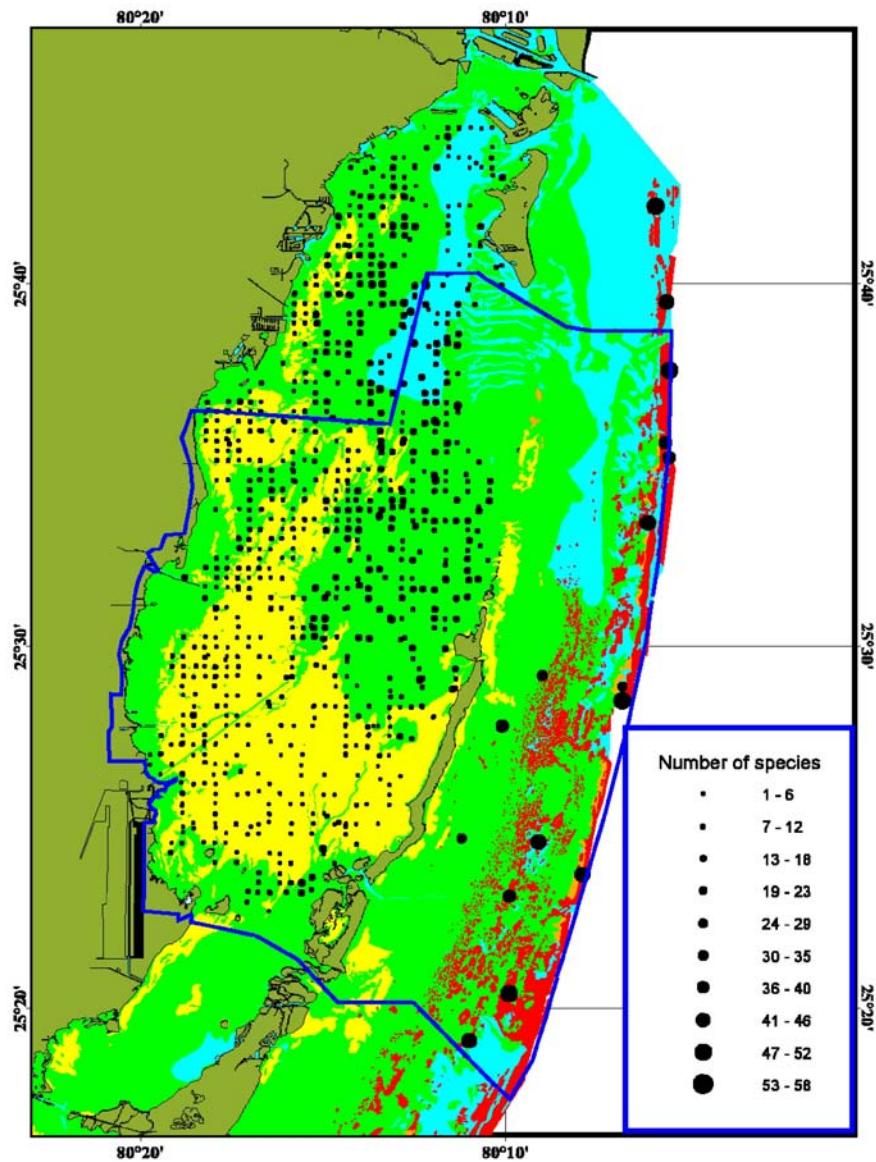
At present, none of the fishes that inhabit BNP are on federal or Florida lists of threatened or endangered species. However, it is only very recently that marine fish species have been proposed for inclusion on national and international rare or endangered animal lists (Musick 1998, 1999; Musick et al. 2000; Hudson and Mason 1996). This situation exists in part because: (1) there is societal and scientific doubt that marine fish species can become extinct, (2) the out of sight – out of mind concept; and, (3) they have traditionally been of lower conservation concern than their terrestrial counterparts. In 1996, the World Conservation Union (IUCN) and the World Wildlife Fund (WWF) published rare/threatened marine species criteria and revised animal lists to include marine fish species. The IUCN list includes 18 species found in Biscayne National Park (**Table 3**). Concurrently, the American Fisheries Society (AFS) has evaluated the risk of extinction for marine fish species using new quantitative criteria adopted by IUCN (Hudson and Mace 1996), and published a list of 82 marine fish species at risk in North America (Musick et al. 2000). Of these 82 marine finfish species, 22 are found in BNP.

### 3.3 Fish Habitats and Community Diversity

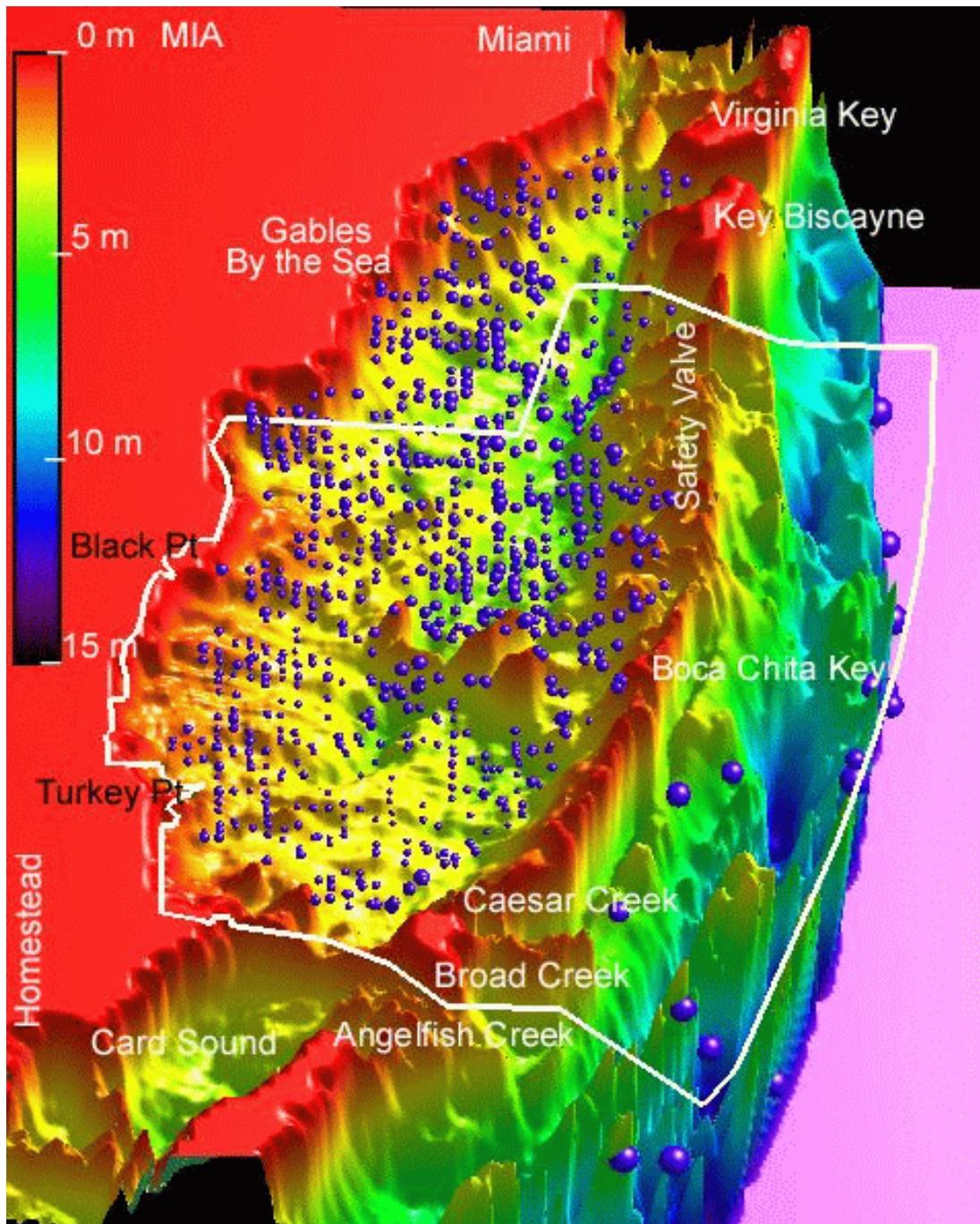
Habitats of BNP were described in terms of bottom substrates (**Figure 5**), bathymetry (**Figure 6**) and seasonal salinity patterns (**Figures 7 and 8**). The coastal bay-lagoonal environment of BNP exhibits a basin topography, with shallower (0-2 m) areas along the mainland (western) and leeward island (eastern) shorelines and deeper (2-4 m) areas in the central, mid-basin region. Bottom substrates of the coastal bay zone were grouped into three basic types: seagrass, hard bottom, and bare bottom (**Figure 5**). Seagrass consisted of sandy or silt-clay sediments vegetated by the seagrasses *Thalassia* spp., *Halodule* spp., or *Syringodium* spp. Seagrasses in the coral reef tract were not identified to species. Hard bottom was characterized by a foundation of oolitic limestone covered by a thin sediment layer populated with a variety of soft coral and sponge species. Bare bottom was substrate generally devoid of large benthic organisms. Seasonal salinity patterns in the coastal bay zone (**Figures 7 and 8**) highlight three broad regions with respect to magnitude and variability of salinity. The first region is located in the eastern bay adjacent to the Atlantic Ocean

**Table 3.** - Draft list of marine and estuarine fish stocks at risk in Biscayne National Park and surrounding waters. Source: Tom Schmidt, NPS. Superscript <sup>1</sup> by common name indicates species were not observed in RVC surveys.

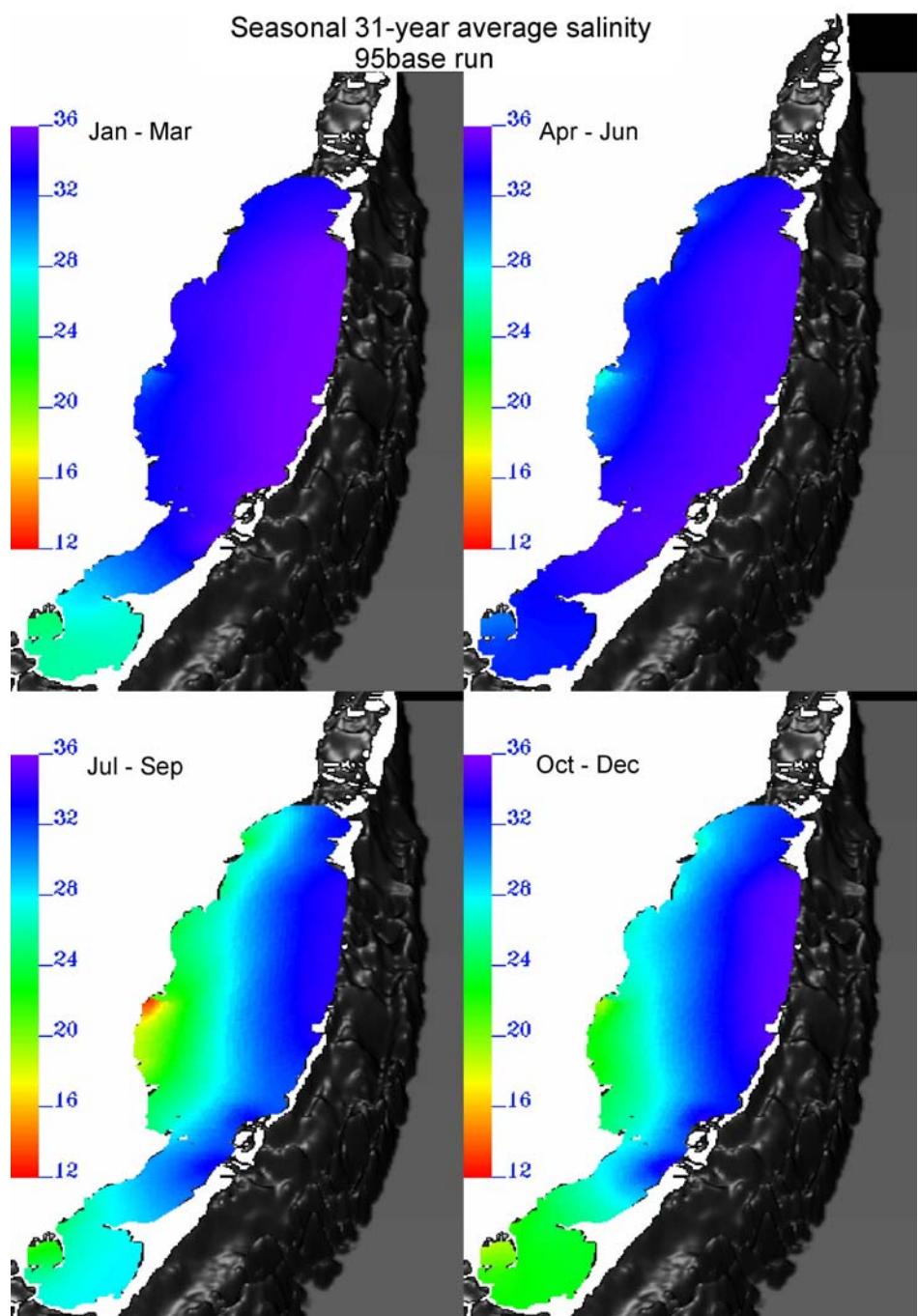
Family	Common Name	Scientific Name	BNP Habitat	Protection Criteria
Acanthuridae	Gulf surgeonfish <sup>1</sup>	<i>Acanthurus randalli</i>	Coral, seagrass	AFS vulnerable
Balistidae	Queen triggerfish	<i>Balistes vetula</i>	Coral reefs	IUCN vulnerable
Carcharhinidae	Blacktip shark	<i>Carcharhinus limbatus</i>	Coastal bays and reefs	IUCN vulnerable
Carcharhinidae	Dusky shark <sup>1</sup>	<i>Carcharhinus obscurus</i>	Coral, grassbeds	IUCN endangered
Centropomidae	Swordspine snook	<i>Centropomus ensiferus</i>	Mangrove, estuarine	AFS vulnerable
Centropomidae	Fat snook <sup>1</sup>	<i>Centropomus parallelus</i>	Mangrove, estuarine	AFS vulnerable
Centropomidae	Tarpon snook <sup>1</sup>	<i>Centropomus pectinatus</i>	Mangrove, estuarine	AFS vulnerable
Gobiidae	Spot-tail goby	<i>Gobionellus stigmaturus</i>	Seagrass, tidal flats	AFS vulnerable
Gobiidae	Orangespotted goby	<i>Nes longus</i>	Mud and sand bottoms	AFS vulnerable
Labridae	Hogfish	<i>Lachnolaimus maximus</i>	Coral reefs, seagrass	IUCN vulnerable
Lutjanidae	Mutton snapper	<i>Lutjanus analis</i>	Coral reefs, seagrass	IUCN vulnerable
Lutjanidae	Cubera snapper	<i>Lutjanus cyanopterus</i>	Coral reefs, seagrass	IUCN vulnerable
Myliobatidae	Spotted eagle ray	<i>Aetobatus narinari</i>	Coastal bays and reefs	State of Florida protected
Pristidae	Smalltooth sawfish <sup>1</sup>	<i>Pristis pectinata</i>	Coastal bays	IUCN/AFS endangered, FL protected
Scaridae	Scarus guacamia	<i>Rainbow parrotfish</i>	Coral reefs, seagrass	IUCN vulnerable
Sciaenidae	Blue croaker <sup>1</sup>	<i>Bairdella batabana</i>	hardbottoms, seagrass	AFS vulnerable
Scombridae	Bluefin tuna <sup>1</sup>	<i>Thunnus thynnus</i>	Oceanic	IUCN endangered
Serranidae	Speckled hind	<i>Epinephelus drummondhayi</i>	Coral reefs	IUCN/AFS critically endangered
Serranidae	Yellowedge grouper	<i>Epinephelus flavolimbatus</i>	Coral reefs	AFS endangered
Serranidae	Jewfish	<i>Epinephelus itajara</i>	Coral reefs, mangroves	AFS endangered, U.S./FL protected
Serranidae	Marbled grouper	<i>Epinephelus inermis</i>	Coral reefs	IUCN vulnerable
Serranidae	Warsaw grouper <sup>1</sup>	<i>Epinephelus nigritus</i>	Coral reefs, hardbottoms	IUCN/AFS critically endangered
Serranidae	Snowy grouper <sup>1</sup>	<i>Epinephelus niveatus</i>	offshore hardbottoms	IUCN/AFS vulnerable
Serranidae	Nassau grouper	<i>Epinephelus striatus</i>	Coral reefs, seagrass	AFS/IUCN threatened, U.S./FL protected
Serranidae	Blue hamlet	<i>Hypoplectus gemma</i>	Coral reefs	AFS vulnerable
Serranidae	Black grouper	<i>Mycteroperca bonaci</i>	Coral reefs, hardbottoms	AFS vulnerable
Serranidae	Yellowmouth grouper	<i>Mycteroperca interstitialis</i>	Coral reefs, hardbottoms	AFS vulnerable
Serranidae	Gag grouper	<i>Mycteroperca microlepis</i>	Coral reefs, seagrass	AFS/IUCN vulnerable
Serranidae	Scamp	<i>Mycteroperca phenax</i>	Coral reefs, hardbottoms	AFS vulnerable
Syngnathidae	Fringed pipefish <sup>1</sup>	<i>Anarchopterix cringer</i>	Seagrass	AFS vulnerable
Syngnathidae	Lined seahorse	<i>Hippocampus erectus</i>	Seagrass	IUCN vulnerable
Syngnathidae	Longsnout seahorse	<i>Hippocampus reidi</i>	Seagrass	AFS/IUCN vulnerable
Syngnathidae	Dwarf seahorse	<i>Hippocampus zosterae</i>	Seagrass	AFS/IUCN vulnerable
Syngnathidae	Opposum pipefish <sup>1</sup>	<i>Microphis brachyurus</i>	Seagrass	AFS vulnerable



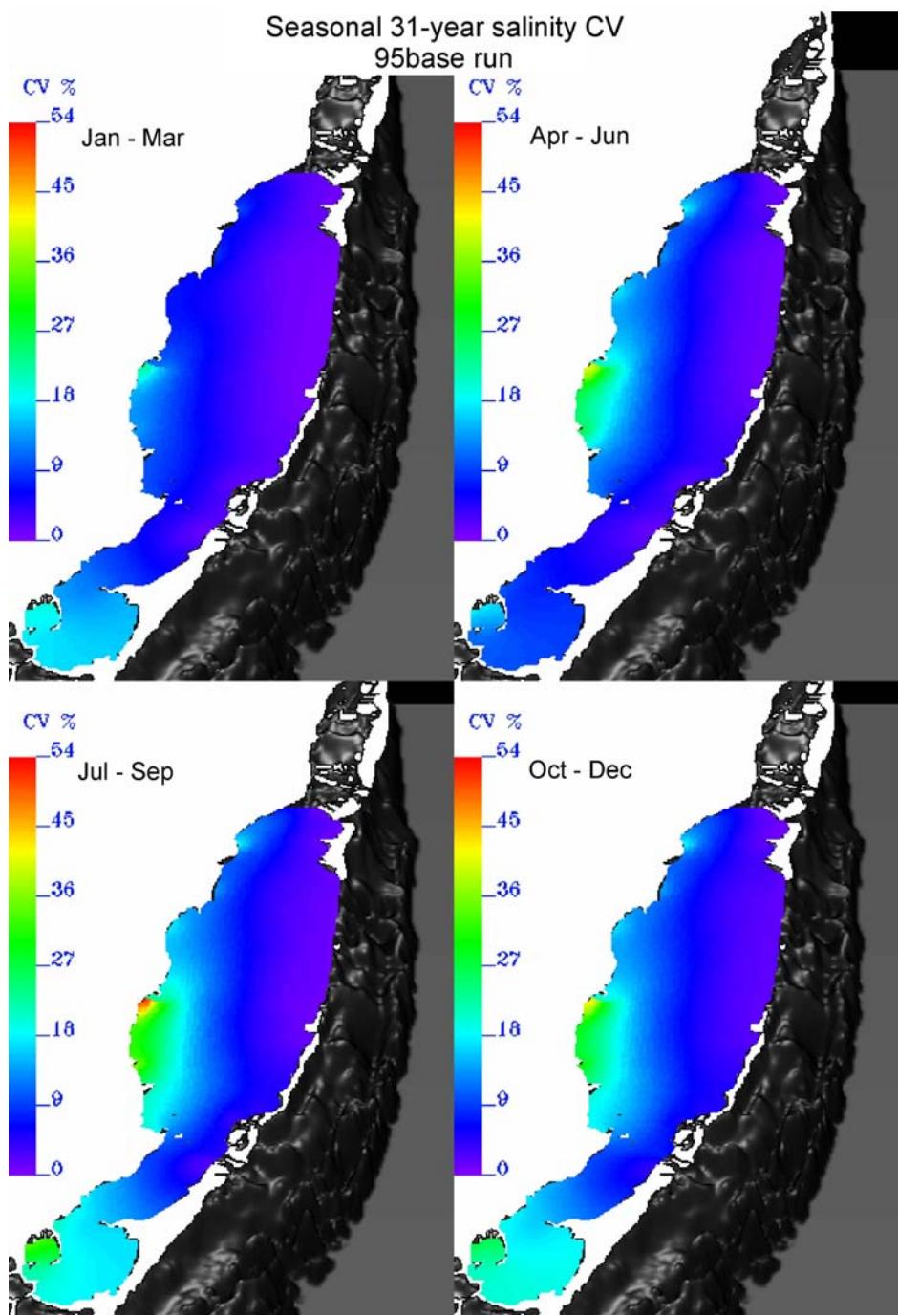
**Figure 5.** - Diversity of BNP fish community (number of species per surveyed site as determined by TRAWL and RVC sampling methods) overlaid on digital map of benthic substrate types (green is seagrass, red is coral reef reefs, yellow is hardbottom mixed with seagrass, orange is hardbottom, light blue is mud or sand substrate).



**Figure 6.-** Biscayne Bay and BNP regional 3-dimensional bathymetry from Miami to North Key Largo. Depth scale (m) is shown in upper right. Shallowest is red while deepest is blue. White line indicates boundary of BNP.



**Figure 7.-** Maps for Biscayne National Park showing 31-year averages of water column salinity for the 1995 Base inflow (South Florida Water Management District) as computed from the Wang et al. (2001) hydrodynamic model shown by season: (A) January to March; (B) April to June; (C) July to September; and (D) October to December.



**Figure 8.-** Maps for Biscayne National Park showing 31-year seasonal coefficient of variation (CV) of water column salinity for the 1995 Base inflow (SFWMD) as computed from the Wang et al. (2001) hydrodynamic model: (A) January to March; (B) April to June; (C) July to September; and, (D) October to December.

and is characterized by near-oceanic salinities that vary little throughout the year. The second mid-basin region is characterized by somewhat lower average salinities during the peak of the wet season (Jul-Sep) that also vary to a moderate degree. The third is a lower-salinity region with high variability located in the western bay, an area influenced by freshwater discharges along the coastline from drainage canals.

The reef environment extends eastward from the barrier island shallow (0-2 m) shoreline area to the deeper (>20-25 m) outer edge of the coral reef tract (**Figure 5**). Bottom substrates include large areas of seagrass, hard bottom, and bare sand categories; however, coral reefs are the most prominent substrate feature. Two types of coral reef communities are present in the BNP reef system, inshore patch reef and offshore platform margin reef. The platform margin reef or ‘reef tract’ community is characterized by coral reefs that form a quasi-continuous offshore platform or shelf edge parallel to the axis of the Florida Current. Inshore patch reefs are comprised of small and moderate size discrete coral communities that occur between the barrier island shoreline and the western edge of the platform margin reef. Salinities are oceanic with very little variability year-round in the reef and adjacent deeper pelagic environments (**Figures 7 and 8**).

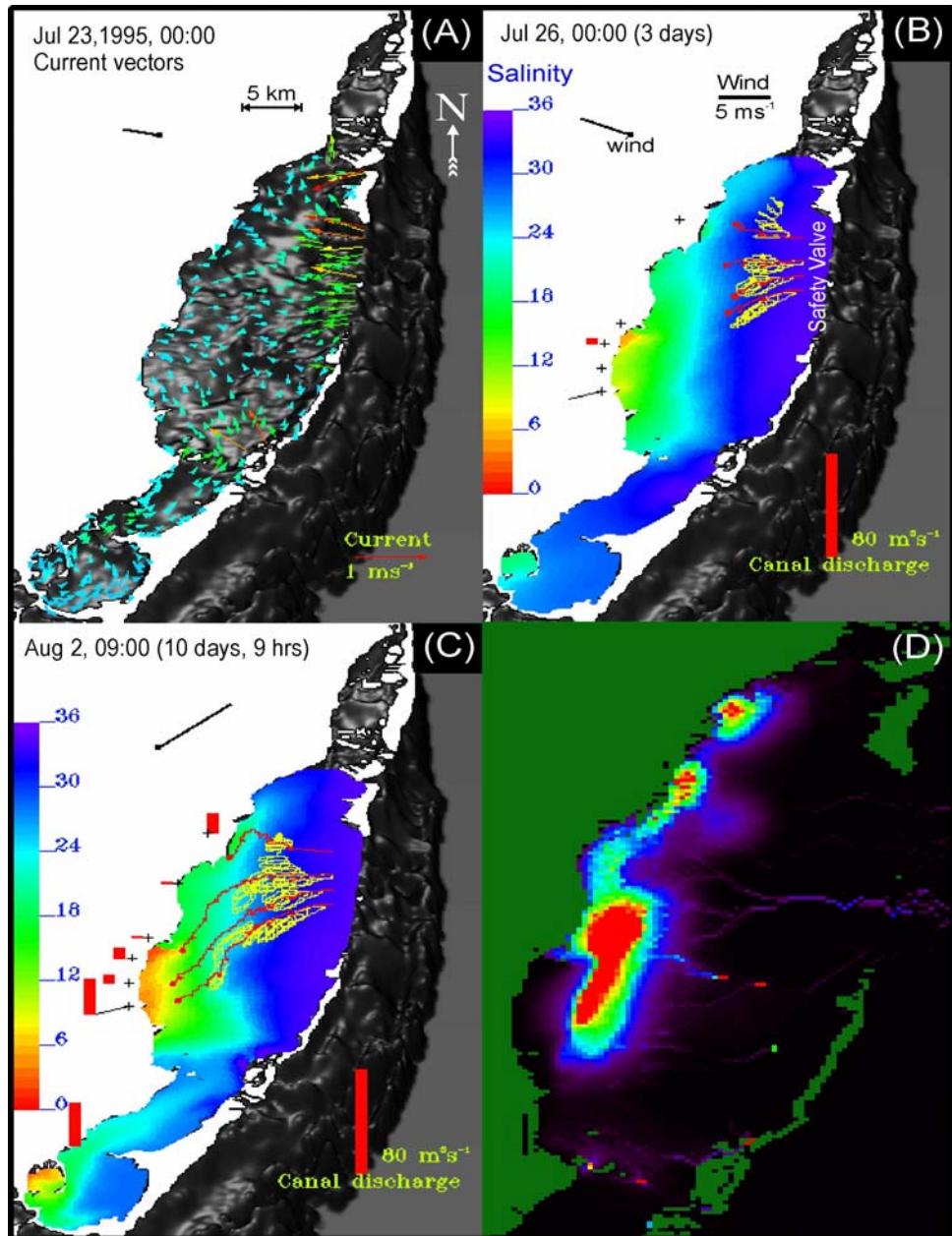
Spatial point values of fish community species richness, a measure of diversity, were overlain on maps of bottom substrate (**Figure 5**) and bathymetry (**Figure 6**). Values in the coastal bay environment represent the number of fish species captured at an individual TRAWL station location (sampling area 1,200 m<sup>2</sup>). Point values in the reef system represent the number of fish species observed by divers within a 200m by 200m primary sampling unit (area 40,000 m<sup>2</sup>). For primary units sampled repeatedly over multiple years, point values represent the annual average species richness for the latest 3-year period.

Although a comparable number of species were observed in the RVC and TRAWL surveys (**Table 2**), diversity was substantially higher at reef sampling locations compared to bay sampling locations (**Figures 5 and 6**). These differences are perhaps partly due to the smaller station sampling area and restricted gear size-selectivity of the TRAWL survey compared to the RVC survey. Within the bay, diversity was generally higher in mid-basin seagrass habitats. Low diversity was apparent in the southern bay hard bottom habitat and also in the highly variable salinity zone proximal to the mainland (**Figures 5 and 8**). In the reef system, diversity was higher along the platform margin reef and somewhat lower in inshore patch reefs.

### 3.4 Water Currents and Juvenile Recruitment Pathways

The hydrodynamics of Biscayne Bay have been well studied (Wang et al. 1988, Wang et al. 2001). Principal flows enter and exit the Bay through the Safety Valve, and Angelfish-Broad-Caesar’s creeks (**Figure 9**). Residence time in the Bay varies widely from several months in the more enclosed Barnes Sound, to on the order of a month in western parts of south Biscayne Bay, and to near zero in the vicinity of ocean inlets (e.g., Safety Valve).

The hydrodynamic model was coupled to a biological dynamics model for the Lagrangian drift dynamics and recruitment of pink shrimp (Ault et al. 1999b, Wang et al. 2001). In model simulated larval drift and transport experiments, we placed particles (i.e., cohorts of shrimp and fishes) in the physical circulation model near the Safety Valve entrance. Both passive (driven only by advection by currents) and behavioral (swimming vertically) cohorts were used in transport simulations. Passive particles cycled in drift trajectories corresponding to tidal cycles (**Figure 9**). Behavioral particles moved directly into preferred low salinity (~20 ppt) areas. Passive particles took twice as long to reach the Bay’s western shoreline. Simulations of drift trajectories of pink



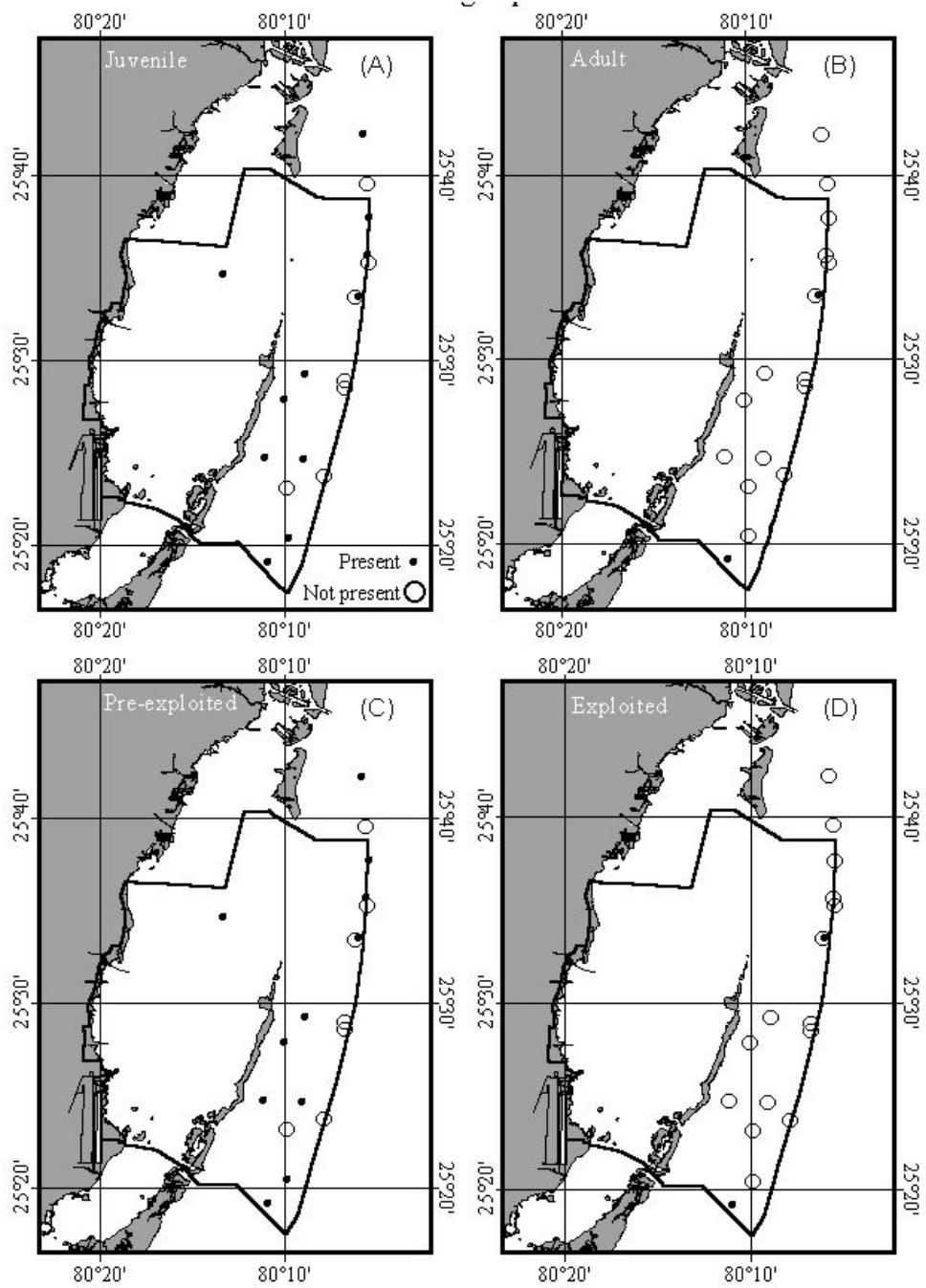
**Figure 9.-** Drift trajectories of passive (yellow) and active (red) particles from model simulations (cf., Wang et al. 2001): (A) simulated current vectors for 0000 July 23, 1995; (B) 3 days into simulation; (C) 4 days and 19 hours; and, (D) spatial distribution of simulated settled juveniles. The size of the map is approximately 40 km across and 82 km from top to bottom. Current vectors are pointing in direction of motion and length and color of individual vectors indicate speed. The background colors in panels B and C and the color scale indicate the salinity obtained from the hydrodynamic model. The vertical bars at the western shore of the Bay indicate the canal discharge based on the scale in the lower right corner. The vector in the upper part of each panel indicates wind direction and speed.

shrimp larvae and recruited juvenile shrimp spatial abundance distributions were in good agreement with settlement patterns of live shrimp from synoptic sampling surveys (Ault et al. 1999a).

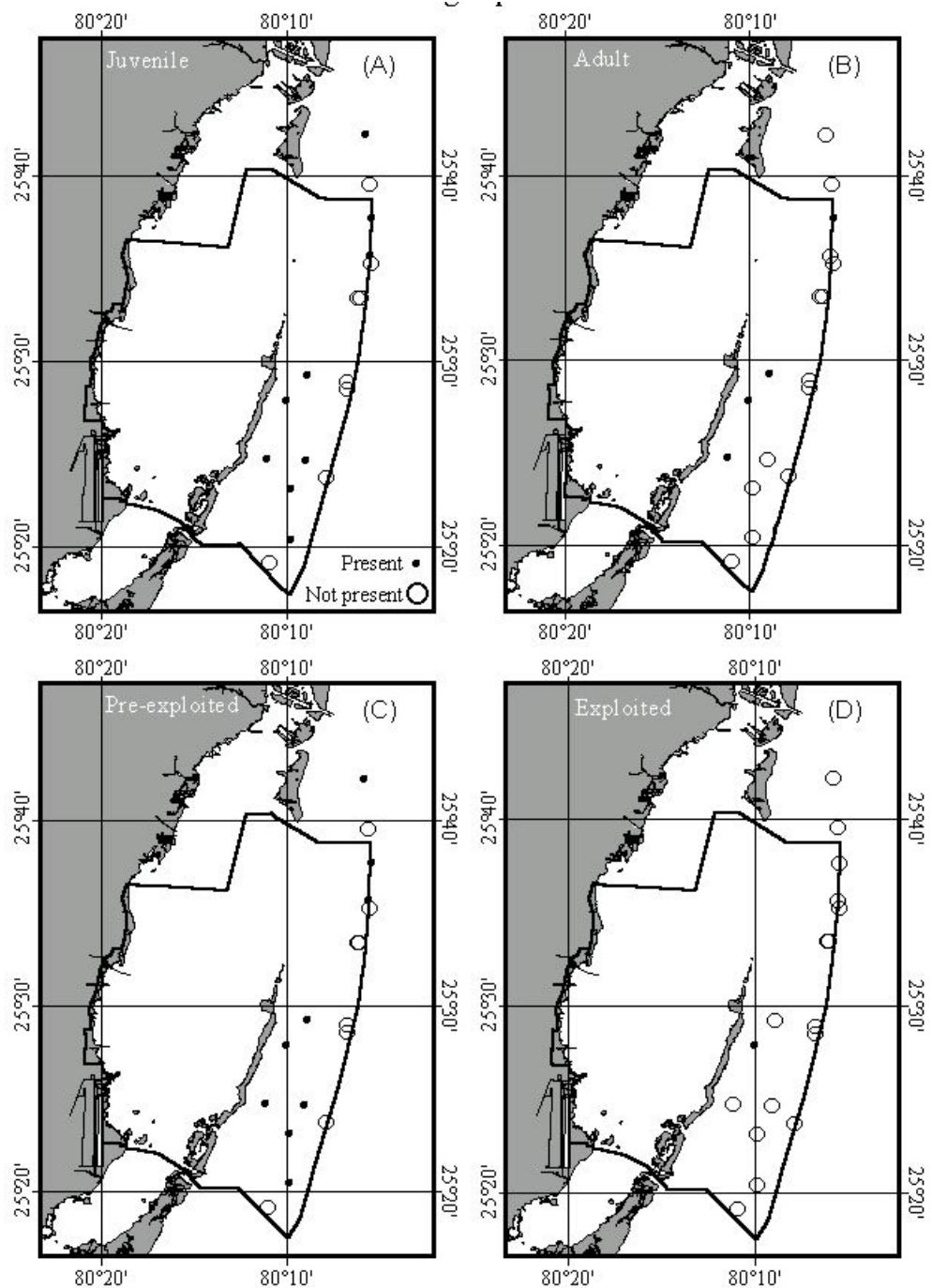
### 3.5 Size Distributions and Spatial Ontogeny for Exploited Species

The three animal survey databases were synthesized to describe spatial distributions of different life stages for species captured by sportfishers in BNP. Life stage was viewed from both biological (juvenile, adult) and fishery (pre-exploited, exploited) perspectives. For a given species, biological life stages were defined according to length at sexual maturity ( $L_m$ ), where juveniles <  $L_m$  adults. Fishery life stages were demarcated using length at first capture ( $L_c$ ), where pre-exploited <  $L_c$  exploited. Presence-absence maps were constructed from fishery-independent survey data (RVC and TRAWL) in the following manner. For the reef system, RVC primary unit point locations where a given species life stage was observed were indicated with a solid dot, whereas an open circle denoted sampling locations where the species life stage was not observed. A similar procedure was used for TRAWL station locations in the coastal bay system, with the exception that only stations where a species life stage was observed were plotted to avoid potential seasonal biases. To aid in the interpretation of the presence-absence maps, we developed length-frequency histograms comparing the size structure for the TRAWL (coastal bay system) and RVC (reef system) surveys. Presence-absence maps and accompanying length-frequency histograms are shown for representative species in the exploited snapper-grouper-grunt complex: black grouper (**Figures 10 and 12B**), red grouper (**Figures 11 and 12A**), mutton snapper (**Figures 13 and 16A**), gray snapper (**Figures 14 and 16B**), yellowtail snapper (**Figures 15 and 16C**), white grunt (**Figures 17 and 19A**), and bluestriped grunt (**Figures 18 and 19B**). CREEL survey data provided very coarse spatial information on distributions of exploited life stages among the general coastal bay, reef, and pelagic environments of BNP functionally limiting its usefulness for spatially-explicit analysis. A list of gear-specific capture regions for species in the CREEL database is provided in **Table 4**. For a given species, gears comprising >5% of database records and capture regions accounting for >10% of gear-specific records are listed.

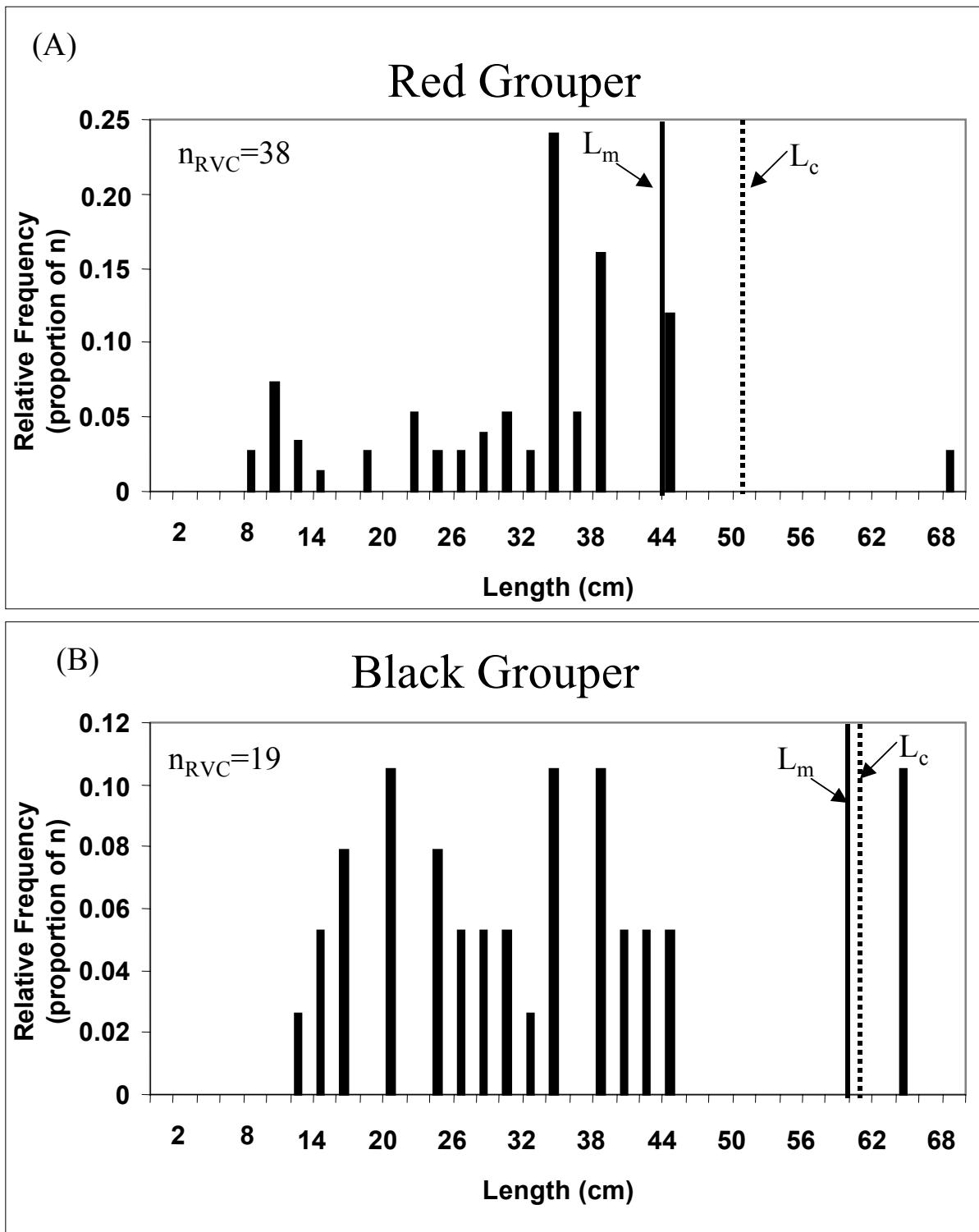
At least three distinct ontogenetic patterns of species' habitat use in BNP are evident in the snapper-grouper-grunt fisheries complex (**Figures 10-19, Table 4**). Mutton snapper, gray snapper, and bluestriped grunt individuals appear to primarily utilize habitats in the coastal bay environment as early juvenile nursery grounds, and then extend their spatial domain out to the reef system as late juveniles and adults. Yellowtail snapper and white grunt individuals seem to utilize both coastal bay and reef system habitats as early juvenile nursery areas, and remain in these general environments as late juveniles and adults. Early juvenile nursery areas in BNP for red and black grouper have not been identified. Sampling surveys conducted in other areas of the Florida Keys indicate that nearshore shallow hard bottom habitats in the reef system may serve this function (personal communication, James Colvocoresses, Florida Marine Research Institute). This particular habitat has not been targeted to date by fishery independent surveys conducted in BNP. Late juvenile and adult groupers primarily utilize the reef system (red grouper) or a mixture of bay and reef habitats (black grouper). Great barracuda, a top-level predator in BNP, occurs in all environments (bay, reef, pelagic) at both juvenile and adult life stages (**Figure 16D**, map not shown). A summary list of species captured or seen in all three animal surveys (TRAWL, RVC, CREEL) is provided in **Table 5**. We can infer the following characteristics for these species: they are subject to exploitation by sportfishers, they occur in both bay and reef systems, and they utilize coastal bay habitats as juvenile nursery grounds to some extent.



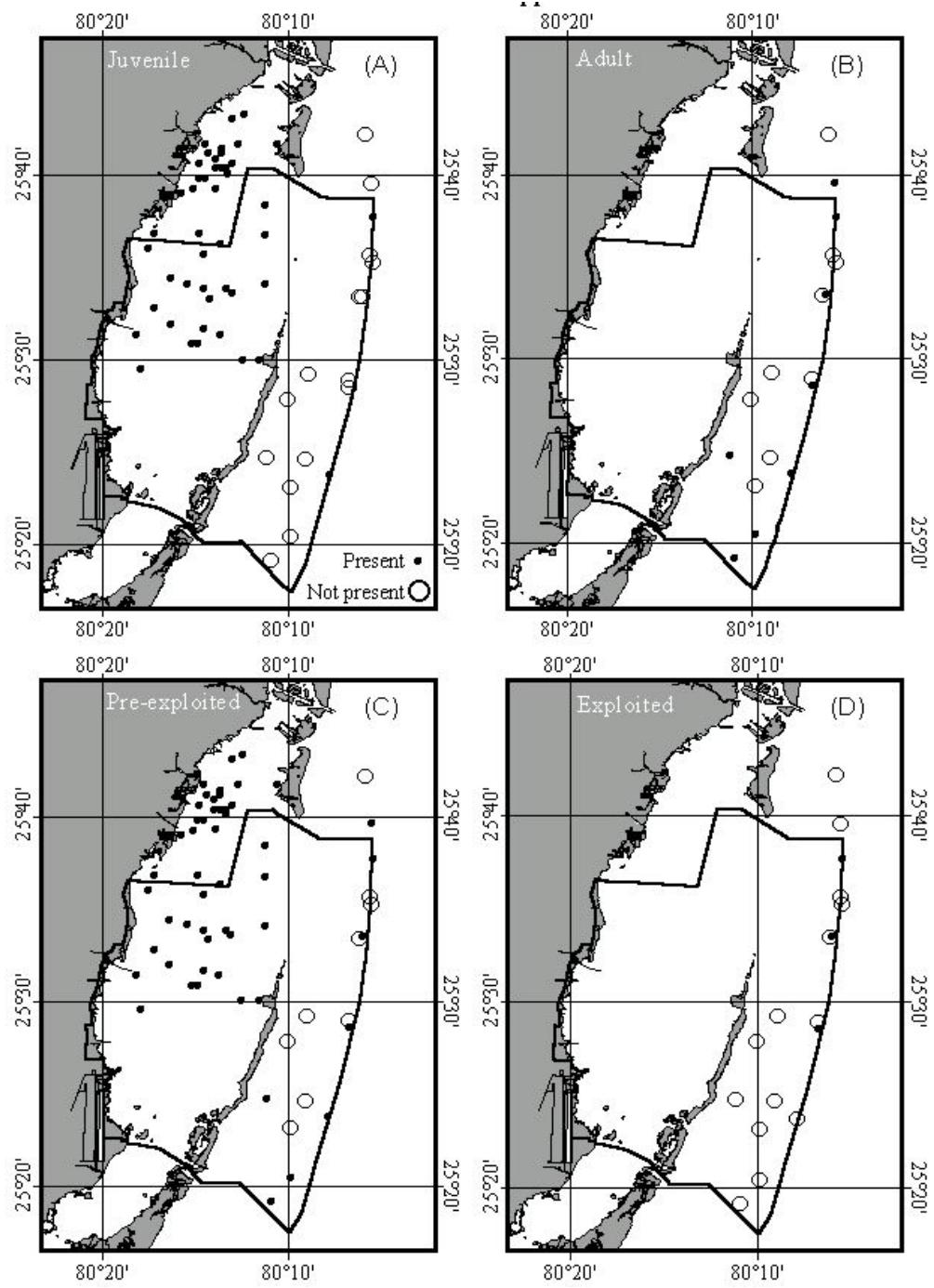
**Figure 10.-** Presence (solid circle) - absence (open circle) of 4 life stages of black grouper in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



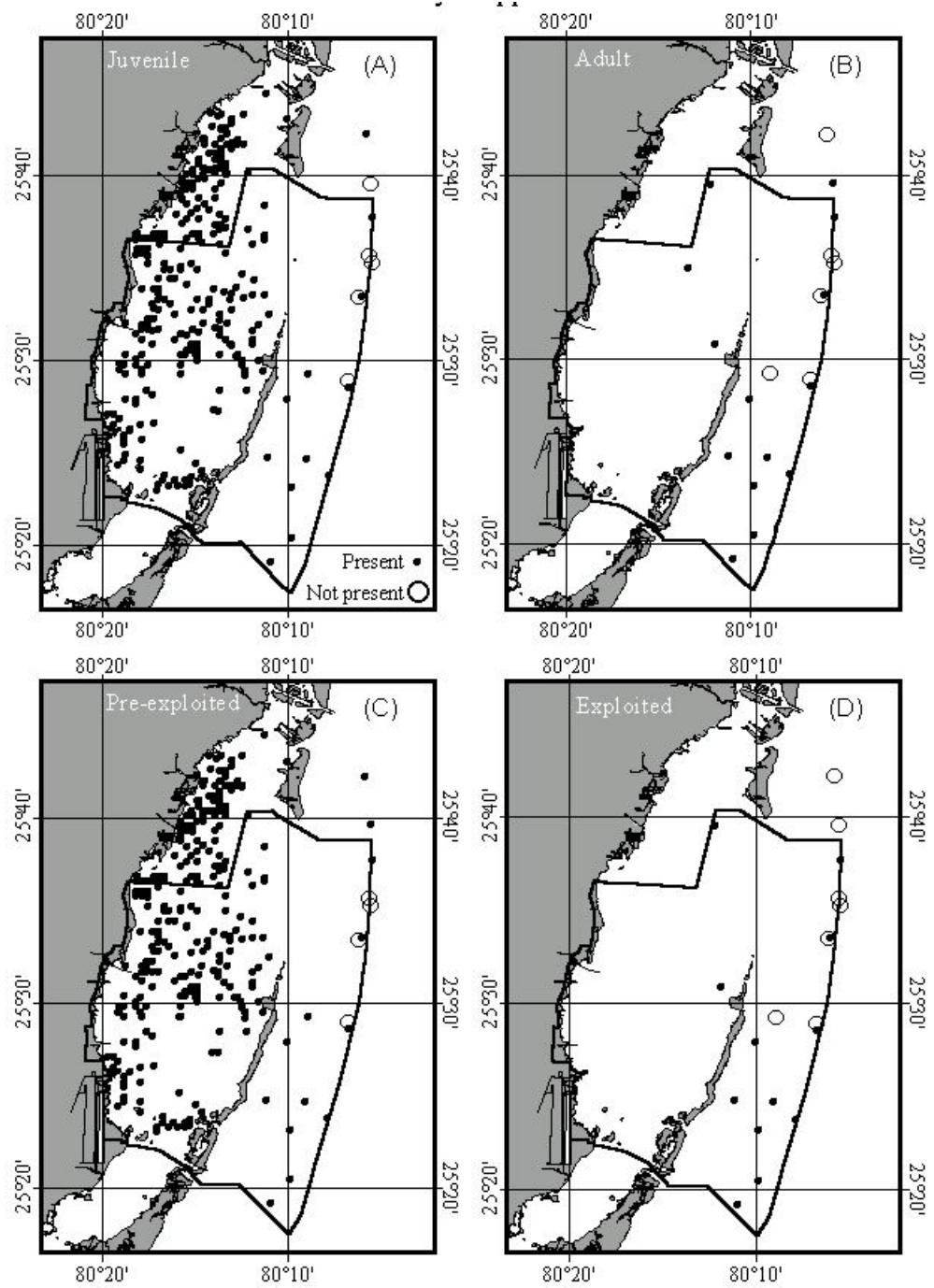
**Figure 11.-** Presence (solid circle) - absence (open circle) of 4 life stages of red grouper in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



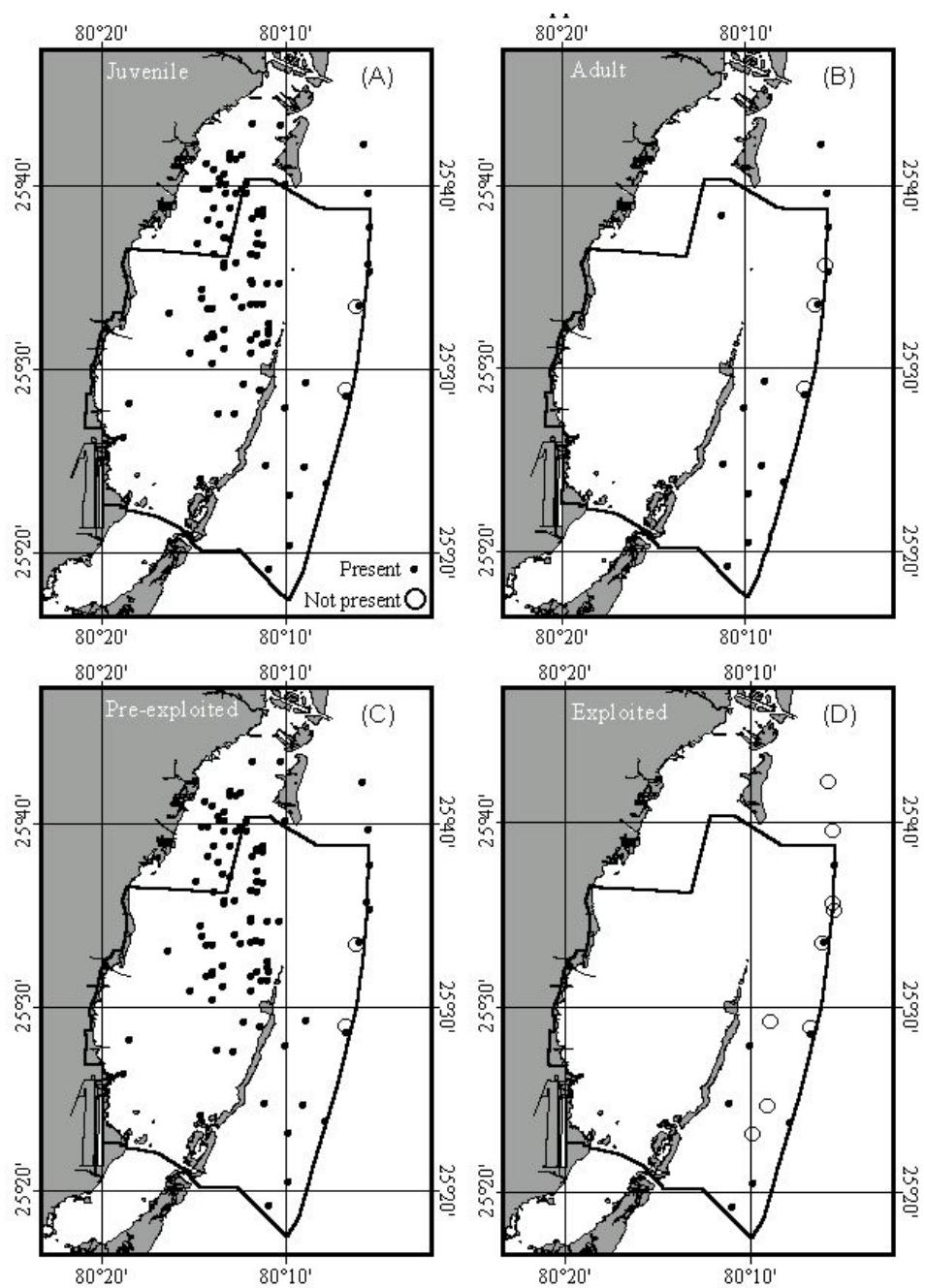
**Figure 12.-** Length frequency distributions for TRAWL (hatched bar) and RVC (solid bar) surveys in Biscayne National Park for: (A) red grouper; and (B) black grouper. Total number of individuals ( $n$ ) observed in each survey, length at maturity ( $L_m$ ), and length at first capture ( $L_c$ ) are denoted for each species.



**Figure 13.-** Presence (solid circle) - absence (open circle) of 4 life stages of mutton snapper in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



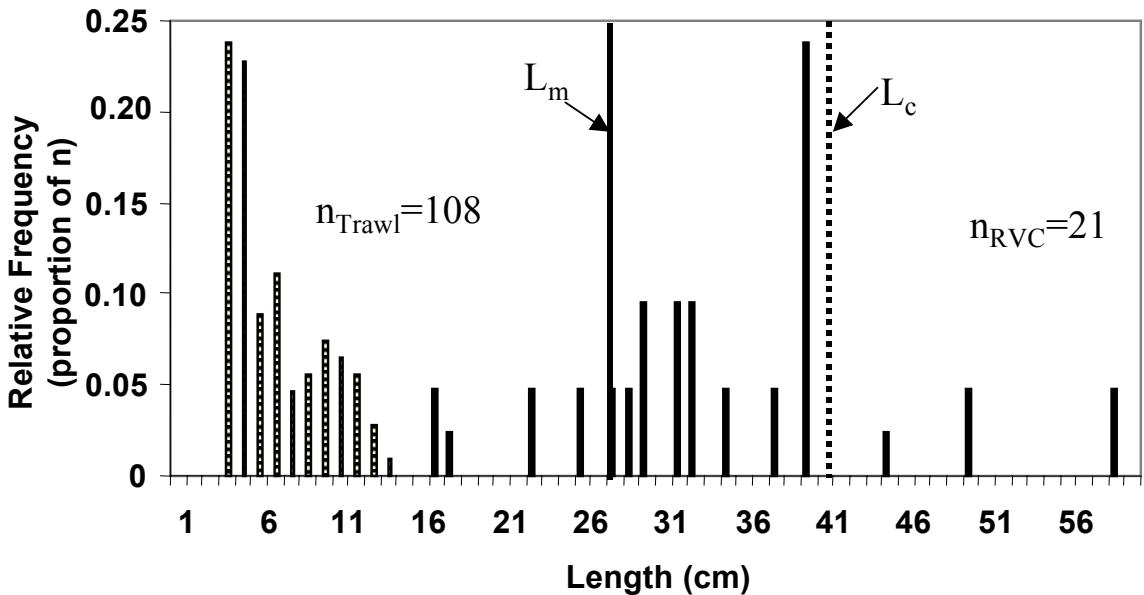
**Figure 14.-** Presence (solid circle) - absence (open circle) of 4 life stages of gray snapper in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



**Figure 15.-** Presence (solid circle) - absence (open circle) of 4 life stages of yellowtail snapper in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.

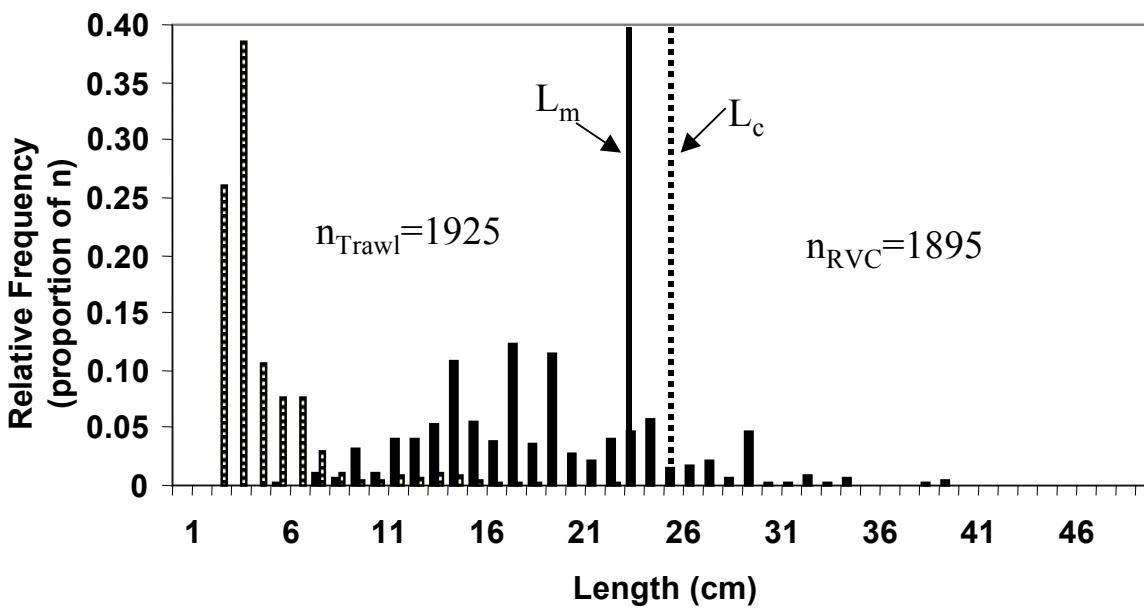
(A)

## Mutton Snapper



(B)

## Gray Snapper



**Figure 16.-** Length frequency distributions for TRAWL (hatched bar) and RVC (solid bar) surveys in Biscayne National Park for: (A) mutton snapper; (B) gray snapper; (C) yellowtail snapper; and (D) great barracuda. Total number of individuals (n) observed in each survey, length at maturity ( $L_m$ ), and length at first capture ( $L_c$ ) are denoted for each species

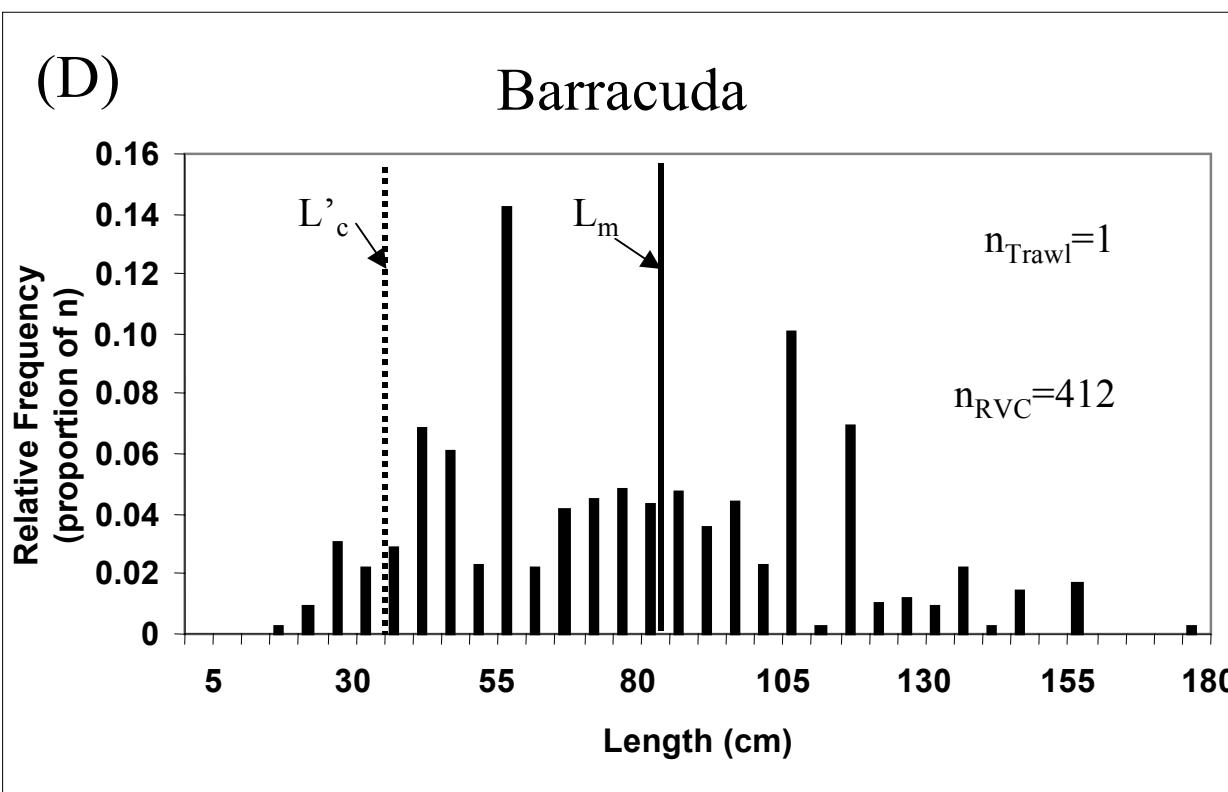
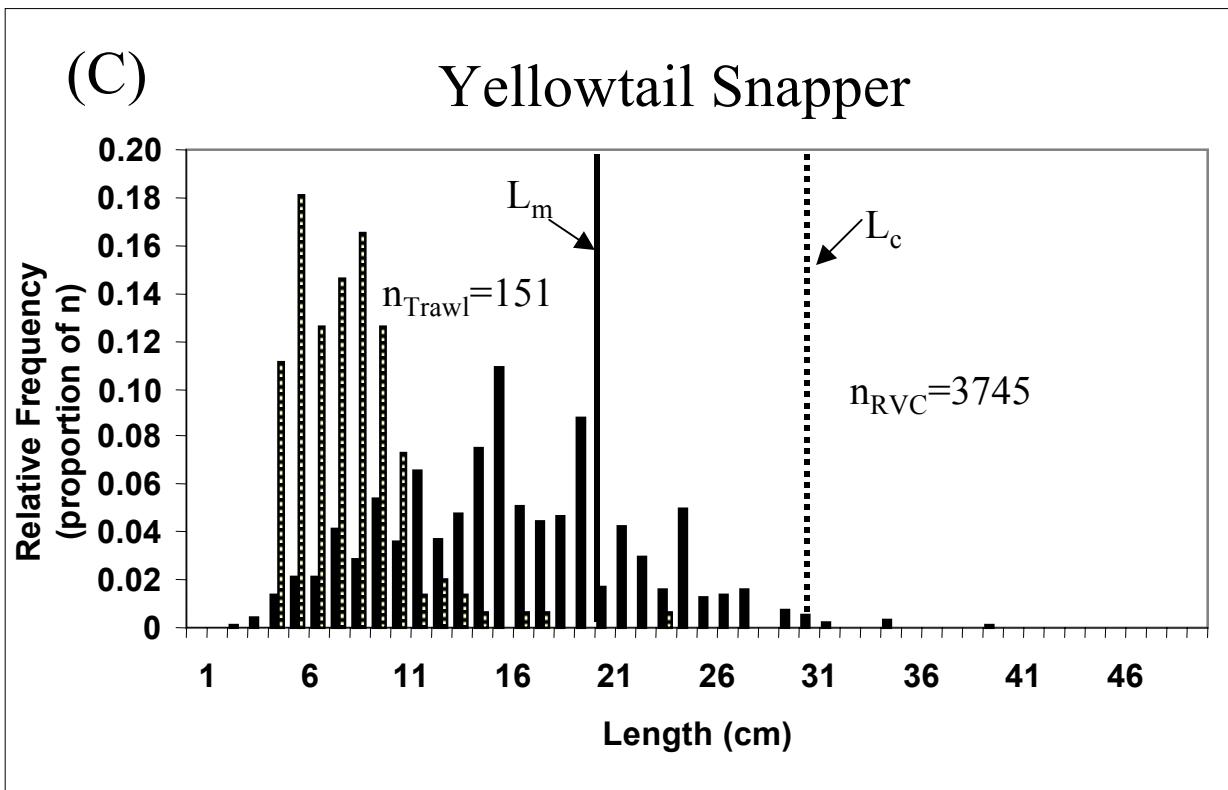
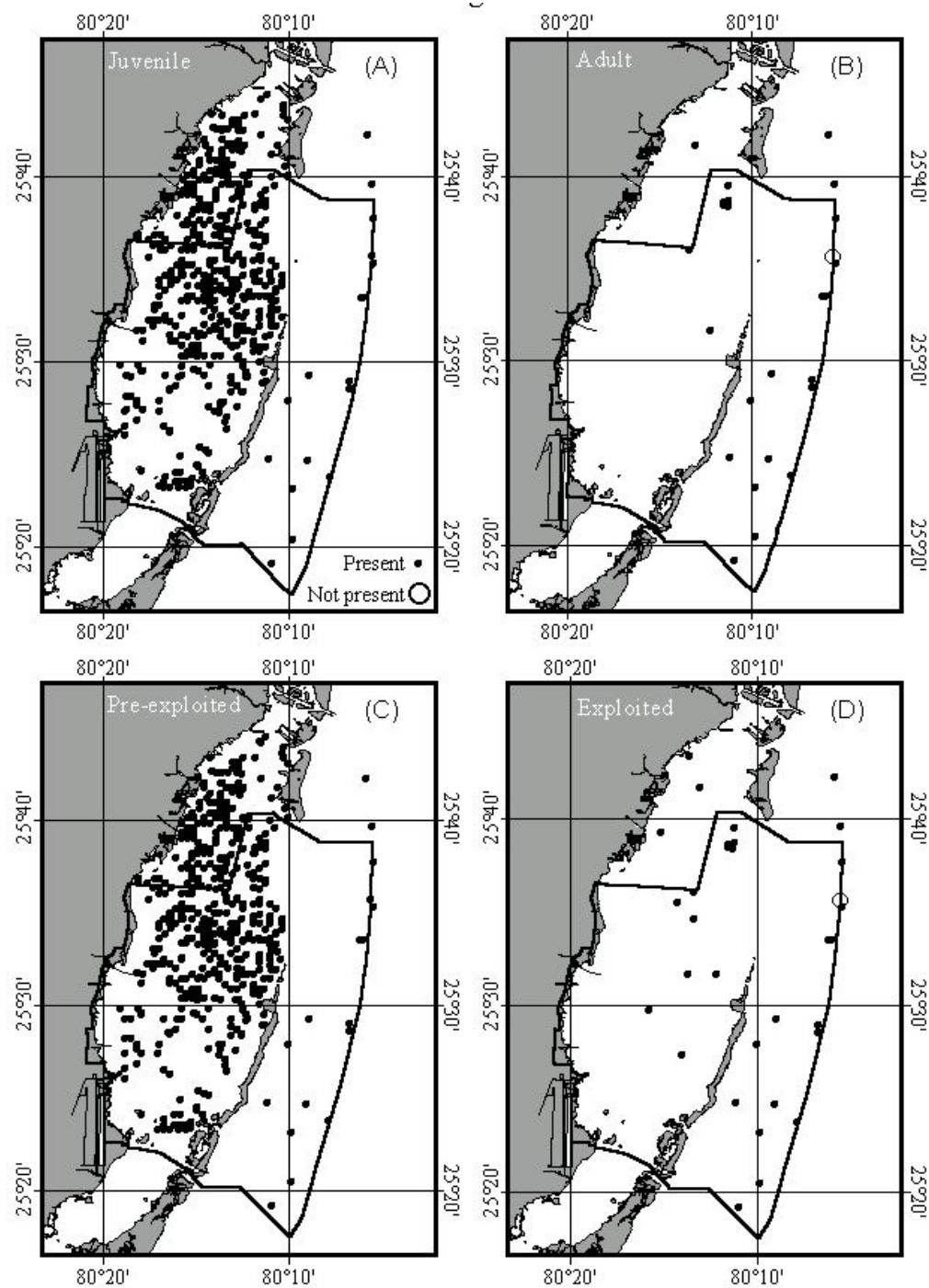
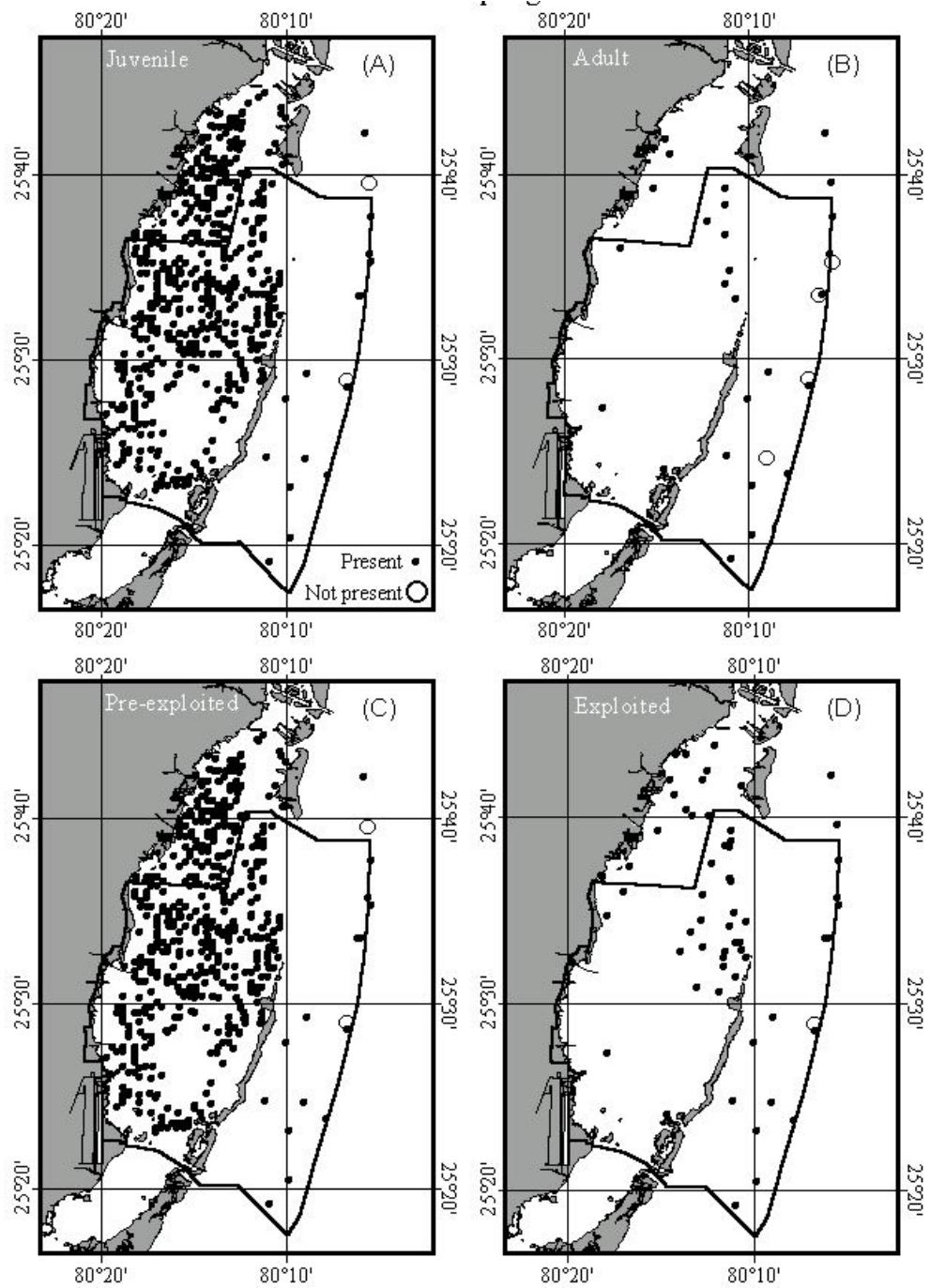


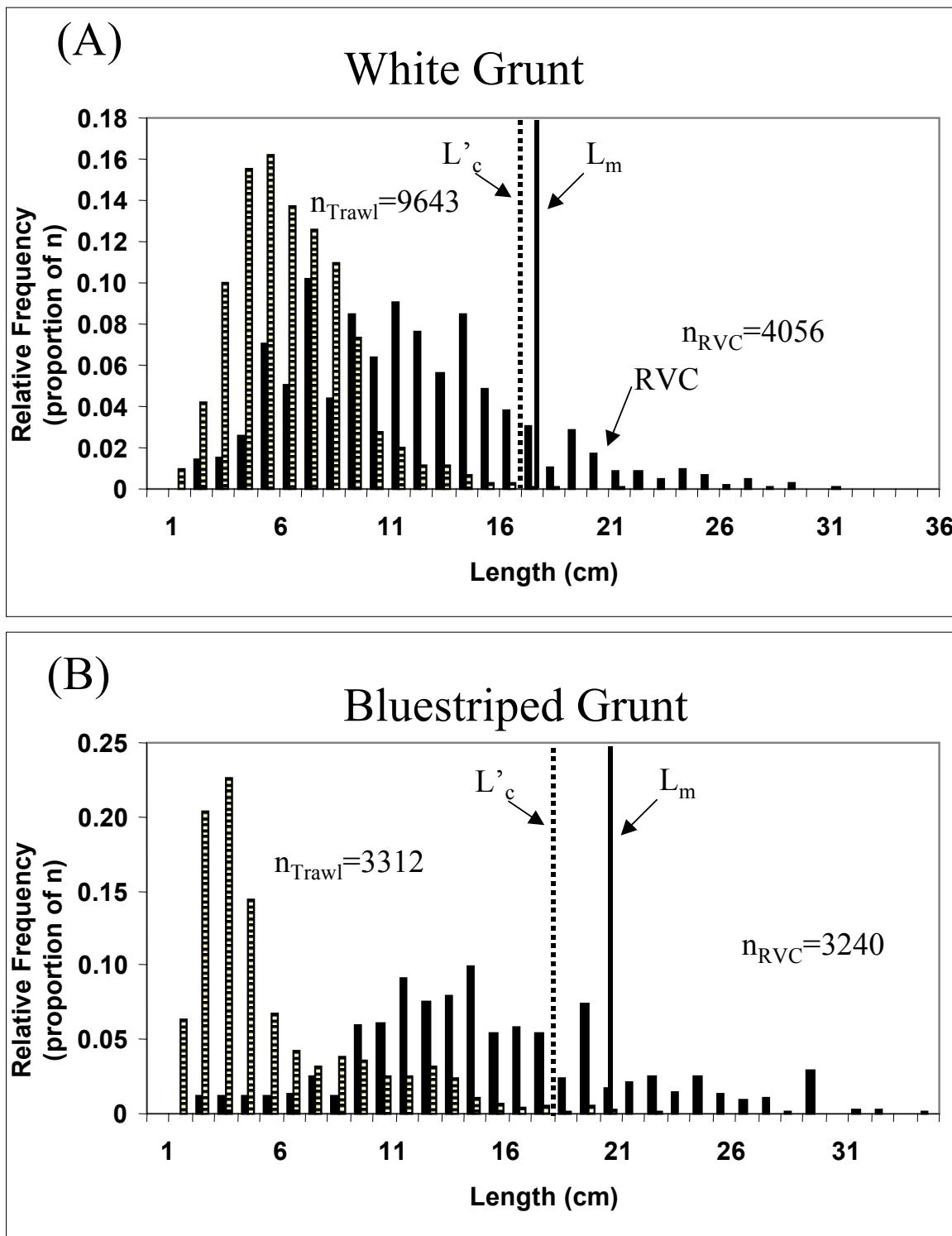
Figure 16.- (continued)



**Figure 17.-** Presence (solid circle) - absence (open circle) of 4 life stages of white grunt in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



**Figure 18.-** Presence (solid circle) - absence (open circle) of 4 life stages of bluestriped grunt in Biscayne National Park as determined by TRAWL baywide and RVC reef fish surveys: (A) juvenile; (B) mature adult; (C) pre-exploited; and (D) exploited phase fish.



**Figure 19.**- Length frequency distributions for TRAWL (hatched bar) and RVC (solid bar) surveys in Biscayne National Park for: (A) white grunt; and (B) bluestriped grunt. Total number of individuals ( $n$ ) observed in each survey, length at maturity ( $L_m$ ), and length at first capture ( $L_c'$ ) are denoted for each species.

**Table 4 -** Summary of CREEL survey catches by Family by gear types and capture regions where species were captured, as well as the principal gear responsible for the majority of captures in the recreational fishery survey.

FAMILY	Scientific Name	Common Name	Fishing Gears & Capture Regions	Principal Gear
<b>Groupers</b>				
Serranidae	<i>Epinephelus adscensionis</i>	rock hind	Hook & Line--Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Epinephelus cruentatus</i>	graysby	Hook & Line--Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Epinephelus drummondhayi</i>	speckled hind	Hook & Line--Reef	Hook & Line
Serranidae	<i>Epinephelus flavolimbatus</i>	yellowedge grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
Serranidae	<i>Epinephelus fulvus</i>	coney	Hook & Line--Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Epinephelus guttatus</i>	red hind	Hook & Line--Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Epinephelus itajara</i>	Goliath grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
Serranidae	<i>Epinephelus morio</i>	red grouper	Hook & Line--Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Epinephelus striatus</i>	nassau grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Mycteroperca bonaci</i>	black grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Mycteroperca interstitialis</i>	yellowmouth grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Mycteroperca microlepis</i>	gag	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Mycteroperca phenax</i>	scamp	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Serranidae	<i>Mycteroperca venenosa</i>	yellowfin grouper	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
<b>Snappers</b>				
Lutjanidae	<i>Lutjanus analis</i>	mutton snapper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Lutjanidae	<i>Lutjanus apodus</i>	schoolmaster	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Lutjanidae	<i>Lutjanus cyanopterus</i>	cubera snapper	Hook & Line--Reef Spearfishing--Reef	Spearfishing
Lutjanidae	<i>Lutjanus griseus</i>	gray snapper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Lutjanidae	<i>Lutjanus jocu</i>	dog snapper	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
Lutjanidae	<i>Lutjanus mahogoni</i>	mahogony snapper	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Lutjanidae	<i>Lutjanus synagris</i>	lane snapper	Hook & Line--Bay, Reef	Hook & Line

Table 4.- (Continued)

FAMILY	Scientific Name	Common Name	Fishing Gears & Capture Regions	Principal Gear
Lutjanidae	<i>Ocyurus chrysurus</i>	yellowtail snapper	Hook & Line--Bay, Reef	Hook & Line
Lutjanidae	<i>Rhomboptilus aurorubens</i>	vermillion snapper	Hook & Line--Reef	Hook & Line
<b>Grunts</b>				
Haemulidae	<i>Anisotremus surinamensis</i>	black margate	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
Haemulidae	<i>Anisotremus virginicus</i>	porkfish	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Haemulidae	<i>Haemulon album</i>	margate	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Haemulidae	<i>Haemulon aurolineatum</i>	tomtate	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Haemulon carbonarium</i>	ceasar grunt	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Haemulidae	<i>Haemulon flavolineatum</i>	french grunt	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Haemulon macrostomium</i>	spanish grunt	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Haemulidae	<i>Haemulon parra</i>	sailors choice	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Haemulon plumieri</i>	white grunt	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Haemulon sciurus</i>	bluestriped grunt	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Haemulon striatum</i>	striped grunt	Hook & Line--Bay, Reef	Hook & Line
Haemulidae	<i>Orthopristis chrysoptera</i>	pigfish	Hook & Line--Bay, Reef	Hook & Line
<b>Other Fish and Shellfish</b>				
Labridae	<i>Lachnolaimus maximus</i>	hogfish	Hook & Line--Bay, Reef Spearfishing--Reef	Spearfishing
Sphyraenidae	<i>Sphyraena barracuda</i>	great barracuda	Hook & Line--Bay, Reef, Pelagic	Hook & Line
Sparidae	<i>Calamus bajonado</i>	jolthead porgy	Hook & Line--Bay, Reef	Hook & Line
Sparidae	<i>Calamus calamus</i>	saucereye porgy	Hook & Line--Bay, Reef	Hook & Line
Carangidae	<i>Caranx bartholomaei</i>	yellow jack	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Carangidae	<i>Caranx cryos</i>	blue runner	Hook & Line--Bay, Reef	Hook & Line
Carangidae	<i>Caranx hippos</i>	crevalle jack	Hook & Line--Pelagic	Hook & Line
Carangidae	<i>Caranx latus</i>	horse-eye jack	Hook & Line--Pelagic	Hook & Line
Carangidae	<i>Caranx ruber</i>	bar jack	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Kyphosidae	<i>Kyphosus sectatrix</i>	bermuda chub	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Balistidae	<i>Balistes capriscus</i>	gray triggerfish	Hook & Line--Bay, Reef	Hook & Line
Balistidae	<i>Balistes vetula</i>	queen triggerfish	Hook & Line--Reef	Hook & Line
Balistidae	<i>Cantherhines sufflamen</i>	ocean triggerfish	Hook & Line--Reef, Pelagic Spearfishing--Reef	Hook & Line
Sciaenidae	<i>Cynoscion nebulosus</i>	spotted seatrout	Hook & Line--Bay	Hook & Line
Carangidae	<i>Trachinotus falcatus</i>	permit	Hook & Line--Bay, Reef Spearfishing--Reef	Hook & Line
Carangidae	<i>Alectis ciliaris</i>	african pompano	Hook & Line--Pelagic	Hook & Line
Coryphaenidae	<i>Coryphaena hippurus</i>	dolphin	Hook & Line--Pelagic	Hook & Line

**Table 4.- (Continued)**

FAMILY	Scientific Name	Common Name	Fishing Gears & Capture Regions	Principal Gear
Scombridae	<i>Sarda sarda</i>	atlantic bonito	Hook & Line--Pelagic	Hook & Line
Scombridae	<i>Euthynnus alletteratus</i>	little tunny	Hook & Line--Reef, Pelagic	Hook & Line
Istiophoridae	<i>Istiophorus platypterus</i>	sailfish	Hook & Line--Pelagic	Hook & Line
Scombridae	<i>Katsuwonus pelamis</i>	skipjack tuna	Hook & Line--Pelagic	Hook & Line
Scombridae	<i>Thunnus atlanticus</i>	blackfin tuna	Hook & Line--Pelagic	Hook & Line
Scombridae	<i>Scomberomorus cavalla</i>	king mackerel	Hook & Line--Pelagic	Hook & Line
Scombridae	<i>Scomberomorus maculatus</i>	spanish mackerel	Hook & Line--Pelagic Spearfishing--Reef	Hook & Line
Scombridae	<i>Scomberomorus regalis</i>	cero	Hook & Line--Bay, Reef, Pelagic Spearfishing--Reef	Hook & Line
Carangidae	<i>Seriola dumerili</i>	greater amberjack	Hook & Line--Reef, Pelagic Spearfishing--Reef	Hook & Line
Lobotidae	<i>Lobotes surinamensis</i>	tripletail	Hook & Line--Pelagic	Hook & Line
Palinuridae	<i>Panulirus argus</i>	Caribbean spiny lobster	Lobster Diving--Bay, Reef	Lobster Diving
Scombridae	<i>Acanthocybium solandri</i>	wahoo	Hook & Line--Pelagic	Hook & Line
Acanthuridae	<i>Acanthurus chirurgus</i>	doctorfish	Hook & Line--Bay, Reef	Hook & Line

**Table 5.-** Species captured or seen in all three fishery surveys (RVC, CREEL, TRAWL) during 1976-1999. Strong bay-to-reef ontogenetic linkages suggest candidate species list for "restoration" indicator species.

Common name	Family	Scientific Name
<b>Groupers</b>		
Black grouper	Serranidae	<i>Mycteroperca bonaci</i>
<b>Snappers</b>		
Mutton snapper	Lutjanidae	<i>Lutjanus analis</i>
Schoolmaster	Lutjanidae	<i>Lutjanus apodus</i>
Yellowtail snapper	Lutjanidae	<i>Ocyurus chrysurus</i>
Gray snapper	Lutjanidae	<i>Lutjanus griseus</i>
Dog snapper	Lutjanidae	<i>Lutjanus jocu</i>
Lane snapper	Lutjanidae	<i>Lutjanus synagris</i>
Hogfish	Labridae	<i>Lachnolaimus maximus</i>
<b>Grunts</b>		
Porkfish	Haemulidae	<i>Anisotremus virginicus</i>
Tomtate	Haemulidae	<i>Haemulon aurolineatum</i>
French Grunt	Haemulidae	<i>Haemulon flavolineatum</i>
Sailors choice	Haemulidae	<i>Haemulon parrai</i>
White grunt	Haemulidae	<i>Haemulon plumieri</i>
Bluestriped grunt	Haemulidae	<i>Haemulon sciurus</i>
<b>Other Reef Fishes</b>		
Great barracuda	Sphyraenidae	<i>Sphyraena barracuda</i>
Atlantic spadefish	Ephippidae	<i>Chaetodipterus faber</i>
Ocean surgeonfish	Acanthuridae	<i>Acanthurus bahianus</i>
Doctorfish	Acanthuridae	<i>Acanthurus chirurgus</i>
Rainbow parrotfish	Scaridae	<i>Scarus guacamaia</i>
Gray triggerfish	Balistidae	<i>Balistes capriscus</i>
Ocean triggerfish	Balistidae	<i>Cantherhines sufflamen</i>
Scrawled filefish	Balistidae	<i>Aluterus scriptus</i>
Trunkfish	Ostraciidae	<i>Lactophrys trigonus</i>
Sea bream	Sparidae	<i>Archosargus rhomboidalis</i>
Littlehead porgy	Sparidae	<i>Calamus proridens</i>
Sand perch	Serranidae	<i>Diplectrum formosum</i>
Spotted moray eel	Muraenidae	<i>Gymnothorax moringa</i>
Gray angelfish	Pomacanthidae	<i>Pomacanthus arcuatus</i>
<b>Coastal Inshore baitfishes</b>		
Ballyhoo	Exocoetidae	<i>Hemiramphus brasiliensis</i>
Yellowfin mojarra	Gerreidae	<i>Gerres cinereus</i>
Blue runner	Carangidae	<i>Caranx cryos</i>
<b>Macroinvertebrates</b>		
Caribbean spiny lobster	Palinuridae	<i>Panulirus argus</i>

### 3.6 Quantitative Assessment of Habitat Use

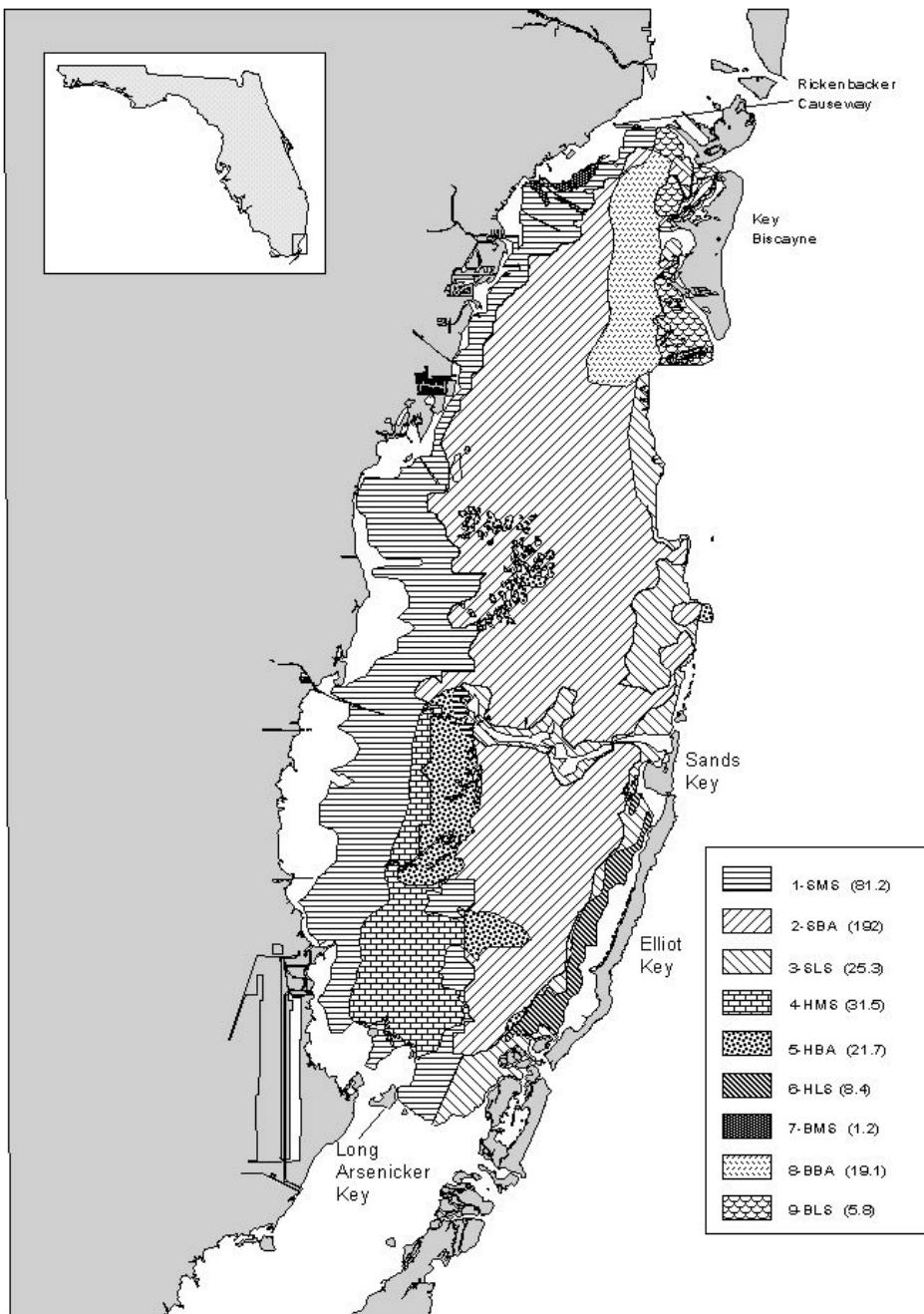
Although the primary focus of this report is to conduct a multispecies stock assessment for exploited species in BNP, assessment and management of important habitats that provide critical support to animals is also a concern. Here we present a case study for the pink shrimp population in Biscayne Bay to demonstrate an analysis approach that provides a more detailed, quantitative understanding of habitat use by animals compared to the more qualitative overview presented above.

Fishery-independent TRAWL survey data (Ault et al. 1999a) were utilized to assess pink shrimp (*Farfantepenaeus duorarum*) habitat use in Biscayne Bay. Since a shift in spatial distribution occurs at the onset of sexual maturation (Ault et al. 1999a), juvenile (6-17 mm carapace length) and subadult (>17 mm CL) life stages were analyzed separately. Nine distinct “habitats” were delineated (**Figure 20, Table 6**) by combining three bottom substrates (seagrass, hard bottom, bare bottom) with three east-west depth gradients (mainland subtidal, 1-2 m; basin axis, >2 m; leeward subtidal, 1-2 m). We designated a basic habitat unit as a 600 m<sup>2</sup> trawl station sampling unit. Drawing on resource selection theory (Manly et al. 1993), three measures of habitat use by pink shrimp were evaluated for each habitat type: (1) probability of use  $p(\text{use})$ , i.e., the proportion of habitat units occupied by at least one animal; (2) per unit amount of use, i.e., animal density (numbers per m<sup>2</sup>); and (3) population amount of use, i.e., animal abundance (number of animals). A design-based framework (Cochran 1977) was used to estimate the mean and variance of each measure. The three measures in concert provide a fairly comprehensive understanding of differential use of habitats.

**Table 6.-** Description of habitat codes of **Figure 20**, and the probability  $p$  of use of each habitat for juvenile and subadult pink shrimp in August and November 1996.

Habitat	Substrate	Depth (m)	Cross-shelf Position	August 1996		November 1996	
				Juvenile $p(\text{use})$	Subadult $p(\text{use})$	Juvenile $p(\text{use})$	Subadult $p(\text{use})$
1	Seagrass	1-2	Mainland	1.0	0.750	1.0	1.0
2	Seagrass	>2	Basin Axis	1.0	0.636	1.0	1.0
3	Seagrass	1-2	Leeward	1.0	0.813	1.0	1.0
4	Hardbottom	1-2	Mainland	1.0	0.545	1.0	1.0
5	Hardbottom	>2	Basin Axis	1.0	0.400	1.0	1.0
6	Hardbottom	1-2	Leeward	1.0	0.0	1.0	1.0
7	Barebottom	1-2	Mainland	1.0	1.0	1.0	1.0
8	Barebottom	>2	Basin Axis	1.0	0.500	1.0	1.0
9	Barebottom	1-2	Leeward	1.0	0.500	1.0	0.500

Habitat-specific estimates of  $p(\text{use})$  for two seasons are given in **Table 6**. In late summer, just after the major period of postlarval immigration and settlement,  $p(\text{use})=1.0$  for juvenile pink



**Figure 20.** - Map of Biscayne Bay, Florida, showing nine habitat types. Habitat codes are as follows: SMS, seagrass mainland subtidal; SBA, seagrass basin axis; SLS, seagrass leeward subtidal; HMS, hard bottom mainland subtidal; HBA, hard bottom basin axis; HLS, hard bottom leeward subtidal; BMS, bare bottom mainland subtidal; BBA, bare bottom basin axis; bare bottom leeward subtidal. Habitat codes are further defined in **Table 6**. Habitat areas in  $\text{km}^2$  are given in parentheses.

shrimp in all habitats. Even though subadult abundance is quite low during this season, from 60% to 80% of seagrass habitat units contained at least one subadult shrimp, with lower  $p(\text{use})$  in other habitats. In late fall, the period between recruitment into (summer) and emigration from (late winter) Biscayne Bay,  $p(\text{use})=1.0$  for both juveniles and subadults in nearly all habitats. These results indicate that virtually every habitat unit in the Bay is occupied by at least one juvenile and one subadult pink shrimp at this time.

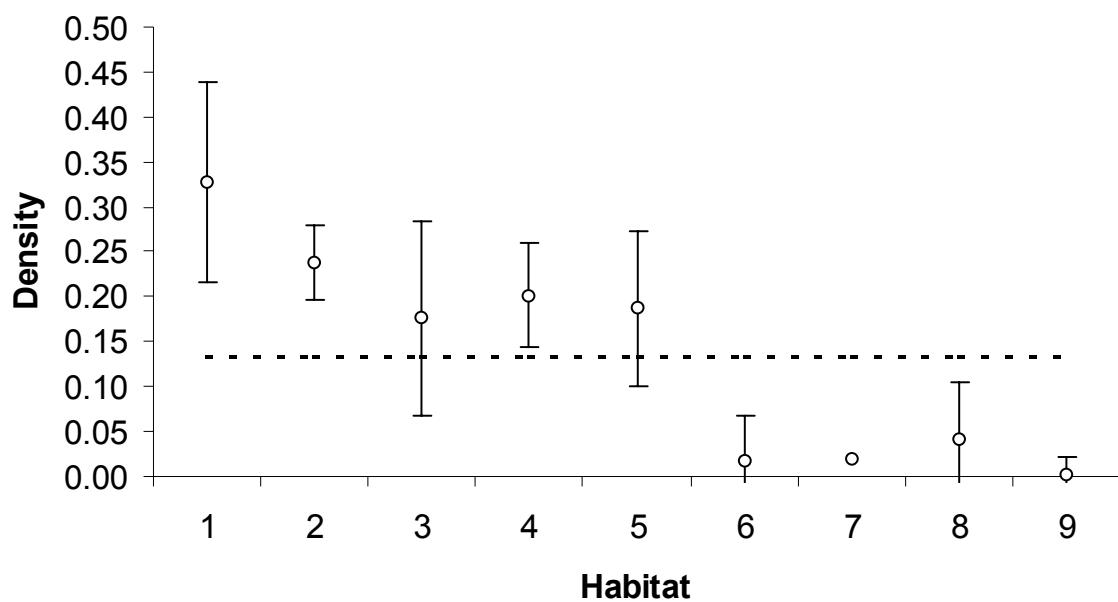
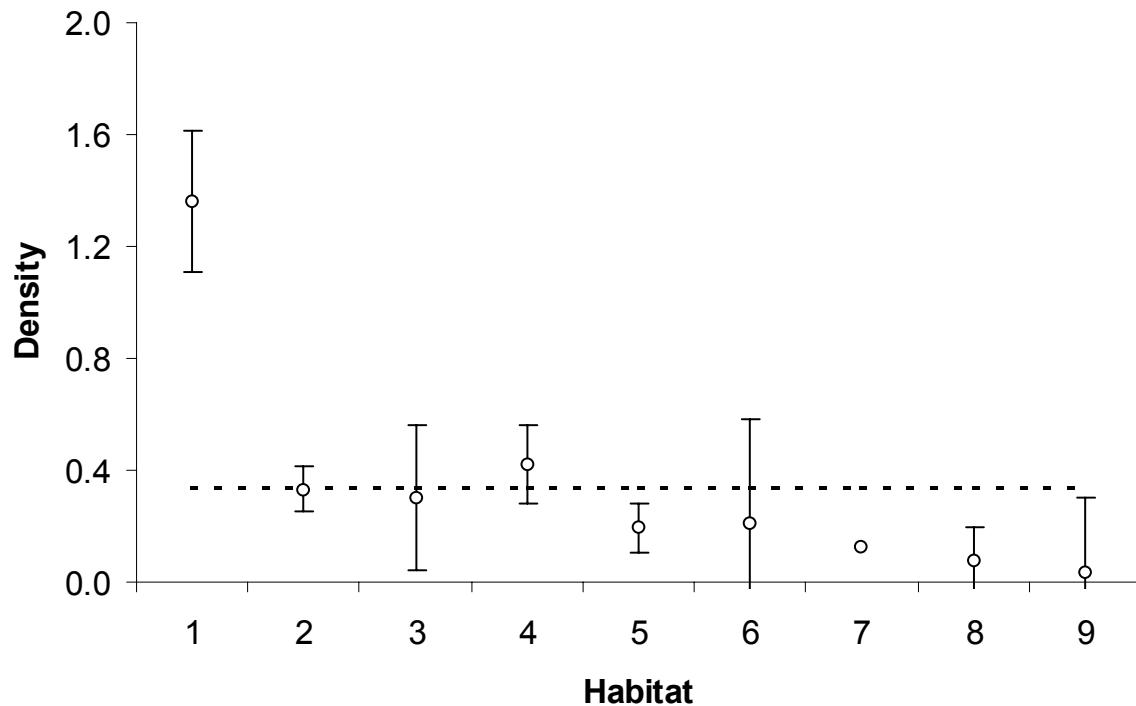
Habitat-specific mean density and corresponding 95% confidence intervals for the late fall season are plotted in **Figure 21** for juveniles (**Figure 21A**) and subadults (**Figure 21B**). The horizontal dotted line is the stratified random estimate of overall mean density in Biscayne Bay. Mean density of juveniles was 3-4 times higher in mainland shallow seagrass (habitat 1) compared to the average Bay value. Juvenile density in other habitats was at or below the average Bay value. Subadult shrimp were found in highest densities in mainland and basin axis seagrass (habitats 1 and 2). Density was also above the Bay average in leeward seagrass (habitat 3) and mainland and basin axis hard bottom (habitats 4 and 5). Lowest densities of subadults occurred in leeward hard bottom (habitat 6) and bare bottom habitats (7-9).

Results for population amount of use are expressed in terms of the proportion of the total population (abundance) that resides in a particular habitat (**Figure 22**). Approximately 80-90% of both juvenile and subadult pink shrimp in Biscayne Bay are found in mainland and basin axis seagrass (habitats 1 and 2), with 10-20% of the population distributed among the remaining habitats (**Figure 22A**). A formal test for habitat selection is made by comparing the population proportion  $p(P)$  against the proportion of total area  $p(A)$  for a given habitat. Statistical differences between  $p(P)$  and  $p(A)$  were evaluated with a standard t-test (significance level " $=0.05$ "), with outcomes interpreted as follows:

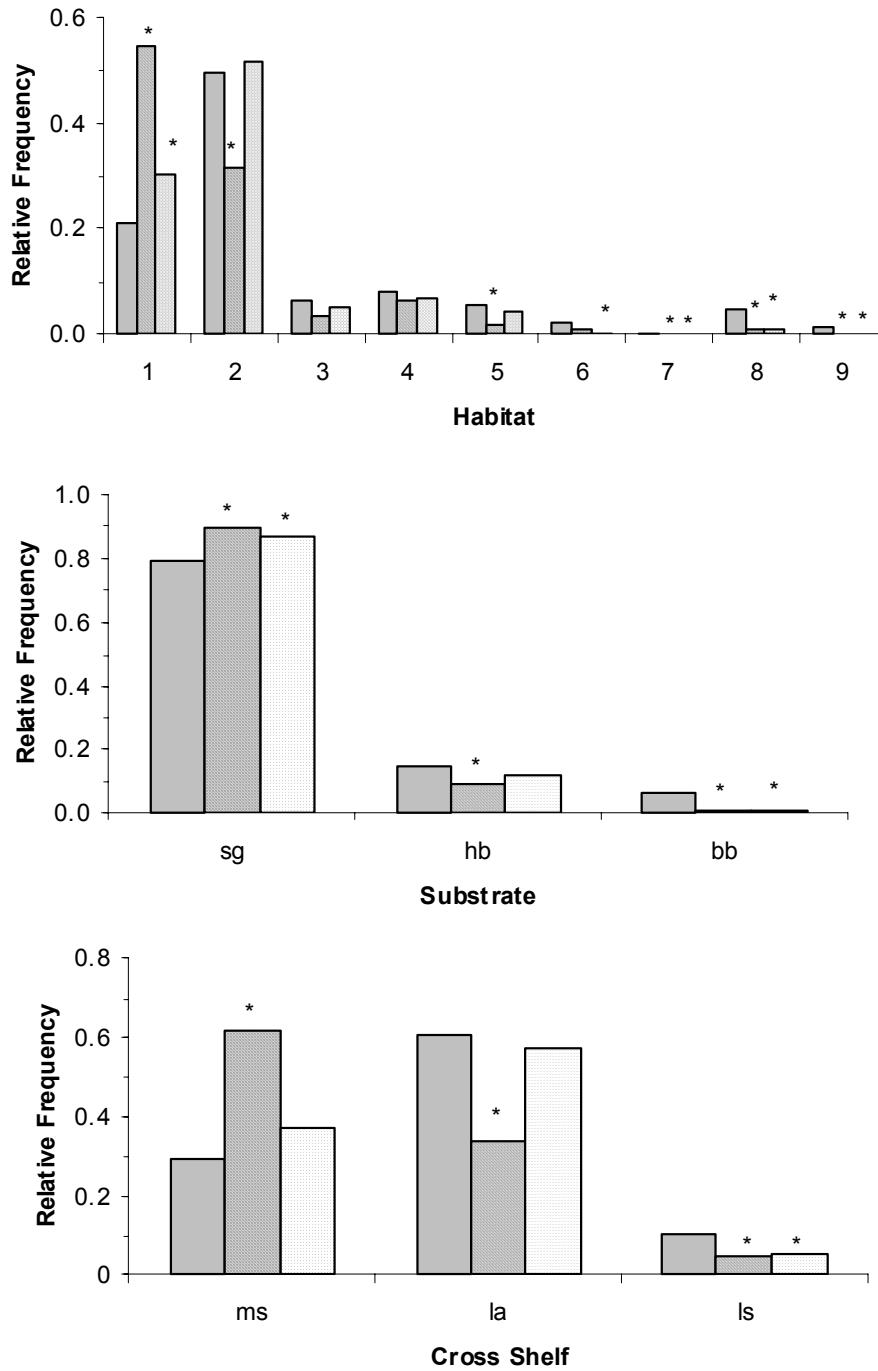
- $p(P) > p(A)$ : positive habitat selection;
- $p(P) = p(A)$ : no selection;
- $p(P) < p(A)$ : negative selection.

While 85% of juveniles are in habitats 1 and 2, they are clearly selecting habitat 1 over habitat 2 (**Figure 22A**). Subadult shrimp also exhibit positive selection of habitat 1, but occupy habitat 2 in equal proportion  $p(P)$  to area  $p(A)$ . Both life stages exhibit negative selection of bare bottom environments (habitats 7-9).

Broad-scale factors underlying pink shrimp habitat selection are illustrated in **Figures 22B** and **22C**, which group habitats in terms of bottom substrate (**Figure 22B**) and salinity zone-depth (**Figure 22C**). While juveniles exhibited positive selection for seagrass over other bottom types (**Figure 22B**), the selection of mainland shallow water environments without regard to bottom substrate is much more striking (**Figure 22C**). In contrast, subadult pink shrimp selected seagrass habitats irrespective of salinity zone and depth. Recruit shrimp (post-larvae) seem to settle on the western shore of Biscayne Bay in waters less than 1 m deep, then move seaward as they age, grow and mature (Ault et al. 1999a, G.A. Diaz, personal communication).



**Figure 21.-** Mean density and corresponding 95% confidence intervals by habitat type for pink shrimp (A) juveniles and (B) subadults. The dashed horizontal line represents the stratified random estimate of mean density for the entire sampling domain (Biscayne Bay).



**Figure 22.-** Population proportion  $p(P)$  of pink shrimp juveniles (hatched bars) and subadults (stippled bars) and corresponding proportion of habitat area  $p(A)$  (shaded bars) for (A) nine habitat types specified in Figure 20, (B) bottom substrate habitats, and (C) cross-shelf salinity zone-depth habitats. Asterisks denote significant differences ( $p < 0.05$ ) between  $p(P)$  and  $p(A)$ . Seagrass is sg, hardbottom is hb, and barebottom is bb. Mainland is ls, basin axis is la, and leeward is ls.

## **4.0 Fishery Overview and Estimation of Stock Status Indices**

In this section we review and analyze a host of fishery-dependent and fishery-independent databases and scientific and technical literature on fishery resources in BNP and the broader Florida Keys region. These results were then used to facilitate evaluation of the current and historical levels of fishery catch and effort. We also use these data to estimate CPUE (catch-per-unit-effort) and  $\bar{L}$  (average length of exploited phase individuals), two principal statistics or indicator variables essential to stock assessments.

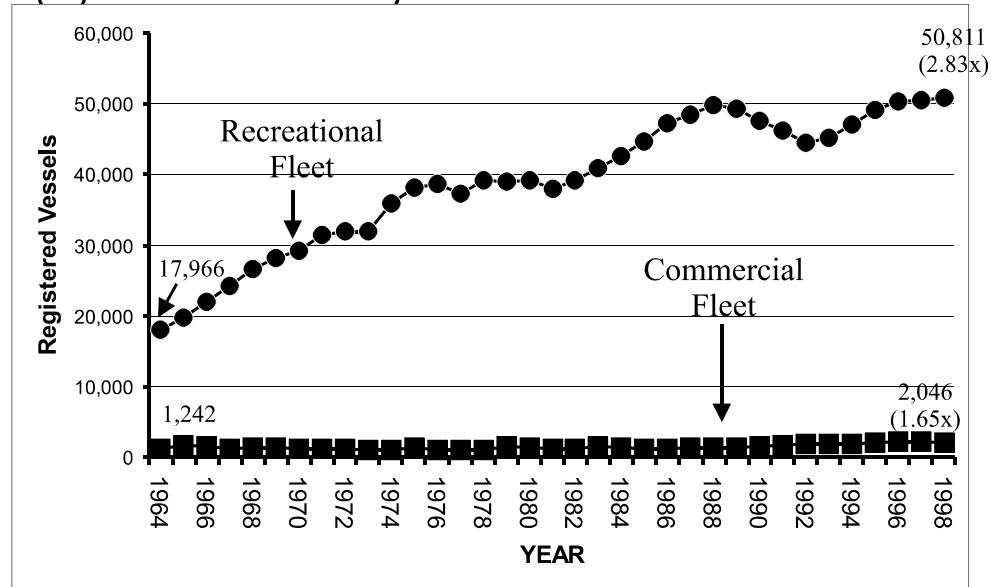
### **4.1 Fishing Effort and Regional Human Population Growth**

South Florida reef fish stocks in the Florida Keys and BNP are exploited by large and diverse commercial and recreational fleets. These fleets have experienced dramatic growth over the last several decades (1964-1998) in both absolute numbers of registered vessels and in the relative “fishing power” of each of those vessels. The recreational fleet has dramatically grown since 1964 (**Figure 23**). In Dade County, the number of registered vessels increased 2.83 times between 1964 (17,966 vessels) and 1998 (50,811). The five county area of south Florida including Dade, Monroe, Collier, Broward and Palm Beach counties, experienced a 444% increase in the nominal number of vessels over the same period of time (37,435 in 1994 to 166,343 in 1998). The commercial fleets have also grown over that same period, with a 1.65 times increase in the number of vessels registered in Dade County (1,242 to 2,046) and 1.97 times increase in the five county area (5,316 to 10,465). The growth of the fishing fleets is directly correlated with the growth of human populations in Florida (**Figure 24**). The Sunshine State has experienced explosive growth over the past 160 years. During 1960 to 2000 Florida’s human population grew an astounding 223% (from 4.95 to 15.98 million persons)! During this same period, in addition to the sheer increase in both recreational and commercial fleet sizes, the relative effective vessel “fishing power” of these fleets has quadrupled due to better hydroacoustics (fish finders and depth gauges), global positioning systems (GPS), improved vessel designs and propulsion systems, air conditioning, and more advanced and effective communication networks utilized by both recreational and commercial fishermen (Bohnsack and Ault 1996, Mace 1997). These increases in fleet sizes and effective fishing power have not only directly impacted multispecies fishery stocks through exploitation in BNP, but have negative indirect impacts through habitat degradation and destruction (Rothschild et al. 1994, Ault et al. 1997b). Excessive boat traffic from a growing fleet and the presence of jet skis on and near flats are disturbing “habitats” (e.g., flats environments) and premier sportfishes like bonefish, tarpon, permit and sharks, and causing a significant increase in manatees and turtles hit and killed by boaters. These conditions have fueled widespread user conflicts between recreational and commercial fishermen in south Florida waters through interactions precipitated by intensive use of gillnets, excessive bycatch from shrimp trawls for food and “bait”, and over-use of baitfish resources compromising the sensitive ecological balance of predator-prey dynamics. Some mitigation has occurred (e.g., banning of jet skis in BNP circa 1998), but serious concern has arisen because of documented “serial overfishing” of reef fishery resources in the Florida Keys (Bohnsack et al. 1994, Ault et al. 1997, 1998).

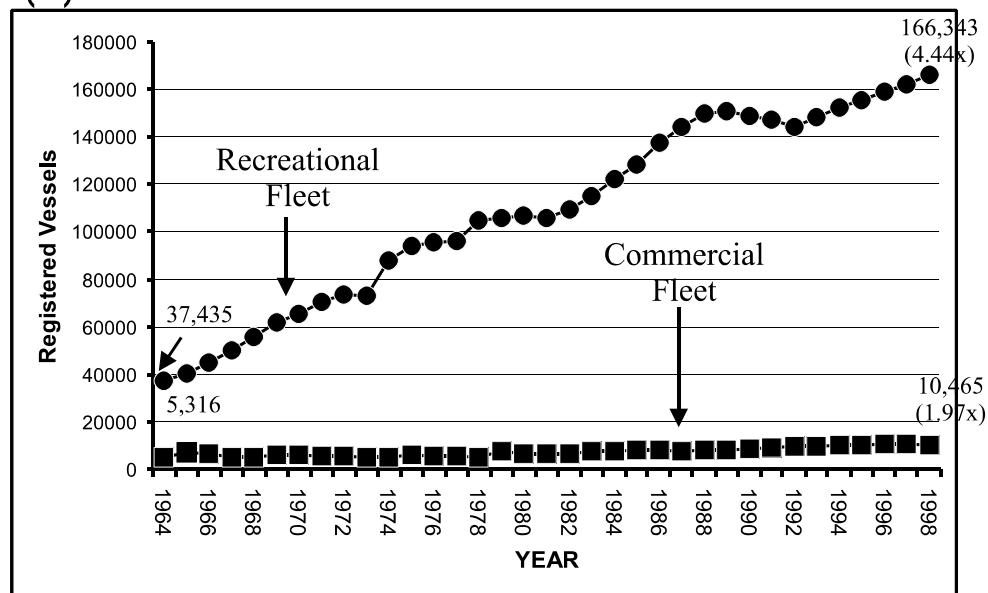
### **4.2 Commercial Landings**

Commercial landings in weight by species reported for the area encompassing Biscayne Bay, Card Sound, and Barnes Sound for 1986-1999 are presented in **Tables 7** and **8**. These data provide a good indication of the magnitude of commercial extractive activities in the coastal bay portion of

(A) Dade County 1964 - 1998

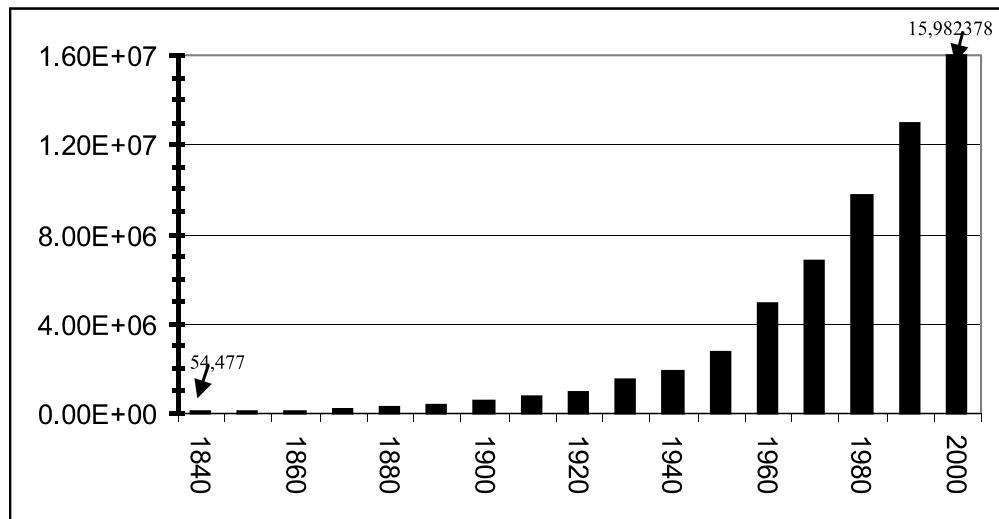


(B) South Florida 1964 - 1998



**Figure 23.**- Time series of two types of nominal fishing effort directed at BNP reef fish from 1964 to 1998 based on recreational (dark circles) and commercial (dark square) vessels registered in: (A) Dade County; and, (B) South Florida (Broward, Collier, Dade, Monroe and Palm Beach counties). Source: National Marine Fisheries Service SEFSC.

## Florida's Human Population 1840 - 2000



**Figure 24.-**The Sunshine State has experienced explosive growth over the past 160 years, making Florida the fourth largest state in the nation. State's human population has grown 223% since 1960. Source: U.S. Census Bureau.

**Table 7.** - Commercial landings (lbs) by species reported for the area encompassing Biscayne Bay, Card Sound, and Barnes Sound for 1986-1996. Source: FFWCC and NOAA.

SPECIES	YEAR										
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
<b>Groupers, Snappers, Grunts</b>											
Red Grouper									5		
Nassau Grouper			14								
Goliath			708								
Black Grouper	1003	1048	42		32	15					30
Gag Grouper		618	36	9		17					
Groupers, Other	7	510									
Gray Snapper	105	4	2197	1186		22	131	3	30		1123
Mutton Snapper		91	22		4					255	407
Yellowtail Snapper	2698	3269	1147	1433	1859	1824	2507	2214	571	479	2190
Snapper, Other	31	17548	10		405		167				
Hogfish			18	16		152					
Grunt Spp.	67	3757	866	59	77		100	11	7	176	327
<b>Other Fishes</b>											
Blue Runner		18		37						1364	530
Crevalle Jack				5			200			1195	6
Jack, Other	32		10	16	205						
Pompano spp.						2	71		84	270	129
King Mackerel		55									
Spanish Mackerel	8					128		95		602	100
Cero							521			2	16
Flyingfish spp.						72	924	155	22		
Cobia		87									10
Great Barracuda						6.25		322			
Shark spp.		99									
White Marlin	1094										
Ingentfish spp.		21									
Porgy spp.				6	108						
Spotted Seatrout	50	2301	395	58							
Seatrout, Other	25	15									
Spot											1687
Mullet spp.	21544	20965	26961	11555	11765	16625	11375	15445	1419	5460	19081
Mullet Roe	530	23						1683	923	886	1193
Sardine spp.											1642
Baitfish (herrings, ballyhoo,, etc)	1895	4548	1739			194		460	3648	312	5002
Misc. Fishes	7193	10609	12906	11273	7358	592	3443	344	2430	186	
<b>Macroinvertebrates</b>											
Blue Crabs		278	2.5			72	1051	9725	36041	23777	41352
Stone Crabs			6	3	326	895	108	167	419	1889	1778
Spiny Lobster	1536	3645	2068	2029	4572	8615	7379	3716	1946	20192	18150
Pink Shrimp	1474	1257	2286.1	8499	17773	29458	37045	33655	58525	72849	135028
Misc. Invertebrates											150
<b>Sponges</b>											
Grass Sponge					11950	6190	2435	59			
Sheepswool Sponge					51813	42531	20241	279			
Yellow Sponge					12866	4295	1802	47			

**Table 8.-** Commercial landings (lbs.) and dockside value (dollars) by species reported for the area encompassing Biscayne Bay, Card Sound, and Barnes Sound for 1997-1999. Source: FFWCC and NOAA.

Species	1997		1998		1999	
	Landings	Value	Landings	Value	Landings	Value
<b>Groupers, Snappers, Grunts</b>						
Red Grouper	31	\$65				
Black Grouper	118	\$200				
Gag Grouper	45	\$95				
Rock Hind			83	\$25		
Gray Snapper	101	\$209	4	\$9	65	\$135
Mutton Snapper	306	\$558				
Yellowtail Snapper	116	\$250	895	\$1,681	28	\$63
Grunt spp.	2,169	\$1,951	501	\$422	217	\$251
<b>Other Fishes</b>						
Blue Runner	1,435	\$1,132	2,598	\$2,838	33	\$28
Crevalle Jack	18	\$18	70	\$70		
King and Cero Mackerel					437	\$672
Spanish Mackerel			491	\$636		
Flyingfish spp.			1,036	\$134		
Great Barracuda			208	\$416		
Shark spp.			104	\$75		
Parrotfish spp.	30	\$45				
Pinfish	113	\$776	212	\$1,647	145	\$1,155
Sheepshead	36	\$45				
Spotted Seatrout	30	\$60				
Seatrout, Other			200	\$140		
Flounder spp.	15	\$9				
Spot	821	\$698				
Mullet spp.	24,830	\$20,754	20,120	\$19,643	26,118	\$27,241
Sardine spp.	3,673	\$2,401	220	\$165		
Misc. Fishes	410	\$185	3,156	\$1,988	4,674	\$3,734
<b>Macroinvertebrates</b>						
Blue Crabs	89,135	\$123,414	77,451	\$105,690	117,858	\$147,393
Stone Crabs	28,382	\$45,245	19,244	\$75,499	12,628	\$55,422
Spiny Lobster	14,953	\$69,031	4,107	\$18,329	4,465	\$19,307
Pink Shrimp	412,775	\$1,225,735	412,265	\$1,135,457	612,489	\$1,343,564
<b>TOTALS</b>	<b>579,542</b>	<b>\$1,492,876</b>	<b>542,965</b>	<b>\$1,364,864</b>	<b>779,157</b>	<b>\$1,598,965</b>

Biscayne National Park. Unfortunately, commercial landings data specific to the offshore coral reef habitat of BNP are not available. The magnitude of commercial catches of groupers, snappers, and grunts in the coastal bay environment of BNP were rather small throughout the reporting period, but nonetheless showed a declining trend. In contrast, commercial landings of macroinvertebrates generally showed an increasing trend. For pink shrimp in particular, this trend may partly be due to a fundamental change in data collection procedures used by the State of Florida and reflect more complete reporting of catches by commercial fishers in recent years (personal communication, Florida Fish & Wildlife Conservation Commission) which were functionally omitted early on. However, this increasing trend in recent years may also reflect increased fishing power of the fleet and a redirection of fishing effort from declining finfish species resources to the much more lucrative macroinvertebrate species. Sponges were landed in significant quantities in the late 1980s and early 1990s prior to the ban on harvest imposed in BNP waters. The aggregate dockside value of commercial catches for 1997-1999 was approximately 4.7 million dollars. Macroinvertebrates (pink shrimp, blue crab, stone crab, and spiny lobster) accounted for 93% of the total dollar value.

#### **4.3 Size at First Capture Restrictions**

To stem the tide of decreasing fisheries catches and resource productivity, the principal methods used by fishery resource managers for regulating and controlling fisheries impacts has traditionally been fish minimum size and fishing effort restrictions. Implementation of minimum size restrictions sets lower bounds on the sizes of fish allowed to be captured and in catches of the commercial and recreational fleets. The history of implementation and use of minimum size regulations in south Florida and the Florida Keys is shown in **Table 9**. The fishery management system for south Florida and BNP was *laissez faire* prior to management measures implemented by the South Atlantic Fishery Management Council in 1983. In 1985 the Florida Marine Fisheries Commission was formed and began implementation of a series of size, bag limit and gear restrictions (**note:** the history of Florida regulations is listed at <http://www.dep.state.fl.us/mfc/MFC-rule-hist.htm>). Some notable changes in size regulations pertaining to the reef fish complex are as follows. In 1985 (due to observed reductions in catches) 18 inch minimum size limits were set for several groupers (Goliath, red, nassau, black, gag, yellowfin), and 12 inch limits were set for several snappers (mutton, red, yellowtail) (**Table 9**). By 1990, non-response of the Goliath grouper stock to recovery by any conventional management efforts prompted a complete catch moratorium, which is still in effect today. In 1990, the red snapper size limit was increased to 13" (20" in 1992), and the FMC added schoolmaster (10"), blackfin, gray, dog, lane, silk, vermillion and queen snappers. Also in 1990, most groupers (and additionally yellowmouth and scamp) had minimum size limits increased to 20 inches. Hogfish size limits were set at 12" in 1994.

Normally, size restrictions are implemented to prevent “growth overfishing” and to prevent capture of individual species of fish before they have reached their individual potential to produce yields (in weight) to the fishery. Variations in setting minimum size limits relates to the fact that different species (and taxa) grow at different rates and reach different maximum sizes (e.g., groupers grow to much larger sizes than grunts and are substantially older). But probably a more important aspect of the setting of minimum sizes relates to the potential production of future generations of fish by the mature parent stock. That is, the minimum size of first capture by the fishery should ideally be set higher than the first size of sexual maturity to ensure that each fish has a chance to produce offspring at least once in its lifetime.

**Table 9.-** Fishing regulations promulgated by SAFMC and FL FMC from 1985-present. Regulations shown are the minimum size of capture (inches) and the year the size limit is implemented. The last column shows the current size restrictions. Ranges indicate size slot limits, and 'moratorium' means that the fishery for the species is completely closed.

	1983	1984	1985	1987	1989	1990	1992	1994	1996	1998	1999	2000	Current
<b>Groupers</b>													
Goliath			18				► moratorium						closed
Red	12"		►18		►20								20
Nassau	12"		►18		►20				► moratorium				closed
Black			18		►20		►24						24
Yellowmouth				20									20
Gag			18		►20		►24						24
Scamp				20									20
Yellowfin			18		►20								20
Black Sea Bass			8				►10						10
Southern Sea Bass			8										8
<b>Snappers</b>													
Mutton Snapper			12				►16						16
Schoolmaster				10									10
Blackfin				12									12
Red Snapper	12"		►12		►13	►20							20
Yellowtail Snapper			12										12
Cubera				12									12
Gray				10									10
Dog				12									12
Mahogany				12									12
Lane				8									8
Silk				12									12
Vermilion				8	►10-20		►10	►11"					11
Hogfish						12							12
Queen				12									12
<b>Pelagics and Others</b>													
Gray Triggerfish					12								12
Permit					10-20								10-20
Pompano				10	►10-20								10-20
African Pompano					24								24
King Mackerel					20		►24	◀ 24					24
Spanish Mackerel					28		12						12
Amberjack													28
Lesser Amberjack						12	14-20	►14-22	◀ 14-22				14-22
Red Gorgy						26-34							12
Snook				24	3	14-24							26-34
Lobster													3
Spotted Sea Trout									►5-20	◀ 15-20			
Tripletail								15					15

## 4.4 Indicator Variables of Population Status

To understand the effects of fishing and environmental changes on fishery resources requires identification of a quantitative measure that reflects the status of a population subjected to fishing or other environmental changes, that is, a stock assessment indicator variable. Because reef fishes integrate aspects of the coastal ocean environment over their lifetime, a robust measure of population "health" or status can provide a sensitive indicator of direct and indirect stress on the stock, and perhaps the regional marine ecosystem (Fausch et al. 1990). The RVC and CREEL survey databases were utilized to produce annual estimates of two biological indicators, average catch-per-unit-effort (CPUE) and average length of exploited phase individuals ( $\bar{L}$ ) for 90 exploited and/or ecologically important species in BNP (Appendix C). A flow diagram illustrating the data processing and analysis procedures employed for each survey is shown (Figure 25).

### 4.4.1 Catch-per-Unit Effort (CPUE)

The average population size (in average numbers of fish during the time interval  $t^* t+1$ ) during a given year  $t$  is written as

$$\bar{N}(t) = \frac{N_0(t)F(t)}{F(t) + M} (1 - e^{-(F(t) + M)}) = EN_0(t)$$

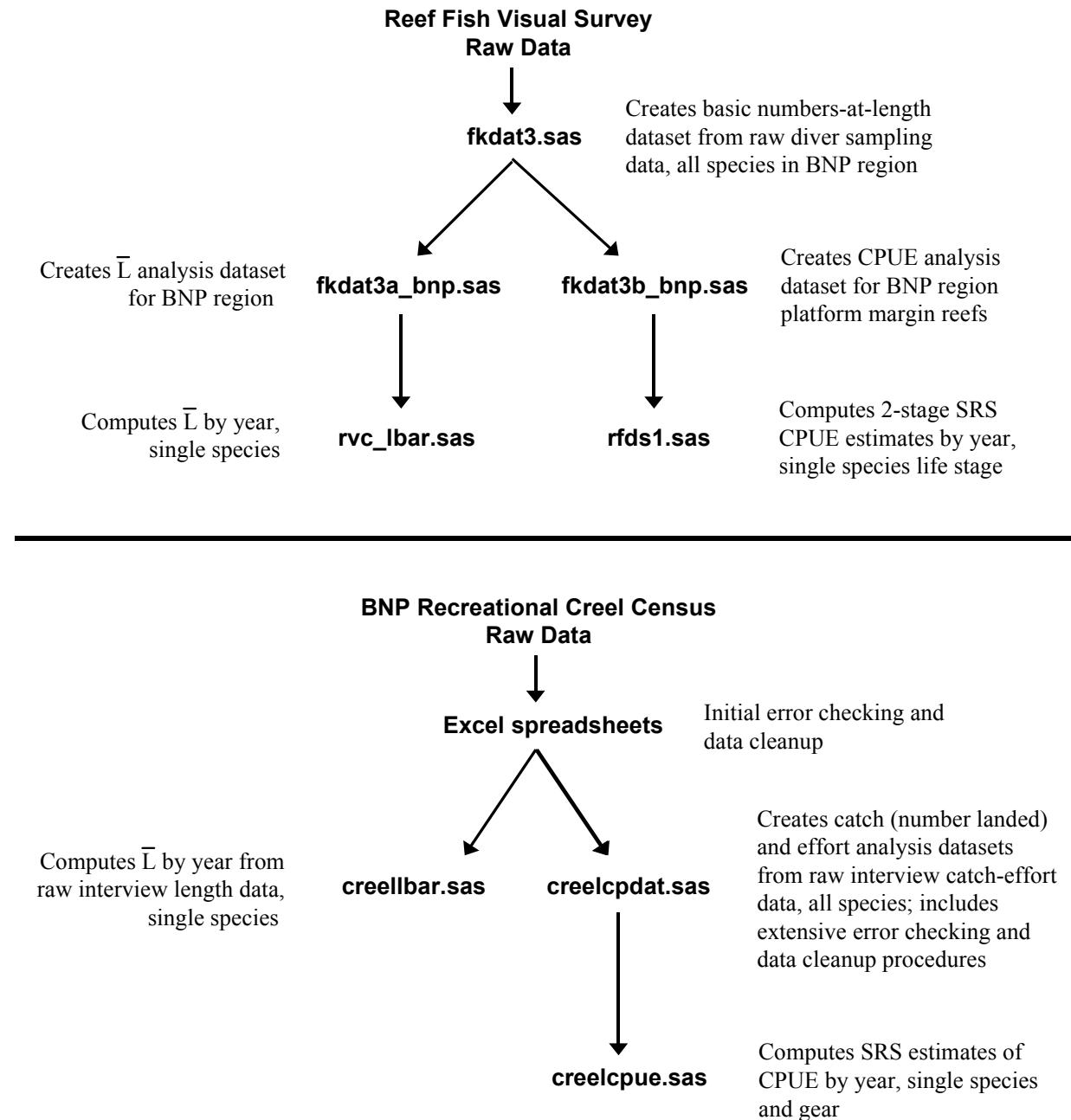
where  $N_0(t)$  is the initial population size in year  $t$ ,  $F(t)$  is fishing mortality rate,  $M$  is the natural mortality rate, and  $E$  is the exploitation rate (Ricker 1975). Catches (or yields in number  $Y_N(t)$  or weight  $Y_w(t)$ ) are the product of fishing mortality and average population size. As a result, by allowing  $F=qf(t)$ , catch per unit nominal fishing effort  $f(t)$  provides a quantitative index of fish population size

$$Y_N(t) = F(t)\bar{N}(t) \Rightarrow \frac{Y_N(t)}{f(t)} = q\bar{N}(t)$$

where  $q$  is the fraction of the stock removed per unit of nominal fishing effort (Beverton and Holt 1956, 1957). The index provides an average measure of relative population abundance  $\bar{N}(t)$  when independent surveys of populations are made with gears or techniques where the individual effort units can be intercalibrated. For the RVC survey, CPUE is defined as the number of animals observed by a diver ( $Y_N$ ) per sampling station ( $f=1$  station). Since  $f$  covers a fixed area of 176 m<sup>2</sup> in this survey, and  $q$  (a measure of capture or 'observation' efficiency) is presumed near 1.0 for reef fish divers, CPUE reflects actual stock density (number per 176 m<sup>2</sup>). For the CREEL survey, CPUE is the number of fish captured and kept ( $Y_N$ ) per person-hour of fishing ( $f$ ). Since  $q$  is unknown in this case, CREEL CPUE is a relative index of stock abundance.

The RVC survey sampled platform margin reef habitats consistently from year to year; however, this was not the case for inshore reefs, and data from these habitats were excluded from the analysis. The annual numbers of diver stations used for CPUE estimation are listed in Table 1. For the RVC survey, annual mean CPUE was estimated using a two-stage simple random sampling (SRS) design-based methodology following Cochran (1977) and shown in Appendix D1. Estimation was carried out for three life stages of each species, juvenile ( $< L_m$ ), adult ( $\sim L_m$ ), and

**Figure 25.-** Data processing, analysis and synthesis flow diagram for estimation ( $\bar{L}$ ) and CPUE from the reef fish diver visual survey (upper panel) and BNP recreational CREEL survey (lower panel). SAS source code for reef fish visual census RVC is listed in Appendix D1. SAS source code for BNP recreational CREEL survey is listed in Appendix D2.



exploited ( $\geq L_c$ ), as defined by the following length intervals:

<b>Life History Phase</b>	<b>Interval</b>	<b>Description</b>
Juvenile Phase	$L_r \rightarrow L_m$	Immature juveniles from the size of first recruitment to the size of first sexual maturity.
Mature Adult Phase	$L_m \rightarrow L_c$	Size of first sexual maturity to the maximum size in the stock.
Exploited Phase	$L_c \rightarrow L$	Size of first capture to the maximum size in the stock.

As shown above (sections 3.5 and 3.6), these intervals reflect logical ontogenetic groupings that pattern animals in space and time over the Biscayne National Park seascape. In many cases, exploited phase CPUE estimates were computed using two different length at first capture  $L_c$  values: ‘legal’ denotes the  $L_c$  value regulated by law in a particular year, whereas ‘actual’ denotes a modified  $L_c$  value (here referred to as  $L'$ ) that sportfishers adhered to as determined from inspection of CREEL survey species length data (see section 4.5 for further discussion). The ‘actual’ exploited phase CPUE estimated from the RVC survey thus corresponds to the life stage comprising the CREEL survey CPUE estimates.

The CREEL database required extensive processing and error checking before estimation of CPUE could be carried out in a reliable fashion (see **Appendix D2**). Interview records with missing or mis-coded key information—e.g., gear type, area fished, number of persons fishing—were necessarily excluded from analysis. CREEL data indicated three principal gear types (hook and line, spearfishing, and lobster diving), and three fishing regions (coastal bay, reef, and pelagic). The annual number of CREEL fishing trip interviews by gear and region considered in CPUE estimation are listed in **Table 10**. A number of interviews recorded catch information for a general family category, e.g., unidentified snappers or groupers, rather than for a particular genus and species. Records containing combined catches for a given species group (e.g., snappers) were excluded from CPUE estimation for a particular species (e.g., gray snapper) in that group.

Annual average CPUE for CREEL survey species was estimated as follows:

$$CPUE = \frac{1}{n} \sum_i CPUE_i$$

where  $CPUE_i$  is catch per person-hour for trip  $i$  and  $n$  is sample size. For a given species, CPUE was estimated from fishing trips for the principal gear type and associated capture regions as listed in **Table 4**. Sample size  $n$  (**Table 10**) was thus the sum of fishing trips for the principal gear over the capture regions inhabited by a given species. These numbers reflect BNP personnel sampling efforts and are not necessarily proportional to true fishing effort. Regions not inhabited by a species were not included in the estimation.

The complete time series of annual CPUE estimates derived from both the RVC and CREEL surveys for 90 species are provided in **Appendix C (Tables C1-C90**, one table per species). A synthesis of these results for selected species is presented in **Table 11**. For ease of interpretation, CREEL CPUE values are expressed as the expected time a party of four persons would need to fish (or dive) to land (capture and keep) one animal of a given species. Shorter fishing times thus reflect

higher stock abundance and longer fishing times reflect lower stock abundance. The fishery-dependent CREEL and fishery-independent RVC abundance indices corresponded quite well for the recent 1995-1998 period, showing the same rank order of reef fish species abundance with the exception of bluestriped grunt. The restricted sampling domain of the RVC survey compared to the more expansive capture regions of the CREEL census may somewhat account for this discrepancy. Comparing CREEL estimates between the periods 1995-1998 and 1985-1988 sheds some light on stock abundance trends over the past 10-15 years in BNP (**Table 11**). Lobster diving in BNP appears to have improved from the late 1980s to the late 1990s, as measured by the decrease in capture time and thus increase in CPUE. It is interesting to note that establishment of the spiny lobster sanctuary, which eliminated lobster fishing in the coastal bay portion of BNP, occurred in 1984. Hook-and-line fishing for dolphin in the pelagic zone, and for grunts (white and bluestriped) in bay-reef environments, has remained steady or improved slightly in the past 10-15 years. In contrast, reef fishing for snappers and groupers seems to have worsened to a lesser (gray and yellowtail snapper) or greater (mutton snapper and red grouper) degree over this time frame. Exploited phase black groupers have apparently been quite rare in BNP for some time.

**Table 10.-** CREEL survey sampling (number of recreational fishing trip interviews) by year, gear type (hook and line, spearfishing, and lobster diving) and region (bay, reef tract, and pelagic zone) from 1976 to 1998. The Bay portion of BNP was declared a lobster sanctuary in 1983.

Year	Hook & Line			Spearfishing		Lobster Diving	
	Bay	Reef	Pelagic	Reef		Bay	Reef
<b>1976</b>	411	424	314	112		56	71
<b>1977</b>	574	714	446	324		139	176
<b>1978</b>	767	793	546	391		158	190
<b>1979</b>	861	713	511	340		106	168
<b>1980</b>	798	627	262	278		167	194
<b>1981</b>	505	653	340	335		53	212
<b>1982</b>	874	975	497	395		67	353
<b>1983</b>	999	795	387	304		51	150
<b>1984</b>	196	148	37	40		1	113
<b>1985</b>	339	455	236	100		1	60
<b>1986</b>	346	328	249	76		3	144
<b>1987</b>	282	282	167	60		4	132
<b>1988</b>	116	225	113	56		0	99
<b>1989</b>	119	217	130	46		0	123
<b>1990</b>	100	236	143	52		3	203
<b>1991</b>	79	257	195	45		2	119
<b>1992</b>	180	279	187	36		0	21
<b>1993</b>	173	231	134	45		0	37
<b>1994</b>	244	277	190	89		0	44
<b>1995</b>	103	122	60	34		2	45
<b>1996</b>	174	167	107	58		1	34
<b>1997</b>	118	137	98	37		1	26
<b>1998</b>	98	150	82	37		0	29

**Table 11.-** Comparison of CREEL and RVC exploited phase (actual) CPUE estimates for selected species. Units for the CREEL census are expressed as the expected time a party of four persons would need to fish (or dive) to land one animal. RVC survey CPUE units are number observed per diver station. Values are 4-year averages for the time period indicated.

Species	CREEL 90's 1995-1998	CREEL 80's 1985-1988	RVC 90's 1995-1998
spiny lobster	10 min	20 min	—
dolphin	1 h	1 h	—
white grunt	1 h	1 h	0.689
gray snapper	2.5 h	1.5 h	0.227
bluestriped grunt	3.5 h	4.5 h	0.605
yellowtail snapper	7 h	5.5 h	0.157
red grouper	23 h	11 h	0.016
mutton snapper	26 h	15 h	0.010
black grouper	71 h	100 h	0.000

#### 4.4.2 Average Size in Exploited Phase $\bar{L}$

To describe baseline status for a fish population in multispecies community settings, a robust population dynamic variable is required to relate current trends in human and environmental stressors to expected future condition of the stocks over relatively broad spatial and temporal scales. A powerful choice is the metabolic-based pool variable average size of animals (in either length or weight) in the exploited phase of the stock (Beverton and Holt 1957, Gulland 1983, Ault 1988, Ault and Ehrhardt 1991, Ehrhardt and Ault 1992). ‘Average size’, denoted as  $\bar{L}$ , is a physiologically-based variable that is a very sensitive indicator of direct and indirect stress on marine ecosystems (Ault et al. 1997a, 1998, Quinn and Deriso 1999). The  $\bar{L}$  of a reef fish stock (or population if closed intra-breeding unit) is strongly correlated with population size in both numbers and biomass, and thus can be used as an indicator variable of population health. The formal definition of  $\bar{L}(t)$  is

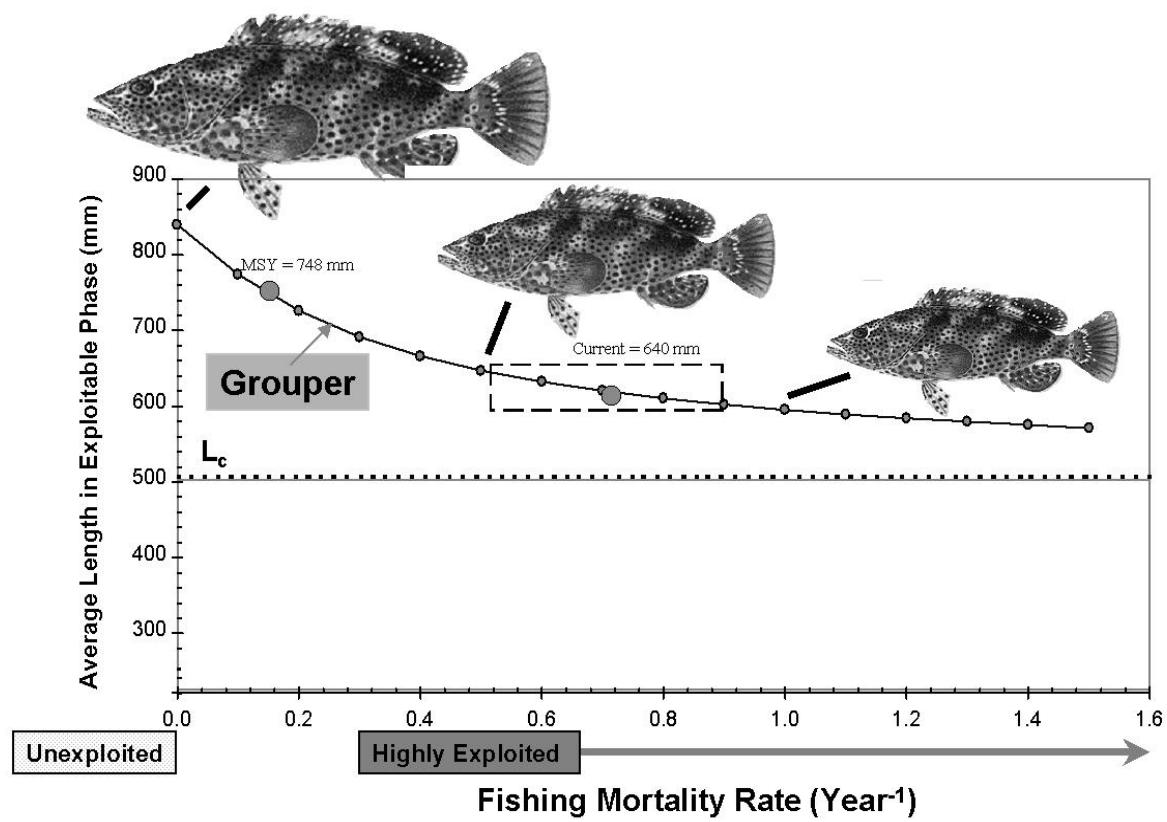
$$\bar{L}(t) = \frac{F(t) \int_{t_c}^{t_\lambda} N(a,t) L(a,t) da}{F(t) \int_{t_c}^{t_\lambda} N(a,t) da}$$

where  $t_c$  is minimum age at first capture,  $t_f$  is oldest age in the stock,  $N(a,t)$  is abundance for age class  $a$ ,  $L(a,t)$  is length, and  $F(t)$  is the instantaneous fishing mortality rate at time  $t$ .

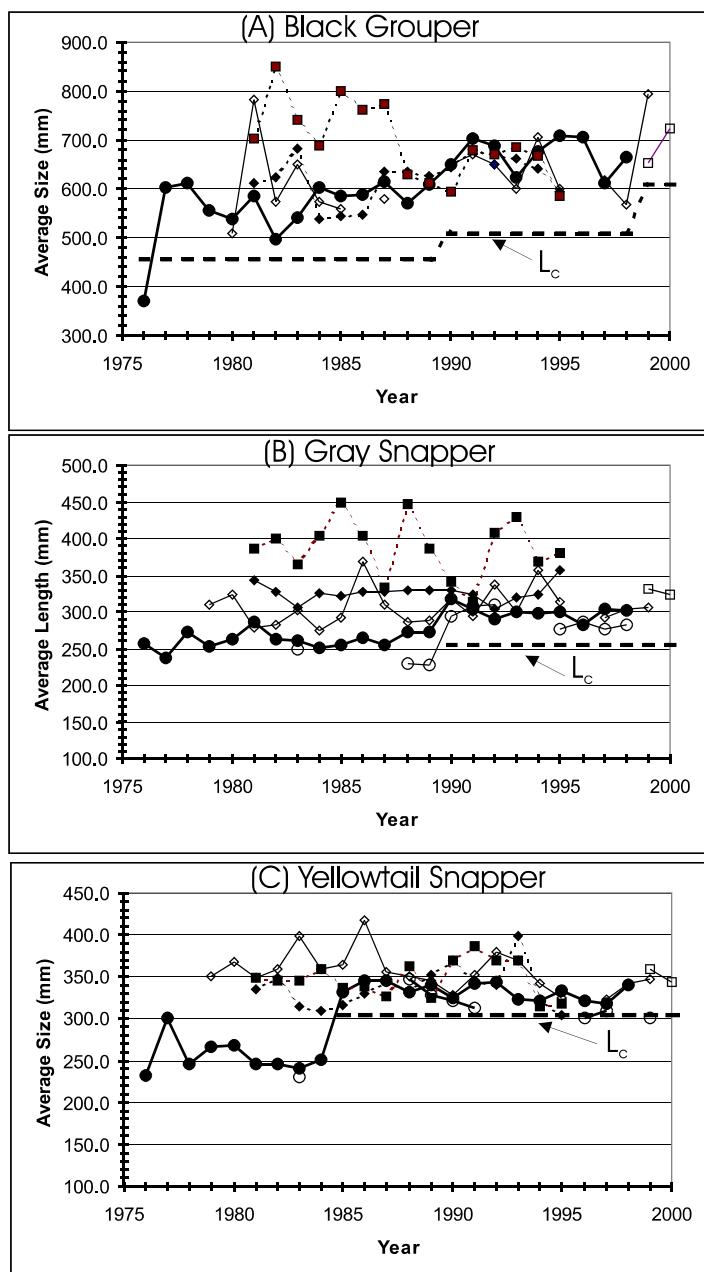
The use of  $\bar{L}$  in stock assessment has deep roots in traditional fisheries management (Beverton and Holt 1956, 1957, Ricker 1975). In general, it is well-known that  $\bar{L}$  is highly correlated with average population size, and so reflects the rate of fishing mortality operating in the fishery. As fishing mortality rate increases,  $\bar{L}$  decreases at a rate proportional to the population-dynamic tolerance of a stock. Minimally, average size is greatest when fishing mortality is lowest (or near zero), and decreases as the rate increases (**Figure 26**). Assuming that mortality occurs proportionally to stock age-size spatial distributions,  $\bar{L}$  will continue to decrease until at high exploitation rates it will be nearly equal to the minimum size of first capture regulated by fishery management. Secondly, there exists a value of  $\bar{L}$  corresponding to a population size that produces maximum sustainable yields on a continuing basis.

We computed ‘average length’ for each of the principal data sources available for BNP. Estimates of the mean, variance, and 95% confidence interval followed Sokal and Rohlf (1969). The complete time series of annual estimates of average length for the RVC and CREEL surveys for the period 1976 to 1999 are provided in **Appendix C** for 90 species. To understand the status of stocks in BNP relative to the greater Florida Keys ecosystem, we also computed  $\bar{L}$  from several region-wide survey databases, both fishery-independent (RVC surveys in the Florida Keys and Dry Tortugas) and fishery-dependent (headboat surveys in the Keys, Tortugas). The time series of  $\bar{L}$  estimates for six different types of survey data are plotted in **Figure 27** for three primary and representative exploited species. We first note that species’ estimates of average size (e.g., black grouper, gray snapper, and yellowtail snapper) have been relatively constant for the past 25 years. This constant “average size” has been very close to the minimum size of first capture. Secondly, the estimates of average size have been lowest in BNP relative to the Keys and Dry Tortugas. The third item to note that reflects the effectiveness of traditional fishery management methods is that many species have had extremely low sizes of average length in the past, and that very little recovery of average length has occurred, even as minimum size limits were imposed.

Estimates of average length for fishery-dependent CREEL surveys and fishery-independent RVC surveys are extremely close for each of the three example species of **Figure 27**, which is characteristic of the other 90+ species analyzed (**Appendix C**). This would indicate that the two data sources are producing similar estimates of the effects of mortality on these stocks. An important factor in the use of the  $\bar{L}$  statistic to measure population mortality rates and to assess the effects of exploitation is that it can be reliably computed from both fishery-dependent and fishery-independent data sources. Theoretically, the average size of fish in the exploited phase landed for any given exploited species should be equal to the average size in the exploited phase of the remaining population in the sea just after fishing. The greater the correlation between the two independent estimates of  $\bar{L}$ , the more robust ‘average length’ should be as an indicator of stock status subject to exploitation. This is a powerful conclusion in that it allows several independent observations of ‘average length’ to be computed and compared for consistency and reliability. Our results for BNP corroborate previous research which demonstrated close agreement between fishery-independent RVC estimates of average length and fishery-dependent headboat survey  $\bar{L}$  estimates for Florida



**Figure 26.** - Theory of reduction of average length in the exploited phase with increasing fishing mortality for black grouper.

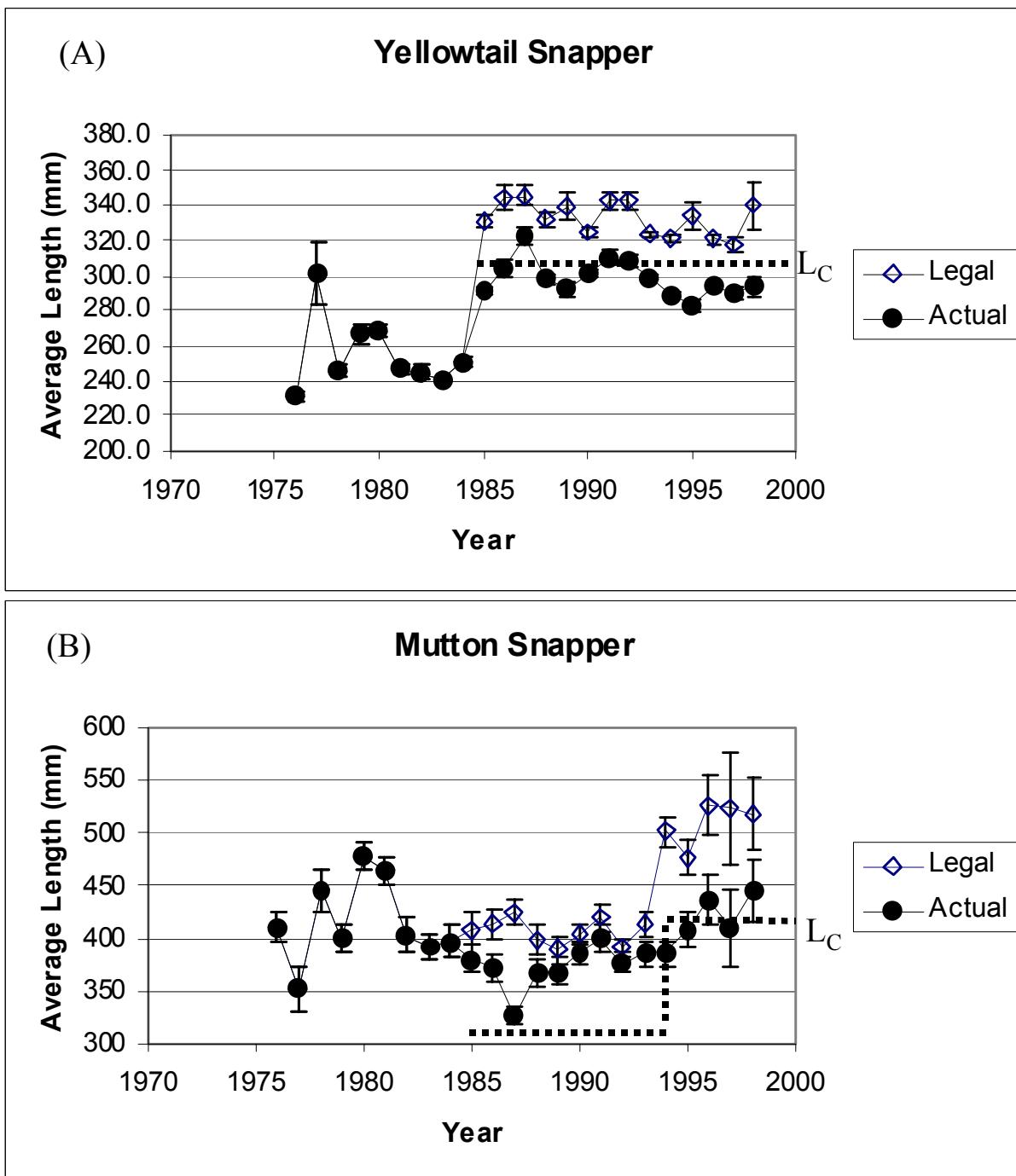


**Figure 27.** Time series of average length estimates derived from fishery-dependent and fishery independent survey data taken from BNP, the Florida Keys coral reef tract, and the Dry Tortugas region from 1976 to 1999 for: (A) Black grouper; (B) Gray snapper; and, (C) Yellowtail snapper. The six data types are: BNP CREEL (black circles); BNP RVC (open circles); Keys-wide RVC (open diamonds); Keys-wide headboats (black diamonds); Dry Tortugas RVC (open squares); Dry Tortugas (black squares). The dashed horizontal line is the minimum size of first capture.

Keys reef fishes (Ault et al. 1997a, 1998).

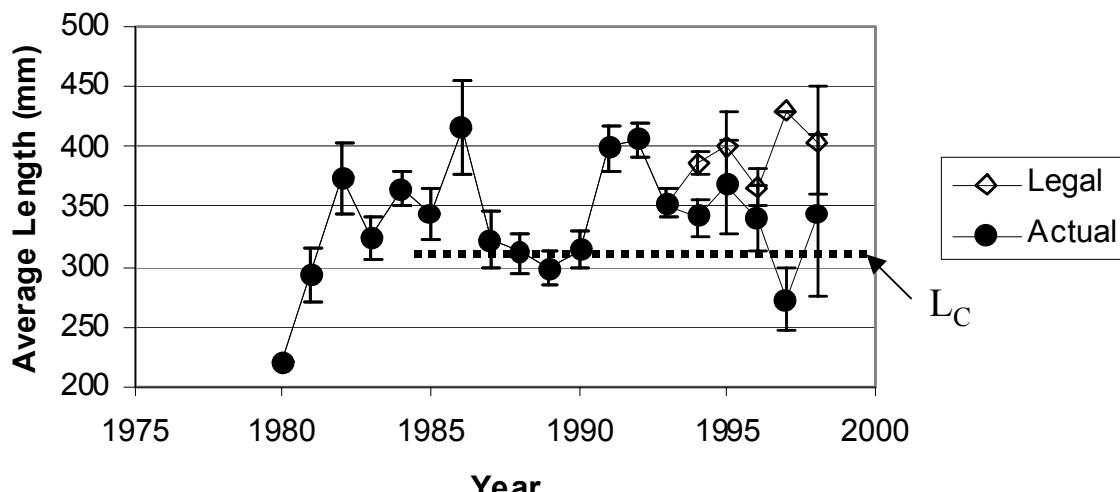
#### **4.5 Non-Compliance with Fishery Minimum Size Regulations**

In computation of ‘average size’ statistics for further assessment of fishery management benchmarks, an alarming observation we noted in analysis of the CREEL database was that a fairly high proportion of the catches returned to the BNP ramp by recreational fishermen contained fishes that were smaller than the minimum size of first capture regulated by regional fishery management. This was particularly evident for several snapper species, e.g., mutton snapper, in which more than 70% of the fish landed were below minimum size (**Figure 28a,b**), but was also evident for hogfish (**Figure 28c**), gray triggerfish (**Figure 28d**), and a number of groupers and grunts.

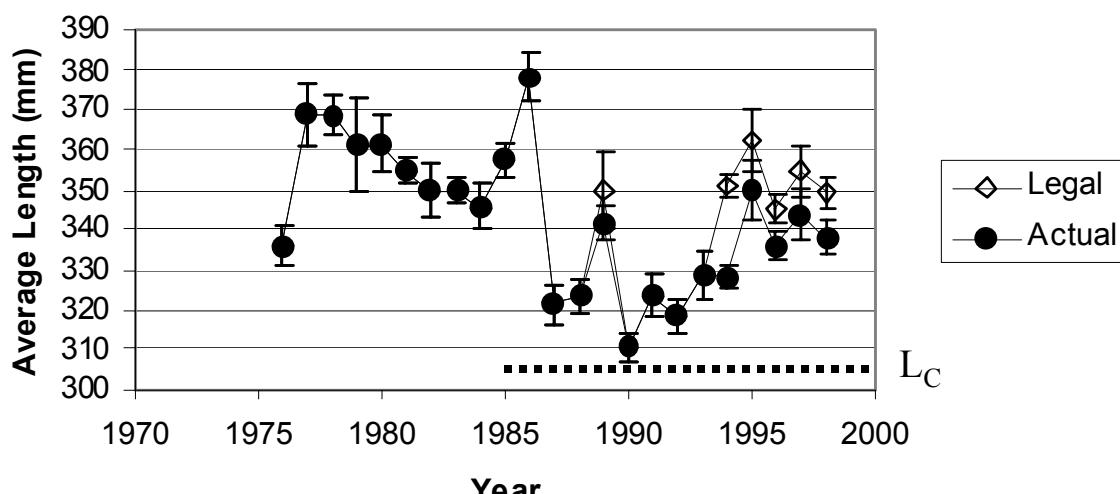


**Figure 28.** - Impacts of non-compliance with regulated minimum size  $L_c$  (dashed line) restrictions. The ‘average length’ in the exploitable phase estimated from the CREEL data is shown for: (A) yellowtail snapper; (B) mutton snapper; (C) gray triggerfish; and, (D) hogfish. The actual statistic  $L'_c$  includes many individuals that are below  $L_c$ , resulting in much lower estimates of average size (and higher fishing mortality rates) than if the law were enforced or received full compliance from recreational fishermen.

(C)

**Gray Triggerfish**

(D)

**Hogfish****Figure 28.-** (continued)

## 5.0 Multispecies Fishery Stock Assessments

In this section, we conduct a formal quantitative assessment of exploited fish stocks in BNP and evaluate their current status with respect to established fishery management benchmarks. An overview of the general assessment procedure, comprised of 8 separate steps, is summarized in the flow diagram of **Figure 29**. Steps 1 to 3 of the procedure were described in previous sections. This section details Steps 4 through 8.

### 5.1 Synthesis of Population Dynamics Parameters

To facilitate assessment of the multispecies fisheries resources in BNP, we conducted a thorough search of the scientific and technical literature (c.f., Claro 1994; FISHBASE, Froese and Pauly 2000) and our own databases to assemble a comprehensive suite of biological and population dynamic information that contains key rate parameters necessary for computing the relevant fishery management benchmarks for sustainability of resources. These parameters included age-growth, weight-length and weight-fecundity relationships, size-age at first recruitment, minimum size-age at first sexual maturity, maximum size-age, sex ratios and age (size) class distributions, natural mortality rates, and other key fisheries indices (**Tables 12 and 13**). These data were required to run our suite of multispecies fishery stock assessment computer models (Ehrhardt and Ault 1992; FAO 1997, Ault et al. 1996, 1997a, 1998). Of the 91 exploited and/or ecologically-important species we identified within the BNP databases, we found that the available population dynamics parameters varied widely in breadth and statistical quality. Therefore, we classified each species' parameter set according to a 'parameter confidence' rating that ranged from no data available (scored 0) to high confidence (scored 3). Given the disparity in quality between data sets available for various stocks, and in some cases the complete lack of critical population dynamic data, we feel some additional refinement of these critical data will be necessary in the longer run, as these data are required to assess exploitation effects and to determine the appropriate management strategies to achieve Park goals. Nonetheless, these data were essential to producing a baseline assessment of BNP multispecies fisheries resources.

### 5.2 Estimation of Total Mortality Rate from 'Average Size' Statistics

While persistent heavy fishing reduces the average fishable population size over time, it also leaves a distinguishing size-age structure signature on the exploited population, which provides a robust basis for mortality estimation (**Figure 30**). We capitalized on this aspect of demographic theory by using the  $\bar{L}$  statistic to assess the current levels of exploitation of the multispecies fishery community in BNP. To estimate the total instantaneous mortality rate  $Z(t)$  given an estimate of  $\bar{L}(t)$ , we used the following equation (Ault and Ehrhardt 1991; Ehrhardt and Ault 1992):

$$\left[ \frac{L_\infty - L_\lambda}{L_\infty - L_c} \right]^{\frac{Z(t)}{K}} = \frac{Z(t)(L_c - \bar{L}(t)) + K(L_\infty - \bar{L}(t))}{Z(t)(L_\lambda - \bar{L}(t)) + K(L_\infty - \bar{L}(t))}$$

where  $L_c$  is size at first capture,  $L_\infty$  is maximum size in the stock,  $K$  and  $L_\lambda$  are parameters of the von Bertalanffy equation, and  $t$  is year. While no explicit formula exists for analytical estimation of  $Z(t)$ ,

**Figure 29.-** Flow chart showing the steps used in the multispecies reef fish assessment. See Ault et al. (1998) for additional details.

**Begin Multispecies Assessment**

P

- Step 1:** Conduct fishery surveys (RVC, CREEL, TRAWL, etc.) for fish community in year  $t$  and intercalibrate sampling efficiency by species, site, and year.

P

**Begin Management Analyses for species s**

P

- Step 2:** Using intercalibrated survey data, compute annual estimates of  $\bar{L}$  and associated 95% confidence intervals from size and abundance data integrated over the range of exploitable sizes.

P

- Step 3:** Compute CPUE by species by lifestage by year  $t$  for each data type.

P

- Step 4:** Use population dynamics parameters (**Table 10**) to parameterize the LBAR (Ault et al., 1996) and REEFS (Ault et al. 1998) computer algorithms.

P

- Step 5:** Use  $\bar{L}(t)$  estimate in LBAR computer algorithm to estimate fishing mortality rates as  $\hat{F}(t) = \hat{Z}(t) - M$  for each species by year for the several data sources, i.e., time series of RVC, CREEL and headboat data.

P

- Step 6:** Use the REEFS numerical model to: (1) compute expected  $\bar{L}(t)$  given the reported population dynamics and  $\hat{F}$  parameter values; (2) compute yield per recruit (YPR) and assess growth overfishing; and, (3) compute spawning stock biomass (SSB) for the fishery in unexploited and (for maximum sustainable yield and current) exploited states (i.e.,  $F=0$ ,  $F=F_{msy}$ , and  $F=\hat{F}(t)$ , respectively) and evaluate spawning potential ratio (SPR) to assess recruitment overfishing.

P

- Step 7:** Use REEFS to compute  $\hat{B}_0$ ,  $B_{msy}$ ,  $\hat{B}(t)$  and assess limit control rules.

P

- Step 8:** From these results make specific fishery management recommendations on control strategies of  $F$  and  $L_c$  consistent with eumetric fishing principles and the precautionary approach of the MSFMCA that minimize the potential for overfishing.

P

Conduct next species analyses?

STOP

**Table 12.-** Parameters, definitions and units for life table variables common to the LBAR and REEFS numerical models used in simulation analysis of Florida Keys reef fish population dynamics. See **Tables 13** for parameter values.

Parameter	Definition	Units
s	Reef fish species ( $s=1, \hat{U}, n$ )	
a	Cohort age class ( $a=1, \dots, t_c$ )	
$t_r$	Age of recruitment	months
$L_r$	Size at recruitment	mm
$t_m$	Minimum age of maturity	months
$L_m$	Minimum size of maturity	mm
$t_c$	Minimum age of first capture	months
$L_c$	Minimum size of first capture	mm
$t_o$	Oldest (largest) age	years
$L_o$	Largest (oldest) size	mm
$W_U$	Ultimate weight	kg
$L_U$	Ultimate length	mm
K	Brody growth coefficient	$\text{year}^{-1}$
$t_0$	Age at which size equals 0	years
" <sub>WL</sub>	Scalar coefficient of weight-length function	dimensionless
$\beta_{WL}$	Power coefficient of weight-length function	dimensionless
$W(a,t)$	Weight at age $a$ at time $t$	g
$L(a,t)$	Length at age $a$ at time $t$	mm
$N(a,t)$	Numbers at age $a$ at time $t$	number of fish
$M(a,t)$	Natural mortality rate at age $a$ at time $t$	$\text{year}^{-1}$
$F(a,t)$	Fishing mortality rate at age $a$ at time $t$	$\text{year}^{-1}$
$S(a)$	Survivorship to age $a$	dimensionless
$Z(t)$	Total mortality rate in year $t$	dimensionless
$\%a$	Sex ratio at age $a$	dimensionless
$B(a,t)$	Biomass at age $a$ in year $t$	kg
$Y_w(t)$	Yield in weight in year $t$	mt
$SSB(t)$	Spawning stock biomass in year $t$	mt
$SPR(t)$	Spawning potential ratio in year $t$	mt

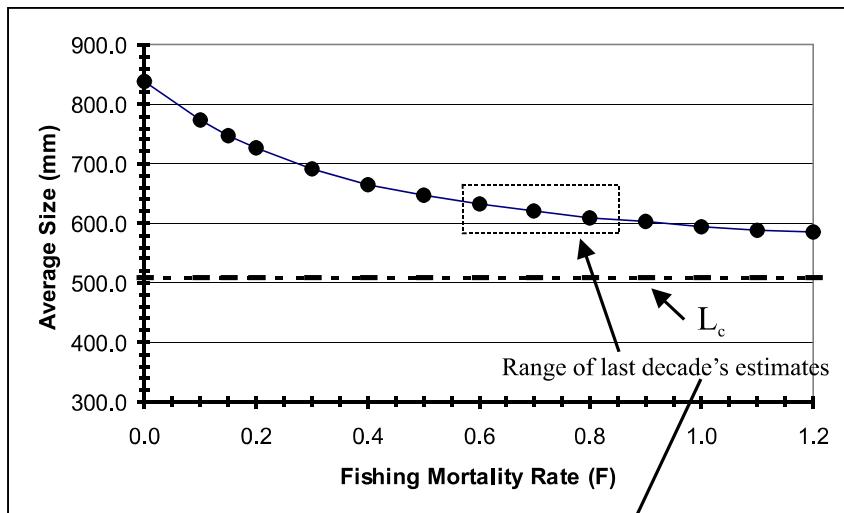
Table 13. - Population dynamics parameters for exploited fishes in Biscayne National Park necessary to LBAR and REEFS assessment and management models

Common Name	Scientific Name	Population Dynamics Rate Parameters										Parameter Confidence		
		M <sub>0,t</sub>	t <sub>a</sub>	L <sub>e</sub>	W <sub>e</sub>	K	t <sub>b</sub>	L <sub>m</sub>	t <sub>n</sub>	L <sub>c</sub>	t <sub>e</sub>	ω <sub>WL</sub>		
<b>Groupers</b>														
1 Rock Hind	<i>Epinephelus adscensionis</i>	0.25	12	486.1	2.27	0.191	-2.16	336	48	200	7	6.00E-06	3.193	453.3
2 Graysby	<i>Epinephelus cruentatus</i>	0.37	8.1	340	0.62	0.35	-0.46	198	24	200	25	1.22E-05	3.044	350
3 Speckled Hind	<i>Epinephelus drummondii</i>	0.20	15	967	16.58	0.13	-1.01	463	48	290	21	1.11E-05	3.073	861
4 Yellowedge Grouper	<i>Epinephelus flavolineatus</i>	0.12	26	1180	40.22	0.11	-1.07	606	68	240	12	2.82E-05	2.980	1150
5 Coney	<i>Epinephelus fuscus</i>	0.67	4.5	340	0.68	0.63	-0.25	198	13	220	17	1.74E-05	3.000	340
6 Red Hind	<i>Epinephelus guttatus</i>	0.18	17	392.7	1.01	0.207	-0.831	251	49	180	26	8.55E-06	3.112	382.9
7 Marbled Grouper	<i>Epinephelus imberbis</i>	0.18	17	937	11.83	0.17	-0.7	493	44	200	9	1.13E-05	3.035	910
8 Goliath Grouper	<i>Epinephelus itajara</i>	0.13	22.3	2010	180.72	0.13	-0.13	978	52	Closed	1.04E-05	3.100	2500	
9 Red Grouper	<i>Epinephelus morio</i>	0.18	17	938	11.86	0.153	-0.099	437	48	508	60	1.13E-05	3.035	889
10 Misty Grouper	<i>Epinephelus mystacinus</i>	0.19	16	1633	63.56	0.18	0	811	38	2.45E-05	2.930	1600	1	1600
11 Warsaw Grouper	<i>Epinephelus nigritus</i>	0.07	41	2394	244.86	0.054	-3.616	807	48	2.09E-05	2.980	2328	3	2328
12 Snowy Grouper	<i>Epinephelus niveatus</i>	0.20	15	1091.3	19.51	0.113	-0.915	466	48	2.45E-05	2.930	909	3	909
13 Nassau Grouper	<i>Epinephelus striatus</i>	0.18	17	698.9	5.87	0.145	-1.08	480	83	Closed	3.83E-06	3.229	648.2	
14 Black Grouper	<i>Mycteroperca bonaci</i>	0.15	20	1200	31.59	0.16	-0.3	597	48	609.6	50	4.27E-06	3.205	1153.1
15 Yellowmouth Grouper	<i>Mycteroperca interstincta</i>	0.18	17	881.8	8.60	0.063	-9.03	469	36	508	55	2.58E-05	2.894	710.7
16 Gay Grouper	<i>Mycteroperca microlepis</i>	0.23	13	1187.2	26.14	0.149	-0.802	687	60	609.6	48	1.21E-05	3.031	1034.4
17 Scamp	<i>Mycteroperca phenax</i>	0.14	21	999.7	19.26	0.126	-1.357	491	48	508	51	2.02E-05	2.993	932.2
18 Yellowfin Grouper	<i>Mycteroperca venenosa</i>	0.20	15	860	15.67	0.17	0	527	67	508	63	2.82E-05	2.980	960
<b>Snappers</b>														
19 Mutton Snapper	<i>Lutjanus analis</i>	0.21	14	938.7	14.15	0.129	-0.738	279	24	406.4	44	1.57E-05	3.012	797.8
20 Schoolmaster	<i>Lutjanus apodus</i>	0.25	12	570	3.28	0.18	0	148	20	254	39	2.04E-05	2.978	503.8
21 Blackfin Snapper	<i>Lutjanus buccanella</i>	0.33	9	729.7	2.41	0.084	-2.896	232	20	304.8	43	7.40E-06	2.974	458.8
22 Red Snapper	<i>Lutjanus campechanus</i>	0.19	16	975	13.68	0.162	-0.01	308	28	508	54	2.04E-05	2.953	955
23 Yellowtail Snapper	<i>Lutjanus cyanopterus</i>	0.21	14	454.7	1.30	0.209	-0.712	197	24	304.8	55	7.75E-05	2.718	433.4
24 Cubera Snapper	<i>Lutjanus cyanopterus</i>	0.15	20	1633	89.57	0.14	-0.71	819	50	304.8	9	1.32E-05	3.060	1600
25 Gray Snapper	<i>Lutjanus griseus</i>	0.30	10	722.3	5.25	0.136	-0.863	233	24	254	28	3.05E-05	2.881	556.2
26 Dog Snapper	<i>Lutjanus jocu</i>	0.33	9	854	10.19	0.1	-2	300	28	304.8	29	4.28E-05	2.857	790
27 Mahogany Snapper	<i>Lutjanus mahogoni</i>	0.30	10	499	1.77	0.29	-0.48	280	29	304.8	33	8.18E-05	2.719	480
28 Lane Snapper	<i>Lutjanus synagris</i>	0.30	10	618.3	3.24	0.097	-1.728	205	29	203.2	29	4.52E-05	2.815	418.4
29 Silk Snapper	<i>Lutjanus viviparus</i>	0.33	9	781.1	9.28	0.092	-2.309	305	37	304.8	37	1.00E-05	3.100	512
30 Black Snapper	<i>Apsilus dentatus</i>	0.68	4.4	638	3.87	0.65	-0.2	349	12	1.49E-05	3.000	650	2	650
31 Vermillion Snapper	<i>Rhomboptilus aurorubens</i>	0.30	10	613.6	9.19	0.206	0.111	314	43	254	32	3.01E-05	3.044	541.6
32 Hogfish	<i>Lachnolaimus maximus</i>	0.25	12	566	3.51	0.19	-0.776	198	18	304.8	40	2.09E-05	2.988	439
<b>Grunts</b>														
33 Black Margate	<i>Anisotremus surinamensis</i>	0.37	8	673	9.33	0.36	-0.35	366	22	220	10	2.39E-06	3.392	639.2
34 Porkfish	<i>Anisotremus virginicus</i>	0.43	7	397	1.72	0.41	-0.35	228	21	160	11	1.01E-05	3.167	380
35 Margate	<i>Haemulon album</i>	0.37	8	752.6	8.57	0.174	-0.45	426	52	200	16	1.52E-05	3.042	710
36 Tomate	<i>Haemulon aurolineatum</i>	0.33	9	310	0.61	0.22	-1.28	130	14	150	21	6.19E-06	3.208	250
37 Caesar Grunt	<i>Haemulon carbonarium</i>	0.43	7	376	0.96	0.1	0	217	103	160	67	1.29E-05	3.056	380
38 Smallmouth Grunt	<i>Haemulon chryargyreum</i>	0.50	6	242	0.38	0.47	-0.35	146	19	160	27	2.77E-03	2.157	230
39 French Grunt	<i>Haemulon fasciatum</i>	0.50	6	284.31	0.57	0.179	0	176	18	160	53	9.06E-06	3.158	300
40 Spanish Grunt	<i>Haemulon macrostomum</i>	0.50	6	448	2.46	0.48	-0.29	254	17	200	11	2.28E-05	3.030	430
41 Cottonwick	<i>Haemulon melanurum</i>	0.33	9	350	0.82	0.32	-0.5	203	26	160	67	2.52E-05	2.953	330
42 Sailors Choice	<i>Haemulon parrae</i>	0.43	7	400.2	1.24	0.22	-0.355	103	12	200	34	2.02E-05	2.993	320.1
43 White Grunt	<i>Haemulon plumieri</i>	0.37	8	511.9	3.06	0.186	-0.776	177	18	170	17	8.35E-06	3.161	410.3
44 Bluestriped Grunt	<i>Haemulon sciurus</i>	0.50	6	412.7	1.36	0.3	0	206	24	180	23	1.94E-05	3.161	460
45 Striped Grunt	<i>Haemulon striatum</i>	0.50	6	294	0.62	0.47	-0.33	174	19	170	18	1.39E-05	3.099	280
46 Pigfish	<i>Orthopristis chrysoptera</i>												0	0

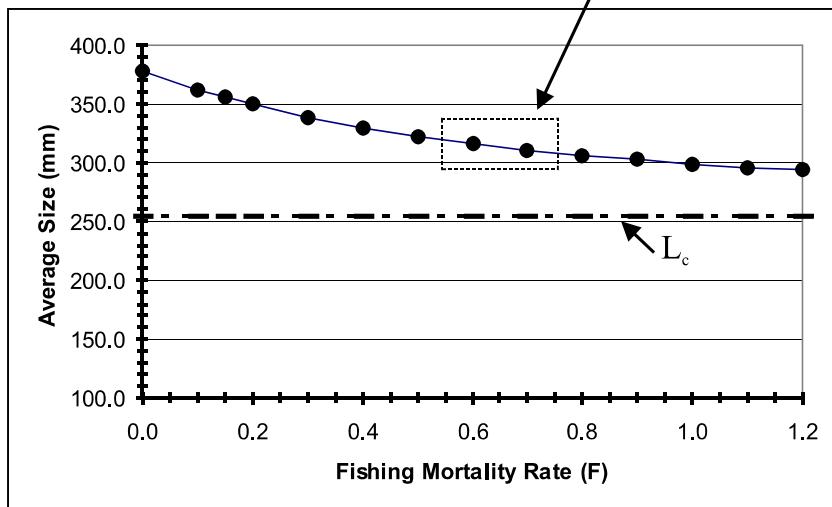
Table 13.- Biscayne National Park, Exploited Species List (continued)

Common Name	Scientific Name	Population Dynamics Rate Parameters										Parameter Confidence
		M <sub>a,0</sub>	s <sub>a</sub>	L <sub>a</sub>	W <sub>a</sub>	K	t <sub>b</sub>	L <sub>m</sub>	t <sub>m</sub>	L <sub>c</sub>	t <sub>c</sub>	
<b>Other Reef Fishes</b>												
47 Great Barracuda	<i>Sphyraena barracuda</i>	0.09	32	1780	42.95	0.09	-1.19	877	77	350	15	4.11E-06
48 Jolthead Porgy	<i>Calamus beauforti</i>	0.23	13	704	7.03	0.22	-0.58	381	36	200	11	6.67E-05
49 Saucereye Porgy	<i>Calamus caranxius</i>	0.43	7	581	3.75	0.41	-0.32	321	20	200	9	6.78E-05
50 Yellow Jack	<i>Caranx bartholomaei</i>	0.20	15	1028	18.41	0.19	-0.6	450	40	260	10	3.20E-05
51 Blue Runner	<i>Caranx cryos</i>	0.27	11	724	5.28	0.26	-0.48	391	30	160	6	1.07E-04
52 Crevalle Jack	<i>Caranx hippos</i>	0.17	18	1271	29.37	0.16	-0.69	648	45	200	5	9.55E-05
53 Horse-eye Jack	<i>Caranx latus</i>	0.25	12	826	20.12	0.24	-0.51	440	31	240	11	4.76E-06
54 Bar Jack	<i>Caranx ruber</i>	0.15	20	520	2.65	0.24	0	240	31	240	31	4.28E-06
55 Bermuda Chub	<i>Cyphosus septicus</i>	0.37	8	785	11.93	0.36	-0.34	420	21	180	5	1.45E-05
56 Gray Angelfish	<i>Pomacanthus arcuatus</i>	0.43	7	622	7.26	0.41	-0.31	341	19			3.71E-05
57 Biocolor Damselfish	<i>Pomacentrus paru</i>											2.96E-05
58 Threespot Damselfish	<i>Pomacentrus planifrons</i>											0
59 Blue Parrotfish	<i>Scarus coeruleus</i>	0.25	12	1231	39.56	0.24	-0.45	629	30			5.27E-05
60 Striped Parrotfish	<i>Scarus crocoleinensis</i>											2.85E-05
61 Rainbow Parrotfish	<i>Scarus guacamaia</i>	0.30	10	1231	39.16	0.29	-0.38	629	25			1.29E-05
62 Princess Parrotfish	<i>Scarus taeniopterus</i>	0.50	6	366	0.58	0.48	-0.31	212	18			1.34E-05
63 Queen Parrotfish	<i>Scarus vetula</i>	0.60	5	551	2.26	0.6	-0.23	306	13			6.55E-05
64 Greenblotch Parrotfish	<i>Spanisoma atomarium</i>	0.60	5	263	0.21	0.57	-0.28	157	16			1.35E-05
65 Redband Parrotfish	<i>Spanisoma aurataeum</i>	0.60	5	294	0.41	0.57	-0.27	174	16			1.14E-05
66 Retailt Parrotfish	<i>Spanisoma chrysopurpureum</i>	0.83	3.6	418	1.43	0.79	-0.19	239	11			1.62E-05
67 Bucktooth Parrotfish	<i>Spanisoma radians</i>	0.60	5	211	0.11	0.57	-0.3	129	17			1.07E-05
68 Retifin Parrotfish	<i>Spanisoma rubriprimum</i>	0.60	5	505	2.50	0.58	-0.24	283	14			3.100
69 Stoplight Parrotfish	<i>Spanisoma viride</i>	0.30	10	663	5.78	0.29	-0.45	361	28			1.94E-05
70 Gray Triggerfish	<i>Balistes capricornus</i>	0.37	8	600	4.15	0.38	-0.36	330	20			3.80E-05
71 Queen Triggerfish	<i>Balistes vetula</i>	0.23	13	759	11.19	0.23	-0.57	408	33			2.91E-05
72 Ocean Triggerfish	<i>Cantherhines maculatus</i>	0.33	9	673	6.78	0.32	-0.4	366	25			2.73E-05
73 Foreye Butterflyfish	<i>Chaetodon capistratus</i>											2.98E-05
74 Doctorfish	<i>Acanthurus chirurgus</i>	0.27	11	332	0.96	0.254	-0.63	194	32	200	36	3.19E-05
<b>Inshore Gamefishes</b>												
75 Spotted Seatrout	<i>Cynoscion nebulosus</i>	0.16	19	794	0.15	-0.87	450	36	360	50	3.60E-06	
76 Permit	<i>Trachinotus falcatus</i>	0.18	17	1170	6.64	0.17	-0.66	601	4	254.508	9	1.01E-06
77 African Pompano	<i>Alectis ciliaris</i>	0.20	15	1530	89.23	0.19	-0.54	767	37	609.6	26	5.19E-05
78 <i>Dolphin</i>	<i>Coryphaena hippurus</i>	0.94	3.2	2340	215.18	0.92	-0.1	1121	7	300	1	7.93E-05
	<i>Sarda sarda</i>	0.71	4.2	640	24.83	0.69	-0.19	350	12	300	9	2.60E-05
79 Atlantic bonito	<i>Euthynnus alletteratus</i>	0.20	15.2	1150	19.77	0.19	-0.62	592	38	290	11	1.30E-05
80 Little Tunny												3.000
81 Sailfish	<i>Istiophorus platypterus</i>	0.45	6.6	3410	167.75	0.44	-0.19	1571	14	500	16	1.10E-04
82 Skipjack Tuna	<i>Katsuwonus pelamis</i>	0.67	4.5	791	10.46	0.64	-0.19	423	12	320	15	2.86E-06
83 Blackfin Tuna	<i>Thunnus atlanticus</i>	0.34	8.7	780	11.29	0.33	-0.39	418	22	320	15	1.22E-05
84 King Mackerel	<i>Scomberomorus cavalla</i>	0.16	19.3	1370	18.71	0.15	-0.75	693	47	609.6	38	8.83E-06
85 Spanish Mackerel	<i>Scomberomorus maculatus</i>	0.21	14.4	964	7.30	0.2	-0.61	505	37	304.8	15	9.21E-06
86 Cero	<i>Scomberomorus regalis</i>	0.18	17	1864	45.99	0.17	-0.58	914	41	360	8	3.20E-05
87 Greater Amberjack	<i>Seriola dumerili</i>	0.26	11.6	1581	48.71	0.25	-0.42	788	28	711.2	24	5.03E-05
88 Tripletail	<i>Lobotes surinamensis</i>	0.20	15	1130	23.99	0.19	-0.59	583	38	381	19	6.78E-05
89 Wahoo	<i>Acanthocybium solandri</i>	0.15	20	2534	123.26	0.15	-0.63	1204	44	600	14	1.58E-06
<b>Macroinvertebrates</b>												
90 Spiny Lobster	<i>Panulirus argus</i>											76.2
91 Pink shrimp	<i>Faxonius漠漠duorum</i>											0
<b>Parameter Confidence:</b>												
												0
												No Data Available
												1
												Based on Max Size
												2
												Max Size but mixed
												3
												Relatively High Confidence

## (A) Black Grouper



## (B) Gray Snapper



**Figure 30.-** Expected distribution of average size on fishing mortality rates for: (A) Black grouper; and, (B) Gray snapper. Horizontal dashed line shows the minimum size of first capture. Stippled box indicates the range of fishing mortality estimated over the last decade.

this can be achieved fairly easily using an iterative numerical algorithm called LBAR (**Appendix F**) developed by Ault et al. (1996) (also found in the FAO stock assessment library, FAO 1997). The algorithm provides a means to an unbiased estimator of total instantaneous population mortality rate  $Z(t)$  (Quinn and Deriso 1999). Estimation of instantaneous fishing mortality rate  $F(t)$  is accomplished by subtracting the rate of natural mortality  $M$  from the  $\hat{Z}(t)$  estimate. The  $\hat{Z}(t)$  statistic is robust to any population survey measure (i.e., visual census, creel, or headboat survey data). Iterative application of the mortality estimation method using annual estimates of  $\bar{L}$  provided time-series information on fishing mortality rates, and thus abundance, for all key species included in the analysis (see **Appendix C**). This estimation procedure is explained in detail in Ault et al. (1998). Current estimates of  $\hat{F}$  are given in **Table 14**.

### 5.3 Management Benchmarks Analyses

To assess the status of the multispecies fishery based on the estimated rates of fishing mortality, we employed a population computer simulation model called REEFS (reef-fish equilibrium exploitation fishery simulator) (**Appendix F**). The model was applied to 35 reef fish species in 5 families: groupers, Serranidae; snappers, Lutjanidae; grunts, Haemulidae; the hogfish, Lachnolaimus maximus, Labridae; and, the great barracuda, Sphyraena barracuda, Sphyraenidae. These are among the primary fishery targets of the recreational and commercial fishing fleets in the south Florida coral reef ecosystem. Other species (e.g., bonefish, tarpon, spiny lobster, etc.) lacked sufficient indices of population status (**Appendix C**) and/or population dynamics data (**Table 13**) necessary for comprehensive quantitative stock assessments in BNP. The hogfish (or hog snapper) was grouped with snappers for analytical purposes.

The REEFS model is a size-based algorithm that embodies a stochastic age-independent model for ensemble number at a given length ( $\bar{N}_y(L_y, t)$ ) for the entire population (Ault and Rothschild 1991, Ault and Olson 1996, Ault 2001)

$$\bar{N}_y(L_y, t) = \int_{t_r}^{t_h} R(\tau - a) S(a) \Theta(a) P(L_y | a) da$$

where  $R(>a)$  is recruitment,  $S(a)$  is survivorship at age  $a$ ,  $\Theta(a)$  is sex ratio at age, and  $P(L|a)$  is the probability of being length  $L$  given the fish is age  $a$  (Ault 1988, Ault and Rothschild 1992, Ault et al. 1997, 1998). The modeled fishing mortality rate of recreational and commercial fishers (or ‘viewing power’ of divers) was assumed to remove (sight) fish with a ‘knife-edged selectivity pattern’ (see Gulland, 1983) over the range of exploitable sizes

$$F(t) = \begin{cases} 0 & \text{if } L|a < L_c \\ \hat{F}(t) & \text{if } L|a \geq L_c \end{cases}$$

where the size of first capture  $L_c$  is that regulated by regional fishery management. Species-specific population dynamics parameters (**Table 13**) were used as model inputs.

The REEFS model was configured to assess several fishery management decision making reference points, or benchmarks, including yield-per-recruit (YPR) and spawning potential ratio (SPR). These two reference points are relatively robust measures of potential yields and recruitment,

Table 14.-

Full fishery management benchmark analysis for 35 reef fish stocks in Biscayne National Park showing current estimates. Species with dashed boxes indicate current minimum size regulations are at or set lower than the minimum sexual maturity.

Taxa	Common name	Ave. L	F	M	K	M/K	L <sub>m</sub>	L <sub>c</sub>	L <sub>a</sub>	SPR	F/F <sub>msy</sub>	B/B <sub>msy</sub>	B <sub>0</sub>	B <sub>msy</sub>	B <sub>now</sub>	
<b>Groupers</b>																
<b>1</b>	Rock Hind	260.00	0.510	0.250	0.191	1.31	336.0	203.2	453.3	5.78	2.04	0.26	18367	4053	1061	
<b>2</b>	Grayshy	250.00	0.275	0.200	0.350	0.57	108.0	203.2	362.7	40.14	1.37	0.83	8824	4286	3542	
<b>3</b>	Speckled Hind	442.95	0.269	0.200	0.130	1.54	460.1	290.0	845.7	18.45	1.34	0.68	120668	32620	22265	
<b>4</b>	Yellowedge	509.58	<b>2.000</b>	0.200	0.170	1.17	524.8	240.0	792.4	3.19	10.02	0.07	126653	58387	4037	
<b>5</b>	Coney	280.00	0.645	0.180	0.145	1.24	185.1	203.2	647.8	8.41	3.58	0.25	22919	7859	1927	
<b>6</b>	Red Hind	279.14	0.146	0.180	0.207	0.87	247.7	203.2	382.8	44.25	0.81	1.18	19520	7350	8638	
<b>7</b>	Goliath	691.26	<b>0.430</b>	0.130	0.130	1.00	97.8	203.2	2178.3	1.27	3.31	0.05	5827829	1548036	73923	
<b>8</b>	Red	<b>560.00</b>	1.065	0.180	0.153	1.18	433.8	508.0	869.0	14.71	5.91	0.30	125310	60588	1834	
<b>9</b>	Warsaw	691.26	0.431	0.080	0.054	1.48	940.5	508.0	2178.3	1.17	5.39	0.05	6322926	1609331	73970	
<b>10</b>	Snowy	493.07	<b>2.000</b>	0.130	0.113	1.15	462.1	508.0	909.8	6.97	15.38	0.13	228770	125243	15337	
<b>11</b>	Nassau	551.86	<b>0.313</b>	0.180	0.145	1.24	480.0	508.0	648.2	46.49	1.74	0.77	48595	29247	22590	
<b>12</b>	Black	628.78	0.625	0.150	0.160	0.94	597.0	508.0	1153.4	5.91	4.17	0.16	532994	191373	31476	
<b>13</b>	Yellowmouth	545.40	0.423	0.180	0.063	2.86	468.0	508.0	710.7	21.32	2.35	0.48	170875	76345	36427	
<b>14</b>	Gag	569.84	1.258	0.230	0.149	1.54	657.0	508.0	1034.4	0.92	5.47	0.03	133456	41424	1234	
<b>15</b>	Scamp	470.25	<b>2.000</b>	0.143	0.126	1.13	491.0	508.0	932.2	4.09	13.99	0.09	319185	138084	13065	
<b>16</b>	Yellowfin	520.00	<b>2.000</b>	0.180	0.170	1.06	524.8	508.0	792.4	3.99	11.11	0.08	151123	74204	6024	
<b>Snappers</b>																
<b>17</b>	Mutton	<b>450.00</b>	1.249	0.214	0.129	1.66	275.8	406.4	797.8	14.59	5.84	0.32	91558	42117	13355	
<b>18</b>	Schoolmaster	280.00	<b>2.037</b>	0.250	0.180	1.39	144.6	254.0	503.8	12.44	8.15	0.27	20614	95653	2665	
<b>19</b>	Blackfin	350.00	0.447	0.230	0.084	2.75	233.4	304.8	459.2	50.65	1.94	0.77	7317	4837	3706	
<b>20</b>	Red	356.00	<b>2.000</b>	0.190	0.162	1.17	303.5	508.0	901.6	1.78	9.99	0.05	146407	49553	2609	
<b>21</b>	Yellowtail	330.00	0.795	0.210	0.209	1.00	194.3	304.8	433.4	35.99	3.78	0.59	17173	10438	6781	
<b>22</b>	Cubera	488.66	0.495	0.150	0.140	1.07	407.3	304.8	1153.1	5.83	3.30	0.19	639420	196466	37284	
<b>23</b>	Gray	300.00	0.966	0.300	0.136	2.21	230.2	254.0	566.5	14.70	3.22	0.36	17396	7077	2558	
<b>24</b>	Dog	358.71	0.588	0.330	0.100	3.30	298.0	304.8	568.5	27.91	1.78	0.64	19822	8627	5560	
<b>25</b>	Lane	245.00	0.573	0.300	0.097	3.09	202.3	203.2	418.3	23.26	1.91	0.57	7396	2998	1720	
<b>26</b>	Silk	260.00	<b>2.000</b>	0.230	0.092	2.50	303.7	304.8	512.0	7.10	8.70	0.13	23033	12217	1636	
<b>27</b>	Black	<b>250.00</b>	0.478	0.300	0.650	0.46	203.0	203.4	650.0	27.61	1.59	0.68	7356	2984	2031	
<b>28</b>	Vermilion	279.21	<b>2.000</b>	0.300	0.206	1.45	310.9	254.0	532.9	0.50	6.68	0.01	11330	4081	57	
<b>29</b>	Hogfish	330.00	1.639	0.250	0.190	1.32	195.5	304.8	515.4	19.86	6.56	0.38	325215	16857	6456	
<b>Grunts</b>																
<b>30</b>	Margate	<b>270.00</b>	0.985	0.374	0.174	2.15	324.4	203.2	578.4	4.72	2.66	0.18	17222	4550	813	
<b>31</b>	Tomtate	206.39	<b>2.000</b>	0.330	0.220	1.50	136.1	203.2	250.0	47.10	6.06	0.65	2533	1845	1193	
<b>32</b>	Sailors choice	235.00	0.760	0.430	0.220	1.95	101.4	203.2	320.1	48.81	1.77	0.80	3139	1926	1532	
<b>33</b>	Bluestriped	226.90	0.762	0.500	0.484	1.03	108.4	203.2	273.5	56.54	1.52	0.87	2269	1481	1283	
<b>34</b>	White	216.50	<b>2.000</b>	0.370	0.186	1.99	174.0	203.2	410.9	11.64	5.41	0.27	8676	3695	1010	
<b>Others</b>										1.16	625.1	508.0	1151.0	1.81	140803	48491
															2543	

respectively. As such, they help to focus on biological (size) and fishing (intensity) controls for managing current and future fishery production. We also used the REEFS stochastic simulation model to assess population risks relative to ‘limit control rules’ (e.g., NMFS 1999). Taken together, these management benchmarks characterize the status of stocks under exploitation relative to Federal fishery management standards. These analyses thus provide the basis for the assessment of the entire reef fish community, and indicate the efficacy of current fishery management practices and their sufficiency to provide sustainable fisheries now and into the future.

### 5.3.1 Fishery Yields and YPR

Since biomass  $B(a,t)$  is the product of numbers-at-age times weight-at-age, yield in weight  $Y_w$  from a given species  $s$  was calculated as

$$Y_w(F, L_c, t) = F(t) \int_{L_c}^{L_\lambda} B(L|a,t) dL = F(t) \int_{L_c}^{L_\lambda} N(L|a,t) W(L|a,t) dL$$

Yield-per-recruit (YPR), or the lifetime yield expected from a single recruited individual, can then be calculated by scaling yield to average recruitment.

### 5.3.2 Spawning Potential Ratios (SPR)

Mature or spawning stock biomass  $SSB(t)$  is a measure of the stock’s reproductive potential or capacity to produce newborn, ultimately realized at the population level as successful cohorts or year classes. Spawning stock biomass is obtained by integrating over individuals between the minimum size of first maturity ( $L_m$ ) and maximum reproductive size (here assumed to be the maximum size  $L_\lambda$ ) in the stock

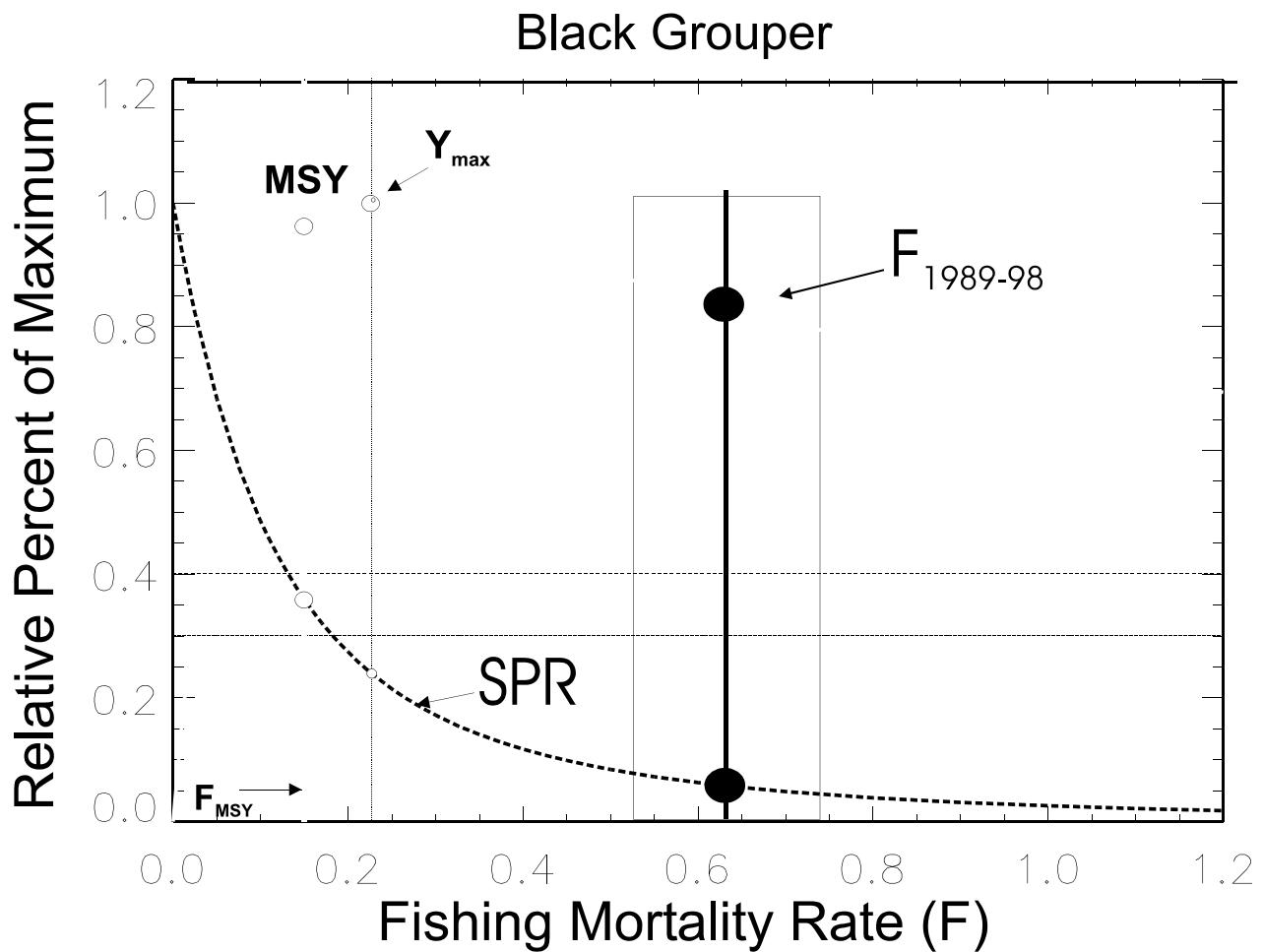
$$SSB(t) = \int_{L_m}^{L_\lambda} B(L|a,t) dL$$

Spawning potential ratio (SPR) is a contemporaneous management reference point that measures the stock’s potential capacity to produce optimum yields on a sustainable basis. SPR is a fraction expressed as the ratio of exploited spawning stock biomass relative to the equilibrium unexploited SSB

$$SPR = \frac{SSB_{exploited}}{SSB_{unexploited}}$$

Resultant estimated SPRs are then compared to the U.S. Federal standards which define 30% SPR as the “overfishing” threshold (Rosenberg et al., 1996).

The relationship between YPR and SPR with respect to fishing mortality rate is shown for black grouper in **Figure 31**. Note that the current estimates of  $F$  for black grouper place SPR and YPR well below optimal levels for sustainability of the fishery resource. An important attribute of the progression of average size as fishing mortality increases is shown in **Figure 32** for black grouper. Increasing exploitation successively eliminates older, more fecund size classes through a process known as “juvenescence”, which ultimately produces an overall younger stock (Ricker 1963, Ault 1988). This fact is extremely important in the context of stock and recruitment, since the fecundity potential of individuals increases exponentially with size. Such a phenomenon will be reflected by reductions of



**Figure 31.**- Example of the response of relative spawning potential ratio SPR and yield-per-recruit YPR theory for Black grouper with increasing exploitation using the REEFS model. Graph shows position of MSY and  $F_{msy}$  and estimated fishing mortality rate for the last decade derived from average size analyses with LBAR in shaded box.

the stock's spawning capacity, which itself is related to the expectation of new recruits to sustain the population over the longer run. For black grouper, fishing at the rate of mortality that produces "maximum sustainable yield" reduces the spawning potential ratio (the proportion of the virgin spawning biomass available) to about 36% (**Figure 31**). Remarkably, the current estimated rate of fishing mortality has reduced the spawning potential ratio to less than 5% of its historical maximum. From the perspective of ecological theory, this is an ominous result in terms of black grouper population stability and resilience. From the perspective of fishers, a current 5% SPR implies that the average size of black grouper (**Figure 32**) is 60% of what it once was (circa 1940).

The summary of the SPRs for the Biscayne National Park exploited reef fish complex in **Figure 33** shows that 13 of 16 groupers, 11 of 13 snappers, barracuda, and 2 of 5 grunts for which there are population dynamics data are below the SPR that constitutes overfishing by Federal definitions. Overall, 77% of the 35 stocks that could be analyzed were overfished.

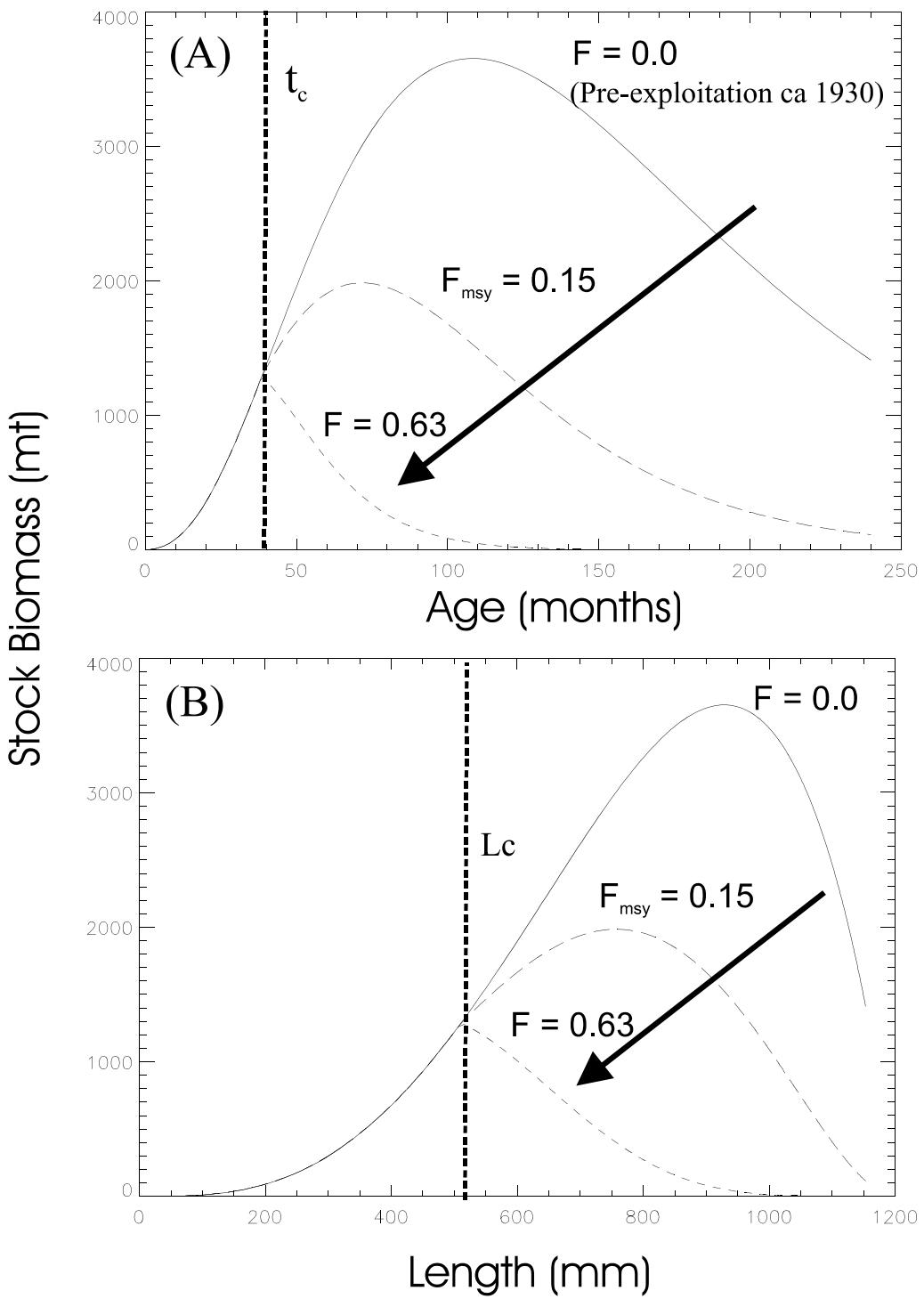
### 5.3.3 Limit Control Rules

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) contains a set of National Standards for fishery conservation and management, the first of which states:

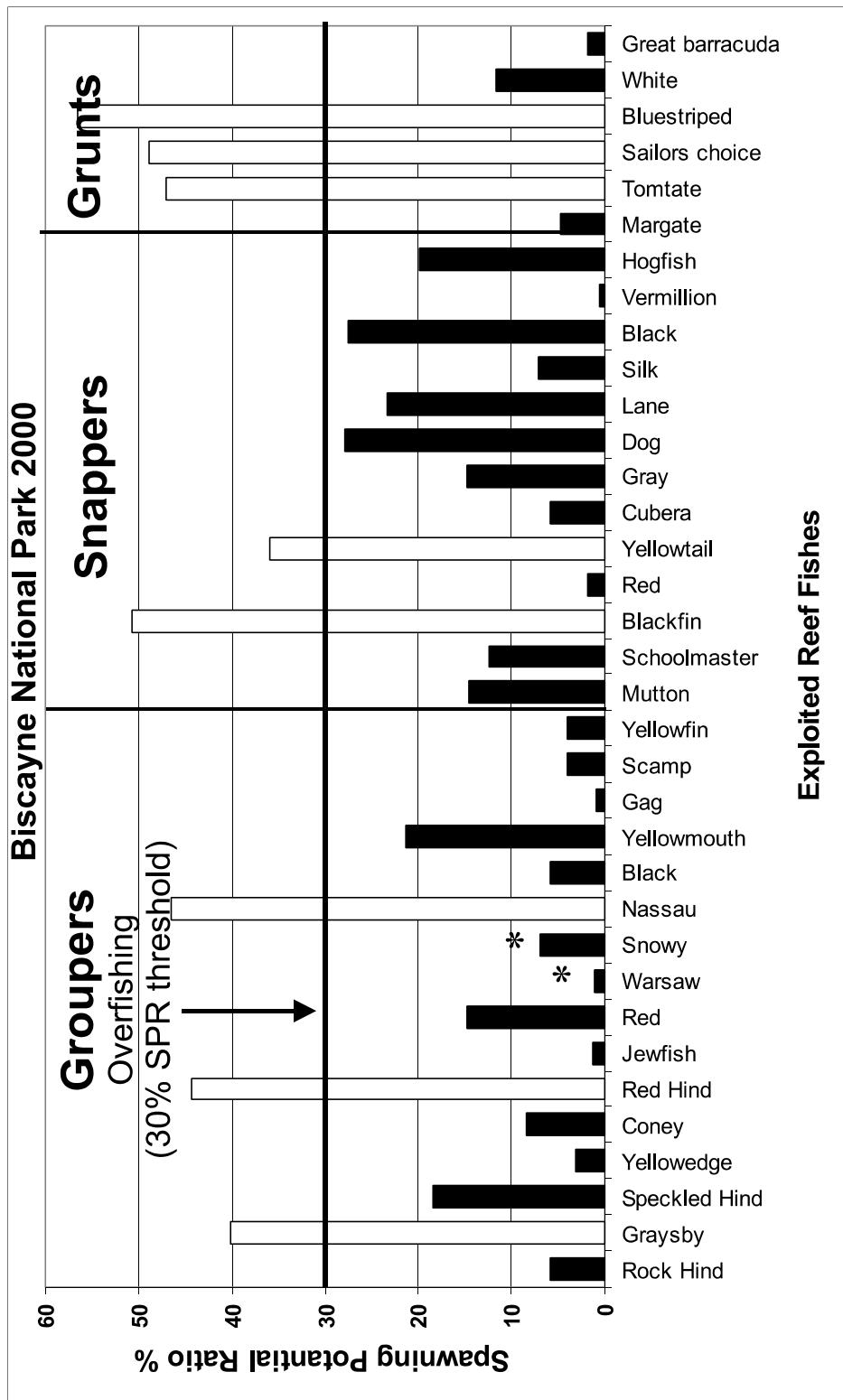
*"Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."*

The MSFCMA also required the Secretary of Commerce to "establish advisory guidelines (which shall not have the force and effect of law), based on the national standards, to assist in the development of fishery management plans". These Guidelines (or national standard guidelines or NSGs) were published as a final rule in May 1998. Following the NSGs, Technical Guidelines were developed (NMFS 1999, Restrepo and Powers 1999) to translate the NSGs into usable scientific criteria so that scientific advice could be offered to the regional Fishery Management Councils to assist in implementing the MSFCMA. Key points arising were: (1) that maximum sustainable yield (MSY) is to be viewed as a limit (i.e., a threshold **NOT** to be exceeded); (2) that two measures were to be used to determine a fish stock's management status, (a) the current fishing mortality rate relative to the fishing mortality rate that would produce MSY (denoted as  $F/F_{msy}$ ), and (b) the current amount of spawning biomass relative to the spawning biomass at MSY (denoted as  $B/B_{msy}$ ); (3) that there should be maximum standards of fishing mortality rates which should not be exceeded, called Maximum Fishing Mortality Threshold (MFMT); (4) that there should be a Minimum Stock Size Threshold (MSST) under which a stock's spawning biomass would be considered as depleted; and (5) that these criteria and measures should be linked together through "control rules" which specify actions to be taken (i.e., changes in management measures to alter fishing mortality rates) depending upon the status of current spawning biomass relative to  $B_{msy}$  and MSST and the status of the fishing mortality rate relative to  $F_{msy}$  and MFMT.

To address these emerging fishery management benchmark criteria for BNP multispecies resources, we conducted a new cutting-edge analysis that established fishery limit control rules consistent with the "precautionary approach" (NMFS 1999, Restrepo and Powers 1999, Darcy and Matlock 1999, Butterworth and Punt 1999). Criteria used to set target catch levels as explained above are explicitly *risk averse*. A risk averse Precautionary Approach would set OY (optimum yield) below MSY as a function of uncertainty. Thus, the greater the uncertainty, the greater the distance between the two. The *precautionary approach* to fisheries management requires avoidance of overfishing, restoration of already overfished stocks, explicit specification of management objectives including



**Figure 32.-** Graphical theory of juvenescence. Comparison of simulations of equilibrium relationships of 'average length in the exploitable phase' dependent on fishing mortality rate  $F$  using the REEFS model for Black grouper: (A) cohort biomass on age; and, (B) cohort biomass on length.



**Figure 33.-** Fishery management benchmark spawning potential ratio SPR analyses for 35 exploited species of BNP-Florida Keys reef fish comprising groupers, snappers and hogfish, grunts and great barracuda. Darkened bars indicate stock “overfishing” and open bars indicate the stock is above the 30% SPR U.S. Federal Standard. Asterisk indicates estimate from headboat data outside BNP. The high SPR estimate for Nassau grouper is dubious.

operational targets and constraints (e.g., target and limit reference points), taking account of uncertainty by being more conservative, and avoidance of excess harvest capacity. In addition, this approach requires formulation of decision rules that stipulate in advance what actions will be taken to prevent overfishing and promote stock rebuilding.

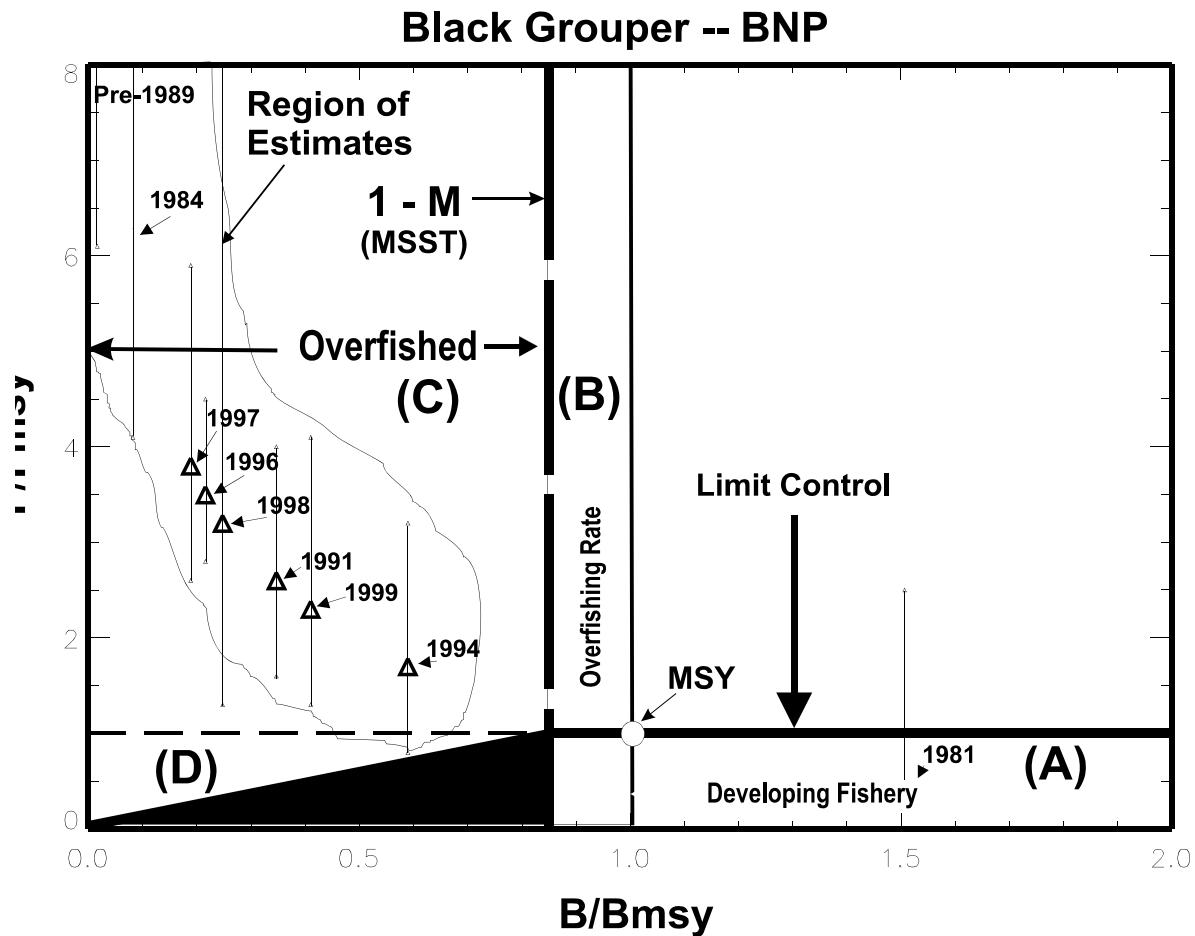
Limit reference points are designed to constrain exploitation within safe biological limits so that stocks retain the ability to produce maximum sustainable yield. Overfishing is a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY on a continuing basis. In this arrangement, the fishing mortality rate which generates MSY should be regarded as the minimum standard for limit reference points. The limit MSST, minimum stock size threshold, is used to decide what level of fishing mortality indicates “overfishing”, and when the stock is in an “overfished” condition. If spawning biomass drops below MSST, then the regional fishery management councils MUST take remedial actions to end overfishing and rebuild overfished stocks to MSY levels very rapidly (generally in 10 years or less).

A graphical application of limit control rule theory is shown in **Figure 34** for black grouper in BNP. The region defined by (A) represents a developing fishery where fishing mortality rates are below the level required to achieve MSY, and the stock biomass is greater than the biomass at MSY. The (B) region defines an area where overfishing is occurring and passes up to the threshold rate that will lead to an overfished stock. The (C) region formally defines an overfished stock that violates principles of sustainability and that requires strong intervention by fishery management. The (D) region defines a stock under recovery where the current fishing mortality rate has been reduced to a level that promotes rebuilding of the resource over a 10 year time horizon. We used the natural mortality rate as a proxy for  $F_{msy}$  (e.g., Gulland 1983). These estimates of  $F_{msy}$  were then input to REEFS to estimate  $\hat{B}_{msy}(t)$ . We note that all the yearly estimates of the black grouper fishery show that substantial overfishing has occurred in BNP, and that most recent estimates place the level of overfishing at 3-5 times the level of fishing required to produce maximum sustainable yield under Federal definitions (note that the 1981 estimate is dubious). Minimally, this means that fleet effort would need to be reduced by some 80% to achieve the longer-term sustainability goals under these standards. However, it should be noted that the National Park Service standards may be even more conservative than those established under the MSFMCA, and thus effort reductions would have to be even more severe to achieve NPS goals for BNP.

The limit control rule technique is demonstrated for black grouper (**Figure 34**); but the process is reflective of the analyses for every fish stock or community member (groupers, snappers, grunts, etc.). Fishing mortality rates were estimated to be from 2 to 10 times higher than  $F_{msy}$  for 71% (i.e., 25/35) of the exploited species analyzed (**Figure 35**). Moreover, the current levels of stock biomass are critically low for more than 70% of the key targeted species. The most current estimates and results are summarized in **Table 14**.

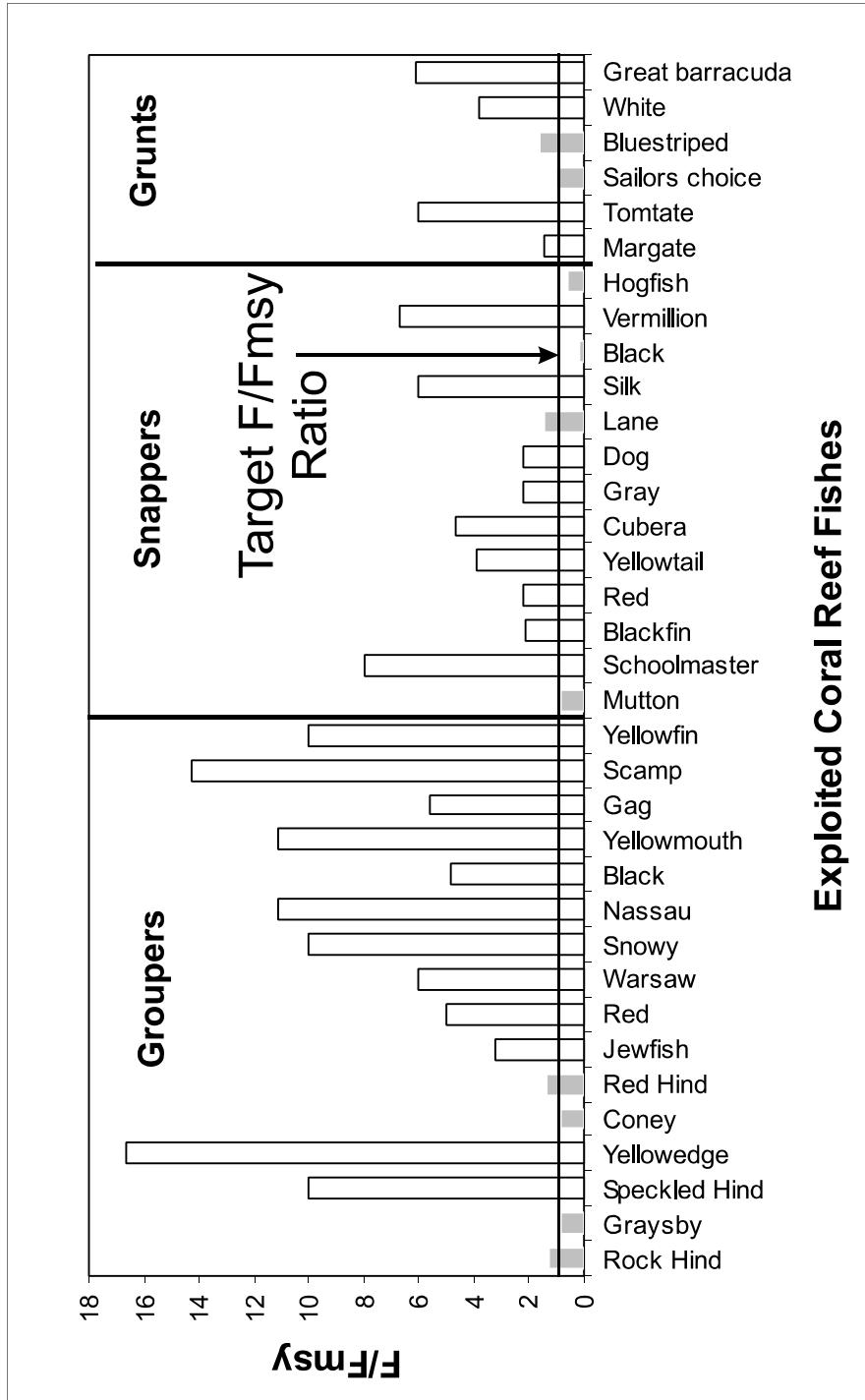
#### 5.4 Baseline Status of BNP Exploited Fish Stocks

Our results indicate that BNP reef fish populations are currently heavily fished (**Figures 33 and 35, Table 14**). Despite using conservative assumptions, the estimated fishery exploitation rates we estimated suggest that many BNP and Florida Keys reef fish stocks are overfished according to definitions for U.S. fisheries (Rosenberg et al., 1996). Many desirable grouper and snapper stocks have extremely low spawning potential ratios (SPRs). Moreover, our analysis indicates that these stocks have experienced high rates of exploitation over at least the last two decades (see also Ault et al. 1998). The estimated average lengths in the exploitable phase from statistically independent data sources were



**Figure 34.-** An example of Limit Control Theory applied to BNP Black grouper. Note the highly “overfished” condition of the stock according to U.S. Federal Standards under the MSFMCA.

## Biscayne National Park 2000



**Figure 35.**- Fishery management control rule benchmark analyses for 35 exploited species of BNP Florida Keys reef fish comprising groupers, snappers and hogfish, grunts, and great barracuda. The  $F/F_{msy}$  criterion is the current fishing mortality rate relative to the fishing mortality rate that would produce MSY. A value of 1.0 is the maximum allowed under Federal Standards according the precautionary approach of the MSFMCA. Values above 1.0 indicate stock “overfishing” and give the magnitude of fleet overcapitalization above and beyond U.S. Federal Standards.

highly comparable for groupers, snappers, and grunts, which supports their use in the multispecies assessment. The trends in average size for grouper, snapper and grunt stocks was relatively flat over the last 25 yr and close to the minimum exploitable length. The flatness is explained by considering expected  $\bar{L}$  from a modeled range of  $F$  in an analytical model, given knowledge about current values of  $\hat{F}$ . The slope of  $\bar{L}$  on  $F$  is very shallow in the range of the analytical model, corroborating empirical estimates. Some stocks appear to have been chronically overfished since at least the late 1970's.

There is also substantial corroborating evidence of these trends from our fishing effort and CPUE analyses. Total fishing effort has increased substantially because of greater average fishing power per vessel and a much larger recreational fishery fleet. The arithmetic increase of recreational fishing vessels is an extremely important factor for any future assessments. However, absolute magnitude of the recreational fishing effect on reef fish stocks is poorly known because the recreational fleet is heterogeneously distributed across south Florida and the Keys seascapes, and has been poorly sampled or studied to date. Inverse relationships between increased fishing effort (particularly by the recreational sector) and the long-term decreased average size and stock biomass of the most desirable species (e.g., groupers and snappers) are of particular concern. Declining CPUE trends observed in CREEL data also support our overfishing conclusions.

We also noted similarities in key relationships within various taxa that separate out into somewhat discrete clusters when plotting maximum size versus maximum age by species. This pattern suggests that species within the various taxa groupings will likely respond to exploitation in a similar manner. The sensitivity to exploitation is highest for groupers, followed by snappers and then grunts. The Florida Keys reef fishery shows the classic pattern of serial overfishing, in which the more vulnerable species are progressively depleted (Munro and Williams, 1985; Russ and Alcala, 1989). The longest lived, latest maturing, and lowest mortality ( $M$ ) stocks (i.e., groupers) are those first to experience significant declines in population biomass, followed in sequence by intermediate-lived (snappers), and finally by short-lived stocks (grunts). Within families, the inverse relationships between the spawning potential ratio and ex-vessel market price is consistent with serial overfishing (Ault et al. 1998). As expected, the most valuable snappers and groupers also tend to have the lowest spawning potentials.

The process of serial overfishing has decimated the grouper stocks and current levels of fishing mortality range from 3 to more than 10 times the exploitation level that would achieve MSY. The only stocks at about the Federal target are rock hind, graysby, coney and red hind. This is because these species rarely reach a maximum size greater than about 16 inches in total length, and thus are not generally targeted by fishermen. However, given the current extremely POOR status of the snapper-grouper fishery in the Florida Keys and BNP, these species too are now becoming targets. The serial overfishing phenomenon is clearly reflected in the fact that snappers, and now grunts, stock sizes are falling below federal target levels under the precautionary approach of the MSFMCA. Now there are hardly any fish big enough or mature enough to support the waning resources, or to affect any hopes of system recovery given the pervasive increases in fishers and fleet fishing power. This is particularly distressing scenario when coupled with pervasive trends in increased coastal development, habitat degradation, and coastal pollution in south Florida.

Our data suggest that there may have been substantial changes in the composition of the biomass and abundance of the reef fish community over the past several decades. While many groupers and snappers have apparently declined in response to growing fishing effort, some grunts have increased in relative abundance. Claro (1991) noted a similar process in the Golfo de Batabano, Cuba, and

hypothesized that chronic over-harvesting of snappers resulted in community shifts in favor of grunts. Another indication of significant change shown by Ault et al. (1998) is the explosive growth of barracuda which may be explained by several factors. First, there is little directed commercial or recreational fishing for barracuda as food Keys-wide due to health concerns. Second, growth of catch-and-release fishing by sport anglers and reduced emphasis on spearfishing may have substantially lowered barracuda mortality. Third, other top predators such as groupers, snappers and sharks have been intensively fished which appears to have lowered competition while barracuda still retain a large and possibly increasing prey base of grunts and other small fishes. Increased abundance and biomass of a top predator like barracuda could be a management concern if barracuda substantially impact reef fish community dynamics. For example, excessive predation on popular sport fishes like snappers could counteract potential reductions in fishing mortality sought by traditional management.

During the time frame of this study, numerous measures have been taken to reduce fishing mortality in state and federal waters. Fish traps were progressively eliminated between 1980 and 1992 and numerous bag limits and minimum size limits were imposed. Fisheries were closed for queen conch (*Strombus gigas*), Goliath grouper (*Epinephelus itajara*), and Nassau grouper (*E. striatus*). These actions are evidence of trends reported in this study. These management measures have been largely ineffectual to reduce the observed declining trends in stock sizes and productivity. The patterns of fishery size regulations in south Florida have followed those characteristic of fisheries under stress, and reflect too little action too late. Ault et al. (1998) have shown the Florida Keys multispecies reef fisheries to have been seriously overfished since at least the late 1970s.

Adjusting minimum sizes of first capture ( $L_c$ ) and fishing mortality rates ( $F$ ) may mitigate the apparent growth and recruitment overfishing conditions in the fishery. A striking result we discovered, however, was that 13 of 35 species we closely analyzed have the minimum size of first capture by the fishery set lower than the minimum size of first sexual maturity (**Table 14**!). However, traditional management actions alone are unlikely to be sufficient because they can be circumvented and habitually fail to effectively control fishing effort, particularly in an open access fishery (Bohnsack and Ault 1996, Ault et al. 1998). For example, bycatch mortality and high fishing effort from the expanding fleets can make size limits ineffective. In theory, every fish can be caught once it reaches minimum legal size resulting in insufficient mature adult survival. The problems we have identified have been compounded by a clear lack of compliance of fishery regulations by sportfishers, and the apparent lack of enforcement of existing regulations. Surprisingly, there has been little to no follow-up plan to evaluate whether regulations and policies invoked are achieving their intended results. What is needed is clear plan of action to ameliorate these trends in declining and to build sustainable fisheries and conserve marine biodiversity in the face of ecosystem changes and regional human population growth.

## **6.0 Conclusions and Recommendations**

In the report we conducted a baseline characterization and fishery management analyses using a new systems methodology comprised of advanced methods in fish population dynamics, mathematical, and statistical modeling to provide a quantitative baseline assessment of the distribution and status of fishery resources and their essential habitats in BNP. We focused on explicit modeling of linkages between fish community distribution, abundance and size structure in relation to key “habitat” characteristics. As a result, precise estimates of the essential parameters are required to provide critical guidance for future cost-effective sampling and resource assessment efforts. A principal key to our ability to assess the multispecies reef fish stocks in BNP was the strategic use of ‘average size’ (in length) of fish in the exploitable phase of the population ( $\bar{L}$ ) as a quantitative indicator of stock status and response to exploitation. The average length statistic is extremely robust to the data source from which the population estimation measure is made (i.e., RVC, CREEL or head boat survey data). In addition, by providing an enhanced and rigorous baseline reference point of reef fish stock status and spatial abundance for the multispecies community, this research will greatly facilitate the assessment of natural system variability versus regional changes that may result from proposed fishery and spatial ecological management strategies. Our principal findings with respect to problems with overfishing, habitat degradation, and fishery management were:

- C An analysis of the Spawning Potential Ratios (SPR) of exploited reef fish shows that 13 of 16 grouper species, 11 of 13 snapper species, barracuda, and 2 of 5 grunt species for which there are reliable population dynamics data are below the SPR that constitutes overfishing by Federal definitions (Magnusson-Stevens Fishery Management Conservation Act).
- C For example, the average size of black grouper is now 60% of what it was in 1940 and the spawning stock is now less than 5% of its historical unfished maximum.
- C Overall, 77% of the 35 individual stocks that could be analyzed are overfished.
- C The current level of fishing mortality for grouper stocks range from 3 to 10 times the exploitation level that would achieve Maximum Sustainable Yield (MSY).
- C Stock biomass is critically low for more than 70% of the key targeted species within the recreational fishery.
- C Some stocks appear to have been chronically overfished since at least the late 1970's.
- C For all of the harvested species analyzed, the average sized fish within these exploited populations for the last 25 years has remained relatively constant and is very close to minimum harvest sizes (for 77% of those analyzed), not natural historical unfished population size.
- C Many species with extremely low average length in the past have had very little change in average length even though new minimum size limits were imposed.
- C The recreational fishing fleet in South Florida has grown at a near exponential rate since 1964 (a 444% increase in recreational boats from 1964 to 1998) with no limits on the number of boats

allowed to fish.

- C The relative effective vessel “fishing power” of the recreational fleet has quadrupled due to depth indicators and fish finders, global positioning systems, improved vessel designs, larger motors, and two-way radio communications.
- C Exceptionally high and sustained exploitation pressures have precipitated “serial overfishing” of key fishery resources. Smaller and less desirable species have consistently increased in the catch as larger more vulnerable species are eliminated.

The following outlines critical habitat-animal relationships, fishery management, policy alternatives and planning, survey design analysis, and fishery statistics that underlie the portent of future problems:

**Bay-to-Reef Dynamics.**- Biscayne Bay and BNP is a very important nursery environment. There are more than 325 fish and macroinvertebrate species in BNP, of these more than 150 of these species are under direct assault or subject to some form of fishing pressure from recreational commercial fishing activities that can have long-term deleterious social, economic and ecological consequences. More than 30 of these species are seen in all three existing survey mechanisms (RVC, creel and trawl surveys), but substantial size differences exist between species and areas of BNP. The species captured by all three gears use the entire seascape on their ontogenetic migrations from the bay-to-reef, making them excellent candidates for “key” indicator species that can assist evaluation of the impacts and successes of Everglades restoration on the sensitive and dynamic coastal environments of BNP. However, many species that are known to occur in the Bay are rarely, if ever, found in the samples. This fact requires innovations in gear deployments, new technologies, and directed efforts to sample fringe environments like mangroves, channels, canals, tidal creeks, etc., to detect species such as pink shrimp (we know they use ALL habitats, as do bonefish, tarpon, snook, permit, black and silver mullet, jack crevalle and yellow jacks, anchovies and sardines, black- and white-tipped sharks, nurse sharks, bonnetheads, sheepshead, red and black drum, etc.). Florida waters have produced 13 of 16 standing world records for bonefish, and they may be one of the most lucrative fisheries in BNP. However, there is little or no information system available to document the status or sustainability of many of these economic and ecologically important resources (i.e., bonefish-tarpon-permit).

The Everglades restoration includes a comprehensive effort to understand and model the physical and biological processes of Florida Bay and it's connectivity to the coral reef tract. As the restoration enters the implementation phase, it is essential to have effective monitoring programs to assess system changes and to run predictive models that guide decision making. Ensuring the sustained function and productivity of this unique environment through prudent use and strategic management decision making will result in substantial biological, ecological and economic benefits to the scientific, commercial fishing and public communities. Concern about overfishing, habitat degradation and progressively escalating resource use resulted in the establishment of the FKNMS in 1990. It is imperative that BNP management link up with the larger regional efforts of NOAA, NPS and the State of Florida decision-making entities on the resource management and sustainability issues critical to the Florida Keys. Fishes are extremely important to monitor with high precision, because in terms of the species composition, size/age structure, and fishery catch and economic productivity, they are a direct public concern and an obvious measure of management success (Bohnsack and Ault 1996, Ault et al. 1998, Meester et al. 1999).

**Fishery Management Problems.**- The history of fishery management actions by the State and Federal Fishery Management Council for BNP waters clearly reflects the characteristics of trying to manage fisheries under increasing stress with conventional approaches. Actions have been taken only after declines have already occurred and were finally acknowledged. Actions are then usually only minimal and not at a level that ensures recovery will take place. (Note: The history of increasingly more restrictive size limits placed on several grouper species until the fishery for some was eventually closed is a prime example of failure in conventional management approaches).

- C A proportion of the fish in catches observed at the Biscayne NP boat ramps during creel surveys are **smaller** than the minimum size limit for legal harvest. This is as high as 70% for yellowtail and mutton snapper!
- C 13 of 35 species closely analyzed have their minimum legal harvest size set lower than the minimum size of first sexual maturity.

In this way, our baseline computations allow BNP resource managers to determine and understand the current status of the fishery resources and habitats prior to consideration and implementation of fishery management alternatives (e.g., spatial protection zones (RNAs), catch and release only zones, etc.) that build sustainable fisheries. These baseline computations will also allow efficacy assessment of any fishery management alternatives applied in the short- or longer-term. As a result, this study forms the precursor to more intensive analyses of the multi species fish community in Biscayne National Park (BNP), and their connections with the broader south Florida coastal ocean ecosystem. Some particular recommendations for research and fishery management are:

**Formulation of Policy Alternatives.**- The tradition of open-access management systems coupled with risk-prone management decisions remains a principal obstacle to achieving renewable resource sustainability (Rosenberg et al., 1993). Reversing adverse trends in the reef fishery are likely to require other innovative approaches to controlling exploitation rates. Rothschild et al. (1996) recommended that fishery management maintain a systems view of the resources, emphasizing strategy over tactics. With this in mind, we recommend consideration of management alternatives that couple traditional management measures with a spatial network of “no take” marine reserves (Fogarty et al. 2001). Marine reserves provide an ecosystem management strategy for achieving long-term goals of protecting biodiversity while maintaining sustainable fisheries. The establishment of a network of small no-take reserves may be a first step. A key to the success of this effort is a conscientious, continuous assessment program using integrated fishery-independent and fishery-dependent data to evaluate their effectiveness (Bohsack and Ault, 1996, Ault et al. 1998). With adaptive management (e.g., Walters, 1986), improvements can be implemented over time.

**Fishery Management Planning.**- Fisheries in Florida were loosely managed prior to the formation of the Florida Marine Fisheries Commission in 1983. The Magnuson-Stevens Conservation and Fishery Management Act explicitly defines a process for managing sustainable resources in the U.S. EEZ. The planning must be based in a ecosystem perspective. However, NPS preferred alternatives for Park status may likely be more conservative than the MSFMCA standards. In addition, management changes have been recently made as part of the Florida Keys National Marine Sanctuary (FKNMS) and Dry Tortugas National Park (DTNP) management plans. The most important change is the use of spatial

protection including the establishment of 'no-take' marine protected areas or research natural areas initiatives (NPS 2000; [www.coralreef.gov](http://www.coralreef.gov)), and these strategies may be appropriate for Biscayne National Park resource management.

**Survey Design Analysis.-** This report also presents the quantitative bases required for future preparation of an optimal sampling design analysis that produces precise statistics required for future implementation of a robust fishery management plan for BNP. This research will lead to subsequent development of an efficient survey and monitoring design that optimizes in a cost-effective way the precision of estimates for key management variables to assess resource status and to evaluate management system efficacy. We recommend:

- Increasing the resolution and precision of base "habitat" maps for key environmental variables (i.e., salinity, benthic substrates, bathymetry, etc.).
- Developing "statistical" fish-habitat suitability models for individual populations, taxa, and community of inshore and reef fishes and macroinvertebrates. Use these models to optimize sampling survey designs for monitoring of trends with implementation of spatial management measures (Ault et al. 1999a, Ault and Luo 1998, Rubec et al. 1999, 2001).
- Conducting and analyzing broad sampling design issues such as key habitats presently not monitored (e.g., baywide, mangroves, reef fish (RVC and CREEL), pelagic environment) but which may provide critical signals for management.

An additional important attribute of this technology is that fishery-independent measures of stock status become even more important when spatial management strategies (i.e., such as marine protected areas or "no-take" marine reserves) are implemented, because these methods are capable of addressing estimation of population mortality rates from both within the "closed" reserve areas and areas outside under exploitation without reliance on estimation of fishery catch data, and does so in a non-intrusive and non-destructive way.

**Fishery-dependent versus Fishery-independent Statistics.-** Over time there will be an increasing need to rely on fishery-independent data because fishery-dependent data will become less available and less useful as larger size limits, closed seasons, closed fishing areas, and prohibitions on species are imposed. Also, the shifting emphasis from commercial to recreational fishing in the Florida Keys makes collecting fishery-dependent data much more difficult and expensive. Fishery-dependent data has the potential to be biased by under-reporting and lack of cooperation on the part of the fishery itself. Although fishery-independent assessments can provide reliable measures of reef fish abundance, population dynamics and community composition (Gunderson, 1993), there have been few applications of the approach for optimizing the performance of multispecies fisheries in tropical coral reefs. We have therefore developed techniques and methods for the extraction of a useful indicator of reef fish stock health from fishery-independent and fishery-dependent monitoring and assessment surveys.

As a result, the quantitative multispecies stock assessment methods presented here should help provide a backbone for the future use of fishery-independent and fishery-dependent assessment surveys in management decisions regarding fish stocks at broader levels. This could lead to development of spatial models of multicohort-multistock dynamics for BNP and the Florida Keys coral reef ecosystem

following Ault and Olson (1996), Ault et al. (1999b), and Cosner et al. (1999). These estimates and models are then the precursors to more exacting management analyses like multispecies stock assessments and modeling of spatial management alternatives. Furthermore, once determined these fundamental relationships could be embedded in a biophysical spatial simulation model (e.g., REEFS model has been generalized to incorporate space as well as time Ault et al. 1999b, 2000; Meester 2000) to assess the consequences of preferred management alternatives for the Park, or to provide quantitative insights into the longer-term goals of maintaining ecosystem integrity, building sustainable fisheries, and conserving marine biodiversity that meet management targets and goals.

## Acknowledgments

This research was conducted for BNP support under NPS grant No. CA-525000024. RVC data were available under support provided from NOAA Fisheries, Florida Keys National Marine Sanctuary program (Grant No. NA67RJ0149), South Florida Ecosystem Restoration Prediction and Modeling Program (Grant No. NA67RJ0149), National Undersea Research Center (Grant No. 37NURPUNCW9926), and the University of Miami RSMAS. NOAA/FMRI provided digital benthic substrate habitat maps. Doug Harper of NMFS/SEFSC provided commercial and recreational vessel registered vessel digital database. Joe O'Hop of FMRI and Pat Eyo of NMFS provided commercial fishing data. Gene Huntsman at NMFS Beaufort, NC, provided headboat survey data. John D. Wang of RSMAS provided salinity data from his 2-D finite element Biscayne Bay-northern Florida Keys coral reef tract hydrodynamic model. Guillermo A. Diaz of RSMAS provided technical assistance on the habitat use analyses. We also thank the Army Corps of Engineers (Grant No. DACW 39-94-K0032) and NOAA Coastal Ocean Program (Grant No. NA-85-WCH0631) for support to conduct rollerframe trawl surveys; FISHBASE ([www.fishbase.org](http://www.fishbase.org)) for access to population dynamic parameters; and, National Sea Grant College Program (Grant No. R-L/R-47B) for development support on fish-habitat models. Last, by not least, we thank a host of folks for technical assistance and reviews required to complete this exciting project including: Rick Clarke, Monica Mayr, Brian Lockwood, Jim Tilmant, Sherri Fields, Tom Schmidt, Pat Kenney, John Hoesterey, Richard Curry, Brenda Lazendorf, Sarah Bellmund and Matt Patterson of NPS; Gary Hickman of TVA; Ken Lindeman of Environmental Defense; Billy Causey, Ben Haskell and Brian Keller of FKNMS; and David McClellan, Anne Marie Eklund, and Joe Serafy of NMFS.

## Literature Cited

- Ault, J.S. 1988. Nonlinear numerical simulation models for assessing tropical fisheries with continuously breeding multicohort populations. Ph.D. Dissertation, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 242 p.
- Ault, J.S. 1996. A fishery management system approach for Gulf of Mexico living resources. In GIS Applications for Fisheries and Coastal Resources Management, Rubec, P.J. and O'Hop, J. (eds.). Gulf States Marine Fisheries Commission 43:106-111.
- Ault, J.S. 2001. Tropical multispecies fishery decision dynamics. Trans. Amer. Fish. Soc. (in preparation)
- Ault, J.S., Bohnsack, J.A., and Meester, G.A. 1997a. Florida Keys National Marine Sanctuary: retrospective (1979-1995) assessment of reef fish and the case for protected marine areas. Pages 385-395 in Developing and Sustaining World Fisheries Resources: The State of Science and Management, D.A. Hancock, D.C. Smith, A. Grant and J.P. Beumer (eds.). 2nd World Fisheries Congress Proceedings, CSIRO Publishing, Collingwood, Australia, 797 p.
- Ault, J.S., Bohnsack, J.A. and G.A. Meester. 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fishery Bulletin 96(3):395-414.
- Ault, J.S., Bohnsack, J.A., and S.L. Miller. 2000a. Multispecies reef fish stock assessment in the Dry Tortugas. National Undersea Research Center UNCW Report 2000-19. 25 p.
- Ault, J.S., Diaz, G.A., Smith, S.G., Luo, J. and J.E. Serafy. 1999a. An efficient sampling survey design to estimate pink shrimp population abundance in Biscayne Bay, Florida. North American Journal of Fisheries Management 19(3):696-712.
- Ault, J.S., and N.M. Ehrhardt. 1991. Correction to the Beverton and Holt Z-estimator for truncated catch length-frequency distributions. ICLARM Fishbyte 9(1):37-39.
- Ault, J.S., Luo, J., Smith, S.G., Serafy, J.E., Wang, J.D., Diaz, G.A., and R. Humston. 1999b. A spatial dynamic multistock production model. Canadian Journal of Fisheries and Aquatic Sciences 56 (Suppl. 1):4-25.
- Ault, J.S. and J. Luo. 1998. Coastal bays to coral reefs: systems use of scientific data visualization in reef fishery management. International Council for the Exploration of the Seas. ICES C.M. 1998/S:3.
- Ault, J.S., McGarvey, R.N., Rothschild, B.J., and J. Chavarria. 1996. Stock assessment computer algorithms. Pages 501-515 in Stock Assessment: Quantitative Methods and Applications for Small Scale Fisheries, Gallucci, V.F., Saila, S., Gustafson, D., and B.J. Rothschild (eds.). Lewis Publishers (Division of CRC Press). Chelsea, Michigan, 527 p.
- Ault, J.S., Meester, G.A., Luo, J., Smith, S.G., and K.C. Lindeman. 2000b. Natural resources affected environment. In Dry Tortugas National Park: Draft General Management Plan Amendment and Environmental Impact Statement. 272 p.
- Ault, J.S. and D.B. Olson. 1996. A multicohort stock production model. Transactions of the American Fisheries Society 125(3):343-363.
- Ault, J.S., and B.J. Rothschild. 1991. A stochastic age-independent simulation model. International Council for Exploration of the Seas, Statistics Session. C.M./S5. 20 p.
- Ault, J.S., Serafy, J.E., DiResta, D., and J. Dandelski. 1997b. Impacts of commercial fishing on key habitats within Biscayne National Park. Biscayne National Park Report. 80p.
- Beverton, R.J.H. and S.J. Holt. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer 140:67-83.

- Beverton, R.J.H. and S.J. Holt 1957. On the dynamics of exploited fish populations. Ministry of Agriculture, Fisheries and Food, Fishery Investigations, Series II Volume XIX, 533 p.
- Bohnsack, J.A., and J.S. Ault. 1996. Management strategies to conserve marine biodiversity. *Oceanography* 9(1):73-82.
- Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. U.S. Dept. Commer., NOAA Tech. Report NMFS 41, 15 p.
- Bohnsack, J.A., D.E. Harper, and D.B. McClellan. 1994. Fisheries trends from Monroe County, Florida. *Bull. Mar. Sci.* 54(3):982-1018.
- Bohnsack, J.A. and 18 coauthors. 1999. Baseline data on reef fish. NOAA Technical Memorandum 425.
- Butterworth, D.S., and A.E. Punt. 1999. Experiences in the evaluation and implementation of management procedures. *ICES Journal of Marine Science* 56:985-998.
- Claro, R. 1991. Changes in fish assemblages structure by the effect of intense fisheries activity. *Trop. Ecol.* 32(1):36-46.
- Claro, R. 1994. Ecología de los peces marinos de Cuba. Centro de Investigaciones de Quintana Roo, Mexico, 547 p.
- Cochran, W.G. 1977. Sampling Techniques. 2<sup>nd</sup> Edition. John Wiley & Sons. 428 p.
- Darcy, G.H., and G.C. Matlock. 1999. Application of the precautionary approach in the national standard guidelines for conservation and management of fisheries in the United States. *ICES Journal of Marine Science* 56:853-859.
- Davis, G.E., and E.B. Thue. 1979. Fishery data management handbook—Everglades National Park. U.S. National Park Service. South Florida Research Center Report T-546. 77 p.
- de Sylva, D.P. 1976. Fishes of Biscayne Bay, Florida. In A. Thorhaug (ed.), Biscayne Bay:Past/Present/Future. Univ of Miami Symposium, April 1976. Miami, FL.
- Diaz, G.A., Smith, S.G., Serafy, J.E., and J.S. Ault. 2001. Allometry of the growth of pink shrimp *Farfantepenaeus duorarum* in a subtropical Bay. *Trans. Amer. Fish. Soc.* 132:141-148.
- Dixon, R.L., and G.R. Hunstman. 1992. Estimating catches and fishing effort of the southeastern United States headboat fleet, 1972-1982. U.S. Dept. Commer., NMFS Tech. Report, 23 p. and append.
- Ehrhardt, N.M., and J.S. Ault. 1992. Analysis of two length-based mortality models applied to bounded catch length frequencies. *Trans. Am. Fish. Soc.* 121: 115-122.
- FAO. 1997. FAO-ICLARM stock assessment tools (FiSAT). United Nations Food and Agricultural Organization. (<http://www.fao.org>)
- Fausch, K.D., J. Lyons, J.R. Karr, and P.L. Angermeier. 1990. Fish communities as indicators of environmental degradation. *Amer. Fish. Soc. Symp.* 8:123-144.
- Froese, R. and D. Pauly. Editors. 2001. FishBase: world wide web electronic publication. [www.fishbase.org](http://www.fishbase.org), 06 February 2001.
- Gilbert, C.R. 1992. Rare and endangered biota of Florida. Vol II. Fishes, University of Florida, Gainesville.
- Glynn, P.W., and J.S. Ault. 2000. A biogeographic analysis and review of the far eastern Pacific coral reef region. *Coral Reefs* 19:4-23.
- Gulland, J.A. 1983. Fish stock assessment: a manual of basic methods. FAO/Wiley Series on Food and Agriculture. Vol. 1, 223 p.
- Harper, D.E., Bohnsack, J.A., and B.R. Lockwood. 2000. Recreational fisheries in Biscayne National Park, Florida, 1976-1991. *Marine Fisheries Review* 62(1):8-26.

- Hudson, E., and G. Mace. 1996. Marine fish and the IUCN Red List of Threatened animals. Report of the workshop held in collaboration with World Wildlife Fund (WWF) and IUCN at the Zoological Society of London, April-May 1996. WWF and IUCN, London.
- Huntsman, G.R. 1994. Endangered marine finfish: neglected resources or beasts of fiction? *Fisheries* 19(7):8-15.
- Knight, G.R. 2000. Tracking list of rare, threatened, and endangered plants, animals and natural communities of Florida. Florida Natural Areas Inventory. Tallahassee, FL. 80 p.
- Lindeman, K.C., Pugliese, R., Waugh, G.T. and J.S. Ault. 2000. Developmental pathways within a multispecies reef fishery: management applications for essential habitats and marine reserves. *Bulletin of Marine Science* 66(3):929-956.
- Mace, P. 1997. Developing and sustaining world fishery resources: state of science and management. Pages 1-20 in Developing and Sustaining World Fisheries Resources: The State of Science and Management, D.A. Hancock, D.C. Smith, A. Grant, and J.P. Beumer (eds.). Proc. Second World Fishery Congress, Brisbane, Australia, 797 p.
- Manly, B.F.J., McDonald, L.L., and D.L. Thomas. 1993. Resource selection by animals: statistical design and analysis for field studies. Chapman & Hall. London. 177 p.
- Meester, G.A., J.S. Ault, and J.A. Bohnsack. 1999. Visual censussing and the extraction of average length as a biological indicator of stock health. *Naturalista sicil.* Vol. XXIII (Suppl.): 205-222.
- Meester, G.A. 2000. A mathematical programming and simulation-based approach to determining critical factors in the design of effective marine reserve plans for coral reef fishes. Doctoral Dissertation. University of Miami. 251 p.
- Munro, J.L. and D.M. Williams. 1985. Assessment and management of coral reef fisheries: Biological, environmental, and socio-economic aspects. Proc. Fifth Intern. Coral Reef Congress. Tahiti. 4:544-578.
- Musick, J.A. 1998. Endangered marine fishes: criteria and identification of North American stocks at risk. *Fisheries* 23 (2):28-30.
- Musick, J.A. 1999. Criteria to define extinction risk in marine fishes. *Fisheries* 24(12):6-14.
- Musick, J.A., M.M. Harbin, S.A. Berkeley, G.H. Burgess, A.M. Eklund, L. Findley, R.G. Gilmore, J.T. Golden, D.S. Ha, G.R. Huntsman, J.C. McGovern, S.J. Parker, S.G. Poss, E. Sala, T.W. Schmidt, G.R. Sedberry, H. Weeks, and S.G. Wright. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific Salmonids. *Fisheries* 25(11):6-30.
- NMFS. 1999. Control parameters and alternatives for control rules for selected stocks under the jurisdiction of the South Atlantic Fishery Management Council. NMFS Technical Memorandum. 44 p.
- NOAA. 1996. Magnuson-Stevens Fishery Management and Conservation Act amended through 11 October 1996. NOAA Technical Memorandum NMFS-F/SPO-23.
- NPS. 2000. Dry Tortugas National Park: Draft General Management Plan Amendment and Environmental Impact Statement. Denver Service Center. 272 p.
- Quinn, T.J., and R. Deriso. 1999. Quantitative Fish Dynamics. Oxford Univ. Press. 542 p.
- Restrepo, V.R., and J.E. Powers. 1999. Precautionary control rules in U.S. fisheries management: specifications and performance. *ICES Journal of Marine Science* 56:846-852.
- Ricker, W.E. 1963. Big effects from small causes: two examples from fish population dynamics. *J. Fish. Res. Board Can.* 20:257-264.

- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191, 382 p.
- Rosenberg, A (Convener), P. Mace, G. Thompson, G. Darcy, W. Clark, J. Collie, W. Gabriel, P. Goodyear, A. MacCall, R. Methot, J. Powers, V. Restrepo, T. Wainwright, L. Botsford, J. Hoenig, K. Stokes. 1996. Scientific review of definitions of overfishing in U.S. fishery management plans. NOAA Technical Memorandum NMFS-F/SPO-17, 205 p.
- Rothschild, B.J., Ault, J.S., Gouletquer, P., and Heäl, M. 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. *Marine Ecology Progress Series* 111(2&3):29-39.
- Rothschild, B.J., Ault, J.S., and Smith, S.G. 1996. A systems science approach to fisheries stock assessment and management. Pages 473-492 in Stock Assessment: Quantitative Methods and Applications for Small Scale Fisheries, Gallucci, V.F., Saila, S., Gustafson, D., and B.J. Rothschild (eds.). Lewis Publishers (Division of CRC Press). Chelsea, Michigan, 527 p.
- Rubec, P.J., Bexley, J.C.W., Coyne, M.S., Monaco, M., Smith, S.G., and Ault, J.S. 1999. Sustainability modeling to delineate habitat essential to sustainable fisheries. *American Fisheries Society Symposium* 22:108-133.
- Russ, G.R., and A.C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. *Mar. Ecol. Prog. Ser.* 56:13-27.
- Schmidt, T.W., Ault, J.S., and J.A. Bohnsack. 1999. Site characterization for the Dry Tortugas region: fisheries and essential habitats. Report to the Florida Keys National Marine Sanctuary and National Park Service. 113 p. plus appendices.
- Serafy, J.E., Lindeman, K.C., Hopkins, T.E., and Ault, J.S. 1997. Effects of freshwater canal discharge on fish assemblages in a subtropical bay: field and laboratory observations. *Marine Ecology Progress Series* 160:161-171.
- Smith-Vaniz, W.F., J.A. Bohnsack and J.D. Williams. 1995. Reef Fishes of the Florida Keys. Pages 279-284 in Our Living Resources. U.S. Department of the Interior - National Biological Service. Washington, D.C.
- Sokal, R.R., and F.J. Rohlf. 1981. Biometry. The principles of practice of statistics in biological research. 2<sup>nd</sup> Ed. Freeman & Co. San Francisco, CA.
- Voss, G.L., F.M. Bayer, C.R. Robins, M.Gomon and E.T. LaRoe. 1969. The marine ecology of the Biscayne National Monument. Rept. to the NPS from the IMS, Univ. Miami, Miami, FL.
- Walters, C.J. 1986. Adaptive Management of Renewable Resources. MacMillan Publishing Co. New York. 374 p.
- Wang, J.D., Cofer-Shabica S.V., and J. Chin Fatt. 1988. Finite element characteristic advection model. *J. Hyd. Eng.*, 114(9):1098-1114.
- Wang, J.D., Luo, J., and J.S. Ault. 2001. Flows, salinity, and biological transport in south Biscayne Bay, Florida. *Bulletin of Marine Science* (in review)

## List of Appendices

**Appendix A.**- Biscayne National Park regional databases used in the site characterization.

**Appendix B.**- Species list comprised of 325 species for Biscayne National Park, ordered by family and Latin name. The number of each species within the three surveys (reef fish visual surveys (RVC), CREEL survey, and TRAWL surveys) used to compute average length estimates is given under the appropriate column, a number greater than 0 indicates that the species is present in the survey. A 1\* indicates that the species was present in the survey, but no lengths were available. Highlighted rows indicate species for which further fisheries assessment is conducted.

**Appendix C.**- Indicators of stock status for BNP exploited fisheries resources (about 90 species) for the period 1976 to 1999 as determined by the BNP Creel survey and the RVC survey databases:  $n$  is the number of survey samples; legal is  $\bar{L}$  computed using the minimum size of first capture regulated by fishery management. SE is the standard error of the mean estimate of  $\bar{L}$ ; Actual is  $\bar{L}$  computed from the minimum size of first capture determined from Creel survey catches; CPUE is catch (number of fish) per person-hours fishing. CPUE for the RVC survey is:  $IM$  computed between the integral limits of  $L_r * L_m$ ; MAT is between  $L_m * L_c$ ; and, Legal is  $L_c * L_r$ .

**Appendix D(1).**- SAS programs used for processing reef fish visual census (RVC) data and estimating average length in the exploited phase and catch per unit effort.

**Appendix D(2).**- SAS programs used for processing recreational creel survey (CREEL) data and estimating average length in the exploited phase and catch per unit effort.

**Appendix E.**- LBAR FORTRAN computer programs, users guide, and data input files.

**Appendix F.**- REEFS FORTRAN computer programs, users guide, and data input files.

## **Appendix A** **Biscayne National Park Region Databases**

### **(A) Benthic Habitat Databases**

#### **[1] NOAA/NOS Hydrographic Surveys**

Source: NOAA Silver Spring, MD; NOS, Boulder, Colorado.

Description: Depth soundings, NOS Hydrographic Survey Data Vol. 1, Ver. 4;

Spatial Coverage: Depth soundings, Florida coast.

Variables: Latitude, Longitude, Depth

#### **[2] FMRI Florida Keys Benthic Habitats Survey**

Source: Chris Friel and Frank Sargeant, FMRI St. Petersburg

Description: Benthic habitat characterization interpreted from aerial photographic surveys.

Spatial Coverage: Entire Florida Keys region, including Biscayne National Park.

Overview: GIS layers of bottom substrate classifications, generally limited to depths shallower than 30 feet.

Variables: Multiple categories of coral reef, seagrass, hardbottom, and sand/rock benthic substrates; land and shoreline coverages.

### **(B) Water Quality Databases**

#### **[3] SFWMD Water Quality Sampling**

Source: South Florida Water Quality Management District, DBHYDRO Database

Description: Point samples of surface, mid-water and bottom water quality parameters.

Time Frame: 1995-1998

Spatial Coverage: 54 sampling stations within southern Biscayne Bay.

Variables: Station ID, Date, Latitude, Longitude, Depth, Temperature, Salinity, Nutrients.

#### **[4] RSMAS / Wang Biscayne Bay Hydrodynamic Model**

Source: John Wang, RSMAS

Description: 2D finite element numerical model of water currents and salinity.

Time Frame: 1995-1998

Spatial Coverage: South Biscayne Bay, Card Sound, Barnes Sound.

Input Data: Information on winds, tides, water currents, canal discharges, salinities, rainfall, evaporation, overland water flow, groundwater flow.

Model Outputs: Water current vectors and salinity, horizontal spatial grid resolution 150-1000 m.

## (C) Animals—Fishery Independent Databases

### [5] NMFS / Bohnsack Reef Fishes Visual Census

Source: James Bohnsack, SEFSC, and Jerald Ault, RSMAS

Description: Fishery-independent diver survey of reef fish population abundance and size structure using the Bohnsack and Bannerot (1986) stationary visual census technique.

Time Frame: 1983-1992, 1995-1999

Spatial Coverage: 17 reef locations in the Biscayne National Park region.

Sampling Overview: 863 total diver samples; 182 species; 47 families.

Variables: Sample ID, Date, Reef ID, Latitude, Longitude, Depth, Bottom type, Reef habitat, Species, Abundance (number observed), Length (cm).

### [6] RSMAS/ Ault Roller Frame Trawl Survey

Source: Jerald Ault, RSMAS

Description: Stratified random fishery-independent roller frame trawl survey of macroinvertebrate and fish population abundance and size structure (Ault et al. 1999).

Time Frame: 1996-1997, 1999-2000

Spatial Coverage: 983 station locations in southern Biscayne Bay.

Sampling Overview: 983 total trawl samples; 155 species; 49 families.

Variables: Sample ID, Date, Latitude, Longitude, Tow area, Depth, Temperature, Salinity, Dissolved Oxygen, Habitat Type, Species, Catch, Length (mm).

## (D) Animals—Fishery Dependent Databases

### [7] BNP Recreational Creel Census

Source: Doug Harper, NOAA Fisheries SEFSC; Brian Lockwood, NPS BNP

Description: Fishery-dependent dockside sampling survey conducted by BNP personnel of recreational fishing effort, species landings and size composition.

Time Frame: 1976-1998

Spatial Coverage: BNP and surrounding area.

Sampling Overview: 29,940 total interviews; 143 species; 45 families.

Variables: Record ID, Date, Area, Gear, Effort, Species, Number landed, Length, Number released.

### [8] NMFS Recreational Headboat Landings

Source: NMFS, Beaufort

Description: Fishery-dependent sampling survey conducted by NMFS personnel of the species and size composition of the recreational headboat catch.

Time Frame: 1981-1995

Spatial Coverage: Florida Keys, including BNP region.

Sampling Overview: 853 total trip samples; 275 species categories.

Variables: Trip ID, Date, Area, Number of Anglers, Species, Catch in Numbers, Catch in Weight, Sex, Length, Weight.

## [9] **NMFS General Canvas Commercial Landings**

Source: Pamela Eyo, NOAA SEFSC

Description: Commercial sector landings data collected by NMFS Port Agents and the State of Florida trip-ticket system for harvested species.

Time Frame: 1986-1999

Spatial Coverage: Water body code #944.2, encompassing Biscayne Bay, Card Sound, and Barnes Sound.

Overview: 57 species categories.

Variables: Year, Species, Total Catch (lbs.), Dockside Value (1997-99 only).

**Appendix B.** - Species list comprised of 325 species for Biscayne National Park, ordered by family and Latin name. The number of each species within the three surveys (reef fish visual surveys (RVC), CREEL survey, and TRAWL surveys) used to compute average length estimates is given under the appropriate column, a number greater than 0 indicates that the species is present in the survey. A 1\* indicates that the species was present in the survey, but no lengths were available. Highlighted rows indicate species for which further fisheries assessment is conducted.

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Acanthuridae	<i>Acanthurus bahianus</i>	ocean surgeon	5897	2	1
Acanthuridae	<i>Acanthurus chirurgus</i>	doctorfish	1553	34	20
Acanthuridae	<i>Acanthurus coeruleus</i>	blue tang	4595	2	0
Albulidae	<i>Albula vulpes</i>	bonefish	0	7	0
Antennariidae	<i>Histrio histrio</i>	sargassumfish	0	0	1
Apogonidae	<i>Apogon planifrons</i>	pale cardinalfish	0	0	1
Apogonidae	<i>Astrapogon alutus</i>	bronze cardinalfish	0	0	1637
Apogonidae	<i>Astrapogon puncticulatus</i>	blackfin cardinalfish	0	0	220
Apogonidae	<i>Astrapogon stellatus</i>	conchfish	0	0	2
Apogonidae	<i>Phaeoptyx pigmentaria</i>	dusky cardinalfish	0	0	1
Atherinidae	<i>Atherinomorus stipes</i>	hardhead silverside	0	0	8
Atherinidae	<i>Hypoatherina harringtonensis</i>	reef silverside	17500	0	0
Atherinidae	<i>Membras martinica</i>	rough silverside	0	0	11
Aulostomidae	<i>Aulostomus maculatus</i>	trumpetfish	285	0	0
Balistidae	<i>Aluterus monocerus</i>	unicorn filefish	0	0	1
Balistidae	<i>Aluterus schoepfii</i>	orange filefish	14	2	0
Balistidae	<i>Aluterus scriptus</i>	scrawled filefish	114	11	18
Balistidae	<i>Balistes capriscus</i>	gray triggerfish	24	208	2
Balistidae	<i>Balistes vetula</i>	queen triggerfish	40	73	0
Balistidae	<i>Cantherhines macrocerus</i>	whitespotted filefish	15	0	0
Balistidae	<i>Cantherhines pullus</i>	orangespotted filefish	37	0	0
Balistidae	<i>Cantherhines sufflamen</i>	ocean triggerfish	25	321	2
Balistidae	<i>Melichthys niger</i>	black durgon	2	0	0
Balistidae	<i>Monacanthus ciliatus</i>	fringed filefish	0	0	2665
Balistidae	<i>Monacanthus hispidus</i>	planehead filefish	15	0	739
Balistidae	<i>Monacanthus tuckeri</i>	slender filefish	6	0	12
Batrachoididae	<i>Opsanus beta</i>	gulf toadfish	0	0	4480
Belonidae	<i>Tylosurus acus</i>	agujon (needlefish)	0	0	1
Belonidae	<i>Tylosurus crocodilus</i>	houndfish	0	42	0
Blenniidae	<i>Hypsoblennius ionthas</i>	freckled blenny	0	0	1
Blenniidae	<i>Ophioblennius atlanticus</i>	redlip blenny	5	0	0
Blenniidae	<i>Scartella cristata</i>	molly miller	1	0	1
Bothidae	<i>Bothus lunatus</i>	peacock flounder	1	0	46
Bothidae	<i>Bothus ocellatus</i>	eyed flounder	2	0	47
Bothidae	<i>Bothus robinsi</i>	twospot flounder	0	0	8
Bothidae	<i>Citharichthys arenaceus</i>	sand whiff	0	0	2
Bothidae	<i>Citharichthys macrops</i>	spotted whiff	0	0	20
Bothidae	<i>Citharichthys spilopterus</i>	bay whiff	0	0	1
Bothidae	<i>Paralichthys alboguttata</i>	gulf flounder	0	1	4
Bythitidae	<i>Ogilbia cayorum</i>	key brotula	0	0	1
Bythitidae	<i>Petrotyx sanguineus</i>	redfin brotula	0	0	1
Callionymidae	<i>Diplogrammus pauciradiatus</i>	spotted dragonet	0	0	44
Carangidae	<i>Alectis ciliaris</i>	african pompano	0	24	0
Carangidae	<i>Caranx bartholomaei</i>	yellow jack	478	524	0
Carangidae	<i>Caranx cryos</i>	blue runner	474	1954	2
Carangidae	<i>Caranx hippos</i>	crevalle jack	0	80	0
Carangidae	<i>Caranx latus</i>	horse-eye jack	0	19	0
Carangidae	<i>Caranx ruber</i>	bar jack	3637	97	0
Carangidae	<i>Decapterus macarellus</i>	mackerel scad	1	32	0
Carangidae	<i>Elagatis bipinnulata</i>	rainbow runner	0	15	0
Carangidae	<i>Oligoplites saurus</i>	leatherjack	0	24	0
Carangidae	<i>Selar crumenophthalmus</i>	bigeye scad	0	15	0
Carangidae	<i>Selene vomer</i>	lookdown	0	44	0
Carangidae	<i>Seriola dumerili</i>	greater amberjack	2	107	0
Carangidae	<i>Seriola fasciata</i>	lesser amberjack	0	4	0
Carangidae	<i>Seriola rivoliana</i>	almaco jack	0	10	0
Carangidae	<i>Trachinotus carolinus</i>	Florida pompano	0	2	0
Carangidae	<i>Trachinotus falcatus</i>	permit	2	24	0

**Appendix B.- (Continued)**

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Carapidae	<i>Carapus bermudensis</i>	pearfish	0	0	1
Carcharhinidae	<i>Carcharhinus brevipinna</i>	spinner shark	0	1	0
Carcharhinidae	<i>Carcharhinus falciformis</i>	silky shark	0	1	0
Carcharhinidae	<i>Carcharhinus limbatus</i>	blacktip shark	0	7	0
Carcharhinidae	<i>Negaprion brevirostris</i>	lemon shark	0	3	0
Centropomidae	<i>Centropomus ensiferus</i>	swordspine snook	0	1	0
Centropomidae	<i>Centropomus undecimalis</i>	common snook	0	1*	0
Chaetodontidae	<i>Chaetodon capistratus</i>	foureye butterflyfish	809	0	3
Chaetodontidae	<i>Chaetodon ocellatus</i>	spotfin butterflyfish	495	0	0
Chaetodontidae	<i>Chaetodon sedentarius</i>	reef butterflyfish	353	0	0
Chaetodontidae	<i>Chaetodon striatus</i>	banded butterflyfish	154	0	0
Cirrhitidae	<i>Amblycirrhitus pinos</i>	redspotted hawkfish	4	0	0
Clinidae	<i>Malacoctenus macropus</i>	rosy blenny	1	0	0
Clinidae	<i>Malacoctenus triangulatus</i>	saddled blenny	1	0	0
Clinidae	<i>Paraclinus marmoratus</i>	marbled blenny	0	0	44
Clupeidae	<i>Harengula jaguana</i>	scaled sardine	10600	0	0
Clupeidae	<i>Jenkinsia majua</i>	little-eye herring	0	0	2
Coryphaenidae	<i>Coryphaena equisetis</i>	pompano dolphin	0	2	0
Coryphaenidae	<i>Coryphaena hippurus</i>	dolphin	0	6993	0
Cyprinodontidae	<i>Cyprinodon variegatus</i>	sheepshead minnow	0	0	2
Cyprinodontidae	<i>Floridichthys carpio</i>	goldspotted killifish	0	0	3
Cyprinodontidae	<i>Lucania parva</i>	rainwater killifish	0	0	61
Dasyatidae	<i>Dasyatis americana</i>	southern stingray	11	0	0
Echeneidae	<i>Echeneis naucrates</i>	sharksucker	13	1	0
Echeneidae	<i>Remora remora</i>	remora	0	5	0
Elopidae	<i>Elops saurus</i>	ladyfish	0	27	0
Elopidae	<i>Megalops atlanticus</i>	tarpon	0	1*	0
Ephippidae	<i>Chaetodipterus faber</i>	atlantic spadefish	276	36	3
Exocoetidae	<i>Chriodus atherinoides</i>	hardhead halfbeak	0	0	4
Exocoetidae	<i>Hemiramphus balao</i>	balao	0	0	1
Exocoetidae	<i>Hemiramphus brasiliensis</i>	ballyhoo	547	38	1
Exocoetidae	<i>Hyporhamphus unifasciatus</i>	silverstripe halfbeak	0	0	10
Fistulariidae	<i>Fistularia petimba</i>	red cornetfish	0	0	2
Fistulariidae	<i>Fistularia tabacaria</i>	bluespotted cornetfish	1	0	0
Gadidae	<i>Urophycis regia</i>	spotted hake	0	0	2
Gasterosteidae	<i>Pungitius pungitius</i>	ninespine stickleback	0	0	1
Gerreidae	<i>Eucinostomus argenteus</i>	spotfin mojarra	0	0	232
Gerreidae	<i>Eucinostomus gula</i>	silver jenny	0	0	3160
Gerreidae	<i>Eucinostomus jonesi</i>	slender mojarra	0	0	50
Gerreidae	<i>Gerres cinereus</i>	yellowfin mojarra	32	18	5
Gobiidae	<i>Bathigobius curacao</i>	notchtongue goby	0	0	1
Gobiidae	<i>Coryphopterus dircrus</i>	colon goby	32	0	2
Gobiidae	<i>Coryphopterus glaucofraenum</i>	bridled goby	1294	0	24
Gobiidae	<i>Coryphopterus personatus</i>	masked goby	653	0	0
Gobiidae	<i>Coryphopterus punctippectophorus</i>	spotted goby	0	0	12
Gobiidae	<i>Gnatholepis thompsoni</i>	goldspot goby	92	0	0
Gobiidae	<i>Gobionellus saepewallens</i>	dash goby	0	0	1
Gobiidae	<i>Gobionellus shufeldti</i>	freshwater goby	0	0	1
Gobiidae	<i>Gobionellus stigmaphilus</i>	spotfin goby	0	0	32
Gobiidae	<i>Gobionellus stigmaturus</i>	spottail goby	0	0	5
Gobiidae	<i>Gobiosoma bosc</i>	naked goby	0	0	1
Gobiidae	<i>Gobiosoma evelynae</i>	sharknose goby	1	0	0
Gobiidae	<i>Gobiosoma oceanops</i>	neon goby	96	0	0
Gobiidae	<i>Gobiosoma randalli</i>	yellownose goby	0	1	0
Gobiidae	<i>Gobiosoma robustum</i>	code goby	0	0	1
Gobiidae	<i>Ioglossus calliurus</i>	blue goby	12	0	0
Gobiidae	<i>Ioglossus heleneae</i>	hovering goby	1	0	0
Gobiidae	<i>Microgobius microlepis</i>	banner goby	0	0	87
Gobiidae	<i>Nes longus</i>	orangespotted goby	0	0	2
Haemulidae	<i>Anisotremus surinamensis</i>	black margate	75	207	0
Haemulidae	<i>Anisotremus virginicus</i>	porkfish	1113	200	9

**Appendix B.- (Continued)**

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Haemulidae	<i>Haemulon album</i>	margate	19	269	0
Haemulidae	<i>Haemulon aurolineatum</i>	tomtate	26483	97	73
Haemulidae	<i>Haemulon carbonarium</i>	ceasar grunt	354	81	0
Haemulidae	<i>Haemulon chrysargyreum</i>	smallmouth grunt	2104	4	0
Haemulidae	<i>Haemulon flavolineatum</i>	french grunt	5975	113	76
Haemulidae	<i>Haemulon macrostomium</i>	spanish grunt	113	35	0
Haemulidae	<i>Haemulon melanurum</i>	cottonwick	106	0	0
Haemulidae	<i>Haemulon parra</i>	sailors choice	187	594	61
Haemulidae	<i>Haemulon plumieri</i>	white grunt	10179	14499	3855
Haemulidae	<i>Haemulon sciurus</i>	bluestriped grunt	3628	4569	2350
Haemulidae	<i>Haemulon striatum</i>	striped grunt	5	78	0
Haemulidae	<i>Orthopristis chrysoptera</i>	pigfish	0	33	57
Holocentridae	<i>Holocentrus adscensionis</i>	squirrelfish	53	57	0
Holocentridae	<i>Holocentrus rufus</i>	longspine squirrelfish	58	0	0
Holocentridae	<i>Holocentrus vexillarius</i>	dusky squirrelfish	8	0	0
Inermiidae	<i>Inermia vittata</i>	boga	180	0	0
Istiophoridae	<i>Istiophorus platypterus</i>	sailfish	0	38	0
Istiophoridae	<i>Makaira nigricans</i>	blue marlin	0	1	0
Istiophoridae	<i>Tetrapturus albidus</i>	white marlin	0	2	0
Kyphosidae	<i>Kyphosus incisor</i>	yellow chub	0	44	0
Kyphosidae	<i>Kyphosus sectatrix</i>	bermuda chub	1472	176	0
Labridae	<i>Bodianus pulchellus</i>	spotfin hogfish	5	0	0
Labridae	<i>Bodianus rufus</i>	spanish hogfish	188	39	0
Labridae	<i>Clepticus parrae</i>	creole wrasse	1148	0	0
Labridae	<i>Halichoeres bivittatus</i>	slippery dick	3200	14	0
Labridae	<i>Halichoeres garnoti</i>	yellowhead wrasse	4382	0	0
Labridae	<i>Halichoeres maculipinna</i>	clown wrasse	3150	0	0
Labridae	<i>Halichoeres pictus</i>	rainbow wrasse	6	0	0
Labridae	<i>Halichoeres poeyi</i>	blackear wrasse	6	0	0
Labridae	<i>Halichoeres radiatus</i>	puddingwife	318	66	0
Labridae	<i>Hemipteronotus martinicensis</i>	rosy razorfish	226	0	0
Labridae	<i>Hemipteronotus novacula</i>	pearly razorfish	13	0	0
Labridae	<i>Hemipteronotus splendidus</i>	green razorfish	28	0	0
Labridae	<i>Lachnolaimus maximus</i>	hogfish	333	6510	163
Labridae	<i>Thalassoma bifasciatum</i>	bluehead	41819	0	0
Lobotidae	<i>Lobotes surinamensis</i>	tripletail	0	50	0
Lutjanidae	<i>Etelis oculatus</i>	queen snapper	0	9	0
Lutjanidae	<i>Lutjanus analis</i>	mutton snapper	22	1966	65
Lutjanidae	<i>Lutjanus apodus</i>	schoolmaster	1940	597	8
Lutjanidae	<i>Lutjanus buccanella</i>	blackfin snapper	0	16	0
Lutjanidae	<i>Lutjanus campechanus</i>	red snapper	0	25	0
Lutjanidae	<i>Lutjanus cyanopterus</i>	cupera snapper	0	11	0
Lutjanidae	<i>Lutjanus griseus</i>	gray snapper	2314	10688	594
Lutjanidae	<i>Lutjanus jocu</i>	dog snapper	11	58	2
Lutjanidae	<i>Lutjanus mahogoni</i>	mahogony snapper	16	32	0
Lutjanidae	<i>Lutjanus synagris</i>	lane snapper	82	409	242
Lutjanidae	<i>Lutjanus vivanus</i>	silk snapper	0	7	0
Lutjanidae	<i>Ocyurus chrysurus</i>	yellowtail snapper	3861	5243	142
Lutjanidae	<i>Rhomboptilus aurorubens</i>	vermillion snapper	0	23	0
Malacanthidae	<i>Malacanthus plumieri</i>	sand tilefish	46	77	0
Mullidae	<i>Mulloidichthys martinicus</i>	yellow goatfish	580	5	0
Mullidae	<i>Pseudupeneus maculatus</i>	spotted goatfish	435	4	0
Muraenidae	<i>Gymnothorax funebris</i>	green moray	5	1	0
Muraenidae	<i>Gymnothorax millaris</i>	goldentail moray	2	0	0
Muraenidae	<i>Gymnothorax moringa</i>	spotted moray	8	0	2
Muraenidae	<i>Gymnothorax nigromarginatus</i>	blackedge moray	0	0	10
Muraenidae	<i>Gymnothorax saxicola</i>	honeycomb moray	1	0	7
Muraenidae	<i>Gymnothorax vicinus</i>	purplemouth moray	1	0	0
Myliobatidae	<i>Aetobatus narinari</i>	spotted eagle ray	1	0	0
Ogcocephalidae	<i>Ogcocephalus corniger</i>	longnose batfish	0	0	2
Opistognathidae	<i>Opistognathus aurifrons</i>	yellowhead jawfish	26	0	0

**Appendix B.- (Continued)**

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Ostraciidae	<i>Lactophrys bicaudalis</i>	spotted trunkfish	13	0	4
Ostraciidae	<i>Lactophrys polygona</i>	honeycomb cowfish	3	0	5
Ostraciidae	<i>Lactophrys quadricornis</i>	scrawled cowfish	15	0	784
Ostraciidae	<i>Lactophrys trigonus</i>	trunkfish	6	8	85
Ostraciidae	<i>Lactophrys triqueter</i>	smooth trunkfish	132	10	0
Palinuridae	<i>Panulirus argus</i>	Caribbean spiny lobster	1*	16764	1*
Palinuridae	<i>Panulirus guttatus</i>	spotted spiny lobster	0	28	0
Pempheridae	<i>Pempheris schomburgki</i>	glassy sweeper	686	0	0
Penaeidae	<i>Penaeus duorarum</i>	pink shrimp	0	0	103896
Pomacanthidae	<i>Centropyge argi</i>	cherubfish	1	0	0
Pomacanthidae	<i>Holacanthus bermudensis</i>	blue angelfish	172	0	0
Pomacanthidae	<i>Holacanthus ciliaris</i>	queen angelfish	174	2	0
Pomacanthidae	<i>Holacanthus tricolor</i>	rock beauty	697	0	0
Pomacanthidae	<i>Pomacanthus arcuatus</i>	gray angelfish	899	2	11
Pomacanthidae	<i>Pomacanthus paru</i>	french angelfish	194	0	0
Pomacentridae	<i>Abudefduf saxatilis</i>	sergeant major	7819	0	0
Pomacentridae	<i>Chromis cyanea</i>	blue chromis	1844	0	0
Pomacentridae	<i>Chromis insolata</i>	sunshinefish	6	0	0
Pomacentridae	<i>Chromis multilineata</i>	brown chromis	797	0	0
Pomacentridae	<i>Chromis scotti</i>	purple reefish	18	0	0
Pomacentridae	<i>Microspathodon chrysurus</i>	yellowtail damselfish	1057	0	0
Pomacentridae	<i>Pomacentrus diencaeus</i>	longfin damselfish	89	0	0
Pomacentridae	<i>Pomacentrus fuscus</i>	dusky damselfish	720	0	0
Pomacentridae	<i>Pomacentrus leucostictus</i>	beaugregory	296	0	1
Pomacentridae	<i>Pomacentrus partitus</i>	bicolor damselfish	30183	0	1
Pomacentridae	<i>Pomacentrus planifrons</i>	threespot damselfish	1702	0	1
Pomacentridae	<i>Pomacentrus variabilis</i>	cocoa damselfish	700	0	1
Pomatomidae	<i>Pomatomus saltatrix</i>	bluefish	0	72	0
Portunidae	<i>Callinectes sapidus</i>	blue crab	0	4	0
Priacanthidae	<i>Priacanthus arenatus</i>	bigeye	4	84	0
Prosobranchia	<i>Strombus gigas</i>	queen conch	0	1*	0
Rachycentridae	<i>Rachycentron canadum</i>	cobia	0	12	0
Rhinodontidae	<i>Ginglymostoma cirratum</i>	nurse shark	8	15	0
Scaridae	<i>Cryptotomus roseus</i>	bluelip parrotfish	145	0	8
Scaridae	<i>Nicholsina usta</i>	emerald parrotfish	0	0	593
Scaridae	<i>Scarus coeruleinus</i>	midnight parrotfish	108	0	3
Scaridae	<i>Scarus coeruleus</i>	blue parrotfish	214	13	0
Scaridae	<i>Scarus croicensis</i>	striped parrotfish	8476	0	24
Scaridae	<i>Scarus guacamaia</i>	rainbow parrotfish	148	0	3
Scaridae	<i>Scarus taeniopterus</i>	princess parrotfish	3329	0	3
Scaridae	<i>Scarus vetula</i>	queen parrotfish	414	0	0
Scaridae	<i>Sparisoma atomarium</i>	greenblotch parrotfish	223	0	12
Scaridae	<i>Sparisoma aurofrenatum</i>	redband parrotfish	8321	0	1
Scaridae	<i>Sparisoma chrysopurpureum</i>	redtail parrotfish	317	0	629
Scaridae	<i>Sparisoma radians</i>	bucktooth parrotfish	31	0	128
Scaridae	<i>Sparisoma rubripinne</i>	redfin parrotfish	396	0	20
Scaridae	<i>Sparisoma viride</i>	stoplight parrotfish	3361	0	6
Sciaenidae	<i>Bairdiella chrysoura</i>	silver perch	0	0	2
Sciaenidae	<i>Cynoscion nebulosus</i>	spotted seatrout	0	565	34
Sciaenidae	<i>Equetus acuminatus</i>	high-hat	55	0	26
Sciaenidae	<i>Equetus lanceolatus</i>	jackknife-fish	0	0	4
Sciaenidae	<i>Equetus punctatus</i>	spotted drum	13	0	0
Sciaenidae	<i>Equetus umbrosus</i>	cubbyu	3	0	0
Sciaenidae	<i>Odontoscion dentex</i>	reef croaker	18	0	0
Scombridae	<i>Acanthocybium solandri</i>	wahoo	0	111	0
Scombridae	<i>Auxis rochei</i>	bullet mackerel	0	2	0
Scombridae	<i>Euthynnus alletteratus</i>	little tunny	0	140	0
Scombridae	<i>Katsuwonus pelamis</i>	skipjack tuna	0	41	0
Scombridae	<i>Sarda sarda</i>	atlantic bonito	0	87	0
Scombridae	<i>Scomberomorus cavalla</i>	king mackerel	0	198	0
Scombridae	<i>Scomberomorus maculatus</i>	spanish mackerel	1	132	0

**Appendix B.- (Continued)**

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Scombridae	<i>Scomberomorus regalis</i>	cero	60	586	0
Scombridae	<i>Thunnus albacares</i>	yellowfin tuna	0	1	0
Scombridae	<i>Thunnus atlanticus</i>	blackfin tuna	0	27	0
Scorpaenidae	<i>Neomerinthe hemingwayi</i>	spinycheek scorpionfish	0	0	1
Scorpaenidae	<i>Scorpaena brasiliensis</i>	barbfish	0	0	296
Scorpaenidae	<i>Scorpaena dispar</i>	hunchback scorpionfish	0	0	1
Scorpaenidae	<i>Scorpaena grandicornis</i>	plumed scorpionfish	0	0	16
Scorpaenidae	<i>Scorpaena inermis</i>	mushroom scorpionfish	0	0	3
Scorpaenidae	<i>Scorpaena plumieri</i>	spotted scorpionfish	7	0	6
Scyllaridae	<i>Scyllarides aequinoctialis</i>	spanish (shovelnose) lobster	0	33	0
Serranidae	<i>Diplectrum bivittatum</i>	dwarf sand perch	0	0	12
Serranidae	<i>Diplectrum formosum</i>	sand perch	2	160	94
Serranidae	<i>Epinephelus adscensionis</i>	rock hind	7	84	0
Serranidae	<i>Epinephelus cruentatus</i>	graysby	567	522	0
Serranidae	<i>Epinephelus drummondhayi</i>	speckled hind	0	5	0
Serranidae	<i>Epinephelus flavolimbatus</i>	yellowedge grouper	0	12	0
Serranidae	<i>Epinephelus fulvus</i>	coney	13	28	0
Serranidae	<i>Epinephelus guttatus</i>	red hind	15	234	0
Serranidae	<i>Epinephelus inermis</i>	marbled grouper	0	1	0
Serranidae	<i>Epinephelus itajara</i>	Goliath grouper	0	4	0
Serranidae	<i>Epinephelus morio</i>	red grouper	42	2093	0
Serranidae	<i>Epinephelus striatus</i>	nassau grouper	10	739	0
Serranidae	<i>Hopplectrus chlorurus</i>	yellowtail hamlet	1	0	0
Serranidae	<i>Hopplectrus gemma</i>	blue hamlet	100	0	0
Serranidae	<i>Hopplectrus guttavarius</i>	shy hamlet	3	0	0
Serranidae	<i>Hopplectrus indigo</i>	indigo hamlet	11	0	0
Serranidae	<i>Hopplectrus nigricans</i>	black hamlet	15	0	0
Serranidae	<i>Hopplectrus puella</i>	barred hamlet	50	0	0
Serranidae	<i>Hopplectrus unicolor</i>	butter hamlet	320	0	0
Serranidae	<i>Liopropoma eukrines</i>	wrasse bass	1	0	0
Serranidae	<i>Mycteroperca bonaci</i>	black grouper	22	618	1
Serranidae	<i>Mycteroperca interstitalis</i>	yellowmouth grouper	2	48	0
Serranidae	<i>Mycteroperca microlepis</i>	gag	1	327	0
Serranidae	<i>Mycteroperca phenax</i>	scamp	2	13	0
Serranidae	<i>Mycteroperca venenosa</i>	yellowfin grouper	1	26	0
Serranidae	<i>Paranthias furcifer</i>	creole-fish	0	2	0
Serranidae	<i>Rypticus saponaceus</i>	greater soapfish	4	3	0
Serranidae	<i>Serranus baldwini</i>	lantern bass	5	0	1
Serranidae	<i>Serranus tabacarius</i>	tobaccofish	123	0	0
Serranidae	<i>Serranus tigrinus</i>	harlequin bass	464	0	0
Soleidae	<i>Achirus lineatus</i>	lined sole	0	0	39
Soleidae	<i>Gymnachirus melas</i>	naked sole	0	0	1
Soleidae	<i>Syphurus diomedianus</i>	spottedfin tonguefish	0	0	1
Soleidae	<i>Syphurus plagiusa</i>	blackcheek tonguefish	0	0	21
Soleidae	<i>Syphurus urospilus</i>	spottail tonguefish	0	0	1
Soleidae	<i>Trinectes inscriptus</i>	scrawled sole	0	0	2
Sparidae	<i>Archosargus rhomboidalis</i>	sea bream	3	113	42
Sparidae	<i>Calamus arctifrons</i>	grass porgy	0	64	65
Sparidae	<i>Calamus bajonado</i>	jolthead porgy	37	1642	0
Sparidae	<i>Calamus calamus</i>	saucereye porgy	159	725	0
Sparidae	<i>Calamus nodosus</i>	knobbed porgy	0	18	0
Sparidae	<i>Calamus penna</i>	sheepshead porgy	0	9	3
Sparidae	<i>Calamus proridens</i>	littlehead porgy	5	66	2
Sparidae	<i>Lagodon rhomboides</i>	pinfish	0	346	8163
Sphyraenidae	<i>Sphyraena barracuda</i>	great barracuda	418	1841	2
Sphyraenidae	<i>Sphyraena picudilla</i>	southern sennet	0	0	1*
Sphymidae	<i>Sphyraena lewini</i>	scalloped hammerhead	2	0	0
Sphymidae	<i>Sphyraena mokarran</i>	great hammerhead	0	4	0
Sphymidae	<i>Sphyraena tiburo</i>	bonnethead shark	0	28	0
Stromateidae	<i>Psenes maculatus</i>	silver driftfish	0	0	5
Syngnathidae	<i>Cosmocampus albirostris</i>	whitenose pipefish	0	0	180

**Appendix B.- (Continued)**

FAMILY	LATIN	COMMON	Survey		
			RVC	CREEL	TRAWL
Syngnathidae	<i>Hippocampus erectus</i>	lined seahorse	0	0	253
Syngnathidae	<i>Hippocampus reidi</i>	longsnout seahorse	0	0	37
Syngnathidae	<i>Hippocampus zosterae</i>	dwarf seahorse	0	0	12
Syngnathidae	<i>Syngnathus floridae</i>	dusky pipefish	0	0	145
Syngnathidae	<i>Syngnathus louisianae</i>	chain pipefish	0	0	3
Syngnathidae	<i>Syngnathus pelagicus</i>	sargassum pipefish	0	0	1
Syngnathidae	<i>Syngnathus scovelli</i>	gulf pipefish	0	0	27
Synodontidae	<i>Synodus foetens</i>	inshore lizardfish	1	0	69
Synodontidae	<i>Synodus intermedius</i>	sand diver	10	0	0
Synodontidae	<i>Trachinocephalus myops</i>	snakefish	0	0	1
Tetraodontidae	<i>Canthigaster rostrata</i>	sharpnose puffer	618	0	3
Tetraodontidae	<i>Chilomycterus antennatus</i>	bridled burrfish	1	0	1
Tetraodontidae	<i>Chilomycterus schoepfi</i>	striped burrfish	1	0	71
Tetraodontidae	<i>Diodon holocanthus</i>	balloonfish	31	0	6
Tetraodontidae	<i>Diodon hystrix</i>	porcupinefish	12	0	1
Tetraodontidae	<i>Sphoeroides maculatus</i>	northern puffer	0	0	7
Tetraodontidae	<i>Sphoeroides nephelus</i>	southern puffer	0	0	1
Tetraodontidae	<i>Sphoeroides spengleri</i>	bandtail puffer	12	0	325
Tetraodontidae	<i>Sphoeroides testudineus</i>	checkered puffer	0	0	2
Triglidae	<i>Prionotus scitulus</i>	leopard searobin	0	0	27
Uranoscopidae	<i>Dactyloscopus tridigitatus</i>	sand stargazer	0	0	2
Urolophidae	<i>Urolophus jamaicensis</i>	yellow stingray	69	0	4
Xanthidae	<i>Menippe mercenaria</i>	Florida stone crab	0	2	0

## Appendix C1.-

**rock hind**  
*Epinephelus adscensionis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.000										
1977				0			0.000										
1978				0			0.001										
1979				1	300.0	0.0	0.004										
1980				3	400.0	57.7	0.001										
1981				5	342.0	42.1	0.002										
1982				11	303.6	23.2	0.005										
1983				12	330.8	31.4	0.001										
1984				0			0.000										
1985				10	312.0	24.1	0.002										
1986				5	394.0	44.5	0.001										
1987				1	300.0	0.0	0.000										
1988				3	346.7	14.5	0.001										
1989				4	342.5	48.7	0.001										
1990				2	295.0	25.0	0.001										
1991				5	276.0	44.5	0.001										
1992				11	260.0	15.4	0.005										
1993				3	350.0	26.5	0.001										
1994				2	325.0	25.0	0.001										
1995				0			0.000										
1996				1	310.0	0.0	0.001										
1997				0			0.000										
1998				4	242.5	19.3	0.001										
1999																	

## Appendix C2.-

**graysby**  
*Epinephelus cruentatus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.000										
1977				0			0.000										
1978				5	242.0	11.1	0.002										
1979				10	277.0	14.6	0.007										
1980				19	252.6	8.3	0.009										
1981				48	256.7	5.8	0.011										
1982				8	242.5	10.8	0.007										
1983				52	251.2	5.2	0.010										
1984				6	253.3	16.3	0.002										
1985				35	260.6	6.1	0.006										
1986				15	268.0	6.3	0.005										
1987				26	248.5	5.0	0.005										
1988				59	256.6	4.1	0.017										
1989				20	264.0	6.0	0.008										
1990				50	248.6	4.5	0.019										
1991				9	255.6	9.6	0.002										
1992				7	267.1	14.1	0.002										
1993				19	250.0	8.3	0.010										
1994				24	248.3	4.7	0.010										
1995				9	242.2	12.3	0.008										
1996				15	250.0	7.7	0.012										
1997				50	236.8	3.9	0.023										
1998				6	236.7	9.2	0.002										
1999																	

## Appendix C3.-

**speckled hind**  
*Epinephelus drummondhayi*

Year	CREEL Survey Data						RVC Survey Data						CPUE					
	Lbar			CPUE			Lbar			CPUE			CPUE					
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976				0			0.000											
1977				0			0.000											
1978				0			0.000											
1979				0			0.000											
1980				0			0.000											
1981				0			0.000											
1982				0			0.000											
1983				0			0.000											
1984				0			0.000											
1985				1	300.0	0.0	0.000											
1986				1	550.0	0.0	0.000											
1987				0			0.000											
1988				1	410.0	0.0	0.000											
1989				0			0.000											
1990				0			0.000											
1991				0			0.000											
1992				0			0.000											
1993				0			0.000											
1994				0			0.000											
1995				0			0.000											
1996				1	500.0	0.0	0.002											
1997				0			0.000											
1998				1	290.0	0.0	0.001											
1999																		

## Appendix C4.-

**yellowedge grouper**  
*Epinephelus flavolimbatus*

Year	CREEL Survey Data						RVC Survey Data						CPUE					
	Lbar			CPUE			Lbar			CPUE			CPUE					
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976				0			0.000											
1977				0			0.000											
1978				0			0.000											
1979				0			0.000											
1980				0			0.000											
1981				0			0.000											
1982				3	256.7	6.7	0.000											
1983				7	497.1	23.8	0.003											
1984				0			0.000											
1985				0			0.000											
1986				0			0.000											
1987				0			0.000											
1988				0			0.000											
1989				0			0.000											
1990				0			0.000											
1991				0			0.000											
1992				1	240.0	0.0	0.000											
1993				1	630.0	0.0	0.000											
1994				0			0.000											
1995				0			0.000											
1996				0			0.000											
1997				0			0.000											
1998				0			0.000											
1999																		

## Appendix C5.-

**coney**  
*Epinephelus fulvus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.000												
1980	1	250.0	0.0		0.000												
1981	0				0.000												
1982	3	253.3	14.5		0.001												
1983	1	220.0	0.0		0.001			0			0.000	0.000				0.000	
1984	0				0.000			0			0.000	0.000				0.000	
1985	0				0.000			0			0.000	0.000				0.000	
1986	0				0.000			0			0.000	0.000				0.000	
1987	4	312.5	34.2		0.001			2	250.0	2.0	0.000	0.081				0.054	
1988	3	246.7	3.3		0.001			0			0.003	0.000				0.000	
1989	0				0.000			1	350.0	0.0	0.000	0.004				0.004	
1990	0				0.000			0			0.009	0.000				0.000	
1991	0				0.000			0			0.040	0.000				0.000	
1992	8	250.0	9.6		0.002			2	250.0	0.0	0.000	0.018				0.018	
1993	2	255.0	15.0		0.001			.			.	.				.	.
1994	1	280.0	0.0		0.000			.			.	.				.	.
1995	1	300.0	0.0		0.001			0			0.000	0.005				0.000	
1996	0				0.000			0			0.000	0.000				0.000	
1997	1	270.0	0.0		0.001			0			0.000	0.000				0.000	
1998	1	280.0	0.0		0.001			0			0.000	0.000				0.000	
1999								0			0.000	0.000				0.000	

## Appendix C6.-

**red hind**  
*Epinephelus guttatus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	2	280.0	10.0		0.004												
1979	6	358.3	26.4		0.012												
1980	21	309.5	10.1		0.009												
1981	28	328.6	11.8		0.006												
1982	25	308.8	14.4		0.015												
1983	13	313.8	21.8		0.003			1	200.0	0.0	0.028	0.000			0.028		
1984	6	345.0	27.7		0.004			0			0.000	0.000			0.000		
1985	43	224.0	11.2		0.005			0			0.000	0.000			0.000		
1986	9	280.0	16.2		0.002			0			0.000	0.000			0.000		
1987	11	302.7	13.1		0.002			0			0.000	0.000			0.000		
1988	20	302.0	8.7		0.009			0			0.007	0.000			0.000		
1989	2	360.0	70.0		0.000			2	260.0	6.0	0.004	0.002			0.006		
1990	3	320.0	17.3		0.001			2	250.0	0.0	0.010	0.000			0.010		
1991	7	264.3	15.1		0.008			0			0.000	0.000			0.000		
1992	9	273.3	12.7		0.005			0			0.000	0.000			0.000		
1993	3	310.0	11.5		0.001			.			.	.			.	.	.
1994	4	295.0	32.8		0.001			.			.	.			.	.	.
1995	5	290.0	9.5		0.005			2	290.0	1.0	0.031	0.005			0.005		
1996	5	302.0	17.7		0.002			0			0.000	0.000			0.000		
1997	2	300.0	20.0		0.001			0			0.000	0.000			0.000		
1998	10	347.0	21.8		0.002			1	200.0	0.0	0.008	0.000			0.008		
1999								1	340.0	0.0	0.014	0.029			0.029		

## Appendix C7.-

**marbled grouper**  
*Epinephelus inermis*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	0															
1977	0															
1978	0															
1979	0															
1980	0															
1981	0															
1982	0															
1983	1	440.0	0.0													
1984	0															
1985	0															
1986	0															
1987	0															
1988	0															
1989	0															
1990	0															
1991	0															
1992	0															
1993	0															
1994	0															
1995	0															
1996	0															
1997	0															
1998	0															
1999																

## Appendix C8.-

**Goliath grouper**  
*Epinephelus itajara*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	0			0			0.000									
1977	0			0			0.000									
1978	0			0			0.000									
1979	0			0			0.001									
1980	0			0			0.000									
1981	3	1170.0	225.0	3	1170.0	225.0	0.001									
1982	0			0			0.000									
1983	1	1010.0	0.0	1	1010.0	0.0	0.001									
1984	0			0			0.000									
1985	0			0			0.000									
1986	0			0			0.000									
1987	0			0			0.000									
1988	0			0			0.000									
1989	0			0			0.000									
1990	0			0			0.000									
1991	0			0			0.005									
1992	0			0			0.000									
1993	0			0			0.000									
1994	0			0			0.000									
1995	0			0			0.000									
1996	0			0			0.000									
1997	0			0			0.000									
1998	0			0			0.000									
1999																

**Appendix C9.-**

**red grouper**  
*Epinephelus morio*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	307	347.6	6.1	307	347.6	6.1	0.004										
1977	91	402.1	13.0	91	402.1	13.0	0.000										
1978	115	431.1	8.5	115	431.1	8.5	0.009										
1979	87	446.3	11.8	87	446.3	11.8	0.043										
1980	133	434.6	9.2	133	434.6	9.2	0.025										
1981	227	426.5	6.0	227	426.5	6.0	0.034										
1982	80	413.8	12.9	80	413.8	12.9	0.019										
1983	232	382.2	6.0	232	382.2	6.0	0.043	0		0				0.000	0.000	0.000	0.000
1984	66	382.7	9.5	66	382.7	9.5	0.031	0		0				0.000	0.000	0.000	0.000
1985	42	511.0	6.8	188	388.0	5.7	0.036	0		0				0.000	0.000	0.000	0.000
1986	25	528.8	15.5	48	450.2	15.1	0.013	0		0				0.000	0.000	0.000	0.000
1987	29	498.6	6.6	69	422.3	9.3	0.024	0		0				0.027	0.000	0.000	0.000
1988	32	503.8	8.0	70	437.4	9.1	0.016	0		0				0.020	0.000	0.000	0.000
1989	22	525.9	11.6	63	428.6	10.8	0.016	0		2	350.0	0.0	0.000	0.000	0.000	0.000	0.000
1990	12	556.7	10.8	24	515.0	10.5	0.006	1	700.0	0.0	3	533.3	8.3	0.013	0.000	0.000	0.000
1991	10	559.0	9.9	13	543.1	11.5	0.006	0		0				0.010	0.000	0.000	0.000
1992	30	592.3	14.4	36	576.1	13.4	0.012	0		1	450.0	0.0	0.000	0.000	0.000	0.000	0.000
1993	14	555.7	9.1	32	513.1	8.2	0.020	.		.	.	.	.	.	.	.	.
1994	31	563.9	8.0	39	547.9	8.2	0.011	.		.	.	.	.	.	.	.	.
1995	9	544.4	12.8	13	525.4	12.1	0.008	0		0				0.030	0.000	0.000	0.000
1996	10	562.0	8.7	12	551.7	10.0	0.017	0		1	450.0	0.0	0.015	0.015	0.000	0.015	0.015
1997	13	530.0	7.3	23	508.7	7.0	0.009	0		0				0.063	0.000	0.000	0.000
1998	23	539.1	7.3	29	529.7	6.8	0.009	0		0				0.008	0.000	0.000	0.000
1999							0			1	460.0	0.0	0.048	0.050	0.000	0.050	0.050

**Appendix C13.-**

**nassau grouper**  
*Epinephelus striatus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	99	439.7	13.2	99	439.7	13.2	0.001										
1977	67	462.1	23.7	67	462.1	23.7	0.000										
1978	98	444.6	8.8	98	444.6	8.8	0.001										
1979	64	450.2	11.4	64	450.2	11.4	0.014										
1980	91	427.0	8.9	91	427.0	8.9	0.012										
1981	120	468.4	6.3	120	468.4	6.3	0.004										
1982	26	450.8	22.5	26	450.8	22.5	0.007										
1983	26	418.8	18.8	26	418.8	18.8	0.002	0		0				0.000	0.000	0.000	0.000
1984	5	398.0	10.2	5	398.0	10.2	0.002	0		0				0.000	0.000	0.000	0.000
1985	10	546.0	20.8	34	415.0	16.7	0.005	0		0				0.000	0.000	0.000	0.000
1986	7	601.4	9.6	14	489.3	32.2	0.002	0		0				0.000	0.000	0.000	0.000
1987	7	555.7	54.1	11	491.8	43.4	0.001	0		0				0.000	0.000	0.000	0.000
1988	7	512.9	16.0	14	446.4	22.3	0.002	0		0				0.000	0.000	0.000	0.000
1989	9	528.9	15.1	12	496.7	20.6	0.002	1	460.0	0.0	1	460.0	0.0	0.002	0.000	0.002	0.002
1990	7	565.7	16.3	7	565.7	16.3	0.000	1	600.0	0.0	1	600.0	0.0	0.000	0.004	0.004	0.004
1991	1	650.0	0.0	1	650.0	0.0	0.000	0		0				0.000	0.000	0.000	0.000
1992	2	515.0	5.0	2	515.0	5.0	0.000	1	600.0	0.0	1	600.0	0.0	0.018	0.009	0.009	0.009
1993	0		0		0.000												
1994	0		0		0.000												
1995	0		0		0.000	0			0					0.036	0.000	0.000	0.000
1996	0		0		0.001	0			0					0.014	0.000	0.000	0.000
1997	0		0		0.000	1	640.0	0.0	1	640.0	0.0	0.000	0.008	0.008	0.008	0.008	0.008
1998	2	590.0	20.0	2	590.0	20.0	0.001	0		0				0.000	0.000	0.000	0.000
1999					0					0				0.000	0.000	0.000	0.000

## Appendix C14.-

**black grouper**  
*Mycteroperca bonaci*

Year	CREEL Survey Data						RVC Survey Data											
	Lbar			CPUE			Lbar			CPUE								
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976	1	370.0	0.0	1	370.0	0.0	0.000											
1977	11	603.6	51.5	11	603.6	51.5	0.000											
1978	25	612.0	39.7	25	612.0	39.7	0.002											
1979	59	555.9	19.7	59	555.9	19.7	0.007											
1980	72	536.8	16.3	72	536.8	16.3	0.006											
1981	93	585.2	17.6	93	585.2	17.6	0.005											
1982	34	497.6	26.6	34	497.6	26.6	0.007											
1983	46	541.5	27.3	46	541.5	27.3	0.002	0		0			0.000	0.000	0.000	0.000		
1984	29	602.1	35.2	29	602.1	35.2	0.005	0		0			0.000	0.000	0.000	0.000		
1985	20	584.5	23.4	53	450.8	17.5	0.006	0		0			0.000	0.000	0.000	0.000		
1986	10	587.0	20.3	14	532.1	28.9	0.001	0		0			0.000	0.000	0.000	0.000		
1987	11	613.6	39.0	18	517.2	38.0	0.002	0		0			0.000	0.000	0.000	0.000		
1988	9	571.1	50.3	15	501.3	38.5	0.001	0		4	380.0	27.0	0.025	0.000	0.000	0.018		
1989	16	607.5	31.7	21	556.7	31.8	0.004	0		0			0.000	0.000	0.000	0.000		
1990	12	650.0	33.6	13	638.5	33.0	0.001	1	650.0	0.0	1	650.0	0.0	0.005	0.004	0.004	0.004	
1991	4	702.5	79.2	5	662.0	73.5	0.000	0		0			0.024	0.000	0.000	0.000		
1992	7	688.6	27.9	7	688.6	27.9	0.000	1	650.0	0.0	1	650.0	0.0	0.010	0.010	0.010	0.010	
1993	7	624.3	32.4	7	624.3	32.4	0.001	.		.		.	.	.	.	.	.	
1994	11	677.3	20.8	11	677.3	20.8	0.002	.		.		.	.	.	.	.	.	
1995	7	708.6	27.9	7	708.6	27.9	0.005	0		0			0.000	0.000	0.000	0.000		
1996	10	706.0	20.7	11	687.3	26.5	0.003	0		0			0.015	0.000	0.000	0.000		
1997	12	610.8	15.2	13	602.3	16.4	0.000	0		0			0.000	0.000	0.000	0.000		
1998	9	663.3	24.2	9	663.3	24.2	0.006	0		0			0.023	0.000	0.000	0.000		
1999							0			0			0.035	0.000	0.000	0.000		

## Appendix C15.-

**yellowmouth grouper**  
*Mycteroperca interstitialis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	1	530.0	0.0	1	530.0	0.0	0.000										
1979	1	520.0	0.0	1	520.0	0.0	0.000										
1980	5	406.0	24.8	5	406.0	24.8	0.001										
1981	26	545.4	29.5	26	545.4	29.5	0.003										
1982	1	780.0	0.0	1	780.0	0.0	0.000										
1983	1	730.0	0.0	1	730.0	0.0	0.000	0		0			0.000	0.000	0.000	0.000	
1984	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1985	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1986	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1987	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1988	8	582.5	35.7	8	582.5	35.7	0.000	0		0			0.000	0.000	0.000	0.000	
1989	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1990	0			0			0.000	0		0			0.008	0.000	0.000	0.000	
1991	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1992	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1993	0			0			0.000	.		.		.	.	.	.	.	
1994	0			0			0.000	.		.		.	.	.	.	.	
1995	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1996	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1997	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1998	0			0			0.000	0		0			0.000	0.000	0.000	0.000	
1999							0			0			0.000	0.000	0.000	0.000	

## Appendix C16.-

**gag**  
*Mycteroperca microlepis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	5	486.0	110.7	5	486.0	110.7	0.000										
1977	9	454.4	45.1	9	454.4	45.1	0.000										
1978	37	566.8	25.8	37	566.8	25.8	0.002										
1979	14	440.7	16.1	14	440.7	16.1	0.005										
1980	34	442.4	13.8	34	442.4	13.8	0.002										
1981	27	532.2	30.9	27	532.2	30.9	0.002										
1982	34	375.0	14.4	34	375.0	14.4	0.008										
1983	46	468.3	20.8	46	468.3	20.8	0.004	0		0				0.000	0.000	0.000	0.000
1984	13	443.8	39.6	13	443.8	39.6	0.004	0		0				0.000	0.000	0.000	0.000
1985	7	644.3	61.7	14	508.6	48.6	0.001	0		0				0.000	0.000	0.000	0.000
1986	4	685.0	33.0	6	580.0	71.9	0.001	0		0				0.000	0.000	0.000	0.000
1987	8	511.3	24.2	19	428.4	20.1	0.003	0		0				0.000	0.000	0.000	0.000
1988	15	560.0	22.1	15	560.0	22.1	0.003	0		0				0.000	0.000	0.000	0.000
1989	1	630.0	0.0	3	423.3	103.5	0.001	0		0				0.000	0.000	0.000	0.000
1990	2	720.0	170.0	3	633.3	130.9	0.000	0		0				0.000	0.000	0.000	0.000
1991	11	603.6	15.4	11	603.6	15.4	0.002	0		0				0.000	0.000	0.000	0.000
1992	1	530.0	0.0	3	510.0	10.0	0.000	0		0				0.000	0.000	0.000	0.000
1993	6	710.0	37.8	6	710.0	37.8	0.001	.		.			.	.	.	.	.
1994	5	574.0	30.9	8	541.3	24.6	0.005	.		.			.	.	.	.	.
1995	2	585.0	45.0	5	528.0	27.5	0.001	0		0				0.000	0.000	0.000	0.000
1996	3	633.3	37.6	3	633.3	37.6	0.000	0		0				0.000	0.000	0.000	0.000
1997	0		0			0.000	0			0				0.000	0.000	0.000	0.000
1998	1	570.0	0.0	1	570.0	0.0	0.000	0		0				0.000	0.000	0.000	0.000
1999						0				0				0.000	0.000	0.000	0.000

## Appendix C17.-

**scamp**  
*Mycteroperca phenax*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0		0			0.000											
1977	0		0			0.000											
1978	0		0			0.000											
1979	2	320.0	20.0	2	320.0	20.0	0.000										
1980	3	346.7	6.7	3	346.7	6.7	0.000										
1981	4	587.5	47.5	4	587.5	47.5	0.000										
1982	0		0			0.000											
1983	0		0			0.000	0		0					0.000	0.000	0.000	
1984	0		0			0.000	0		0					0.000	0.000	0.000	
1985	0		0			0.000	0		0					0.000	0.000	0.000	
1986	1	350.0	0.0	1	350.0	0.0	0.000	0		0				0.000	0.000	0.000	
1987	0		0			0.000	0		0					0.000	0.000	0.000	
1988	0		0			0.000	0		0					0.000	0.000	0.000	
1989	0		0			0.000	0		0					0.000	0.000	0.000	
1990	0		0			0.000	0		0					0.000	0.000	0.000	
1991	0		0			0.000	0		0					0.000	0.000	0.000	
1992	0		0			0.000	0		0					0.000	0.000	0.000	
1993	0		0			0.000	.		.					.	.	.	
1994	0		0			0.000	.		.					.	.	.	
1995	0		0			0.000	0		0					0.000	0.000	0.000	
1996	0		0			0.000	0		0					0.000	0.000	0.000	
1997	0		0			0.000	0		0					0.000	0.000	0.000	
1998	1	580.0	0.0	1	580.0	0.0	0.000	0		0				0.000	0.000	0.000	
1999						0			0					0.050	0.000	0.000	

## Appendix C18.-

**yellowfin grouper**  
*Myxteroperca venenosa*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	5	564.0	52.8	5	564.0	52.8	0.006										
1979	1	450.0	0.0	1	450.0	0.0	0.009										
1980	10	401.0	11.1	10	401.0	11.1	0.002										
1981	1	590.0	0.0	1	590.0	0.0	0.000										
1982	8	640.0	45.5	8	640.0	45.5	0.012										
1983	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1984	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1985	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1986	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1987	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1988	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1989	0			1	300.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1990	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1991	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1992	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1993	0			0			0.000	.		.		.	.	.	.	.	
1994	0			0			0.000	.		.		.	.	.	.	.	
1995	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1996	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1997	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1998	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1999							0			0		0.000	0.000	0.000	0.000	0.000	

## Appendix C19.-

**mutton snapper**  
*Lutjanus analis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	134	409.6	13.7	134	409.6	13.7	0.000										
1977	62	351.5	20.8	62	351.5	20.8	0.000										
1978	70	445.3	18.8	70	445.3	18.8	0.004										
1979	62	399.8	14.3	62	399.8	14.3	0.021										
1980	138	477.8	11.9	138	477.8	11.9	0.022										
1981	149	463.9	12.2	149	463.9	12.2	0.019										
1982	64	402.5	17.0	64	402.5	17.0	0.015										
1983	161	392.4	11.9	161	392.4	11.9	0.016	1	300.0	0.0	1	300.0	0.0	0.000	0.028	0.028	0.028
1984	64	396.9	15.4	64	396.9	15.4	0.017	0			0			0.000	0.000	0.000	0.000
1985	55	408.9	14.3	67	381.0	13.8	0.006	0			0			0.000	0.000	0.000	0.000
1986	51	413.5	14.5	69	371.2	13.8	0.012	0			0			0.000	0.000	0.000	0.000
1987	82	424.1	12.8	198	325.1	8.0	0.029	0			0			0.000	0.000	0.000	0.000
1988	62	397.4	14.2	80	367.3	12.7	0.018	4	382.5	69.3	5	364.0	56.8	0.000	0.048	0.044	0.048
1989	65	389.7	13.2	76	368.9	12.7	0.020	2	355.0	25.0	2	355.0	25.0	0.000	0.007	0.007	0.007
1990	67	404.6	10.4	78	385.6	10.4	0.017	3	360.0	20.8	3	360.0	20.8	0.000	0.009	0.009	0.009
1991	56	419.3	12.4	63	400.8	12.9	0.023	3	433.3	33.3	3	433.3	33.3	0.000	0.040	0.040	0.040
1992	82	391.1	9.6	94	376.6	9.3	0.022	1	400.0	0.0	4	292.5	37.3	0.027	0.018	0.009	0.036
1993	78	413.2	11.6	95	385.2	11.4	0.028										
1994	36	501.7	14.7	99	385.1	10.8	0.023										
1995	15	476.7	16.6	29	408.6	16.8	0.017	0			0			0.000	0.000	0.000	0.000
1996	13	526.9	29.6	26	436.9	23.7	0.007	0			0			0.000	0.000	0.000	0.000
1997	6	523.3	52.8	14	409.3	37.0	0.007	1	400.0	0.0	1	400.0	0.0	0.000	0.013	0.013	0.013
1998	14	517.9	34.5	23	445.2	29.0	0.007	0			0			0.000	0.000	0.000	0.000
1999							1	450.0	0.0	1	450.0	0.0	0.013	0.025	0.025	0.025	

## Appendix C20.-

**schoolmaster**  
*Lutjanus apodus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	4	305.0	26.0	4	305.0	26.0	0.002										
1979	11	286.4	18.4	11	286.4	18.4	0.003										
1980	15	264.7	12.5	15	264.7	12.5	0.004										
1981	51	262.5	6.5	51	262.5	6.5	0.005										
1982	12	267.5	5.2	12	267.5	5.2	0.004										
1983	55	306.9	10.8	55	306.9	10.8	0.003	0		0		0.000	0.000	0.000	0.000	0.000	
1984	4	272.5	23.9	4	272.5	23.9	0.001	0		0		0.000	0.000	0.000	0.000	0.000	
1985	10	249.0	9.9	10	249.0	9.9	0.002	0		0		0.000	0.000	0.000	0.000	0.000	
1986	27	270.4	9.4	27	270.4	9.4	0.002	0		0		0.000	0.000	0.000	0.000	0.000	
1987	37	264.9	10.5	37	264.9	10.5	0.008	0		0		0.000	0.000	0.000	0.000	0.000	
1988	30	267.7	5.6	30	267.7	5.6	0.005	177	244.8	3.0	177	244.8	3.0	0.021	1.072	0.887	0.887
1989	45	264.0	4.8	45	264.0	4.8	0.013	123	269.7	3.4	123	269.7	3.4	0.225	0.587	0.403	0.403
1990	26	303.8	10.2	30	295.3	9.7	0.005	277	283.4	2.3	285	282.4	2.3	0.211	3.037	1.176	1.225
1991	15	288.0	11.5	18	280.0	10.4	0.003	9	297.8	12.9	9	297.8	12.9	0.021	0.281	0.094	0.094
1992	38	284.7	5.5	42	280.5	5.4	0.008	9	280.4	11.4	10	276.3	11.0	0.280	0.918	0.086	0.086
1993	17	286.5	7.6	19	281.6	7.5	0.006	.		.		.	.	.	.	.	.
1994	57	272.8	3.3	61	270.7	3.2	0.011	.		.		.	.	.	.	.	.
1995	14	281.4	9.9	16	276.3	9.3	0.011	33	285.2	5.0	33	285.2	5.0	0.045	0.842	0.379	0.379
1996	9	271.1	9.2	13	261.5	7.5	0.004	110	305.2	3.1	110	305.2	3.1	0.154	1.972	1.521	1.521
1997	16	270.6	4.0	18	267.2	4.3	0.007	61	301.1	4.9	64	298.2	4.9	0.125	1.308	1.021	1.071
1998	24	290.4	3.8	24	290.4	3.8	0.002	1	280.0	0.0	1	280.0	0.0	0.265	0.409	0.008	0.008
1999							0			0		0.013	0.050	0.000	0.000		

## Appendix C21.-

**blackfin snapper**  
*Lutjanus buccanella*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0													
1977	0			0													
1978	0			0													
1979	0			0													
1980	4	315.0	9.6	4	315.0	9.6											
1981	0			0													
1982	0			0													
1983	2	385.0	5.0	2	385.0	5.0											
1984	0			0													
1985	0			0													
1986	0			0													
1987	0			0													
1988	0			0													
1989	0			0													
1990	0			0													
1991	3	360.0	32.1	5	320.0	30.2											
1992	0			3	233.3	3.3											
1993	0			0													
1994	0			0													
1995	0			0													
1996	0			0													
1997	0			0													
1998	0			0													
1999																	

## Appendix C22.-

**red snapper**  
*Lutjanus campechanus*

Year	CREEL Survey Data						RVC Survey Data								IM			Mat		Legal		Actual	
	Lbar			CPUE			Lbar			CPUE			IM			Mat		Legal		Actual			
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual						
1976	0		0																				
1977	0		0																				
1978	0		0																				
1979	0		0																				
1980	0		0																				
1981	0		0																				
1982	0		0																				
1983	7	345.7	13.1	7	345.7	13.1																	
1984	0		0																				
1985	1	740.0	0.0	1	740.0	0.0																	
1986	5	356.0	6.0	5	356.0	6.0																	
1987	0		0																				
1988	0		0																				
1989	0		0	10	210.0	3.0																	
1990	0		0																				
1991	0		0																				
1992	0		0																				
1993	0		0																				
1994	0		0																				
1995	0		0																				
1996	0		0																				
1997	0		0																				
1998	0		0																				
1999																							

## Appendix C23.-

**yellowtail snapper**  
*Ocyurus chrysurus*

Year	CREEL Survey Data						RVC Survey Data								IM			Mat		Legal		Actual	
	Lbar			CPUE			Lbar			CPUE			IM			Mat		Legal		Actual			
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual						
1976	237	231.7	2.4	237	231.7	2.4	0.002																
1977	55	300.9	18.1	55	300.9	18.1	0.000																
1978	171	245.7	3.9	171	245.7	3.9	0.032																
1979	104	266.7	5.2	104	266.7	5.2	0.107																
1980	341	268.7	3.7	341	268.7	3.7	0.153																
1981	272	246.3	3.3	272	246.3	3.3	0.125																
1982	175	245.0	3.8	175	245.0	3.8	0.141																
1983	422	241.3	2.4	422	241.3	2.4	0.095	73	230.9	3.4	73	230.9	3.4	2.556	1.750	2.028	2.028						
1984	165	251.0	3.1	165	251.0	3.1	0.070	0		0				0.000	0.000	0.000	0.000						
1985	137	331.0	3.4	338	290.9	2.3	0.085	0		0				0.000	0.000	0.000	0.000						
1986	47	344.5	7.1	98	303.8	5.3	0.021	0		0				0.429	0.143	0.000	0.000						
1987	91	345.5	5.4	131	322.9	4.8	0.025	0		3	266.7	8.8	0.324	0.270	0.000	0.081							
1988	79	331.6	4.4	179	297.9	3.1	0.047	3	346.7	29.1	10	288.0	15.3	1.837	0.379	0.008	0.040						
1989	41	339.5	7.8	118	292.0	4.3	0.043	8	328.8	17.7	153	259.2	1.8	1.059	1.334	0.026	0.419						
1990	93	324.6	2.9	174	300.5	2.6	0.040	47	321.0	3.6	171	279.2	2.3	3.085	1.308	0.190	0.683						
1991	78	342.4	5.8	137	310.3	4.6	0.043	4	312.5	12.5	12	277.2	8.6	3.845	0.488	0.048	0.136						
1992	130	343.3	4.8	250	308.4	3.5	0.046	0		0				1.288	0.109	0.000	0.000						
1993	158	323.4	1.8	305	298.9	1.8	0.093																
1994	139	321.5	2.5	386	289.3	1.6	0.078																
1995	23	333.9	7.9	93	282.8	3.8	0.048	0		2	265.0	5.0	2.141	0.120	0.000	0.016							
1996	52	320.8	3.1	122	293.7	2.7	0.030	1	300.0	0.0	36	258.2	2.2	1.669	0.861	0.014	0.500						
1997	21	317.1	3.9	54	290.4	3.6	0.019	1	310.0	0.0	5	266.0	11.7	1.321	0.221	0.013	0.077						
1998	44	339.8	14.3	118	293.8	6.3	0.048	0		3	250.0	0.0	0.323	0.127	0.000	0.038							
1999								1	300.0	0.0	1	300.0	0.0	0.292	0.086	0.013	0.013						

## Appendix C25.-

**gray snapper**  
*Lutjanus griseus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	549	255.9	2.9	549	255.9	2.9	0.008										
1977	209	237.0	3.2	209	237.0	3.2	0.000										
1978	293	271.8	4.1	293	271.8	4.1	0.026										
1979	234	253.3	3.5	234	253.3	3.5	0.285										
1980	496	262.8	2.8	496	262.8	2.8	0.281										
1981	635	285.4	2.9	635	285.4	2.9	0.241										
1982	339	262.9	3.6	339	262.9	3.6	0.197										
1983	1108	260.6	1.9	1108	260.6	1.9	0.254	4	250.0	0.0	4	250.0	0.0	0.000	0.111	0.111	0.111
1984	501	251.2	2.7	501	251.2	2.7	0.298	0		0				0.000	0.000	0.000	0.000
1985	1138	254.5	1.8	1138	254.5	1.8	0.201	0		0				0.000	0.000	0.000	0.000
1986	438	265.0	3.1	438	265.0	3.1	0.114	0		0				0.000	0.000	0.000	0.000
1987	555	254.7	2.1	555	254.7	2.1	0.161	0		0				0.000	0.000	0.000	0.000
1988	335	272.3	3.1	335	272.3	3.1	0.111	35	229.7	5.2	35	229.7	5.2	0.091	0.057	0.106	0.106
1989	440	272.5	2.9	440	272.5	2.9	0.157	135	227.7	2.9	135	227.7	2.9	0.135	0.074	0.120	0.120
1990	179	318.2	4.9	193	312.5	4.7	0.041	163	293.7	3.8	232	277.7	3.1	0.058	0.074	0.074	0.074
1991	175	303.0	4.1	185	299.6	4.0	0.063	4	307.5	7.5	4	307.5	7.5	0.688	0.042	0.042	0.042
1992	321	290.6	2.7	328	289.5	2.7	0.074	24	310.4	12.1	27	302.5	11.5	0.979	0.201	0.187	0.198
1993	366	300.6	2.8	390	296.9	2.8	0.154										
1994	539	297.5	2.5	574	294.0	2.4	0.124										
1995	221	299.2	3.2	234	295.9	3.2	0.107	12	276.1	9.8	14	271.0	8.7	1.334	0.076	0.031	0.055
1996	301	281.4	2.1	318	279.2	2.0	0.087	6	286.7	5.6	6	286.7	5.6	0.239	0.083	0.083	0.083
1997	199	303.0	4.4	211	299.4	4.3	0.088	73	277.0	3.0	73	276.7	3.0	0.375	0.356	0.348	0.356
1998	258	302.4	3.8	276	298.3	3.7	0.135	29	281.7	5.5	30	281.0	5.5	0.773	0.417	0.409	0.417
1999								0			1	240.0	0.0	0.438	0.050	0.000	0.050

## Appendix C26.-

**dog snapper**  
*Lutjanus jocu*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	0			0			0.000										
1979	2	600.0	20.0	2	600.0	20.0	0.004										
1980	4	300.0	33.4	4	300.0	33.4	0.004										
1981	16	393.1	46.9	16	393.1	46.9	0.009										
1982	3	226.7	3.3	3	226.7	3.3	0.007										
1983	3	593.3	31.8	3	593.3	31.8	0.001	0		0				0.000	0.000	0.000	0.000
1984	8	272.5	26.7	8	272.5	26.7	0.003	0		0				0.000	0.000	0.000	0.000
1985	2	470.0	250.0	2	470.0	250.0	0.004	0		0				0.000	0.000	0.000	0.000
1986	0			0			0.000	0		0				0.000	0.000	0.000	0.000
1987	0			0			0.000	0		0				0.000	0.000	0.000	0.000
1988	8	376.3	35.1	8	376.3	35.1	0.001	0		0				0.000	0.000	0.000	0.000
1989	2	415.0	175.0	2	415.0	175.0	0.001	2	350.0	0.0	2	350.0	0.0	0.000	0.008	0.008	0.008
1990	2	400.0	70.0	2	400.0	70.0	0.001	1	350.0	0.0	1	350.0	0.0	0.000	0.004	0.004	0.004
1991	0			0			0.000	0		0				0.000	0.000	0.000	0.000
1992	0			0			0.000	1	300.0	0.0	1	300.0	0.0	0.000	0.010	0.010	0.010
1993	0			0			0.000										
1994	1	420.0	0.0	1	420.0	0.0	0.002										
1995	0			0			0.000	0		0				0.109	0.000	0.000	0.000
1996	1	430.0	0.0	1	430.0	0.0	0.004	0		0				0.000	0.000	0.000	0.000
1997	0			0			0.000	0		0				0.000	0.000	0.000	0.000
1998	0			0			0.000	0		0				0.000	0.000	0.000	0.000
1999							0			0				0.000	0.000	0.000	0.000

## Appendix C27.-

**mahogany snapper**  
*Lutjanus mahogoni*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	0			0			0.000										
1979	0			0			0.000										
1980	0			0			0.000										
1981	0			0			0.000										
1982	2	440.0	10.0	2	440.0	10.0	0.000										
1983	0			0			0.000	0		0		0.000	0.000		0.000		
1984	0			0			0.000	0		0		0.000	0.000		0.000		
1985	0			0			0.000	0		0		0.000	0.000		0.000		
1986	12	213.3	12.3	12	213.3	12.3	0.002	0		0		0.000	0.000		0.000		
1987	3	316.7	24.0	3	316.7	24.0	0.000	0		0		0.000	0.000		0.000		
1988	0			0			0.000	2	225.0	25.0	2	225.0	25.0	0.008	0.000		0.008
1989	2	380.0	10.0	2	380.0	10.0	0.000	4	257.5	40.5	4	257.5	40.5	0.011	0.008		0.015
1990	2	320.0	10.0	2	320.0	10.0	0.000	1	300.0	0.0	1	300.0	0.0	0.000	0.008		0.004
1991	2	380.0	50.0	2	380.0	50.0	0.000	0		0		0.000	0.000		0.000		
1992	0			0			0.000	0		0		0.000	0.000		0.000		
1993	0			0			0.000	.	.	.	.	.	.	.	.	.	.
1994	4	350.0	24.8	4	350.0	24.8	0.000	.	.	.	.	.	.	.	.	.	.
1995	0			0			0.000	0		0		0.000	0.000		0.000		
1996	0			0			0.000	0		0		0.028	0.000		0.000		
1997	1	370.0	0.0	1	370.0	0.0	0.001	0		0		0.000	0.000		0.000		
1998	0			0			0.000	0		0		0.015	0.000		0.000		
1999							0			0		0.000	0.000		0.000		

## Appendix C28.-

**lane snapper**  
*Lutjanus synagris*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	9	241.1	13.6	9	241.1	13.6	0.010										
1979	6	300.0	13.4	6	300.0	13.4	0.009										
1980	32	253.4	5.8	32	253.4	5.8	0.016										
1981	35	239.4	8.5	35	239.4	8.5	0.013										
1982	18	225.0	9.4	18	225.0	9.4	0.013										
1983	26	235.0	8.7	26	235.0	8.7	0.011	0		0		0.000	0.000	0.000	0.000		
1984	5	202.0	8.6	5	202.0	8.6	0.002	0		0		0.000	0.000	0.000	0.000		
1985	49	241.4	9.6	49	241.4	9.6	0.007	0		0		0.000	0.000	0.000	0.000		
1986	18	242.2	11.6	18	242.2	11.6	0.005	0		0		0.000	0.000	0.000	0.000		
1987	43	242.1	7.7	43	242.1	7.7	0.009	3	230.0	0.0	3	230.0	0.0	0.027	0.081	0.081	0.081
1988	46	229.8	6.2	46	229.8	6.2	0.014	0		0		0.000	0.000	0.000	0.000		
1989	21	255.7	11.8	21	255.7	11.8	0.008	15	293.6	12.9	15	293.6	12.9	0.015	0.045	0.056	0.056
1990	13	236.2	5.7	15	230.0	6.5	0.002	0		0		0.012	0.000	0.000	0.000		
1991	24	236.7	6.4	26	233.1	6.4	0.009	5	216.8	8.9	5	216.8	8.9	0.028	0.056	0.069	0.069
1992	5	240.0	14.1	6	231.7	14.2	0.001	3	300.0	11.5	3	300.0	11.5	0.000	0.009	0.009	0.009
1993	8	251.3	21.6	9	244.4	20.2	0.001	.	.	.	.	.	.	.	.	.	.
1994	5	240.0	11.8	5	240.0	11.8	0.002	.	.	.	.	.	.	.	.	.	.
1995	1	290.0	0.0	1	290.0	0.0	0.009	0		0		0.000	0.000	0.000	0.000		
1996	4	207.5	7.5	5	204.0	6.8	0.003	0		0		0.000	0.000	0.000	0.000		
1997	0			0			0.000	1	250.0	0.0	1	250.0	0.0	0.006	0.017	0.017	0.017
1998	0			0			0.000	1	255.0	0.0	1	255.0	0.0	0.000	0.008	0.008	0.008
1999							2	273.3	109.1	2	273.3	109.1	0.050	0.075	0.125	0.125	

## Appendix C29.-

**silk snapper**  
*Lutjanus campechanus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0													
1977	0			0													
1978	0			0													
1979	0			0													
1980	0			0													
1981	0			0													
1982	0			0													
1983	0			0													
1984	0			0													
1985	5	244.0	2.4	5	244.0	2.4											
1986	0			0													
1987	0			0													
1988	2	260.0	20.0	2	260.0	20.0											
1989	0			0													
1990	0			0													
1991	0			0													
1992	0			0													
1993	0			0													
1994	0			0													
1995	0			0													
1996	0			0													
1997	0			0													
1998	0			0													
1999																	

## Appendix C31.-

**vermillion snapper**  
*Rhomboplites aurorubens*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	0			0			0.000										
1979	0			0			0.000										
1980	0			0			0.000										
1981	1	250.0	0.0	1	250.0	0.0	0.001										
1982	13	260.0	14.3	13	260.0	14.3	0.003										
1983	0			0			0.000										
1984	0			0			0.000										
1985	6	208.3	8.3	6	208.3	8.3	0.000										
1986	1	290.0	0.0	1	290.0	0.0	0.000										
1987	1	270.0	0.0	1	270.0	0.0	0.000										
1988	0			0			0.000										
1989	0			0			0.000										
1990	0			0			0.000										
1991	0			0			0.000										
1992	0			0			0.000										
1993	0			0			0.000										
1994	0			0			0.000										
1995	0			0			0.000										
1996	0			0			0.000										
1997	0			0			0.000										
1998	0			0			0.000										
1999																	

## Appendix C32.-

**hogfish**  
*Lachnolaimus maximus*

Year	CREEL Survey Data						Actual	RVC Survey Data						CPUE				
	Lbar			CPUE				Lbar			CPUE			IM	Mat	Legal	Actual	
	n	Legal	S.E.	n	Actual	S.E.		n	Legal	S.E.	n	Actual	S.E.					
1976	389	335.8	4.8	389	335.8	4.8	0.515											
1977	157	369.2	7.8	157	369.2	7.8	0.558											
1978	360	368.7	5.1	360	368.7	5.1	0.663											
1979	84	361.3	11.7	84	361.3	11.7	0.554											
1980	231	361.3	7.0	231	361.3	7.0	0.579											
1981	687	354.8	3.3	687	354.8	3.3	0.719											
1982	189	349.9	6.6	189	349.9	6.6	0.567											
1983	773	349.9	3.1	773	349.9	3.1	0.706	13	227.1	5.6	13	227.1	5.6	0.201	0.354	0.354	0.354	
1984	145	345.9	5.9	145	345.9	5.9	0.690	1	250.0	0.0	1	250.0	0.0	0.000	0.250	0.250	0.250	
1985	457	357.7	4.2	457	357.7	4.2	0.543	0						0.000	0.000	0.000	0.000	
1986	310	378.0	6.0	310	378.0	6.0	0.500	0						0.143	0.000	0.000	0.000	
1987	215	321.4	5.1	215	321.4	5.1	0.546	4	242.5	14.4	4	242.5	14.4	0.027	0.108	0.108	0.108	
1988	264	323.2	4.2	264	323.2	4.2	0.497	25	252.0	7.2	25	252.0	7.2	0.028	0.111	0.111	0.111	
1989	212	349.8	9.4	211	341.6	4.7	0.615	27	259.6	8.7	27	259.6	8.7	0.045	0.075	0.075	0.075	
1990	342	310.9	3.4	342	310.9	3.4	0.666	31	274.8	7.6	31	274.8	7.6	0.039	0.080	0.080	0.080	
1991	197	323.4	5.4	197	323.4	5.4	0.404	7	297.1	37.8	7	297.1	37.8	0.135	0.088	0.088	0.088	
1992	263	318.6	4.2	263	318.6	4.2	0.648	18	265.0	18.9	18	265.0	18.9	0.235	0.133	0.133	0.133	
1993	184	328.9	6.0	184	328.9	6.0	0.882											
1994	299	351.0	3.2	426	328.2	2.9	0.887											
1995	103	362.7	7.8	121	349.8	7.2	0.579	5	390.0	55.7	8	342.5	40.8	0.073	0.071	0.030	0.050	
1996	178	345.1	3.7	205	335.9	3.7	0.792	1	370.0	0.0	3	293.3	39.3	0.000	0.056	0.014	0.042	
1997	95	354.6	6.8	109	344.0	6.5	0.510	1	305.0	0.0	7	263.1	8.8	0.198	0.083	0.008	0.054	
1998	116	349.1	4.4	138	338.0	4.3	0.389	1	320.0	0.0	3	274.0	19.7	0.043	0.053	0.000	0.023	
1999								2	310.0	17.3	4	284.3	20.8	0.231	0.164	0.056	0.102	

## Appendix C33.-

**black margate**  
*Anisotremus surinamensis*

Year	CREEL Survey Data						Actual	RVC Survey Data						CPUE				
	Lbar			CPUE				Lbar			CPUE			IM	Mat	Legal	Actual	
	n	Legal	S.E.	n	Actual	S.E.		n	Legal	S.E.	n	Actual	S.E.					
1976	0				0.000													
1977	0				0.000													
1978	0				0.001													
1979	4	337.5	37.7		0.006													
1980	9	394.4	29.9		0.006													
1981	20	332.0	15.1		0.020													
1982	3	360.0	50.3		0.013													
1983	10	387.0	23.1		0.010			0						0.000	0.000	0.000		
1984	3	383.3	46.7		0.010			0						0.000	0.000	0.000		
1985	14	343.6	13.5		0.044			0						0.000	0.000	0.000		
1986	17	344.7	25.0		0.013			0						0.000	0.000	0.000		
1987	13	430.8	25.6		0.024			0						0.000	0.000	0.000		
1988	21	335.7	15.0		0.022			11	338.2	19.2		0.049	0.020		0.061			
1989	7	327.1	21.9		0.007			11	289.1	14.7		0.043	0.008		0.051			
1990	21	339.5	10.5		0.013			22	332.3	10.6		0.058	0.020		0.078			
1991	12	338.3	10.6		0.012			13	314.6	11.2		0.188	0.000		0.135			
1992	14	340.0	11.4		0.032			2	295.0	5.0		0.019	0.000		0.019			
1993	8	380.0	26.4		0.008													
1994	12	341.7	15.8		0.006													
1995	7	350.0	14.5		0.019			7	318.2	11.3		0.104	0.000		0.104			
1996	7	361.4	12.0		0.011			1	250.0	0.0		0.014	0.000		0.014			
1997	2	310.0	20.0		0.000			0						0.000	0.000			
1998	3	283.3	12.0		0.009			1	290.0	0.0		0.008	0.000		0.008			
1999								0						0.000	0.000	0.000		

## Appendix C34.-

**porkfish**  
*Anisotremus virginicus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE			IM				
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	31	298.4	9.6		0.000												
1979	1	210.0	0.0		0.001												
1980	1	250.0	0.0		0.005												
1981	14	250.0	16.3		0.002												
1982	5	236.0	6.8		0.001												
1983	12	206.7	8.9		0.003			5	206.0	16.6	0.222	0.028			0.139		
1984	0				0.001			2	230.0	0.0	0.000	0.500			0.500		
1985	4	250.0	8.2		0.000			0			0.000	0.000			0.000		
1986	8	262.5	8.4		0.001			0			0.000	0.000			0.000		
1987	12	256.7	18.4		0.002			9	244.4	7.1	0.027	0.216			0.243		
1988	3	250.0	20.0		0.001			103	220.6	4.0	0.398	0.171			0.507		
1989	6	265.0	27.9		0.001			117	243.1	5.2	0.218	0.338			0.526		
1990	12	252.5	6.4		0.003			96	234.3	5.9	0.195	0.140			0.290		
1991	8	238.8	14.9		0.002			55	219.4	3.1	0.539	0.270			0.712		
1992	20	219.0	7.4		0.004			35	207.7	6.8	0.443	0.131			0.328		
1993	1	240.0	0.0		0.000			.	.	.	.	.			.	.	.
1994	21	220.5	7.0		0.005												
1995	7	220.0	18.3		0.002			27	207.6	8.1	0.355	0.044			0.220		
1996	15	216.0	8.9		0.004			9	206.7	18.3	0.128	0.042			0.126		
1997	6	208.3	11.9		0.002			18	244.2	13.1	0.235	0.183			0.256		
1998	4	222.5	14.4		0.002			17	230.3	12.3	0.142	0.142			0.225		
1999								5	205.6	19.1	0.228	0.050			0.227		

## Appendix C35.-

**margate**  
*Haemulon album*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE			IM				
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	21	224.3	5.1		0.001												
1979	6	345.0	47.8		0.003												
1980	8	475.0	36.2		0.002												
1981	12	337.5	26.7		0.002												
1982	44	289.3	11.7		0.006												
1983	18	365.6	29.0		0.002			0			0.000	0.000			0.000		
1984	3	236.7	14.5		0.001			0			0.000	0.000			0.000		
1985	20	266.0	16.4		0.003			0			0.000	0.000			0.000		
1986	21	323.3	22.8		0.006			0			0.000	0.000			0.000		
1987	21	316.7	20.8		0.004			0			0.000	0.000			0.000		
1988	5	320.0	40.4		0.002			0			0.000	0.000			0.000		
1989	7	282.9	28.5		0.001			0			0.000	0.000			0.000		
1990	17	270.0	17.2		0.004			7	323.9	46.4	0.026	0.004			0.030		
1991	4	380.0	41.0		0.000			0			0.000	0.000			0.000		
1992	19	287.4	29.9		0.003			0			0.000	0.000			0.000		
1993	7	392.9	20.1		0.001			.	.	.	.	.			.	.	.
1994	10	249.0	12.6		0.002			.	.	.	.	.			.	.	.
1995	2	565.0	15.0		0.000			0			0.000	0.000			0.000		
1996	0				0.000			0			0.000	0.000			0.000		
1997	6	270.0	34.2		0.002			0			0.000	0.000			0.000		
1998	3	416.7	26.0		0.000			1	220.0	0.0	0.091	0.000			0.015		
1999								0			0.000	0.000			0.000		

Appendix C36.-

**tomtate**  
*Haemulon aurolineatum*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.000												
1980	5	176.0	14.4		0.001												
1981	1	170.0	0.0		0.000												
1982	2	210.0	10.0		0.001												
1983	8	168.8	4.4		0.002			1123	175.9	0.6	29.993	37.674			31.181		
1984	0				0.001			0			0.000	3.750			0.000		
1985	17	161.2	7.7		0.005			0			0.000	0.000			0.000		
1986	0				0.000			2	160.0	0.0	6.536	19.607			0.261		
1987	7	171.4	4.6		0.001			988	192.3	0.9	18.904	52.204			26.709		
1988	23	169.6	6.2		0.004			642	164.3	0.4	8.267	6.629			2.318		
1989	6	176.7	2.1		0.003			1004	176.5	0.8	12.867	7.469			5.595		
1990	24	180.8	6.8		0.009			296	152.4	0.6	7.514	3.429			1.203		
1991	0				0.000			42	153.5	0.8	0.677	0.677			0.432		
1992	0				0.000			20	180.0	0.0	5.745	1.190			0.227		
1993	0				0.000			.	.	.	.	.			.		
1994	0				0.000			.	.	.	.	.			.		
1995	0				0.000			67	157.7	1.1	4.391	0.760			0.667		
1996	0				0.007			66	199.2	0.8	6.482	0.944			0.917		
1997	0				0.000			102	195.8	0.8	3.150	1.700			1.692		
1998	0				0.000			177	174.6	1.9	3.264	2.521			2.266		
1999								5	180.6	6.0	0.000	0.500			0.450		

Appendix C37.-

**ceasar grunt**  
*Haemulon carbonarium*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	1	240.0	0.0		0.000												
1980	1	210.0	0.0		0.001												
1981	0				0.000												
1982	0				0.001												
1983	1	200.0	0.0		0.000			0			0.000	0.000			0.000		
1984	0				0.000			0			0.000	0.000			0.000		
1985	3	313.3	41.8		0.000			0			0.000	0.000			0.000		
1986	0				0.000			0			0.000	0.000			0.000		
1987	9	217.8	12.4		0.002			0			0.000	0.000			0.000		
1988	6	206.7	15.6		0.000			8	202.5	5.6	0.052	0.008			0.037		
1989	4	235.0	2.9		0.001			17	210.0	10.2	0.117	0.023			0.063		
1990	17	187.6	6.4		0.003			33	208.8	4.3	0.112	0.039			0.138		
1991	3	230.0	10.0		0.001			2	230.0	20.0	0.024	0.010			0.024		
1992	2	295.0	5.0		0.000			9	173.3	6.3	0.040	0.009			0.018		
1993	14	228.6	7.6		0.004			.	.	.	.	.			.		
1994	4	235.0	6.5		0.001			.	.	.	.	.			.		
1995	2	200.0	10.0		0.002			3	210.0	20.0	0.587	0.010			0.021		
1996	6	233.3	9.9		0.002			4	237.5	19.3	0.278	0.042			0.056		
1997	6	250.0	12.6		0.001			18	236.4	5.5	0.233	0.225			0.300		
1998	0				0.000			8	207.6	9.9	0.341	0.053			0.117		
1999								0			0.000	0.000			0.000		

Appendix C39.-

**french grunt**  
*Haemulon flavolineatum*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.002												
1980	0				0.000												
1981	3	240.0	5.8		0.000												
1982	4	185.0	6.5		0.003												
1983	6	186.7	11.2		0.001			70	183.4	2.4		4.139	1.361		1.944		
1984	1	220.0	0.0		0.000			0				0.000	0.000		0.000		
1985	42	243.1	5.8		0.009			0				0.000	0.000		0.000		
1986	14	226.4	8.4		0.004			34	173.6	0.9		4.821	1.607		4.821		
1987	6	191.7	7.9		0.001			49	206.1	3.7		1.216	1.135		1.324		
1988	10	172.0	4.4		0.001			78	172.1	2.1		3.322	0.105		0.364		
1989	1	280.0	0.0		0.000			269	187.0	1.9		3.239	0.849		1.357		
1990	5	184.0	10.3		0.001			165	176.3	1.7		2.363	0.227		0.613		
1991	3	246.7	12.0		0.002			20	186.5	5.3		2.865	0.142		0.260		
1992	2	185.0	5.0		0.000			15	164.0	2.7		4.280	0.011		0.151		
1993	1	170.0	0.0		0.000			.	.	.							
1994	6	171.7	4.0		0.003												
1995	3	176.7	3.3		0.008			316	219.6	1.3		3.288	1.573		1.677		
1996	0		0.000					40	178.4	0.9		2.121	0.403		0.549		
1997	1	160.0	0.0		0.000			34	192.4	2.0		3.508	0.542		0.565		
1998	1	160.0	0.0		0.001			13	206.9	7.3		3.000	0.152		0.197		
1999								8	173.5	5.6		0.931	0.052		0.209		

Appendix C40.-

**spanish grunt**  
*Haemulon macrostomium*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	2	300.0	90.0		0.000												
1980	0				0.000												
1981	4	297.5	29.5		0.001												
1982	4	292.5	24.3		0.001												
1983	1	370.0	0.0		0.001			0				0.000	0.000		0.000		
1984	1	240	0		0.000			0				0.000	0.000		0.000		
1985	2	320.0	50.0		0.000			0				0.000	0.000		0.000		
1986	3	300.0	5.8		0.000			0				0.000	0.000		0.000		
1987	2	290.0	10.0		0.000			0				0.000	0.000		0.000		
1988	5	286.0	9.3		0.001			2	280.0	50.0		0.008	0.004		0.076		
1989	1	270.0	0.0		0.000			19	231.6	10.2		0.113	0.017		0.023		
1990	2	345.0	85.0		0.000			11	288.2	17.9		0.024	0.029		0.000		
1991	1	290.0	0.0		0.000			2	230.0	0.0		0.056	0.000		0.000		
1992	0		0.000					1	270.0	0.0		0.000	0.009		0.188		
1993	0		0.000					.	.	.							
1994	2	240.0	10.0		0.000			.	.	.							
1995	2	275.0	45.0		0.000			2	235.0	15.0		0.071	0.000		1.016		
1996	2	285.0	15.0		0.000			3	293.3	29.6		0.028	0.028		0.014		
1997	0		0.000					7	300.7	7.9		0.006	0.108		0.000		
1998	1	290.0	0.0		0.000			2	233.3	13.3		0.189	0.000		0.000		
1999								0				0.013	0.000		0.022		

Appendix C42.-

**sailors choice**  
*Haemulon parra*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar				CPUE		Lbar				CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		0					0.000										
1977		0					0.000										
1978		2	205.0	5.0	0.001												
1979		4	280.0	16.3	0.004												
1980		19	232.6	9.5	0.005												
1981		23	268.3	7.5	0.003												
1982		0			0.002												
1983		14	255.7	6.4	0.004			0			0.000	0.000		0.000			
1984		1	300.0	0.0	0.002			0			0.000	0.000		0.000			
1985		8	233.8	9.4	0.003			0			0.000	0.000		0.000			
1986		22	236.4	5.4	0.002			2	240.0	10.0	0.000	0.429		0.286			
1987		48	266.5	4.2	0.007			3	260.0	10.0	0.000	0.081		0.081			
1988		89	239.0	2.7	0.025			10	255.0	10.4	0.000	0.063		0.051			
1989		37	263.0	6.0	0.014			25	231.0	7.8	0.000	0.109		0.065			
1990		25	238.8	4.8	0.006			64	231.7	3.3	0.008	0.332		0.255			
1991		18	241.7	5.3	0.007			1	300.0	0.0	0.000	0.035		0.010			
1992		23	251.3	7.2	0.005			0			0.021	0.054		0.000			
1993		33	241.8	3.9	0.017												
1994		33	244.5	5.6	0.007												
1995		50	222.4	2.9	0.019			3	216.7	16.7	0.000	0.047		0.036			
1996		55	235.6	3.7	0.018			0			0.000	0.000		0.000			
1997		16	238.1	6.5	0.012			4	254.3	8.9	0.000	0.065		0.058			
1998		22	237.3	7.2	0.013			1	260.0	0.0	0.000	0.132		0.008			
1999								1	260.0	0.0	0.000	0.025		0.013			

Appendix C43.-

**white grunt**  
*Haemulon plumieri*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar				CPUE		Lbar				CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		1039	205.7	0.8	0.085												
1977		154	216.1	2.5	0.008												
1978		371	223.7	1.4	0.195												
1979		168	237.9	2.8	0.327												
1980		433	228.0	1.6	0.345												
1981		664	224.8	1.2	0.375												
1982		164	221.0	2.1	0.371												
1983		694	225.3	1.3	0.189			17	217.1	4.8	0.083	0.472		0.472			
1984		320	215.5	1.6	0.173			0			0.000	0.000		0.000			
1985		1391	224.6	0.8	0.256			0			0.000	0.000		0.000			
1986		848	235.5	1.2	0.187			1	170.0	0.0	0.857	0.000		0.143			
1987		706	237.4	1.3	0.184			47	227.0	5.4	0.520	1.155		1.264			
1988		730	231.5	1.1	0.240			155	198.9	2.5	3.113	0.651		0.801			
1989		584	224.9	1.1	0.202			521	205.0	1.6	2.854	1.065		1.128			
1990		821	226.6	1.0	0.255			370	207.5	1.8	3.513	1.032		1.279			
1991		414	221.1	1.3	0.117			95	210.9	2.1	0.396	1.210		1.266			
1992		703	226.1	1.1	0.178			49	201.9	5.6	2.226	0.299		0.373			
1993		953	220.3	0.8	0.308												
1994		968	221.1	0.8	0.277												
1995		383	219.6	1.2	0.227			196	189.7	2.0	12.014	0.538		1.613			
1996		659	217.9	1.0	0.315			53	199.7	3.1	3.360	0.612		0.737			
1997		382	219.9	1.1	0.183			81	222.0	3.8	2.700	1.115		1.242			
1998		454	216.5	1.2	0.175			40	210.1	4.6	1.532	0.432		0.462			
1999								10	192.6	7.3	1.125	0.215		0.316			

## Appendix C44.-

**bluestriped grunt**  
*Haemulon sciurus*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	394	214.7	1.3	0.050												
1977	140	209.9	1.7	0.010												
1978	122	245.3	3.4	0.043												
1979	55	252.2	3.9	0.082												
1980	168	242.5	2.1	0.067												
1981	191	235.3	1.9	0.058												
1982	112	241.4	2.5	0.131												
1983	245	222.8	1.6	0.049				2	235.0	5.0	0.000	0.056	0.056			
1984	183	230.8	2.1	0.061				1	230.0	0.0	0.000	0.250	0.250			
1985	237	237.2	2.2	0.053				0			0.000	0.000	0.000			
1986	202	240.0	1.9	0.041				0			0.286	0.000	0.000			
1987	288	235.5	1.6	0.069				17	241.2	4.1	0.081	0.459	0.459			
1988	206	230.0	1.8	0.061				56	214.1	5.0	0.151	0.079	0.178			
1989	167	234.1	2.0	0.042				304	224.5	1.9	0.640	0.637	0.861			
1990	211	226.6	1.7	0.059				247	232.1	3.0	1.580	0.351	0.664			
1991	180	228.8	2.2	0.055				146	208.2	1.6	2.628	0.715	1.998			
1992	321	231.3	1.5	0.068				64	199.6	3.2	2.083	0.029	0.429			
1993	189	225.3	1.6	0.066				.	.	.	.	.	.			
1994	233	225.3	1.5	0.054				.	.	.	.	.	.			
1995	130	226.1	1.9	0.064				23	223.0	5.1	1.208	0.135	0.188			
1996	194	226.7	1.5	0.076				40	216.6	3.9	1.457	0.225	0.564			
1997	156	220.6	1.6	0.073				91	265.8	4.7	2.152	1.206	1.433			
1998	81	226.3	2.9	0.056				33	204.9	5.2	0.811	0.106	0.295			
1999								6	190.3	8.4	0.496	0.010	0.126			

## Appendix C45.-

**striped grunt**  
*Haemulon striatum*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	0				0.000											
1977	0				0.000											
1978	0				0.000											
1979	0				0.001											
1980	0				0.001											
1981	3	216.7	21.9		0.001											
1982	0				0.000											
1983	0				0.000			0			0.000	0.000	0.000			
1984	0				0.000			0			0.000	0.000	0.000			
1985	0				0.000			0			0.000	0.000	0.000			
1986	0				0.000			0			0.000	0.000	0.000			
1987	0				0.000			0			0.000	0.000	0.000			
1988	0				0.000			0			0.000	0.000	0.000			
1989	0				0.000			0			0.000	0.000	0.000			
1990	3	253.3	18.6		0.001			0			0.005	0.000	0.000			
1991	1	250.0	0.0		0.000			0			0.042	0.000	0.000			
1992	0				0.000			0			0.000	0.000	0.000			
1993	0				0.000			.	.	.	.	.	.			
1994	3	223.3	18.6		0.000			.	.	.	.	.	.			
1995	0				0.000			0			0.000	0.000	0.000			
1996	0				0.000			0			0.000	0.000	0.000			
1997	20	221.5	6.3		0.010			0			0.000	0.000	0.000			
1998	47	227.4	4.1		0.025			0			0.000	0.000	0.000			
1999								0			0.000	0.000	0.000			

## Appendix C46.-

**pigfish**  
*Orthopristis chrysoptera*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	5	194.0	6.8	0.000													
1977	0			0.000													
1978	0			0.000													
1979	0			0.001													
1980	2	265.0	5.0	0.000													
1981	0			0.000													
1982	1	230.0	0.0	0.000													
1983	9	232.2	5.2	0.002													
1984	0			0.000													
1985	0			0.000													
1986	5	184.0	5.1	0.001													
1987	2	225.0	55.0	0.001													
1988	0			0.000													
1989	0			0.000													
1990	6	178.3	4.0	0.003													
1991	0			0.000													
1992	0			0.000													
1993	0			0.000													
1994	0			0.000													
1995	0			0.000													
1996	0			0.000													
1997	0			0.000													
1998	0			0.000													
1999																	

## Appendix C47.-

**great barracuda**  
*Sphyraena barracuda*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	179	553.1	13.9	0.040													
1977	38	722.6	37.5	0.028													
1978	138	622.8	18.0	0.028													
1979	38	554.7	27.2	0.030													
1980	88	581.0	23.2	0.053													
1981	54	666.5	28.7	0.036													
1982	44	583.2	39.4	0.038													
1983	66	591.7	28.5	0.023				0			0.000	0.000				0.000	
1984	15	640.0	54.6	0.020				0			0.000	0.000				0.000	
1985	79	610.5	21.6	0.018				2	1300.0	15.0	0.000	0.333				0.333	
1986	123	597.8	20.6	0.026				1	600.0	0.0	0.143	0.000				0.143	
1987	116	534.8	13.6	0.038				1	1100.0	0.0	0.000	0.027				0.027	
1988	35	636.6	37.0	0.018				22	871.8	8.0	0.027	0.030				0.057	
1989	50	539.4	31.6	0.029				97	754.5	2.6	0.086	0.065				0.151	
1990	69	646.1	19.1	0.024				124	857.8	2.9	0.086	0.142				0.228	
1991	83	554.6	18.2	0.026				92	923.5	3.1	0.448	0.514				0.962	
1992	81	638.6	24.9	0.025				6	733.3	16.5	0.000	0.000				0.000	
1993	73	650.0	24.1	0.022				.	.	.	.	.				.	.
1994	114	576.3	20.1	0.028				.	.	.	.	.				.	.
1995	47	516.2	26.4	0.027				25	886.0	5.6	0.179	0.097				0.204	
1996	49	640.2	32.3	0.026				17	617.7	5.8	0.321	0.042				0.237	
1997	53	592.8	28.0	0.024				3	824.0	15.3	0.071	0.017				0.038	
1998	26	583.5	33.5	0.038				3	770.0	29.7	0.023	0.013				0.036	
1999								0			0.000	0.000				0.000	

## Appendix C48.-

**jolthead gorgy**  
*Calamus bajonado*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.018												
1977	0				0.085												
1978	27	317.4	12.8		0.145												
1979	4	312.5	14.9		0.099												
1980	29	285.2	9.9		0.082												
1981	132	290.9	4.8		0.073												
1982	86	305.8	5.7		0.039												
1983	87	290.8	5.5	0.028				2	240.0	0.0	0.056	0.000			0.056		
1984	104	286.8	6.3	0.048				0			0.000	0.000			0.000		
1985	229	318.7	4.2	0.039				0			0.000	0.000			0.000		
1986	43	319.1	10.8	0.009				0			0.286	0.000			0.000		
1987	59	318.3	9.3	0.013				0			0.000	0.000			0.000		
1988	130	292.1	4.5	0.039				0			0.020	0.000			0.000		
1989	80	323.4	6.5	0.023				6	233.3	1.1	0.013	0.000			0.002		
1990	137	290.2	4.7	0.026				5	250.0	1.4	0.065	0.000			0.020		
1991	77	281.9	4.3	0.023				0			0.000	0.000			0.000		
1992	144	304.3	4.6	0.038				0			0.000	0.000			0.000		
1993	58	298.4	8.2	0.018				.			.	.			.	.	.
1994	69	297.1	5.8	0.016				.			.	.			.	.	.
1995	24	282.9	10.9	0.011				0			0.000	0.000			0.000		
1996	24	291.3	12.1	0.011				0			0.000	0.000			0.000		
1997	23	310.0	10.2	0.009				0			0.000	0.000			0.000		
1998	43	280.9	9.0	0.022				0			0.013	0.000			0.000		
1999								0			0.000	0.000			0.000		

## Appendix C49.-

**saucereye gorgy**  
*Calamus calamus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.000												
1980	31	303.9	10.1		0.017												
1981	125	271.9	5.6		0.038												
1982	26	262.7	9.5		0.004												
1983	44	265.0	5.9	0.005				0			0.000	0.000			0.000		
1984	3	253.3	12.0	0.002				1	280.0	0.0	0.250	0.000			0.250		
1985	144	268.9	3.7	0.020				0			0.000	0.000			0.000		
1986	46	283.0	6.8	0.006				2	290.0	0.0	0.286	0.000			0.286		
1987	17	275.9	11.6	0.002				7	210.7	0.7	0.243	0.000			0.189		
1988	6	266.7	29.9	0.002				0			0.081	0.000			0.000		
1989	13	233.1	8.3	0.004				8	230.0	1.3	0.050	0.000			0.026		
1990	48	254.8	6.0	0.014				9	222.2	0.7	0.138	0.000			0.033		
1991	21	282.9	11.4	0.005				2	275.0	2.5	0.028	0.000			0.028		
1992	33	287.9	7.7	0.008				0			0.032	0.000			0.000		
1993	54	250.9	6.4	0.023				.			.	.			.	.	.
1994	41	259.3	5.8	0.010				.			.	.			.	.	.
1995	11	257.3	12.8	0.006				5	250.0	2.2	0.179	0.000			0.031		
1996	13	242.3	7.7	0.005				1	260.0	0.0	0.028	0.000			0.014		
1997	2	240.0	30.0	0.001				3	225.0	1.8	0.110	0.000			0.027		
1998	2	270.0	10.0	0.001				0			0.076	0.000			0.000		
1999								3	233.7	1.9	0.351	0.000			0.106		

## Appendix C50.-

**yellow jack**  
*Caranx bartholomaei*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		0			0.000												
1977		0			0.000												
1978		0			0.000												
1979		0			0.001												
1980	6	440.0	69.3		0.002												
1981	46	435.4	18.5		0.007												
1982	13	405.4	31.6		0.002												
1983	23	452.6	34.6	0.003				65	300.7	6.2	2.056	0.000		1.806			
1984	3	360.0	45.8	0.001				0			0.000	0.000		0.000			
1985	19	336.3	13.2	0.002				0			0.000	0.000		0.000			
1986	16	451.3	29.8	0.001				0			0.000	0.000		0.000			
1987	38	391.1	13.9	0.007				29	276.6	7.3	0.838	0.027		0.784			
1988	44	389.5	18.6	0.010				19	340.0	15.4	0.558	0.004		0.187			
1989	16	385.0	30.8	0.004				37	418.6	19.7	0.079	0.037		0.104			
1990	45	399.8	18.5	0.006				61	385.4	11.6	0.063	0.043		0.106			
1991	27	388.9	17.4	0.005				3	450.0	28.9	0.010	0.021		0.031			
1992	52	382.3	12.2	0.009				71	250.0	0.0	0.060	0.000		0.000			
1993	60	317.0	9.7	0.010				.	.	.	.	.		.	.		
1994	36	363.1	17.3	0.004													
1995	18	371.7	21.9	0.001				7	307.1	20.4	0.119	0.000		0.067			
1996	15	372.0	21.7	0.003				1	330.0	0.0	0.014	0.000		0.014			
1997	10	395.0	19.0	0.006				9	338.9	10.9	0.042	0.000		0.042			
1998	14	330.7	9.4	0.006				7	303.2	26.5	0.114	0.015		0.030			
1999								0			0.013	0.000		0.000			

## Appendix C51.-

**blue runner**  
*Caranx cryos*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	1	300.0	0.0		0.011												
1977	1	440.0	0.0		0.007												
1978	0				0.004												
1979	0				0.015												
1980	29	282.1	20.3		0.022												
1981	113	260.7	6.3		0.042												
1982	86	251.6	4.7		0.041												
1983	155	250.7	3.9	0.033				22	303.6	20.6	0.611	0.000		0.611			
1984	14	279.3	18.9	0.023				0			0.000	0.000		0.000			
1985	91	282.7	7.4	0.033				0			0.667	0.000		0.000			
1986	237	260.1	4.5	0.047				0			0.000	0.000		0.000			
1987	183	259.5	3.7	0.045				2	210.0	10.0	0.054	0.000		0.054			
1988	127	250.7	3.6	0.045				10	300.0	9.1	0.058	0.000		0.058			
1989	102	263.0	5.1	0.031				91	223.5	5.0	0.079	0.000		0.079			
1990	72	261.1	4.5	0.037				183	302.1	6.4	0.704	0.042		0.738			
1991	78	245.4	5.4	0.027				0			0.028	0.000		0.000			
1992	99	250.0	3.6	0.021				2	180.0	20.0	0.000	0.000		0.000			
1993	70	268.1	5.3	0.030				.	.	.	.	.		.	.		
1994	98	245.6	3.3	0.055										.	.		
1995	65	231.4	5.2	0.032				30	250.0	3.9	0.313	0.000		0.313			
1996	99	241.6	3.2	0.035				23	300.0	0.0	0.319	0.000		0.319			
1997	73	243.6	3.4	0.056				20	183.0	3.2	0.250	0.000		0.250			
1998	136	246.1	3.2	0.098				4	257.1	11.1	0.045	0.000		0.045			
1999								10	226.0	6.4	0.250	0.000		0.250			

## Appendix C52.-

**crevalle jack**  
*Caranx hippos*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		0			0.000												
1977		0			0.000												
1978		0			0.000												
1979		0			0.004												
1980	3	486.7	63.6		0.004												
1981	0				0.002												
1982	12	285.8	18.6		0.009												
1983	13	400.8	26.0		0.009												
1984	1	270.0	0.0		0.000												
1985	2	245.0	45.0		0.001												
1986	4	282.5	17.5		0.001												
1987	5	340.0	41.5		0.001												
1988	9	236.7	5.8		0.000												
1989	3	320.0	110.0		0.001												
1990	4	410.0	51.2		0.002												
1991	0				0.000												
1992	1	250.0	0.0		0.001												
1993	3	433.3	83.5		0.002												
1994	9	343.3	22.4		0.008												
1995	2	260.0	10.0		0.000												
1996	2	320.0	40.0		0.002												
1997	1	390.0	0.0		0.000												
1998	2	255.0	15.0		0.004												
1999																	

## Appendix C53.-

**horse-eye jack**  
*Caranx latus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		0			0.000												
1977		0			0.000												
1978		0			0.000												
1979		0			0.000												
1980	1	290.0	0.0		0.001												
1981	4	430.0	63.4		0.001												
1982	1	310.0	0.0		0.000												
1983	6	296.7	16.7		0.001												
1984	0				0.000												
1985	2	630.0	30.0		0.002												
1986	2	425.0	85.0		0.001												
1987	0				0.000												
1988	0				0.000												
1989	0				0.000												
1990	0				0.000												
1991	1	240.0	0.0		0.000												
1992	0				0.000												
1993	0				0.000												
1994	0				0.000												
1995	1	690.0	0.0		0.000												
1996	0				0.000												
1997	0				0.000												
1998	0				0.000												
1999																	

## Appendix C54.-

**bar jack**  
*Caranx ruber*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	1	320.0	0.0	0.000													
1979	0			0.000													
1980	2	525.0	125.0	0.000													
1981	15	326.0	23.1	0.002													
1982	1	320.0	0.0	0.001													
1983	2	330.0	40.0	0.001				45	310.0	4.1	2.639	1.250	1.250				
1984	0			0.000				0			3.500	0.000	0.000				
1985	7	348.6	17.9	0.002				0			0.000	0.000	0.000				
1986	7	391.4	17.9	0.001				1	250.0	0.0	0.143	0.143	0.143				
1987	8	350.0	21.2	0.001				1	320.0	0.0	3.568	0.027	0.027				
1988	5	400.0	20.5	0.000				14	262.0	6.4	1.950	0.051	0.051				
1989	1	280.0	0.0	0.000				77	255.2	2.1	1.694	0.297	0.297				
1990	5	338.0	41.9	0.001				84	403.7	18.3	1.777	0.361	0.361				
1991	4	270.0	0.0	0.001				8	266.3	6.0	1.901	0.092	0.092				
1992	4	305.0	42.7	0.000				6	266.4	9.1	1.705	0.047	0.047				
1993	9	331.1	26.1	0.006				.	.	.	.	.	.				
1994	11	367.3	14.9	0.000				.	.	.	.	.	.				
1995	0			0.000				20	286.9	13.2	1.226	0.190	0.190				
1996	2	345.0	15.0	0.000				10	250.0	0.0	4.864	0.139	0.139				
1997	5	344.0	21.6	0.001				4	295.0	19.8	0.167	0.021	0.021				
1998	3	330.0	17.3	0.002				3	322.0	34.4	1.847	0.038	0.038				
1999								2	312.5	108.3	0.061	0.163	0.163				

## Appendix C55.-

**bermuda chub**  
*Kyphosus sectatrix*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0.000													
1977	0			0.000													
1978	0			0.000													
1979	0			0.004													
1980	6	340.0	49.3	0.010													
1981	30	280.3	19.5	0.005													
1982	21	264.3	11.7	0.006													
1983	17	223.5	10.4	0.002				0			0.000	0.000	0.000				
1984	7	250.0	20.8	0.002				0			0.000	0.000	0.000				
1985	11	252.7	16.2	0.001				0			0.000	0.000	0.000				
1986	11	304.5	39.8	0.002				0			0.000	0.000	0.000				
1987	16	276.3	17.9	0.003				0			0.000	0.000	0.000				
1988	0			0.000				186	285.1	3.8	0.840	0.000	0.833				
1989	0			0.000				323	275.0	2.3	1.059	0.000	1.049				
1990	1	250.0	0.0	0.002				74	275.8	4.7	0.314	0.000	0.298				
1991	14	370.0	13.1	0.002				194	249.3	4.1	2.806	0.000	2.100				
1992	6	278.3	23.3	0.001				8	298.8	20.6	0.055	0.000	0.046				
1993	12	261.7	13.6	0.004				.	.	.	.	.	.				
1994	4	290.0	15.8	0.001				.	.	.	.	.	.				
1995	0			0.000				178	239.2	2.9	2.912	0.000	2.192				
1996	0			0.000				132	256.8	4.2	2.602	0.000	1.836				
1997	0			0.000				47	261.7	6.0	0.850	0.000	0.694				
1998	19	280.0	14.3	0.016				26	223.4	10.5	0.591	0.000	0.392				
1999								2	206.7	22.3	0.300	0.000	0.225				

## Appendix C56.-

**gray angelfish**  
*Pomacanthus arcuatus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976																	
1977																	
1978																	
1979																	
1980																	
1981																	
1982																	
1983								2	350.0	0.0	0.306	0.056					
1984								1	380.0	0.0	0.250	0.250					
1985								0			0.000	0.000					
1986								0			0.286	0.000					
1987								5	392.0	15.0	0.162	0.135					
1988								10	370.0	5.6	0.552	0.044					
1989								18	371.8	6.9	0.358	0.028					
1990								33	367.3	4.5	0.513	0.079					
1991								0			0.334	0.000					
1992								4	397.5	18.9	0.315	0.023					
1993								.	.	.	.	.					
1994								.	.	.	.	.					
1995								0			0.390	0.000					
1996								3	360.0	10.0	0.399	0.042					
1997								2	357.5	13.0	0.600	0.017					
1998								3	365.0	12.7	0.174	0.021					
1999								0			0.163	0.000					

## Appendix C59.-

**blue parrotfish**  
*Scarus coeruleus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976																	
1977																	
1978																	
1979																	
1980																	
1981																	
1982																	
1983								0			0.028	0.000					
1984								0			0.000	0.000					
1985								0			0.000	0.000					
1986								0			0.000	0.000					
1987								0			0.027	0.000					
1988								0			0.075	0.000					
1989								0			0.066	0.000					
1990								0			0.106	0.000					
1991								0			0.049	0.000					
1992								0			0.048	0.000					
1993								.	.	.	.	.					
1994								.	.	.	.	.					
1995								0			0.070	0.000					
1996								0			0.083	0.000					
1997								0			0.008	0.000					
1998								0			0.114	0.000					
1999								0			0.074	0.000					

## Appendix C61.-

**rainbow parrotfish**  
*Scarus guacamaia*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983							0					0.000	0.000			
1984							0					0.000	0.000			
1985							0					0.000	0.000			
1986							0					0.000	0.000			
1987							0					0.000	0.000			
1988							0					0.039	0.000			
1989							5	650.0	0.0			0.060	0.011			
1990							0					0.032	0.000			
1991							0					0.014	0.000			
1992							0					0.028	0.000			
1993							.					.	.			
1994							.					.	.			
1995							0					0.071	0.000			
1996							0					0.083	0.000			
1997							0					0.050	0.000			
1998							0					0.087	0.000			
1999							0					0.000	0.000			

## Appendix C62.-

**princess parrotfish**  
*Scarus taeniopterus*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983							0					0.278	0.000			
1984							0					0.000	0.000			
1985							0					0.000	0.000			
1986							0					0.000	0.000			
1987							18	277.9	11.0			1.662	0.473			
1988							14	277.1	13.9			0.689	0.064			
1989							19	241.1	6.2			1.264	0.095			
1990							6	280.0	15.3			5.579	0.025			
1991							6	250.0	12.9			1.868	0.076			
1992							30	259.3	5.0			3.395	0.295			
1993							.					.	.			
1994							.					.	.			
1995							1	280.0	0.0			1.224	0.005			
1996							1	240.0	0.0			2.398	0.014			
1997							1	250.0	0.0			1.506	0.015			
1998							0					1.174	0.000			
1999							2	300.8	33.3			0.218	0.058			

## Appendix C63.-

**queen parrotfish**  
*Scarus vetula*

Year	CREEL Survey Data						RVC Survey Data											
	Lbar			CPUE			Lbar			CPUE								
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976																		
1977																		
1978																		
1979																		
1980																		
1981																		
1982																		
1983							0				0.000	0.000						
1984							0				0.000	0.000						
1985							0				0.000	0.000						
1986							0				0.000	0.000						
1987							4	405.0	21.0	0.081	0.108							
1988							10	365.0	11.6	0.111	0.050							
1989							39	383.1	7.1	0.362	0.135							
1990							20	366.5	8.9	0.115	0.083							
1991							13	377.7	10.2	0.256	0.141							
1992							1	320.0	0.0	0.078	0.011							
1993							.	.	.	.	.	.						
1994							.	.	.	.	.	.						
1995							5	350.0	13.8	0.266	0.047							
1996							8	337.5	6.2	0.264	0.111							
1997							2	353.3	48.1	0.056	0.025							
1998							9	340.0	11.7	0.341	0.129							
1999							0			0.013	0.000							

## Appendix C64.-

**greenblotch parrotfish**  
*Sparisoma atomarium*

Year	CREEL Survey Data						RVC Survey Data											
	Lbar			CPUE			Lbar			CPUE								
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976																		
1977																		
1978																		
1979																		
1980																		
1981																		
1982																		
1983							0			0.000	0.000							
1984							0			0.000	0.000							
1985							0			0.000	0.000							
1986							0			0.000	0.000							
1987							0			0.000	0.000							
1988							0			0.000	0.000							
1989							0			0.033	0.000							
1990							0			0.090	0.000							
1991							0			0.146	0.000							
1992							0			0.222	0.000							
1993							.	.	.	.	.	.						
1994							.	.	.	.	.	.						
1995							0			0.479	0.000							
1996							0			0.139	0.000							
1997							0			0.306	0.000							
1998							0			0.273	0.000							
1999							0			0.075	0.000							

## Appendix C65.-

**redband parrotfish**  
*Sparisoma aurofrenatum*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE			IM			
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983								15	186.7	4.9	1.806	0.417				
1984								14	223.6	10.8	0.000	3.500				
1985								0			0.000	0.000				
1986								5	260.6	10.7	1.500	0.643				
1987								27	216.8	9.0	1.811	0.730				
1988								150	206.9	2.5	5.050	0.722				
1989								266	208.5	1.9	4.712	1.072				
1990								134	212.1	2.4	5.054	0.541				
1991								46	198.9	3.8	3.938	0.569				
1992								43	207.8	3.5	3.577	0.403				
1993								.	.	.	.	.				
1994								.	.	.	.	.				
1995								56	208.3	4.3	4.276	0.410				
1996								64	219.1	4.1	6.514	0.885				
1997								47	208.1	4.5	4.386	0.666				
1998								27	218.2	6.7	5.706	0.409				
1999								24	201.3	6.0	3.699	0.660				

## Appendix C65.-

**redband parrotfish**  
*Sparisoma aurofrenatum*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE			IM			
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983								15	186.7	4.9	1.806	0.417				
1984								14	223.6	10.8	0.000	3.500				
1985								0			0.000	0.000				
1986								5	260.6	10.7	1.500	0.643				
1987								27	216.8	9.0	1.811	0.730				
1988								150	206.9	2.5	5.050	0.722				
1989								266	208.5	1.9	4.712	1.072				
1990								134	212.1	2.4	5.054	0.541				
1991								46	198.9	3.8	3.938	0.569				
1992								43	207.8	3.5	3.577	0.403				
1993								.	.	.	.	.				
1994								.	.	.	.	.				
1995								56	208.3	4.3	4.276	0.410				
1996								64	219.1	4.1	6.514	0.885				
1997								47	208.1	4.5	4.386	0.666				
1998								27	218.2	6.7	5.706	0.409				
1999								24	201.3	6.0	3.699	0.660				

## Appendix C68.-

**redfin parrotfish**  
*Sparisoma rubripinne*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE			IM		Mat	
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983							0				0.361	0.000				
1984							0				0.250	0.000				
1985							0				0.000	0.000				
1986							0				0.000	0.000				
1987							2	360.0	40.0	0.270	0.054					
1988							13	382.3	31.0	0.055	0.060					
1989							46	347.0	6.7	0.309	0.182					
1990							18	341.7	9.4	0.041	0.077					
1991							2	425.0	25.0	0.093	0.021					
1992							6	330.0	14.4	0.106	0.057					
1993							.	.	.	.	.	.				
1994							.	.	.	.	.	.				
1995							9	331.1	16.5	0.291	0.089					
1996							6	365.0	15.2	0.328	0.083					
1997							8	313.1	8.2	0.173	0.133					
1998							6	317.5	8.8	0.265	0.091					
1999							3	325.0	16.2	0.089	0.093					

## Appendix C69.-

**stoplight parrotfish**  
*Sparisoma viride*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE			IM		Mat		
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976																	
1977																	
1978																	
1979																	
1980																	
1981																	
1982																	
1983							0				0.861	0.000					
1984							0				0.250	0.000					
1985							0				0.000	0.000					
1986							0				0.000	0.000					
1987							9	405.6	1.1	0.946	0.243						
1988							43	410.2	0.4	1.776	0.167						
1989							60	406.2	0.4	1.782	0.250						
1990							57	414.9	0.4	1.980	0.240						
1991							20	407.5	0.5	1.947	0.236						
1992							5	400.0	0.0	1.644	0.037						
1993							.	.	.	.	.	.					
1994							.	.	.	.	.	.					
1995							4	395.0	0.3	1.805	0.031						
1996							2	400.0	0.0	2.987	0.028						
1997							2	410.0	1.2	2.773	0.023						
1998							2	400.0	0.0	2.314	0.030						
1999							2	477.5	15.8	1.264	0.049						

## Appendix C70.-

**grey triggerfish**  
*Balistes capriscus*

Year	CREEL Survey Data						RVC Survey Data											
	Lbar			CPUE			Lbar			CPUE								
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976	0			0			0.000											
1977	0			0			0.000											
1978	0			0			0.000											
1979	0			0			0.000											
1980	1	220.0	0.0	1	220.0	0.0	0.002											
1981	3	293.3	23.3	3	293.3	23.3	0.001											
1982	15	373.3	28.6	15	373.3	28.6	0.006											
1983	14	323.6	18.0	14	323.6	18.0	0.002	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1984	2	365.0	15.0	2	365.0	15.0	0.002	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1985	7	344.3	22.2	7	344.3	22.2	0.000	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1986	3	416.7	38.4	3	416.7	38.4	0.001	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1987	15	322.7	22.9	15	322.7	22.9	0.002	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1988	15	311.3	17.2	15	311.3	17.2	0.003	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1989	5	298.0	13.2	5	298.0	13.2	0.002	8	247.5	8.6	8	247.5	8.6	0.058	0.000	0.036	0.036	
1990	8	315.0	14.3	8	315.0	14.3	0.001	1	300.0	0.0	1	300.0	0.0	0.004	0.000	0.004	0.004	
1991	27	399.3	18.3	27	399.3	18.3	0.013	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1992	17	405.3	14.6	17	405.3	14.6	0.004	1	240.0	0.0	1	240.0	0.0	0.011	0.000	0.011	0.011	
1993	28	352.5	11.3	28	352.5	11.3	0.013	.		.		.	.	.	.	.	.	
1994	17	386.5	10.3	25	341.6	15.1	0.008	.		.		.	.	.	.	.	.	
1995	3	400.0	30.6	4	367.5	39.0	0.001	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1996	3	366.7	14.5	4	340.0	28.6	0.001	0		1	250.0	0.0	0.042	0.000	0.000	0.014	0.014	0.014
1997	1	430.0	0.0	7	272.9	26.7	0.002	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1998	2	405.0	45.0	3	343.3	66.9	0.001	0		0		0.000	0.000	0.000	0.000	0.000	0.000	
1999							0			0		0.138	0.000	0.000	0.000	0.000	0.000	

## Appendix C71.-

**queen triggerfish**  
*Balistes vetula*

Year	CREEL Survey Data						RVC Survey Data											
	Lbar			CPUE			Lbar			CPUE								
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual	
1976				0			0.000											
1977				0			0.000											
1978				0			0.000											
1979				0			0.001											
1980				3	326.7	33.8	0.001											
1981				7	337.1	20.0	0.001											
1982				1	300.0	0.0	0.001											
1983				7	337.1	15.8	0.001			0		0.000	0.000	0.000	0.000	0.000	0.000	
1984				0			0.000			0		0.000	0.000	0.000	0.000	0.000	0.000	
1985				3	360.0	60.0	0.001			0		0.000	0.000	0.000	0.000	0.000	0.000	
1986				2	285.0	45.0	0.000			0		0.000	0.000	0.000	0.000	0.000	0.000	
1987				6	325.0	16.9	0.002			1	260.0	0.0	0.027	0.000	0.027	0.027	0.027	0.027
1988				1	250.0	0.0	0.000			3	293.3	6.7	0.020	0.000	0.020	0.020	0.020	0.020
1989				7	317.1	6.1	0.004			8	323.8	8.4	0.021	0.000	0.021	0.021	0.021	0.021
1990				10	323.0	10.4	0.002			3	383.3	16.7	0.012	0.000	0.012	0.012	0.012	0.012
1991				4	325.0	17.6	0.001			2	360.0	10.0	0.072	0.000	0.072	0.021	0.021	0.021
1992				1	270.0	0.0	0.000			0		0.000	0.000	0.000	0.000	0.000	0.000	
1993				9	292.2	11.2	0.004			.		.	.	.	.	.	.	
1994				6	331.7	20.6	0.002			.		.	.	.	.	.	.	
1995				0			0.000			0		0.000	0.000	0.000	0.000	0.000	0.000	
1996				1	370.0	0.0	0.000			1	250.0	0.0	0.042	0.000	0.042	0.014	0.014	0.014
1997				3	286.7	29.1	0.005			1	305.0	0.0	0.027	0.000	0.027	0.015	0.015	0.015
1998				1	260.0	0.0	0.000			0		0.000	0.000	0.000	0.000	0.000	0.000	
1999										1	283.8	89.2	0.148	0.000	0.040	0.040	0.040	0.040

## Appendix C72.-

**ocean triggerfish**  
*Cantherhines sufflamen*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.011												
1980	16	412.5	14.8		0.014												
1981	44	436.8	10.7		0.005												
1982	1	290.0	0.0		0.001												
1983	23	443.0	12.4		0.008			0			0.000	0.000				0.000	
1984	1	420.0	0.0		0.001			0			0.000	0.000				0.000	
1985	19	386.8	23.8		0.004			0			0.000	0.000				0.000	
1986	28	439.6	9.7		0.005			0			0.000	0.000				0.000	
1987	20	364.0	14.2		0.003			1	420.0	0.0	0.000	0.027				0.027	
1988	34	399.4	9.8		0.010			8	348.8	24.6	0.025	0.019				0.044	
1989	16	426.3	13.4		0.005			5	382.0	15.6	0.010	0.012				0.022	
1990	38	408.7	10.0		0.008			2	350.0	0.0	0.008	0.000				0.008	
1991	5	346.0	43.4		0.001			1	400.0	0.0	0.000	0.010				0.010	
1992	28	399.6	13.4		0.003			2	300.0	0.0	0.023	0.000				0.023	
1993	12	421.7	19.3		0.003			.	.	.	.	.				.	.
1994	4	490.0	56.1		0.001			.	.	.	.	.				.	.
1995	12	398.3	13.1		0.008			0			0.000	0.000				0.000	
1996	6	430.0	12.4		0.001			1	300.0	0.0	0.014	0.000				0.014	
1997	3	523.3	14.5		0.000			2	340.0	50.5	0.033	0.008				0.033	
1998	6	428.3	36.6		0.002			0			0.000	0.000				0.000	
1999								0			0.000	0.000				0.000	

## Appendix C74.-

**doctorfish**  
*Acanthurus chirurgus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0.000												
1977	0				0.000												
1978	0				0.000												
1979	0				0.000												
1980	0				0.000												
1981	0				0.000												
1982	0				0.000												
1983	1	230.0	0.0		0.001			41	239.8	4.6	2.632	1.146				1.146	
1984	0				0.003			5	278.0	17.1	3.500	1.250				1.250	
1985	1	270.0	0.0		0.000			0			0.000	0.000				0.000	
1986	4	220.0	10.8		0.001			0			0.000	0.000				0.000	
1987	6	255.0	8.5		0.001			9	293.3	21.5	0.216	0.243				0.243	
1988	1	260.0	0.0		0.000			95	264.9	3.4	0.113	0.407				0.407	
1989	4	252.5	36.4		0.001			106	247.6	3.8	0.219	0.234				0.234	
1990	6	280.0	9.7		0.001			74	258.5	4.4	0.449	0.092				0.092	
1991	0				0.000			8	208.8	6.4	0.774	0.105				0.105	
1992	0				0.000			5	264.0	35.3	0.705	0.044				0.044	
1993	0				0.000			.	.	.	.	.				.	.
1994	0				0.000			.	.	.	.	.				.	.
1995	3	243.3	3.3		0.001			13	216.2	4.7	0.583	0.097				0.097	
1996	1	250.0	0.0		0.003			4	205.0	5.0	2.192	0.056				0.056	
1997	3	246.7	14.5		0.001			22	221.9	7.7	1.549	0.282				0.282	
1998	3	260.0	11.5		0.002			15	262.4	7.0	0.621	0.200				0.200	
1999								7	223.6	12.9	2.027	0.232				0.232	

## Appendix C75.-

**spotted seatrout**  
*Cynoscion nebulosus*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	33	357.3	9.2	0.002												
1977	18	443.9	7.8	0.016												
1978	43	374.0	8.6	0.034												
1979	14	382.1	14.1	0.018												
1980	34	412.1	11.6	0.011												
1981	19	425.8	18.1	0.007												
1982	144	375.3	5.2	0.028												
1983	119	349.0	5.1	0.017												
1984	31	356.1	9.2	0.024												
1985	24	356.3	11.2	0.009												
1986	9	372.2	17.7	0.003												
1987	10	412.0	17.7	0.002												
1988	0			0.000												
1989	1	510.0	0.0	0.002												
1990	0			0.000												
1991	0			0.000												
1992	7	381.4	6.7	0.016												
1993	0			0.000												
1994	2	360.0	10.0	0.008												
1995	12	377.5	6.3	0.019												
1996	0			0.000												
1997	0			0.000												
1998	9	407.8	9.2	0.011												
1999																

## Appendix C76.-

**permit**  
*Trachinotus falcatus*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal
1976	0		0		0.000											
1977	0		0		0.000											
1978	0		0		0.000											
1979	1	1010.0	0.0	1	1010.0	0.0	0.000									
1980	0		0		0.000											
1981	3	643.3	63.3	3	643.3	63.3	0.001									
1982	1	270.0	0.0	1	270.0	0.0	0.000									
1983	3	723.3	26.7	3	723.3	26.7	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1984	2	585.0	85.0	2	585.0	85.0	0.001	0		0		0.000	0.000	0.000	0.000	0.000
1985	1	710.0	0.0	1	710.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1986	1	580.0	0.0	1	580.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1987	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1988	3	476.7	27.3	3	476.7	27.3	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1989	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1990	6	573.3	40.1	6	573.3	40.1	0.001	2	500.0	0.0	2	500.0	0.0	0.008	0.000	0.008
1991	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1992	1	700.0	0.0	1	700.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1993	0		0		0.000											
1994	0		0		0.000											
1995	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1996	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1997	0		0		0.000	0			0			0.000	0.000	0.000	0.000	0.000
1998	1	680.0	0.0	1	680.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000
1999					0				0			0.000	0.000	0.000	0.000	

## Appendix C77.-

**african pompano**  
*Alectis ciliaris*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0				0												0.000
1977	0				0												0.000
1978	0				0												0.000
1979	1	680.0	0.0	1	680.0	0.0	0.001										
1980	1	300.0	0.0	1	300.0	0.0	0.000										
1981	0				0												0.000
1982	2	465.0	115.0	2	465.0	115.0	0.001										
1983	1	500.0	0.0	1	500.0	0.0	0.000										
1984	0				0												0.000
1985	7	384.3	30.9	7	384.3	30.9	0.004										
1986	3	526.7	80.9	3	526.7	80.9	0.006										
1987	0				0												0.000
1988	1	620.0	0.0	1	620.0	0.0	0.001										
1989	0				0												0.000
1990	2	800.0	10.0	2	800.0	10.0	0.001										
1991	6	335.0	8.5	6	335.0	8.5	0.001										
1992	0				0												0.000
1993	0				0												0.000
1994	0				0												0.000
1995	0				0												0.000
1996	0				0												0.000
1997	0				0												0.000
1998	0				0												0.000
1999																	

## Appendix C78.-

**dolphin**  
*Coryphaena hippurus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	422	567.6	9.0		0.464												
1977	167	612.9	12.9		0.299												
1978	297	614.2	10.4		0.315												
1979	118	642.9	20.3		0.242												
1980	220	614.9	12.7		0.188												
1981	493	567.9	8.7		0.386												
1982	344	601.7	7.9		0.480												
1983	248	661.9	13.3		0.302												
1984	5	660.0	93.8		0.107												
1985	561	583.3	4.9		0.335												
1986	388	724.0	8.5		0.218												
1987	148	614.9	14.5		0.151												
1988	218	563.8	9.2		0.206												
1989	493	532.3	5.8		0.552												
1990	365	590.9	8.4		0.213												
1991	448	590.4	7.0		0.222												
1992	458	576.4	8.3		0.225												
1993	443	527.9	6.2		0.304												
1994	506	566.0	5.7		0.297												
1995	166	657.5	13.8		0.258												
1996	222	575.8	11.6		0.253												
1997	202	538.2	10.1		0.290												
1998	11	596.4	28.2		0.214												
1999																	

## Appendix C79.-

**atlantic bonito**  
*Sarda sarda*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.023										
1977				0			0.015										
1978				0			0.010										
1979				0			0.008										
1980				7	475.7	16.6	0.012										
1981				28	542.1	28.1	0.011										
1982				4	422.5	68.0	0.005										
1983				6	478.3	101.4	0.003										
1984				0			0.000										
1985				3	636.7	55.5	0.001										
1986				28	425.4	31.8	0.010										
1987				0			0.000										
1988				0			0.000										
1989				3	316.7	16.7	0.001										
1990				0			0.000										
1991				4	715.0	55.2	0.002										
1992				1	670.0	0.0	0.000										
1993				1	620.0	0.0	0.000										
1994				0			0.001										
1995				0			0.000										
1996				0			0.000										
1997				1	450.0	0.0	0.002										
1998				0			0.000										
1999																	

## Appendix C80.-

**little tunny**  
*Euthynnus alletteratus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.000										
1977				0			0.000										
1978				0			0.000										
1979				0			0.002										
1980				0			0.000										
1981				0			0.000										
1982				1	490.0	0.0	0.000										
1983				13	578.5	25.1	0.002										
1984				0			0.000										
1985				4	677.5	70.8	0.001										
1986				1	370.0	0.0	0.000										
1987				12	503.3	44.5	0.003										
1988				7	452.9	73.8	0.003										
1989				6	651.7	40.0	0.002										
1990				11	446.4	52.5	0.002										
1991				11	569.1	50.4	0.002										
1992				8	570.0	50.6	0.002										
1993				15	444.0	35.5	0.007										
1994				18	476.7	33.4	0.004										
1995				2	475.0	175.0	0.001										
1996				18	620.0	42.1	0.006										
1997				2	490.0	180.0	0.001										
1998				6	423.3	38.7	0.006										
1999																	

## Appendix C81.-

**sailfish**  
*Istiophorus platypterus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	1	1750	0	0	0.002												
1977	0				0.001												
1978	0				0.002												
1979	1	1750.0	0.0	0	0.001												
1980	2	1740.0	60.0	0	0.002												
1981	1	1650.0	0.0	0	0.002												
1982	2	1870.0	140.0	0	0.002												
1983	4	1875.0	97.2	0	0.002												
1984	0				0.000												
1985	5	1708.0	75.6	0	0.001												
1986	1	2450.0	0.0	0	0.001												
1987	1	1870.0	0.0	0	0.001												
1988	1	1590.0	0.0	0	0.002												
1989	1	1670.0	0.0	0	0.001												
1990	1	1590.0	0.0	0	0.000												
1991	1	1750.0	0.0	0	0.001												
1992	0				0.001												
1993	1	1780.0	0.0	0	0.000												
1994	2	1615.0	35.0	0	0.001												
1995	1	1600.0	0.0	0	0.002												
1996	1	1700.0	0.0	0	0.001												
1997	0				0.000												
1998	0				0.000												
1999																	

## Appendix C82.-

**skipjack tuna**  
*Katsuwonus pelamis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0	0.000												
1977	0			0	0.000												
1978	0			0	0.000												
1979	0			0	0.002												
1980	0			0	0.000												
1981	0			0	0.000												
1982	0			0	0.000												
1983	11	590.9	21.1	0	0.002												
1984	1	500.0	0.0	0	0.003												
1985	0			0	0.000												
1986	0			0	0.000												
1987	3	660.0	47.3	0	0.002												
1988	1	640.0	0.0	0	0.000												
1989	0			0	0.002												
1990	7	625.7	25.4	0	0.002												
1991	0			0	0.000												
1992	5	560.0	10.5	0	0.003												
1993	2	530.0	20.0	0	0.001												
1994	3	606.7	58.1	0	0.002												
1995	0			0	0.000												
1996	2	585.0	55.0	0	0.003												
1997	1	650.0	0.0	0	0.001												
1998	1	610.0	0.0	0	0.000												
1999																	

## Appendix C83.-

**blackfin tuna**  
*Thunnus atlanticus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.000										
1977				0			0.000										
1978				0			0.000										
1979				0			0.000										
1980				1	580.0	0.0	0.005										
1981				0			0.001										
1982				3	520.0	65.1	0.003										
1983				2	460.0	20.0	0.001										
1984				0			0.002										
1985				1	730.0	0.0	0.001										
1986				7	588.6	71.9	0.002										
1987				0			0.000										
1988				0			0.000										
1989				0			0.000										
1990				1	800.0	0.0	0.001										
1991				0			0.000										
1992				1	780.0	0.0	0.000										
1993				5	594.0	51.0	0.004										
1994				1	320.0	0.0	0.001										
1995				0			0.000										
1996				0			0.000										
1997				2	560.0	0.0	0.002										
1998				2	365.0	15.0	0.006										
1999																	

## Appendix C84.-

**king mackerel**  
*Scomberomorus cavalla*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	42	741.7	20.4	42	741.7	20.4	0.000										
1977	11	733.6	35.3	11	733.6	35.3	0.000										
1978	6	720.0	58.0	6	720.0	58.0	0.001										
1979	6	721.7	79.4	6	721.7	79.4	0.005										
1980	9	834.4	42.2	9	834.4	42.2	0.010										
1981	10	757.0	66.1	10	757.0	66.1	0.007										
1982	11	821.8	36.4	11	821.8	36.4	0.007										
1983	9	731.1	26.4	9	731.1	26.4	0.006										
1984	0			0			0.007										
1985	7	931.4	75.3	7	931.4	75.3	0.003										
1986	2	910.0	40.0	2	910.0	40.0	0.002										
1987	9	747.8	48.9	9	747.8	48.9	0.009										
1988	4	800.0	59.6	4	800.0	59.6	0.002										
1989	6	668.3	30.2	6	668.3	30.2	0.004										
1990	16	848.1	52.9	16	848.1	52.9	0.009										
1991	13	773.8	27.1	13	773.8	27.1	0.006										
1992	3	740.0	49.3	3	740.0	49.3	0.002										
1993	11	788.2	41.9	11	788.2	41.9	0.004										
1994	9	860.0	65.0	9	860.0	65.0	0.004										
1995	2	875.0	105.0	2	875.0	105.0	0.005										
1996	4	845.0	38.6	4	845.0	38.6	0.009										
1997	1	1090.0	0.0	1	1090.0	0.0	0.000										
1998	3	880.0	90.7	3	880.0	90.7	0.003										
1999																	

## Appendix C85.-

**spanish mackerel**  
*Scomberomorus maculatus*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	28	571.4	14.2				0.000										
1977	11	606.4	38.5				0.000										
1978	4	575.0	32.8				0.002										
1979	3	410.0	10.0				0.002										
1980	4	505.0	42.5				0.011										
1981	13	533.8	25.1				0.005										
1982	18	567.8	21.8				0.019										
1983	2	495.0	65.0				0.003										
1984	0																0.002
1985	3	400.0	15.3				0.001										
1986	2	660.0	160.0				0.012										
1987	8	463.8	30.2				0.007										
1988	1	460.0	0.0				0.002										
1989	0						0.000										
1990	1	450.0	0.0				0.001										
1991	11	550.0	38.7				0.006										
1992	9	533.3	21.8				0.003										
1993	3	606.7	58.1				0.002										
1994	2	415.0	25.0				0.001										
1995	3	516.7	18.6				0.002										
1996	0						0.000										
1997	1	470.0	0.0				0.001										
1998	1	510.0	0.0				0.000										
1999																	

## Appendix C86.-

**cero**  
*Scomberomorus regalis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976		0			0.000												
1977		0			0.000												
1978		3	783.3	53.6	0.000												
1979		22	495.0	18.9	0.007												
1980		72	512.2	13.5	0.008												
1981		59	508.8	12.2	0.009												
1982		21	546.7	24.2	0.006												
1983		31	521.3	19.4	0.004				3	566.7	6.0	0.111	0.000				
1984		4	487.5	76.0	0.003				0			0.000	0.000				
1985		29	491.0	19.7	0.002				0			0.000	0.000				
1986		45	612.7	18.5	0.005				0			0.000	0.000				
1987		61	482.0	10.6	0.010				1	500.0	0.0	0.027	0.000				
1988		27	505.2	17.1	0.004				9	514.4	3.3	0.054	0.000				
1989		8	558.8	35.8	0.002				3	463.3	1.3	0.009	0.000				
1990		24	521.7	24.9	0.004				16	513.8	3.7	0.068	0.004				
1991		12	480.8	33.8	0.002				7	562.9	9.3	0.108	0.000				
1992		29	478.6	17.4	0.005				0			0.000	0.000				
1993		57	498.1	10.4	0.013				.	.	.	.	.				
1994		22	484.1	18.6	0.003				.	.	.	.	.				
1995		17	511.2	20.8	0.005				4	525.0	9.7	0.036	0.000				
1996		6	476.7	18.2	0.001				6	488.3	5.0	0.097	0.000				
1997		11	495.5	34.1	0.002				0			0.006	0.000				
1998		9	592.2	31.5	0.003				3	436.7	2.1	0.041	0.000				
1999									0			0.000	0.000				

## Appendix C87.-

**greater amberjack**  
*Seriola dumerili*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	1	1060.0	0.0	1	1060.0	0.0	0.000										
1979	4	845.0	119.1	4	845.0	119.1	0.002										
1980	4	877.5	76.6	4	877.5	76.6	0.003										
1981	25	970.8	62.3	25	970.8	62.3	0.005										
1982	11	1106.4	22.5	11	1106.4	22.5	0.002										
1983	7	835.7	139.9	7	835.7	139.9	0.001	0		0		0.000	0.000	0.000	0.000	0.000	
1984	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1985	4	467.5	90.6	4	467.5	90.6	0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1986	7	702.9	65.1	7	702.9	65.1	0.001	0		0		0.000	0.000	0.000	0.000	0.000	
1987	15	1058.7	50.9	15	1058.7	50.9	0.003	0		0		0.000	0.000	0.000	0.000	0.000	
1988	1	1020.0	0.0	1	1020.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1989	6	596.7	164.7	6	596.7	164.7	0.002	0		0		0.000	0.000	0.000	0.000	0.000	
1990	0			1	400.0	0.0	0.000	2	1675.0	155.0	2	1675.0	155.0	0.000	0.008	0.008	0.008
1991	8	1017.5	24.5	9	953.3	67.7	0.001	0		0		0.000	0.000	0.000	0.000	0.000	
1992	0			0			0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1993	1	1000.0	0.0	1	1000.0	0.0	0.000	.		.		.	.	.	.	.	
1994	2	945.0	75.0	2	945.0	75.0	0.000	.		.		.	.	.	.	.	
1995	2	1110.0	110.0	2	1110.0	110.0	0.001	0		0		0.000	0.000	0.000	0.000	0.000	
1996	2	1050.0	20.0	3	900.0	150.4	0.002	0		0		0.000	0.000	0.000	0.000	0.000	
1997	0			1	670.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1998	1	1010.0	0.0	1	1010.0	0.0	0.000	0		0		0.000	0.000	0.000	0.000	0.000	
1999							0			0		0.000	0.000	0.000	0.000	0.000	

## Appendix C88.-

**tripletail**  
*Lobotes surinamensis*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	0			0			0.000										
1977	0			0			0.000										
1978	0			0			0.000										
1979	0			0			0.000										
1980	0			0			0.000										
1981	4	380.0	44.2	4	380.0	44.2	0.004										
1982	5	372.0	32.0	5	372.0	32.0	0.006										
1983	0			0			0.000										
1984	0			0			0.000										
1985	1	370.0	0.0	1	370.0	0.0	0.000										
1986	4	402.5	8.5	4	402.5	8.5	0.001										
1987	0			0			0.001										
1988	0			0			0.000										
1989	3	366.7	47.0	3	366.7	47.0	0.001										
1990	2	430.0	80.0	2	430.0	80.0	0.002										
1991	7	434.3	26.4	7	434.3	26.4	0.002										
1992	3	480.0	45.8	3	480.0	45.8	0.001										
1993	2	350.0	50.0	2	350.0	50.0	0.002										
1994	9	430.0	11.9	9	430.0	11.9	0.003										
1995	1	480.0	0.0	1	480.0	0.0	0.003										
1996	1	400.0	0.0	2	385.0	15.0	0.005										
1997	0			1	340.0	0.0	0.001										
1998	1	480.0	0.0	1	480.0	0.0	0.001										
1999																	

## Appendix C89.-

**wahoo**  
*Acanthocybium solandri*

Year	CREEL Survey Data						RVC Survey Data										
	Lbar			CPUE			Lbar			CPUE							
	n	Legal	S.E.	n	Actual	S.E.	Actual	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976				0			0.001										
1977				3	940.0	181.5	0.001										
1978				3	860.0	113.6	0.002										
1979				3	1066.7	23.3	0.006										
1980				10	1056.0	67.0	0.004										
1981				6	931.7	106.4	0.003										
1982				8	1015.0	69.9	0.003										
1983				4	1150.0	143.6	0.003										
1984				2	1130.0	90.0	0.021										
1985				4	1127.5	57.9	0.001										
1986				8	1003.8	45.8	0.003										
1987				5	1162.0	74.8	0.004										
1988				7	985.7	63.8	0.008										
1989				3	1150.0	75.1	0.001										
1990				2	1015.0	5.0	0.003										
1991				9	1134.4	43.5	0.005										
1992				4	1055.0	26.3	0.002										
1993				8	1183.8	91.3	0.006										
1994				7	1002.9	79.8	0.004										
1995				2	1095.0	25.0	0.003										
1996				6	1045.0	86.1	0.005										
1997				1	1200.0	0.0	0.002										
1998				2	890.0	210.0	0.003										
1999																	

## Appendix C90.-

**spiny lobster**  
*Panulirus Argus*

Year	CREEL Survey Data						RVC Survey Data									
	Lbar			CPUE			Lbar			CPUE						
	n	Legal	S.E.	n	Actual	S.E.	n	Legal	S.E.	n	Actual	S.E.	IM	Mat	Legal	Actual
1976	313	838.9	3.5	313	838.9	3.5	1.067									
1977	674	855.2	3.0	674	855.2	3.0	0.814									
1978	1175	846.4	2.2	1175	846.4	2.2	0.880									
1979	658	842.9	2.8	658	842.9	2.8	1.059									
1980	1350	844.9	2.0	1350	844.9	2.0	0.944									
1981	771	859.4	3.0	771	859.4	3.0	0.672									
1982	1695	829.5	1.6	1695	829.5	1.6	0.926									
1983	700	829.8	2.5	700	829.8	2.5	0.759									
1984	624	836.3	2.5	624	836.3	2.5	0.603									
1985	373	845.9	3.4	373	845.9	3.4	0.796									
1986	1190	852.2	2.0	1190	852.2	2.0	0.813									
1987	879	843.0	2.4	879	843.0	2.4	0.822									
1988	732	835.7	2.3	732	835.7	2.3	0.761									
1989	873	848.0	2.3	873	848.0	2.3	0.863									
1990	1653	857.2	1.8	1653	857.2	1.8	0.780									
1991	278	869.7	4.8	278	869.7	4.8	1.359									
1992	107	854.4	7.2	107	854.4	7.2	1.523									
1993	231	857.9	4.6	231	857.9	4.6	1.079									
1994	295	861.6	4.8	295	861.6	4.8	1.443									
1995	429	863.2	3.1	429	863.2	3.1	2.184									
1996	329	859.4	4.3	329	859.4	4.3	1.416									
1997	168	844.9	5.2	168	844.9	5.2	1.222									
1998	130	869.5	8.1	130	869.5	8.1	1.375									
1999																

**Appendix D1:** SAS programs for processing reef fish visual census data and estimating average length in the exploited phase and catch per unit effort (see Figure 21).

```

run;
/*program fkdat3.sas*/
/*processes FK reef fish 99 bio data*/
/*applies 2-stage numbers-at-length algorithm*/
/*bnp region, all species*/
options nodate nonumber;
data rl1;
  infile '/us4/sgsmith/reefsamp/rf99/under5.txt';
  input species$ 1-4 species$ 17-24 @33 catch
    @40 meansize @48 minsize @56 maxsize;
  proc sort;
    by species;
  quit;
  data s1;
    infile '/us4/sgsmith/reefsamp/species.prn';
    input species$ 1-8 latin$ 16-47 common2$ 49-77 family$ 79-99
      specimen 101-104 famnum 111-113 bbrrawl 121 creel 129 rvc 137;
    if rvc=1;
    keep species specimen;
  run;
  proc sort;
    by species;
  quit;
  /*proc print;
  quit;*/
  data s2;
    merge r1 s1;
    by species;
    if catch=. then delete;
  run;
  /*proc print;
  quit;*/
  /*proc freq;
  tables species;
  quit;*/
  proc sort;
    by smpcode;
  quit;
  /*proc print;
  quit;*/
  data p1;
    infile '/us4/sgsmith/reefsamp/rf99_rf99_fkphys.txt';
    input month 1-2 day 4-5 rfb lk$ 10-16 stn 18 div$ 20
      smpcode$ 22-35 observ 37-38 @40 ddllong @60 depth
      rekey 67 subreg 69 spa 71-72 reeftype 74;
    if yr=99 then yr=1999;
    else yr=yr;
  run;
  proc sort;
    by smpcode;
  quit;
  /*proc print;
  quit;*/
  data m1;
    merge m1 s2;
    by smpcode;
  run;

```

```

quit;/*
data s3;
set s1;
run;
proc sort;
by specimen;
quit;/*
/*proc print;
data m9;
merge m8 $3;
by specimen;
if catch=. then delete;
run;
/*proc print;
quit;/*
data r2;
set m9;
if meansize=. then meansize=0;
else meansize=meansize;
if minsize=0 then minsize=.;
else minsize=minsize;
if maxsize=0 then maxsize=.;
else maxsize=maxsize;
run;
/*proc print;
quit;/*
/*proc univariate;
var minsize maxsize;
quit;/*
data r3a;
set r2;
if minsize=. ;
L3=meansize;
A3=catch;
L1=.;
A1=.;
A2=.;
L2=.;
A2=.;
L4=.;
A4=.;
A5=.;
L5=.;
A5=.;
drop catch minsize maxsize;
run;
data r3b;
if minsize ne . ;
if catch<-1;
L3=meansize;
A3=catch;
L1=.;
A1=.;
L2=.;
A2=.;
L4=.;
A4=.;
A5=.;
L5=.;
A5=.;
drop catch minsize maxsize;
run;
data r3c;
if minsize ne . ;
if catch<-1;
L3=meansize;
A3=catch;
L1=.;
A1=.;
L2=.;
A2=.;
L4=.;
A4=.;
L5=.;
A5=.;
L2=(L3+L1)/2;
A2=(catch-(A1+A3+A5))/2;
L4=(L3+L5)/2;
A4=A2;
drop catch minsize maxsize;
run;

```

```

ddlat ddlong specnum species len abund;
run;
/*proc print;
quit;*/
data r6;
if catch99=.;
if minsize ne .;
if catch99;
L1=minsize;
A1=0.01*catch;
L3=meansize;
A3=0.15*catch;
L5=maxsize;
A5=0.01*catch;
L2=(L3+L1)/2;
A2=(catch-(A1+A3+A5))/2;
L4=(L3+L5)/2;
A4=A2;
drop catch minsize meansize maxsize;
run;
/*proc print;
quit;*/
data r4;
set r3a r3b r3c r3d r3e r3f r3g;
run;
/*proc print;
quit;*/
data r5a;
set r4;
if L1=. then delete;
len=L1;
abund=A1;
ddlat ddlong specnum species len abund;
run;
data r5b;
set r4;
if L2=. then delete;
len=L2;
abund=A2;
keep yr month day regkey depth reeftype rfbblk stn div
ddlat ddlong specnum species len abund;
run;
data r5c;
set r4;
if L3=. then delete;
len=L3;
abund=A3;
keep yr month day regkey depth reeftype rfbblk stn div
ddlat ddlong specnum species len abund;
run;
data r5d;
set r4;
if L4=. then delete;
len=L4;
abund=A4;
keep yr month day regkey depth reeftype rfbblk stn div
ddlat ddlong specnum species len abund;
run;
data r5e;
set r4;
if L5=. then delete;
len=L5;
abund=A5;
keep yr month day regkey depth reeftype rfbblk stn div
ddlat ddlong specnum species len abund;
run;
/*program fkdat3a_bnp.sas*/
/*processes BNP region reef fish data*/
/*creates lbar analysis dataset*/
/*all species*/
options nodate nonumber;
data bl;
infile '/us4/sgsmith/reefsamp/fkdat3_7996.txt';
input yr 1-4 month 6-7 day 9-10 rfbblk$ 12-18 specnum 20-22
@24 ddlat @34 dlong @44 depth regkey 51 reeftype 53
species$ 55-62 stns$ 64-72 @74 len @81 num;
run;

```

```

if len>0;
keep yr species len num;
run;
data b2;
infile '/us4/sgsmith/reefsamp/rf9798/fkdat3_9798.txt';
input yr 1-4 month 6-7 day 9-10 rfb lk$ 12-18 stn$ 20-28
@30 ddat @40 ddlon @50 depth regkey 57 reeftype 59
species$ 61-68 specimen 70-72 @74 len @81 num;
if len>0;
keep yr species len num;
run;
data b3;
infile '/us4/sgsmith/reefsamp/rf99/fk99/fkdat3_99.txt';
input yr 1-4 month 6-7 day 9-10 rfb lk$ 12-18 stn$ 20-28
@30 ddat @40 ddlon @50 depth regkey 57 reeftype 59
species$ 61-68 specimen 70-72 @74 len @81 num;
if len>0;
keep yr species len num;
run;
data b4;
set b1 b2 b3;
proc sort;
by specimen yr;
quit;
/*proc print;
quit;*/
data b5;
format len 6.1 num 10.3;
file '/us4/sgsmith/bnp/rvc_lbardat.txt';
put yr 1-4 species$ 6-13 specimen 15-17 @19 len @26 num;
run;
/*program rvc_lbbar.sas*/
/*processes BNP region reef fish data*/
/*computes lbar*/
/*by species and year*/
options nodate nonumber;
data b1;
infile '/us4/sgsmith/bnp/rvc_lbardat.txt';
input yr 1-4 species$ 6-13 specimen 15-17 len @19 len @26 num;
if specimen=133;
keep yr species len num rfb lk stn;
run;
data r1;
set b1;
if yr<1985 and len<19 then delete;
if yr>=1985 and len<30 then delete;
/*if yr>1990 and len<51 then delete;*/
/*if len>100 then delete;*/
run;
/*proc print;
quit;*/
/*proc univariate plot;
var len;
proc means noprint vardef=wdf;
class species yr;
var len;
weight num;
id specimen;
output out=r2 mean=lbar var=s2 sumwgt=n;
run;
data b4;
set b1 b2 b3;

```

```

run;
proc sort;
by specimen yr;
quit;
/*proc print;
quit;*/
data b5;
set b4;
format len 6.1 num 10.3;
file '/us4/sgsmith/bnp/rvc_cbfledat.txt';
put yr 1-4 species$ 6-13 specimen 15-17 rfbblk$ 19-25 stns$ 27-35
@37 len @44 num;
run;

/*program rfdsl.sas*/
/*2-stage SRS design, FK reef fish data*/
options nodate nonumber;
data rdl;
infile '/us4/sgsmith/bnp/rvc_cbfledat.txt';
input yr 1-4 species$ 6-13 specimen 15-17 rfbblk$ 19-25 stns$ 27-35
@37 len @44 num;
if specimen=232;
run;
/*proc print;
quit;*/
data rdl;
set rdl;
if len<87.7 then jnum=num;
else jnum=0;
if len=0 or len>=87.7 then anum=num;
else anum=0;
if len=0 or len>=35.0 then enum=num;
else enum=0;
/*if len=0 or (yr<1990 and len>=30) or
(yr>=1990 and len>=51) then enum=num;
else enum=0;*/
run;
/*proc print;
quit;*/
proc means noprint;
class yr rfbblk stns;
var jnum anum enum;
output out=r1 sum=j_cpi var=vari;
quit;
data r2;
set r1;
if _type_=7;
drop _type_ -freq_;
run;
/*proc print;
quit;*/
proc means noprint;
class yr rfbblk;
var e_abund;
id species specimen;
output out=r3 mean=cpi var=vari;
quit;
data r4;
set r3;
if _type_=3;

```

---

**Appendix D2:** SAS programs for processing BNP recreational creel survey data and estimating average length in the exploited phase and catch per unit effort (see Figure 21).

```

/*program creelbar.sas*/
/*processes creel fish length data, 1976-1998*/
/*computes lbar by species and year*/
options number nodate;
data f1a;
infile '/us4/sgsmith/bnp/creel/creel_len_7687.prn';
input month 7-8 day 14-15 yr 22-23 intnum 26-30 specode 33-36
      len 40-43 commons 51-72 area 75;
if area=0 then delete;
drop common intnum;
run;
data f1b;
infile '/us4/sgsmith/bnp/creel/creelln_8891.prn';
input month 6-7 day 13-14 yr 21-22 intnum 25-29 specode 32-35
      len 40-43 commons 52-71 area 74;
if area=0 then delete;
drop common intnum;
run;
/*proc print;
quit;*/
data f1c;
infile '/us4/sgsmith/bnp/creel/creellent.txt';
input obs 1-6 month 12-13 day 19-20 yr 24-27 area 32-33
      specode 40-43 commons 49-69 len 72-74;
if specode=9999 then delete;
if area=. then area=37;
else area=area;
if area=17 or area=36 or area=37 then delete;
if yr<1999;
drop obs common;
run;
data f2;
set f1a f1b f1c;
if len=0 then delete;
run;
/*proc print;
quit;*/
proc sort;
by specode;
quit;
data s1;
infile '/us4/sgsmith/bnp/creel/creelspecies.prn';
input specode spectrum;
run;
proc sort;
by specode;
quit;
/*proc print;
quit;*/
data f3;
merge s1 f2;
by specode;
if len=. then delete;
run;
proc sort;
by spectrum;
quit;
/*proc univariate plot;
var len;
quit;*/
proc means noproctitle;
class species yr;

```

```

var len;
id specimen;
output out=r4 n=n mean=lbar stderr=se_lbar;
quit;
data r4;
if type_=3;
  if se_lbar=. then se_lbar=0;
  format lbar 7.2 se_lbar 6.2;
  drop _type_ _freq_;
run;
data y1;
infile '/us4/sgsmith/bnp/creel/yr_ts.txt';
input yr id;
input yr id;
data r6;
merge r5 y1;
by yr;
if n=. then n=0;
else n=n;
if specimen=. then specimen=16;
else specimen=specnum;
if species='BAL CAFR' then species='BAL CAFR';
else species=species;
drop id;
run;
proc print noobs;
title ' ';
quit;
/*program creelcpdat.sas*/
/*processes creel_cpe data, 1976-1998*/
/*creates analysis dataset, all species*/
options nonumber nodate;
data c1;
infile '/us4/sgsmith/bnp/creel/creelint_7687.prn';
input @1 intid persons 17-18 eff_hrs 25-26 trgspec 31-36
area 41-42 party 51-52 month 58-59 day 65-66 yr 73-74
specode 76-80 catch 81-85;
if eff_hrs=0 then delete;
if area=17 or area=30 then delete;
trip=intid*10;
yr=yr+1900;
type=0;
drop intid;
run;
data c2;
infile '/us4/sgsmith/bnp/creel/creelint_8891.prn';
input @1 intid persons 18-19 eff_hrs 26-27 trgspec 32-37
area 42-43 party 53-54 month 60-61 day 66-67 yr 74-75
specode 76-80 catch 81-85;
if area=17 then delete;
trip=intid*10;
yr=yr+1900;
type=0;
drop intid;
run;
data c3a;
infile '/us4/sgsmith/bnp/Census_91-93.prn';
input trip 3-8 specode 14-18 catch 26-30;
if specode=. then specode=0;
run;
set c1 c2 c3 c4;

```

```

run;
proc sort;
by yr trip;
quit;
/*proc print;
quit;*/
/*proc freq;
tables yr party type area;
quit;*/
var trip catch;
quit;
proc sort;
by specode;
quit;
data s1;
infile '/us4/sgsmith/bnp/creel/creelspecies.prn';
input specode spectrum;
run;
proc sort;
by specode;
quit;
/*proc print;
quit;*/
data c6;
merge s1 c5;
by specode;
if spectrum=. then delete;
run;
proc sort;
by specum;
quit;
/*proc print;
quit;*/
/*proc freq;
tables specode;
quit;*/
data r1;
infile '/us4/sgsmith/reefsamp/species.prn';
input species$ 1-8 latin$ 16-47 commor$ 49-77 family$ 79-99
specnum 101-104 famnum 111-113 bbtrawl 121 creel 129 rvc 137;
keep species specum family;
run;
proc sort;
by specum;
quit;
/*proc print;
quit;*/
/*proc freq;
tables specode;
quit;*/
data r2;
merge rl c6;
by specum;
run;
proc sort;
by species;
quit;
/*proc print;
quit;*/
data r3;
set r2;
if party=0 then delete;
run;

```

---

```

data f7;
set f6;
if type=3;
if lob>0 and fsh=0 then gear='DL';
else if lob=0 and fsh>0 then gear='DF';
else if lob>0 and fsh>0 then gear='DM';
else if lob=0 and fsh=0 then gear='DC';
else gear='DU';
keep yr trip gear;
run;

data f8;
merge f5 f7;
by yr trip;
if gear='DU' and trgspec=1211 then gear='DL';
else if gear='DU' and (trgspec=0 or trgspec=9999) then gear='DM';
else if gear='DU' and 5300<=trgspec<8800 then gear='DF';
else gear=gear;
if gear='DU' or gear='DC' then delete;
drop lob fsh unk con;
run;
data f9;
set f4;
if party<=5;
if trip=; then delete;
gear='HK';
run;
data f10;
set f8 f9;
if specimen=700 then species='UNK SPE.' ;
proc sort;
by yr trip;
quit;
data u1;
set f10;
if specimen=700 then unk=1;
else unk=0;
if specimen ne 700 then oth=1;
else oth=0;
run;
proc means noprint;
class yr trip;
var unk oth;
output out=u2 sum=unk oth=;
quit;
data u3;
set u2;
if type=3;
if unk>0 and oth=0 then crct=1;
else crct=0;
keep yr trip crct;
run;
data u4;
merge f10 u3;
by yr trip;
if crct=1 and catch>0 then delete;
drop crct;
run;
data al;
set u4;
if area=16 or 24<=area<=25 or 34<=area<=35 then delete;

```

---

```

if 1<=area<=4 or 7<=area<=11 or area=18 or 20<=area<=22
or area=27 or area=31 or area=38 then reg='BAY';
else if area=5 or area=19 or area=23 then reg='REF';
else if area=6 or area=26 then reg='PEL';
else if 12<=area<14 or area=28 or area=32 then reg='BRF';
else if area=15 then reg='PRF';
else if 29<=area<30 or area=33 then reg='BPL';
else reg='UNK';
if reg='BPL' then delete;
run;
proc sort;
by yr trip;
data a2;
set al;
if 87<=specnum<=98 or specnum=100 or specnum=123
or 125<=specnum<=126 or 129<=specnum<=133 or specnum=269
or 190<=specnum<=203 or 214<=specnum<=218 or specnum=227
or specnum=706 or specnum=724 or specnum=731 then reef=1;
else reef=0;
if specnum=34 or 37<=specnum<=38 or specnum=286
or specnum=290 or specnum=303 or 306<=specnum<=307
or 193<=specnum<=194 or specnum=309 then pela=1;
else pala=0;
if reef=0 and pela=0 then mixd=1;
else mixd=0;
run;
proc means noprint;
class yr trip;
var reef pala mixd;
output out=a3 sum=reef pala mixd;
quit;
data a4;
set a3;
if type=3;
if reef=0 and pela=0 then spc='R';
else if pala>0 and reef=0 then spc='P';
else if reef=0 and pala>0 then spc='B';
else spc='U';
keep yr trip spc;
run;
data a5;
merge al a4;
by yr trip;
if spc='B' and (reg='BAY' or reg='BRF') then delete;
if spc='B' and (reg='PEL' or reg='REF') then reg='PRF';
else reg=reg;
if spc='P' then reg='PEL';
else reg=reg;
if spc='R' and (reg='PEL' or reg='PRF') then reg='REF';
else reg=reg;
run;
proc sort;
by gear species reg;
quit;
/*proc print;
quit;*/
/*proc freq;
tables species*reg;
quit;*/
data a6;

```

```

format species $char8.;

set a5;
file '/u4/smith/bnp/creel/creel_catch.txt';
put yr 1-4 trip 6-11 specnum 13-15 species$ 17-24 catch 26-30;
run;
data z1;
  set a5;
  if specnum=713 and catch>0 then trig=1;
  else trig=0;
  if specnum=702 and catch>0 then jack=1;
  else jack=0;
  if specnum=706 and catch>0 then grunt=1;
  else grunt=0;
  if specnum=722 and catch>0 then chub=1;
  else chub=0;
  if specnum=724 and catch>0 then snap=1;
  else snap=0;
  if specnum=729 and catch>0 then tuna=1;
  else tuna=0;
  if specnum=731 and catch>0 then group=1;
  else group=0;
  if specnum=711 and catch>0 then porgy=1;
  else porgy=0;
run;
/*proc print;
quit;*/
/*proc freq;
tables specnum*pres;
quit;*/
proc means noprint;
class yr trip;
var trig jack grunt chub snap tuna group porgy;
id persons eff_hrs gear regi;
output out=z2 sum=trig jack grunt chub snap tuna
group porgy;
quit;
data z3;
  set z2;
  if _type_=3;
  drop _type_ _freq_;
run;
/*proc print;
quit;*/
/*proc freq;
tables gear*reg;
quit;*/
data z4;
  set z3;
  file '/u4/smith/bnp/creel/creel_effort.txt';
  put yr 1-4 trip 6-11 gear$ 13-14 reg$ 16-18 persons 20-21
eff_hrs 23-24 trig 26 jack 28 grunt 30 chub 32 snap 34
tuna 36 group 38 porgy 40;
run;
/*program creelopue.sas*/
/*processes creel cpue data, 1976-1998*/
/*computes CPUE by year*/
/*single species and gear*/
options nonumber nodate;
data cl;
  infile '/u4/smith/bnp/creel/creel_catch.txt';
  input yr 1-4 trip 6-11 specnum 13-15 species$ 17-24 catch 26-30;

```

```

cpue=catch/effort;
if cpue>20 then delete;
keep yr trip spectrum species gear cpue;
run;/*
/*proc print;
quit;*/
/*proc univariate plot;
var cpue;
quit;*/
proc means noprint;
class spectrum yr;
var cpue;
id species gear;
output out=r2 n=n mean=avcp var=varcp;
quit;
data r3;
set r2;
if _type_=3;
vbar_cp=varcp/n;
se_cp=sqrt (vbar_cp);
if avcp>0 then cv_cp=(se_cp/avcp)*100;
else cv_cp=0;
run;
proc print noobs;
var spectrum species gear yr n avcp se_cp cv_cp;
quit;

```

---

## Appendix E. - PROGRAM LBAR

```

C***** COMPUTES Z FROM THE LENGTH-BASED FORMULA OF
C EHRHARDT, N.M. and J.S. AULT. 1992.
C Transactions of the American Fisheries Society 121:115-122. *
C ~/meab/lbar/lbar.f
C
C***** open unit=4,file='lbar_sr_block.dat',status='old')
C
C***** READ(4,* XLINEF,XLL,XK,XN,ITS,XF
C
C***** READ(4,* XTL,TC,T0
C
C***** READ(4,* XLC,XLBAR
C
C***** XZ=XN+XF
C
C***** WRITE(6,* )'CALCULATING MORTALITY ESTIMATE'
C***** EHRHARDT & AULT
C
DO 1000 I=1,ITS
  Z=I*.0001
  X1=(XLINEF-XLL)/(XLINEF-XLC) ** (Z/XK)
  X2=((Z*(XLC-XLBAR)+(XK*XLINEF-XLBAR)))/
  $ ((Z*(XLL-XLBAR))+(XK*(XLINEF-XLBAR)))
  XX=XZ-X1
  IF (XX.LE.0) GOTO 1010
  1000 CONTINUE
  1010 WRITE(6,* )'COMPLETED MORTALITY ITERATIONS'
  ZERR=((Z-XZ)/XZ)*100.
  C*** BEVERTON & HOLT
  ZBH=(XK*XLINEF-XLBAR)/(XLBAR-XLC)
  ZERBH=( (ZBH-XZ)/XZ)*100.
  C*** SSENTONGO & LARKIN
  Y=- ALOG(1.-XLBAR/XLINEF)
  XC=- ALOG(1.-XLC/XLINEF)
  ZSL=XK*(1./(Y-XC))
  ZSLER=( (ZSL-XC)/XZ)*100
  XLLO=XLINEF*(1.-EXP(-XK*((TC)-T0)))
  XLHI=XLINEF*(1.-EXP(-XK*((TL)-T0)))
  XF2EA=Z-XM
  WRITE(6,* )'XLLO = ',XLLO,'XLHI = ',XLHI
  WRITE(6,* )'INPUT PARAMETERS: '
  WRITE(6,* )'LINEF = ',XLINEF,'L-LAMBDA = ',XLL
  WRITE(6,* )'LC = ',XLC,'K = ',XK
  WRITE(6,* )'LBAR = ',XLBAR,'Z = ',XZ
  WRITE(6,* )'E&A Z EST = ',Z
  WRITE(6,* )'ESTIMATED ERROR E&A = ',ZERR
  WRITE(6,* )'ESTIMATED F = ',XF2EA
  WRITE(6,* )
  C
  WRITE(6,* )'B&H Z EST = ',ZBH
  C
  WRITE(6,* )'ESTIMATED ERROR B&H = ',ZERBH
  C
  WRITE(6,* )'S&L Z EST = ',ZSL
  C
  WRITE(6,* )'ESTIMATED ERROR S&L = ',ZSLERR
  9999 STOP
END

```

## Appendix F. - PROGRAM REEFS

```

C***** DO 13 I=1,NMT
DO 12 J=1,(MFR-1)
XM(I,J)=0.0
12 CONTINUE
13 CONTINUE
DO 34 I=1,NMT
C XM(I,45)=XNM/XDT * 0.36
C 34 CONTINUE
DO 40 I=1,NMT
DO 35 J=MFR,NMT
XM(I,J)=XNM/XDT
35 CONTINUE
40 CONTINUE
GOTO 92
C***** AVAILABILITY ARRAY
C***** SELECTIVITY PATTERNS
C VARIABLE NAME = NAVA
C CONSTANT FOR ALL INTERVALS = 1
C SEASONALLY AVAILABLE = 2
C 92 IF(NAVA.EQ.1) GOTO 41
IF(NAVA.EQ.2) GOTO 91
41 DO 43 I=1,NMT
DO 42 J=1,(MFC-1)
A(I,J)=0.0
42 CONTINUE
43 CONTINUE
DO 50 I=1,NMT
DO 45 J=MFC,NM
A(I,J)=0.0
45 CONTINUE
50 CONTINUE
IF(LLS.EQ.0) GOTO 1566
IF(LLS.EQ.1) GOTO 1560
1560 DO 1564 I=1,NMT
DO 1562 J=LOL,LU
A(I,J)=0.
1562 CONTINUE
1564 CONTINUE
C***** SELECTION ARRAYS
C 1566 READ(13,*) (ST(J,1),ST(J,2),ST(J,3),ST(J,4),J=1,NM)
cc 1500 FORMAT(4F10.0)
K=0
LL=1
DO 1505 I=1,NDT
K=K+1
LL=LL+1
1505 CONTINUE
IF(K.LT.3) GOTO 1505
K=0
S(J,1)=ST(J,LL)
1504 CONTINUE
IF(NFOT.EQ.1) GOTO 21
IF(NFOT.EQ.2) GOTO 60
DO 107 I=1,NLL
C***** SEASONAL AVAILABILITY
C***** 91 DO 107 I=1,NLL
DO 106 M=1,12
K=(I-1)*12+M
IF(AM(M).EQ.0) GOTO 95
IF(AM(M).EQ.1) GOTO 97
95 X=K
J=1
DO 96 JJ=X,1,-1
IF(J.GT.NMT) GOTO 96
A(J,J)=0.0
J=J-1
96 CONTINUE
DO 98 JJ=X,1,-1
IF(J.GT.NMT) GOTO 98
A(J,J)=1.0
J=J-1
98 CONTINUE
106 CONTINUE
107 CONTINUE
GOTO 200
C***** BIRTH RATE FUNCTION ARRAYS
C***** CALCULATION OF AGE(SIZE) SPECIFIC BIRTH RATES
C (NET MATERNITY LMIX) BY MANIPULATION OF THE
C FECUNDITY ON WEIGHT RELATIONSHIP
C***** 200 RHO=0.8
XLAMBD=0.8
FECUN=0.0
SMPEC=0.0
DO 201 JJ=1,MFM
FEC(JJ)=0.0
201 CONTINUE
DO 206 JJ=MRM,NM
FEC(JJ)=ALPHA*(WT(JJ)**BETA)
IF(RHO.NE.XLAMBD) GOTO 202
IF(RHO.EQ.XLAMBD) GOTO 203
202 BT(JJ)=FEC(JJ)*((XLAMBD**JJ-1)-RHO*)
* GOTO 205
203 BT(JJ)=FEC(JJ)*(JJ+1-MRM)*(RHO*(JJ-MRM))
GOTO 205
205 BIRTHS(JJ)=BT(JJ)*(EXP(-XMM(JJ))-1)*(JJ-1)
FECUN=FECUN+FEC(JJ)
206 CONTINUE
DO 207 JJ=1,NM
PBIRTH(JJ)=FEC(JJ)/FECUN
PBIRTH(JJ)=PBIRTH(JJ)*10.
SMPEC=SMPEC+PBIRTH(JJ)
207 CONTINUE
C***** FISHING MORTALITY ARRAY
C***** VARIATE NAME = NFOT
POPE'S.(1971) METHOD = 1
C FISHING MORTALITY PATTERNS
C CONSTANT FOR ALL INTERVALS = 2
C SEASONAL FISHING STRATEGY = 3
C***** IF(NFOT.EQ.1) GOTO 21
IF(NFOT.EQ.2) GOTO 60

```

```

C*****IF(NFOT.EQ.3) GOTO 130
C*****POPE'S MID-YEAR APPROXIMATION
21 DO 20 I=1,NMT
   DO 19 L=-1,14
      L=0
      L1=(L-1)*12
      IF(I.EQ.L1) GOTO 18
      IF(I.NE.L1) GOTO 19
18 DO 17 J=1,NMT
   F(I,J)=FMORT/XDT
17 CONTINUE
   GOTO 20
19 CONTINUE
   DO 15 J=1,NMT
   F(I,J)=0.
15 CONTINUE
20 CONTINUE
GOTO 84
C****F CONSTANT EVERY INTERVAL
60 DO 62 I=1,NMT
   DO 61 J=1,(MFC-1)
   F(I,J)=0.
61 CONTINUE
62 CONTINUE
DO 63 I=1,NMT
   F(I,45)=FMORT/XDT * 0.36
C 63 CONTINUE
DO 67 I=1,NMT
   DO 64 J=MFC,NMT
   F(I,J)=FMORT/XDT
64 CONTINUE
67 CONTINUE
GOTO 84
C****SEASONAL FISHING MORTALITY STRATEGY
130 DO 149 I=1,NLL
   DO 148 M=1,12
   K=(I-1)*12+M
   IF(FP(M).EQ.0) GOTO 131
   IF(FP(M).EQ.1) GOTO 135
131 X=K
J=1
130 DO 141 JJ=X,1,-1
   IF(J.GT.NMT) GOTO 141
   F(JJ,J)=0.
   J=J+1
141 CONTINUE
   GOTO 148
135 X=K
J=1
135 DO 142 JJ=X,1,-1
   IF(J.GT.NMT) GOTO 142
   F(JJ,J)=FMORT/XNMF
   J=J+1
142 CONTINUE
148 CONTINUE
149 CONTINUE
GOTO 84
C*****RECRUITMENT ARRAYS
C*****RECRUITMENT DISTRIBUTION FUNCTIONS
C VARIABLE NAME = NROT
C DISCRETE = 1
C CONTINUOUS UNIFORM = 2
TRIGONOMETRIC DISTRIBUTION = 3
BETA DISTRIBUTION = 4
C TR = TOTAL ANNUAL MAGNITUDE OF RECRUITMENT
C*****DISCRETE ANNUAL RECRUITMENT
86 NNTL=NNTL+1
   DO 71 I=1,NNTL
   DO 70 J=1,NDT
      IF(J.NE.1) GOTO 68
      IF(J.EQ.1) GOTO 69
59 L=(I-1)*12+J
      R(L)=TR
      GOTO 70
68 L=(I-1)*12+J
      R(L)=0.0
      70 CONTINUE
71 CONTINUE
GOTO 79
C*****CONTINUOUS UNIFORM RECRUITMENT
87 DO 85 I=1,NMT
   R(I)=TR/XDT
85 CONTINUE
GOTO 79
C*****TRIGONOMETRIC RECRUITMENT
C VARIABLE NAME = PER
C PER = 12 (BIMODAL ANNUALLY)
C PER = 24 (UNIMODAL ANNUALLY)
C*****CONTINUOUS UNIFORM RECRUITMENT
88 PI=3.1415927
AMP1=(2*PI)/PER
SUM0=
S2=0.
S3=0.
DO 138 J=1,12
   RA(J)=STN(AMP1*J)
   RA(J)=ABS(RA(J))
   SUM=SUM+RA(J)
138 CONTINUE
RC(J)=RA(J)/SUM
S2=S2+RC(J)
187 LCOUNT=0
CONTINUE
DO 189 I=1,NTL
   S3=0.
   K=0.
   DO 186 J=1,12
   K=LCOUNT-J
   R(K)=RC(J)*TR
   S3=S3+R(K)
186 CONTINUE
LCOUNT=LCOUNT+12
189 CONTINUE
IF(MOS.EQ.0) GOTO 79
DO 184 J=NMC,NMT
   KK=I-NM
   R(J)=RC(KK)*TR
184 CONTINUE

```

```

K=0.
GOTO 79
C***** BETA DISTRIBUTION
C      Beta Distribution
C      Parameters of the Beta Distribution
C      PARM1 = ALPHA 1
C      PARM2 = ALPHA 2
C***** Parameters
C
90 PI=3.1415927
A1P=PARM1-1.
A2P=PARM2-1.
A3P=PARM1+PARM2)-1.
XN1F=EXP(-A1P)*(A1P*A1P)*(SQRT(2*PI*A1P))
XN2F=EXP(-A2P)*(A2P*A2P)*(SQRT(2*PI*A2P))
XN3F=EXP(-A3P)*(A3P*A3P)*(SQRT(2*PI*A3P))
BETADS=(XN1F*XN2F)/XN3F
GOTO 221
SUM=0.
C
C      DO 220 J=1,12
C      TIME=J/12.
C      RA(J)=( (TIME**A1P)*( (1-TIME)**A2P) ) /BETADS
C      SUM=SUM+RA(J)
C
220 CONTINUE
C      DO 219 J=1,NDT
C      RC(J)=RA(J) / SUM
C      S2=S2+RC(J)
C
219 CONTINUE
C      LCOUNT=0.
C      NNTL=NTL+1
DO 218 I=1,NNTL
S3=S3+R(K)
C
217 CONTINUE
LCOUNT=LCOUNT+12
K=0.
DO 217 J=1,12
K=LCOUNT+J
R(K)=RC(J)*TR
S3=0.
C
216 CONTINUE
GOTO 79
C***** CONSTRAINED BETA WGT TIME
C***** CONstrained Beta Wgt Time
C***** MFC=MFC+NTS
221 XCON=6.
SUM=0.
C
222 J=1,NDT
TIME=J/XCON
IF (J GT XCON) GOTO 226
RA(J)=( (TIME**A1P)*( (1-TIME)**A2P) ) /BETADS
SUM=SUM+RA(J)
GOTO 222
RA(J)=0.
C
222 CONTINUE
DO 223 J=1,NDT
WRITE(*,*) TIME,RA(J)
DO 223 J=1,NNTL
NNTL=NTL+1
DO 225 I=1,NNTL
S3=0.
K=0.
DO 224 J=1,NDT
K=LCOUNT+J
IF (J GT XCON) GOTO 227
R(K)=RC(J)*TR
WRITE(*,*) I,J,R(K)
GOTO 224
R(K)=0.
GOTO 224
S3=S3+R(K)
LCOUNT=LCOUNT+12
K=0.
C
225 CONTINUE
IF (MOS.EQ.0) GOTO 79
DO 236 J=NMC,NMT
KK=J-NM
R(J)RC(KK)*TR
C
236 CONTINUE
C***** STATIONARY CONDITIONS
C***** STATIONARY CONDITIONS
C***** STATIONARY VECTORS
C
79 WRITE(*,*) 'CALCULATING STATIONARY VECTORS'
IF (NPR.EQ.0) GOTO 80
DO 490 NF=1,NFRANGE
WRITE(*,*) 'YPR SIMULATION'
write(*,*) NTL, NTSS
XFM=0.
MTL=NTL*NTSS+1
DO 480 KK=1,MTL
YPR=0.
FPR=0.
IF (NP.GT.1) GOTO 491
FMX=0.
GOTO 492
491 XFM=XFM+1.
FMX=XFM*step
492 NTC=0
DO 480 KK=1,MTL
YPR=0.
FPR=0.
IF (KK.GT.1) GOTO 493
MFC=0
XMFC=0.
GOTO 494
493 MFC=MFC+NTS
XMFC=XMFC+XXNTS
494 WRITE(*,*) 'YPR AT' , FMX, XMFC, '( ,MFC, ' )
DO 479 I=1,NNLT
DO 475 J=1,(MFC-1)
F(I,J)=0.
A(I,J)=0.
475 CONTINUE
479 CONTINUE
DO 470 I=1,NNMT
DO 465 J=1,MFC
F(I,J)=0.
A(I,J)=1.0
465 CONTINUE

```

```

470 CONTINUE
  IF (MFC .LT. MFR) GOTO 463
  DO 1010 K=1,NWT
    SMOS=1
    CALL DYNSTIM(K,SMOS)
1010  CONTINUE
    GOTO 462
  463  YPR=0.
    FPR=0.
    GOTO 464
  464  YPR=TWJ/R,(NM)
    FPR=SSB/PPAMAX
    WRITE(*,*) FMX, SLT(MFC), XMFC, YPR, FPR
  464  XKK=0.1358
    T00=-0.863
    ULL=Z22.32
    SLL=DUL*(-XKK*(XMFC-T00))
    WRITE(14,* ) FMX, XMFC, SLL, YPR
    WRITE(15,* ) FMX, XMFC, SLL, FPR
  480  CONTINUE
    GOTO 4001
  490  CONTINUE
    WRITE(*,*) 'NORMAL SIMULATION'
    DO 1000 K=1,NM
      SMOS=1
      CALL DYNSTIM(K,SMOS)
1000  CONTINUE
    K=NW
    IF (NW .GT. K) GOTO 230
    SMOS=1
    CALL LAPD(K,SMOS,NAMP,NDIST)
    CALL SCANDET(K,NM,DTL)
    NEO=1
    ***Non-equilibrium switch
    IF (NSEARCH/230 .gt. 229
229  CALL SCANPB(K,NM,NDIST,DTL)
    WRITE(6,* ) 'RETURNED SCANPB'
    230  GOTO 3000
C***** DYNAMIC CONDITIONS *****
C***** CALCULATING TRANSITIONAL VECTORS' //'
3799  WRITE(6,3800)
3800  FORMAT(7X,'CALCULATING TRANSITIONAL VECTORS' //')
    DO 4000 K=NMC,NMT
      SMOS=SMOS+1
      CALL DYNSTIM(K,SMOS)
      IF (K .LT. NMT) GOTO 250
      CALL LAPD(K,SMOS,NAMP,NDIST)
      CALL SCANDET(K,NM,DTL)
      WRITE(*,*) 'RETURNED FROM SCANDET',NSRCH,K
      NEQ=1
      IF (NSEARCH/250 .gt. 249
249  CALL SCANPB(K,NM,NDIST,DTL)
      WRITE(*,*) 'RETURNED FROM SCANPB'
      250  GOTO 3000
C***** WRITING TO DATA FILES *****
C***** No Path to Statements
C      X=K
C      J=1
C      DO 820 I=X,1,-1
C        WRIT

```



```

112 BMJ=BMJ+BIOM(J)
PJ=PJ+P(I,J)
TL(I)=RN(I,J)*SLT(J)
TOTLP=TOTLP+TL(J)
IF (I .LT. MFC) GOTO 150
FPJ=FPJ+P(I,J)
FBM=FBM+BIOM(J)
FRP=FRP+RN(I,J)
VSM=0.

BMJ=0.
RPU=0.
FBM=0.
FRPU=0.
FPJ=0.
PJ=0
YNU=0.
AVGL=0.
EYPR=0.
SSB=0.
PPA=0.
AL=0.
ALC=0.
AVWT=0.
AVWT=0.
AFBM=0.
AFPN=0.
AAC=0.
TLPGTC=0.
ALPGTC=0.
XK=
J=1
write(*,*)'in dynsim', ' k = ', K, R(K)
IF (L1.GT.1) GOTO 99
LL=1
DO 500 I=X,SMOS,-1
BIOM(I)=0.
POPP(I)=0.
TL(I)=0.
ALC(I)=0.
TWC(I)=0.
TWC(I)=TOTWC/YNU
IF (I .LT. R(K))
Z(I,J)=XM(I,J)+(A(I,J)*F(I,J)*S(J,LL))
P(I,J+1)=P(I,J)*(EXP(-Z(I,J)))
IF (Z(I,J))83.83,83
RN(I,J)=(P(I,J)/Z(I,J))*(1.0-EXP(-Z(I,J)))
GOTO 83
110 Z(I,J)=0.
Z(I,J)=XM(I,J)+(A(I,J)*F(I,J)*S(J,LL))
P(I,J)=P(I,J-1)*EXP(-Z(I,J-1))
IF (Z(I,J))EQ.0. GOTO 111
RN(I,J)=0.
RN(I,J)=(P(I,J)/Z(I,J))*1.0-EXP(-Z(I,J)))
RPJ=RPJ+RN(I,J)
GOTO 83
111 YN(I,J)=0.
RN(I,J)=0.
IF (J .LT. MFR) GOTO 150
RM(J)=1./(.1.+EXP(-(RM1+RM2*SLT(J))))
RM(J)=WT(J)*RN(I,J)*RM(J)
IF (J .LT. MFR) GOTO 112
SSB=SSB+BIOM(J)
POPP(J)=RN(I,J)*FEC(J)
PPA=PPA+POPP(J)

SUBROUTINE LAPD(K,SMOS,NAMP,NDIST)
C***** LENGTH @ AGE PROBABILITY DISTRIBUTIONS *****
C***** DIMENSION PDM(492),PDYLD(492)
COMMON P(492,492),Z(492,492),A(492,492),XM(492,492),F(492,492),
$ R(492),RN(492,492),SE(492),SLT(492),
COMMON B/FRQ(492),SE(492),SLT(492),
COMMON E/PD(492,35),PDY(492,35),XLD(492,35)
INTEGER SMOS
X=K
J=1
DO 1 I=1,31
1 CONTINUE
GOTO 991

```

```

DO 990 I=K,SMOS,-1
PDM(J)=P(I,J)
PDYLD(J)=YN(I,J)
DO 970 KK=1,NDIST
IF (KK.LE.15) GOTO 968
IF (KK.EQ.16) GOTO 966
IF (KK.GT.16) GOTO 966
968 XTEMP=FLOAT(1.6-KK)*0.2
XLD(J,KK)=SLT(J)-XTEMP*SE(J)*NAMP
PD(J,KK)=DM(J)*FRQ(KK)
PDY(J,KK)=DM(J)*FRQ(KK)
IF (XLD(J,KK).LE.0.) GOTO 970
IF (PD(J,KK).LE.0.) GOTO 970
XX=FLOAT(J/12)
WRITE(7,*),XLD(J,KK),PD(J,KK),XX
GOTO 970
967 XLD(J,KK)=SLT(J)
PD(J,KK)=DM(J)*FRQ(KK)
IF (XLD(J,KK).LE.0.) GOTO 970
XX=FLOAT(J/12)
WRITE(7,*),XLD(J,KK),PD(J,KK),XX
GOTO 970
966 XTEMP=FLOAT(1.6-KK)*0.2
XLD(J,KK)=SLT(J)+XTEMP*SE(J)*NAMP
PD(J,KK)=DM(J)*FRQ(KK)
PDY(J,KK)=DM(J)*FRQ(KK)
IF (XLD(J,KK).LE.0.) GOTO 970
IF (PD(J,KK).LE.0.) GOTO 970
XX=FLOAT(J/12)
WRITE(7,*),XLD(J,KK),PD(J,KK),XX
970 CONTINUE
980 CONTINUE
J=J+1
990 CONTINUE
991 X=FLOAT(K)
J=1
RETURN
END

C*****SUBROUTINE SCANDET(K,NM,DTL)*****
C   SEARCHING ROUTINE FOR SCANNING DETERMINISTIC
C   POPULATION LENGTH DISTRIBUTION
C*****COMMON P(492,492),Z(492,492),A(492,492),XM(492,492),F(492,492),
$   COMMON /B/FRQ(40),RN(492,492),YN(492,492),YW(492,492),MFR
$   COMMON /D/XDLENPT(1000),DYPD(1000),TDL(1000),TYD,
$   TPD,TDL,C,DALC
$   WRITE(*,'*') 'ENTERED SCANDET',
XLMAX=0.
XLMIN=0.
NTOTLL=0.
RANGEI=0.
TYD=0.
XMAXLEN=SLT(NM)-50.0*SE(NM)
XLMIN=SLT(MFR)-12.0*SE(MFR)

XLMIN=INT(XLMIN)
XLMAX=INT(XLMAX)
IF (XLMIN.GE.0) GOTO 1958
XLMIN=0.
1958 NTOTLL=INT((XLMAX-XLMIN)/DTL)
WRITE(*,'*') 'CALCULATED # OF LENGTH INCREMENTS'
RANGEI=XLMAX-XLMIN
DO 1955 ZZ=1,NTOTLL
DPOP(ZZ)=0.
DYPD(ZZ)=0.
TDL(ZZ)=0.
IF (ZZ.NE.1) GOTO 1940
XMINLEN=XLMIN
XMAXLEN=XLMIN+DTL
GOTO 1942
1940 XMINLEN=XMAXLEN
XMAXLEN=XMINLEN+DTL
1942 XDLENPT(ZZ)=(XMAXLEN+XMINLEN)/2.
X=K
J=1
DO 1950 I=X,1,-1
IF (I.LT.MFR) GOTO 1949
IF (SLT(J,LE,XMAXLEN)) GOTO 1947
GOTO 1949
1947 IF (SLT(J).GE.XMINLEN) GOTO 1945
GOTO 1949
1945 DPOP(ZZ)=DPOP(ZZ)+P(I,J)
DYPD(ZZ)=DYPD(ZZ)+YN(I,J)
TDL(ZZ)=TDL(ZZ)+(YN(I,J)*XDLENPT(ZZ))
1949 J=J-1
1950 CONTINUE
TYD-TPD+DYPD(ZZ)
TPD-TPD+DPOP(ZZ)
TDLC=TDLC+TDL(ZZ)
IF (TPOP(ZZ).LE.0) GOTO 1955
WRITE(12,*),XDLENPT(ZZ),DYPD(ZZ)
1955 CONTINUE
WRITE(*,'*') 'COMPLETED SEARCH LOOP',
I.F (TYD.LE.0.) goto 2000
DALC-TDLC/TYD
2000 WRITE(6,*),TDLC,TYD,DALC
RETURN
END

C*****SUBROUTINE SCANPB(K,NM,NDIST,DTL)*****
C   SEARCHING ROUTINE FOR SCANNING PROBABILISTIC
C   POPULATION LENGTH DISTRIBUTIONS
C*****COMMON P(492,492),Z(492,492),A(492,492),XM(492,492),F(492,492),
$   COMMON /B/FRQ(40),RN(492,492),YN(492,492),MFR
$   COMMON /C/POPLN(1000),SYLND(1000),XLLENPT(1000),TSY(1000),
$   COMMON /E/PDI(492,35),PDY(492,35),XLD(492,35)
$   write(*,'*') 'Entered SCANPB',
TSYC=0.
SALC=0.
XLMAX=0.
XLMIN=0.
NTOTLL=0.
RANGEI=0.
XMAXLEN=0.
TYP=0.
TPD=0.
TDL=0.
DALC=0.
TYD=0.
XMAXLEN=SLT(NM)-50.0*SE(NM)
XLMIN=SLT(MFR)-12.0*SE(MFR)

SUBROUTINE SCANPB(K,NM,NDIST,DTL)
C   SEARCHING ROUTINE FOR SCANNING PROBABILISTIC LENGTH DISTRIBUTIONS
C*****COMMON P(492,492),Z(492,492),A(492,492),XM(492,492),F(492,492),
$   COMMON /B/FRQ(40),RN(492,492),YN(492,492),MFR
$   COMMON /C/POPLN(1000),SYLND(1000),XLLENPT(1000),TSY(492,492),MFR
$   COMMON /E/PDI(492,35),PDY(492,35),XLD(492,35)
$   write(*,'*') 'Entered SCANPB',
TSYC=0.
SALC=0.
XLMAX=0.
XLMIN=0.
NTOTLL=0.
RANGEI=0.
XMAXLEN=0.

```

```

XLMAX=SLT(NM)+50.0*SE(NM)
XLMIN=SLT(MFR)-12.0*SE(MFR)
XLMIN=INT(XLMIN)
XLMAX=INT(XLMAX)
IF (XLMIN .GE. 0 ) GOTO 958
XLMIN= 0.0
NTOTLI= INT( (XLMAX-XLMIN) /DTL )
RANGEL=XLMAX-XLMIN
WRITE(*,* , XLMAX,XLMIN,NTOTLI,DTL)
DO 955 ZZ=1,NTOTLI
POPLIN(ZZ)=0.
SYLIND(ZZ)=0.
TSI(ZZ)=0.
IF (ZZ .NE. 1) GOTO 940
XMINLEN=XLMIN
XMAXLEN=XLMIN+DTL
GOTO 942
XMINLEN=XMAXLEN
XMAXLEN=XMINLEN+DTL
942 XLENPT(ZZ)=(XMAXLEN+XMINLEN)/2.
X=K
J=1
DO 950 I=X,1,-1
DO 949 KK=1,NDIST
IF (J .LT. MFR) GOTO 949
IF (XLD(J,KK) .LE. XMAXLEN) GOTO 947
GOTO 949
IF (XID(J,KK) .GE. XMINLEN) GOTO 945
GOTO 949
SYLIND(ZZ)=SYLIND(ZZ)+PDY(J,KK)
POPLIN(ZZ)=POPLIN(ZZ)+PDY(J,KK)
TSI(ZZ)=TSI(ZZ)+(PDY(J,KK)*XLENPT(ZZ))
949 CONTINUE
J=J+1
950 CONTINUE
TSY=TSY+SYLIND(ZZ)
TSLC=TSLC-TSL(ZZ)
IF (POPLIN(ZZ) .LE. 0.) GOTO 955
WRITE(11,* )XLENPT(ZZ),SYLIND(ZZ)
WRITE(11,* )XLENPT(ZZ),POPLIN(ZZ)
955 CONTINUE
IF (TSY .LE. 0.) GOTO 1000
SALC=TSLC/TSY
1000 RETURN
END

```