NOAA Technical Memorandum NMFS-SEFSC-427

Baseline Data for Evaluating Reef Fish Populations in the Florida Keys, 1979-1998

James A. Bohnsack, David B. McClellan, Douglas E. Harper, Guy S. Davenport, George J. Konoval, Anne-Marie Eklund, Joseph P. Contillo, Stephania K. Bolden, Peter C. Fischel, G. Scott Sandorf, Joaquin C. Javech, Michael W. White, Matthew H. Pickett, Mark W. Hulsbeck, and James L. Tobias

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

and

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

Rosenstiel School of Marine and Atmospheric Sciences
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

September 1999

NOAA Technical Memorandum NMFS-SEFSC-427

Baseline Data for Evaluating Reef Fish Populations in the Florida Keys, 1979-1998

James A. Bohnsack, David B. McClellan, Douglas E. Harper, Guy S. Davenport, George J. Konoval, Anne-Marie Eklund, Joseph P. Contillo, Stephania K. Bolden, Peter C. Fischel, G. Scott Sandorf, Joaquin C. Javech, Michael W. White, Matthew H. Pickett, Mark W. Hulsbeck, James L. Tobias, Jerald S. Ault, Geoffrey A. Meester, Steven G. Smith, and Jiangang Luo

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

National Oceanic and Atmospheric Administration
D. James Baker, Undersecretary for Oceans and Atmosphere

National Marine Fisheries Service
Penelope D. Dalton, Assistant Administrator for Fisheries

Southeast Fisheries Science Center
Miami, Florida

September 1999

NOTICE

This report should be cited as follows:

James A. Bohnsack, David B. McClellan, Douglas E. Harper, Guy S. Davenport, George J. Konoval, Anne-Marie Eklund, Joseph P. Contillo, Stephania K. Bolden, Peter C. Fischel, G. Scott Sandorf, Joaquin C. Javech, Michael W. White, Matthew H. Pickett, Mark W. Hulsbeck, James L. Tobias, Jerald S. Ault, Geoffrey A. Meester, Steven G. Smith, and Jiangang Luo. Baseline Data for Evaluating Reef Fish Populations in the Florida Keys, 1979-1998. NOAA Technical Memorandum NMFS-SEFSC-427. 61 p.

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

EXECUTIVE SUMMARY

Reef fishes are an essential and conspicuous component of the South Florida Marine Ecosystem that support important commercial, recreational, and aesthetic fisheries. Fishes are the ultimate downstream integrators of environmental conditions and human activities. Factors that increase mortality, such as fishing, loss of habitat, and pollution are eventually reflected in adult population abundance, individual size and condition. Over the last two decades, the Florida reef tract ecosystems and Florida Bay have undergone dramatic environmental changes from human and natural forces. These changes are a general concern and the focus of an intensive effort to restore the ecosystem by altering the hydrology to a more natural condition. Fishes are a direct public concern and obvious measure of restoration success. Success of restoration and management changes should be reflected in reef fish communities in terms of the species composition, the size/age structure of fishes, and in fisheries. Fishery resources are regulated by several state and federal agencies under different levels of spatial protection. Understanding and modeling the dynamics of physical and biological processes of Florida Bay and the Florida reef tract requires a good database on fish composition by habitat.

The Florida Keys National Marine Sanctuary (FKNMS) final management plan became effective on 1 July 1997 creating the first planned network of 'no-take' marine reserves in North America. These reserves included 18 'no-take' Sanctuary Protected Areas (SPAs) and one large 'no-take' ecological reserve. This action provides a unique research opportunity to examine the processes and effects of reserve protection at replicated sites of different size. An important goal of the FKNMS management plan is to evaluate changes resulting from establishing no-take marine reserves five years after they became established. In addition, new ecological reserves are being proposed for the Tortugas region.

Biological data on reef fish biodiversity have been collected continuously since 1979 by highly trained and experienced divers using open circuit SCUBA and visual methods. Visual methods are ideal for assessing reef fishes in the Florida Keys because of prevailing good visibility and management concerns requiring the use of nondestructive assessment methods. Data were collected from randomly selected 7.5 m radius plots using a standard fishery-independent, stationary plot method (Bohnsack and Bannerot 1986). Data collected show reef fish species composition, abundance (density per plot), frequency-of-occurrence, and individual sizes of fishes at reef sites extending from Miami through the Tortugas. These data can be used to assess changes in reef fish communities in the Florida Keys as the result of changes in zoning, regional fishery management practices, and restoration efforts in Florida Bay.

This report provides a summary of a 20 year historical data base that will form the baseline for assessing future changes in reef fish communities in the FKNMS. A total of 263 fish taxa from 54 families were observed from 118 sites in the Florida Keys from 6,673 visual stationary plot samples from 1979 through 1998. The ten most abundant species accounted for 59% of all individuals observed. Ten species had a frequency-of-occurrence in samples greater than 50% and only ten species accounted for 55% of the total observed biomass.

Bray-Curtis similarity analysis of 90 reef sites was conducted to analyze spatial distribution patterns. The analysis showed that reef sites clustered primarily between inshore patch reefs and offshore reefs irrespective of region. Within offshore reefs, Tortugas deeper reefs were distinguished from

sites in the rest of the Florida Keys. In the main Keys, offshore reefs clustered into high relief forereef and low relief hard bottom habitats. Within habitat types, reef sites clustered primarily by geographical region.

Trophic composition of fishes differed greatly in terms of number of individuals and total biomass. Fishes were numerically dominated by planktivores (44%) followed by macroinvertivores (26%), herbivores (17%), piscivores (8%), microinvertivores (3%), and browsers (1%). In terms of biomass, piscivores (42%) dominated, followed by macroinvertivores (25%), herbivores (21%), planktivores (5%), browsers (4%), and microinvertivores (3%).

Data collected from 1994-1997 form a baseline for assessing changes at study sites during the first five years of protection under the FKNMS management plan. Annual mean density (number of fish observed per plot sample) with 95% confidence intervals were calculated for selected species and projected through 2002 as a prediction of future performance based on the assumption of no changes in population parameters over time.

Since only one full year of data were available following the establishment of no-take zones, it is premature to make conclusion about the impacts of marine reserves on changes in abundance or sizes of multispecies reef fish stocks. It is encouraging, however, that after only one year of no-take protection, the annual mean densities of exploited species in no-take sites were the highest observed for yellowtail snapper, combined grouper, and hogfish and the second highest for gray snapper compared to the baseline period. In comparison, similar uniform responses were not observed for the same species at fished sites nor for two species without direct economic importance (striped and stoplight parrotfish).

Size of reef fishes are also being monitored to assess population changes. Mean fish size in exploitable and non-exploitable phases for stocks of economically important species were examined as baseline statistics for evaluating future community changes in response to management actions. Because adult growth rates are relatively slow, size changes were unlikely to change much after only one year of protection and may lag other parameters.

The 20 year data set provides an excellent long-term baseline for assessing future changes in reef fish biodiversity, population abundance, and average sizes in the Florida Keys resulting from changes in Florida Keys National Marine Sanctuary zoning, regional fishery management practices, and restoration efforts involving Florida Bay.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Fig. A and for 1994-1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size by site.

Figure 12. Changes in hogfish mean density (total number of individuals observed per plot). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; and (D) fished sites excluding the Tortugas. Bars show annual mean ± 95% CI. Vertical lines show annual mean ± 1 SE Shaded areas show 95% CI for annual means through 1997 in Fig. A and for 1994-1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size by site.

Figure 13. Changes in stoplight parrotfish mean density (total number of individuals observed per plot). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; and (D) fished sites excluding the Tortugas. Bars show annual mean ± 95% CI. Vertical lines show annual mean ± 1 SE Shaded areas show 95% CI for annual means through 1997 in Fig. A and for 1994-1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size by site.

Figure 14. Changes in striped parrotfish mean density (total number of individuals observed per plot). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; and (D) fished sites excluding the Tortugas. Bars show annual mean ± 95% CI. Vertical lines show annual mean ± 1 SE Shaded areas show 95% CI for annual means through 1997 in Fig. A and for 1994-1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Data for 1998 are plotted but not considered part of the baseline. Table 1 shows annual sample size by site.

Figure 15. Changes in gray snapper mean density (total number of individuals observed per plot) for (A) exploitable (≥ 25.4 cm FL) and (B) non-exploitable sizes (< 25.4 cm FL) from all sites (1979-1998). Bars show annual mean ± 95% CI. Vertical lines show ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Data for 1998 are plotted but not considered part of the baseline. Table 1 shows annual sample size.

Figure 16. Changes in yellowtail snapper mean density (total number of individuals observed per plot) for (A) exploitable (≥ 30.5 cm FL) and (B) non-exploitable sizes (< 30.5 cm FL) from all sites (1979-1998). Bars show annual mean ± 95% CI. Vertical lines show ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Data for 1998 are plotted but not considered part of the baseline. Table 1 shows annual sample size.

Figure 17. Changes in combined grouper mean density (total number of individuals observed per plot) for (A) exploited sizes and (B) unexploited sizes from all sites (1979-1998). Size at first capture varies between species. Bars show annual mean ± 95% CI. Vertical lines show ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Data for 1998 are plotted but not considered part of the baseline. Table 1 shows annual sample size.

Figure 18. Changes in hogfish mean density (total number of individuals observed per plot) for (A) exploited sizes (≥ 30.5 cm FL) and (B) unexploited sizes (< 30.5 cm FL) from all sites (1979-1998). Bars show annual mean ± 95% CI. Vertical lines show ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Data for 1998 are plotted but not considered part of the baseline. Table 1 shows annual sample size.

INTRODUCTION

Reef fishes are an essential and conspicuous component of the South Florida Marine Ecosystem. They support important commercial, recreational, and aesthetic fisheries and are the ultimate downstream integrators of environmental conditions and human activities. Factors that increase mortality, such as pollution, fishing, and loss of habitat, are eventually reflected in adult population abundance, individual size and condition. The Caribbean and the Florida Keys have experienced increased human use and resource degradation from coastal development, increased diving, and expanding recreational and commercial fishing related to a growing resident and tourist population (Richards and Bohnsack 1990). In response to these growing threats, the U.S. Congress established the Florida Keys National Marine Sanctuary (FKNMS) in 1990. The final management plan (FMP) became effective on July 1, 1997. An important change is the use of spatial protection in the FKNMS including the establishment of the first planned network of 'no-take' marine reserves. These included 18 'no-take' Sanctuary Protected Areas (SPAs) and one large 'no-take' ecological reserve. This action provides a unique research opportunity to examine the processes and effects of reserve protection on restoring reef fish populations (e.g. PDT 1990, Bohnsack 1996). An important goal of the FKNMS management plan is to evaluate changes resulting from establishing no-take marine reserves five years after establishment.

Many reef species use inshore habitats and Florida Bay as nursery and forage areas for part of their life history before moving out to reef habitats as adults. Examples include barracuda, hogfish, spiny lobster, most snapper and grouper, and many grunts. Florida Bay is a critical nursery habitat for pink shrimp, spiny lobster and many fish species in the Florida Keys. Over the last two decades, Florida Bay has undergone dramatic environmental changes which are the focus of an intensive effort to restore the ecosystem by altering the hydrology to a more natural condition[1]. This restoration program includes a comprehensive effort to understand and model the physical and biological processes of Florida Bay. Success of restoration and management changes should be reflected in reef fish communities in terms of the species composition, the size/age structure of fishes, and in fisheries. Fishes are a direct public concern and obvious measure of restoration success. Understanding and modeling the dynamics of physical and biological processes of Florida Bay and the reef tract requires a good database on fish composition by habitat.

Visual methods are ideal for assessing reef fishes in the Florida Keys because of the prevailing clear water conditions on coral reefs and general management concerns requiring the use of non-destructive assessment methods. This report describes the 20 year Southeast Fisheries Science Center (SEFSC) visual database consisting of non-destructive, fishery-independent, stationary plot data on reef fish composition, abundance, and sizes from reefs in the Florida Keys from Miami through the Tortugas. These data form a historical baseline for assessing future changes in reef fish communities in the Florida Keys as the result of zoning changes in the FKNMS management plan, regional fishery management practices, and restoration efforts in Florida Bay. This research is a cooperative effort between investigators at the SEFSC under the direction of Dr. James Bohnsack and at the University of Miami under the direction of Dr. Jerald Ault. Support was provided by the NOAA South Florida

[1]Armentano, T.V., J. Hunt, D. Rudnick, N. Thompson, P. Ortner, M. Robblee, and R. Halley. 1997. Strategic Plan for the Interagency Florida Bay Science Program. Florida Bay Program Management Committee. 42p.

Ecosystem Restoration Prediction and Modeling (SFERPM) program.

BACKGROUND

The distribution and ecology of southern Florida reef ecosystems (Fig. 1) has been described in terms of geological history (Shinn 1963, Hoffmeister 1974), habitat (Japp 1984), and oceanographic processes (Lee et al. 1992, 1994). The complex geology, hydrography, and marine ecology of the Keys and surrounding areas were described in several reviews (Jaap 1984; Continental Shelf Associates, Inc. 1990; NOAA 1996).

Robins (1971) described the regional distribution and ecological patterns of fishes. Starck (1968) listed a total of 517 fish species in the Florida Keys of which 389 were considered primary or secondary reef species. Limouzy-Paris et al. (1994) described the diversity of fish larvae in the Florida Keys. Other studies have examined fish populations in mangrove prop roots (Thayer et al. 1987) and among basin and channel habitats in Florida Bay (Thayer and Chester 1989). Fish and fisheries have been reviewed for southern Florida (Bannerot, 1990), the Florida Keys (Chiappone and Sluka 1996), and the Tortugas (Longley and Hildebrand 1941, McKenna 1997, Schmidt et al., in prep). Bohnsack et al. (1994) described total fish landings in the Florida Keys. McClellan (1996) used aerial surveys to describe boating activity patterns in the Keys.

Database History. In response to limitations of existing sampling methods, Bohnsack and Bannerot (1983, 1986) developed a stationary plot technique as a new, objective, and reliable method for assessing reef fish community structure in any habitat. Bohnsack and Harper (1988) later developed length-to-weight conversion formulae for estimating biomass of individual species. Procedures were later developed to objectively distinguish length-frequency distributions for exploitable and non-exploitable phases of individual species for use in multispecies fishery assessments (Ault et al.1998; Meester et al., in press). Other reports discussed applications for coral reefs (Bohnsack 1997), passive assessments (Bohnsack 1995), and artificial reefs (Bortone and Bohnsack 1991)[2].

The reef fish visual census sampling database described in this report was first used to assess the effects of spearfishing on reef fish community structure at reefs protected from and exposed to spearfishing (Bohnsack 1982). Later, reef fish assemblages were assessed in different habitats of Looe Key National Marine Sanctuary (Bohnsack et al. 1987). Preliminary changes in community structure in response to management changes at Looe Key Reef were reported by Clark et al. (1989). The database contributed to the development and location of protection zones in the FMP for Florida Keys National Marine Sanctuary (DOC 1996; Bohnsack 1997, 1998). With the creation of the FKNMS, the number of sampling sites was expanded to assess regional reef fish biodiversity (Smith-Vanix et al.1995; Bohnsack and Ault, 1996). Ault et al. (1997, 1998) demonstrated that visual estimates of fish sizes agreed closely with measurements obtained independently from fishery dependent samples of headboat landings in the Florida Keys. The database was also used to assess condition and retrospective changes in reef fish stocks in the Florida Keys (Ault et al. 1997, 1998). They showed that a total of 13 of 16 groupers, 7 of 13 snappers, and 2 of 5 grunts were found to

---

[2]Bohnsack, J.A. 1995. Visually based methods for monitoring coral reef fishes. Pages 45-47 *in* Proceedings of the reef fish workshop for the southeast area monitoring and assessment program (Seamap). SEAMAP Reef Fish Work Group. Gulf States Marine Fisheries Commission. 76 p.

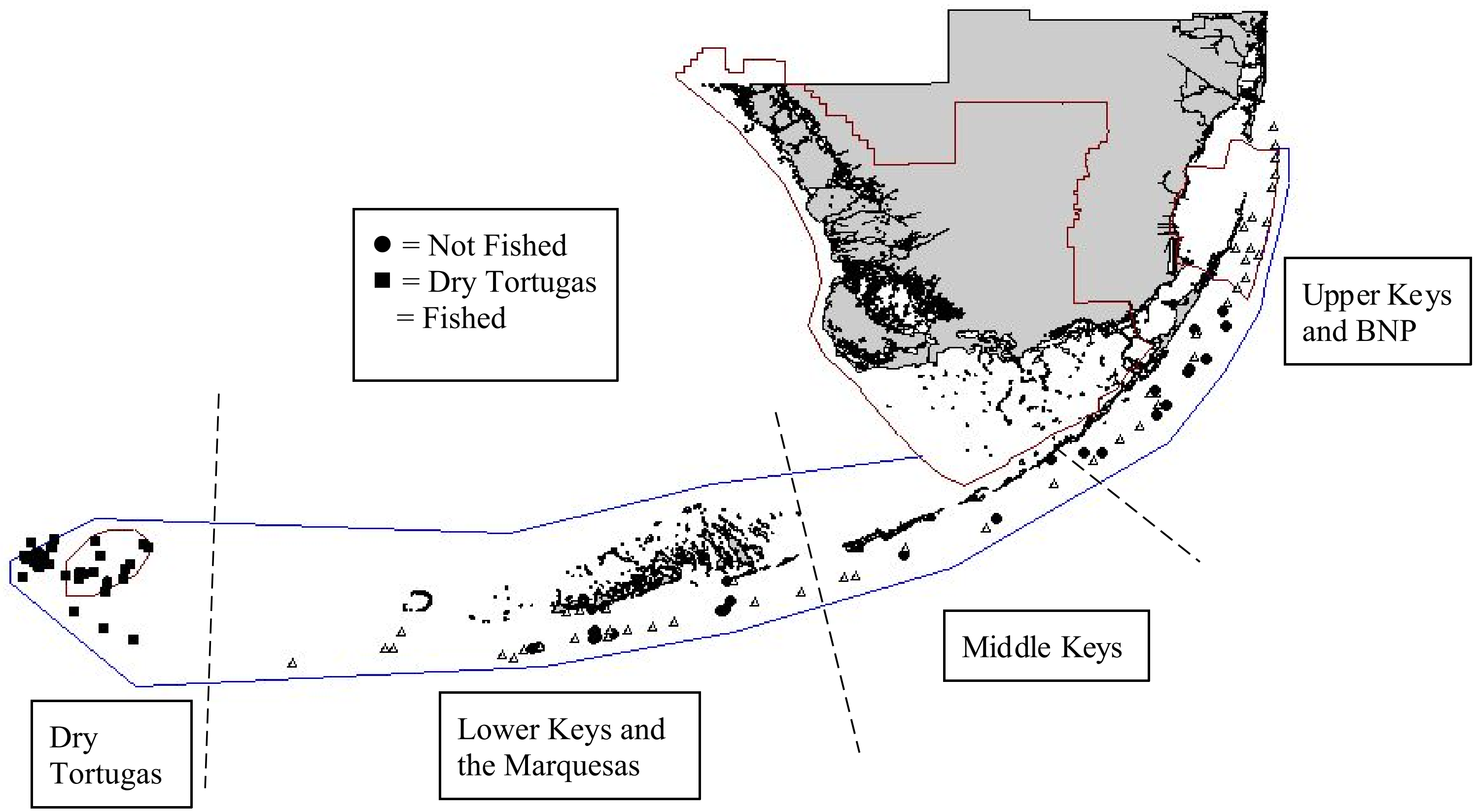


Figure 1. Map of the Florida Keys showing regional subdivisions and sampled reef sites (1979-1998). No fishing zones were established July 1, 1997 as part of the Florida Keys National Marine Sanctuary final management plan.

be below the 30% spawning potential ratio (SPR) federal definition of overfishing and that some stocks appeared to have been chronically overfished since the late 1970's. The visual database most recently was used to facilitate site locations for marine reserves in the Tortugas region (Schmidt et al. 1999, in prep.) and to assess reef fishes in Biscayne National Park[3].

The stationary plot method also has been used to assess reef fishes in Broward County, Florida[4], the Dry Tortugas (McKenna 1997), the U.S. Virgin Islands (Beets 1993), and other locations (e.g. Bortone et al. 1986). Additional visual monitoring of reef fishes in the Florida Keys is being conducted by the Reef Environmental Education Foundation (REEF) using volunteer divers and a rover diver technique (Schmitt and Sullivan 1996, Pattengill-Semmens and Semmens1999)[5,6,7,8].

---

[3]Harper, D.E., J.A. Bohnsack and B. Lockwood. (in review) Recreational Fisheries in Biscayne National Park, Florida, 1976-1991.

[4]Spieler, R.E. 1999. The marine fishes of Broward County, Florida: Report of 1998-99 Survey Results. Unpublished Progress Report to the Southeast Fisheries Science Center (NOAA/NMFS Order # 40GEN800140). 14 p.

[5]Bohnsack, J.A. 1996. Two visually based methods for monitoring coral reef fishes. Pages 31-36 *in* M.P. Crosby, G.R. Gibson, Jr., and K.W. Potts (eds). A coral reef symposium on practical, reliable, low cost monitoring methods for assessing the biota and habitat conditions of coral reefs, January 26-27, 1995. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, Silver Spring, MD. 80 p.

[6]Schmitt, E. (Compiler). 1996. Status of reef fishes in the Florida Keys National Marine Sanctuary. The Nature Conservancy, Marine Science Conservation Center, U. of Miami, Coral Gables, FL. 90 p.

Ongoing Activities

This report describes data collected from 1979 through 1998 which will provide a baseline for testing multiple hypotheses concerning no-take marine reserves. Current monitoring is targeted to provide a 5-year review of the FKNMS Management Plan and to eventually evaluate changes in fish communities as the result of Florida Bay restoration efforts. Spatial effects will be directly tested by comparing fish communities in similar habitats inside and outside of different management zones and areas impacted by different water quality. Current research under funding from the South Florida Ecosystem Restoration Program (SFERP) is monitoring marine reserves and surrounding reference areas in the Florida Keys.

METHODS

Study Area

The Florida reef tract extends approximately 370 km from Key Biscayne to the Dry Tortugas (Fig. 1). The Florida Keys are situated parallel to the Straits of Florida and the Florida current to the south and Florida Bay to the north. This coastal ecosystem encompasses many varied habitats

---

[7]Schmitt, E., D.W. Feeley, and K.M. Sullivan. 1998. Surveying coral reef fishes: A manual for data collection, processing, and interpretation of fish survey information for the tropical northwest Atlantic. The Nature Conservancy, Marine Science Conservation Center, U. of Miami, Coral Gables, FL. 139 p.

[8]Pattengill-Semmens, C.V. and B.X. Semmens. 1999b. Assessment and monitoring applications of a community-based monitoring program: The Reef Environmental Education Foundation. A poster presented at the National Coral Reef Institute Meeting, April 1999, Ft. Lauderdale. Reef Environmental Education Foundation, P.O. Box 246, Key Largo, FL. 13 p.

including freshwater marshes, estuaries, lagoons, mangrove stands, coral islands, sea grass beds, and coral reefs. Florida Bay and adjacent coastal estuaries serve as nursery areas for spiny lobster and many juvenile fishes that migrate to reefs as adults. For reporting purposes, study sites were divided into four regions: Upper, Middle, and Lower Keys, and the Tortugas (Table 1, Fig. 1).

Protected areas in the Florida Keys were described by Smith-Vaniz et al. (1995) and the U.S. Department of Commerce[9]. The Florida Keys National Marine Sanctuary (FKNMS) covers the largest total area, 9,515 km^2 (3,673 mi^2), and extends from Miami in the east to beyond the Dry Tortugas in the west. Other protected areas, moving approximately east to west, include Biscayne National Park (BNP), Key Largo National Marine Sanctuary, John Pennekamp Coral Reef State Park, Biscayne Bay and Card Sound Aquatic Preserve, and Lignumvitae Aquatic Preserve in the Upper Keys. The Lower and Middle Keys include the National Key Deer Refuge, Coupon Bight Aquatic Preserve, Looe Key National Marine Sanctuary, the Great White Heron National Refuge, and the Key West Wildlife Refuge. Further west is Dry Tortugas National Park (DTNP). Everglades National Park (ENP) includes aquatic areas in Florida Bay north of the Keys.

Fisheries are regulated by state and federal agencies. The state of Florida is responsible for managing fisheries within state waters which include areas 3 nmi offshore on the Atlantic side and 9 nmi offshore on the Gulf of Mexico side of the Keys. The federal government has responsibility outside state waters to the 200 mi limit of the Exclusive Economic Zone (EEZ). In 1976, the U.S. Congress passed the Magnuson Fishery Conservation and Management Act that established regional Fishery Management Councils (FMCs) to regulate fisheries in federal waters. The South Atlantic FMC regulates federal waters on the Atlantic side of the Florida Keys while the Gulf of Mexico FMC regulates federal waters on the Gulf side.

Levels of protection for individual reef sites in the Florida Keys have varied in space and time. Before July 1, 1997 five levels of protection existed (Tables 1 and 2). Since the 1960's the most protected sites in the upper Keys were within Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary which prohibited spearfishing and tropical collecting (level 3). Biscayne National Park prohibited spearfishing (level 2). The lower and middle Keys were only managed solely by regional fishery regulations (level 1). During this time Dry Tortugas National Park offered the highest level of protection (level 5) by allowing only recreational hook-and-line. Looe Key Reef in the lower Keys moved from level 1 to level 3 (no spearfishing) in 1981 with the establishment of the Looe Key National Marine Sanctuary.

On July 1, 1997, the FKNMS FMP became effective resulting in 8 levels of protection with the addition of three zone types that further limited extractive usage (Table 2). Catch-and-release trolling (level 6) was the only extractive activity allowed at Alligator, Conch, Sombrero, and Sand Key reefs. Two kinds of 'no-take' zones were also added. Level 7 'no-take' zones included one large (79 km^2) marine ecological reserve (MER) in the Sambo region of the Lower Keys and 19 small (range 0.16 - 4 km^2) Sanctuary Preservation Areas (SPAs) scattered throughout the Keys. Level 8 protection does not allow any extraction or

[9]USDOC (U.S. Department of Commerce). 1996. Florida Keys National Marine Sanctuary: Final Management Plan/Environmental Impact Statement, Vol 1. Sanctuaries and Reserves Division, National Oceanic and Atmospheric Administration. 319 p.

Table 1. Annual distribution of sampling effort by region and study site. Levels of protection are described in Table 2 and apply before and after 1 July 1997 when the FKNMS final management plan became effective. Boxed areas denote the protected sites. Locations are given in Appendix B.

Geog. Posit.	Site	Pre-Protection Level	Post-Protection Level	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	***Total***
													Number of Point Samples											
	Outside Sanctuary																							
1	GROUPER SITE	1	1							6	8	40	40	21							12		7	***134***
2	KEY BISCAYNE SITE	1	1					36	4															***40***
	Total Outside Samples			***0***	***0***	***0***	***0***	***36***	***4***	***6***	***8***	***40***	***40***	***21***	***0***	***0***	***0***	***0***	***0***	***0***	***12***	***0***	***7***	***174***
	Biscayne National Park (BNP)																							
3	BNP: NE CORNER REEF	2	2										31	29	25	12	22			12		12	9	***152***
4	FOWEY ROCKS	2	2																	8		12	9	***29***
5	BNP: BREWSTER REEF	2	2										20	51	29	12	24			12		12	12	***172***
6	BACHE SHOAL	2	2																		12	12	9	***33***
7	BNP: TRIUMPH REEF	2	2											26	30	13	32			24	12	12	12	***161***
8	BNP: MARKER 14	2	2										22	46	30		20			11		13	9	***151***
9	BNP: PETREL POINT	2	2											12	28					11		12	9	***72***
10	BNP: STAR CORAL	2	2										22		16					13		12	10	***73***
11	BNP: AJAX REEF	2	2										10	16	32	12	28			24	12	12	12	***158***
12	BNP: ALINA'S	2	2										32	31	31					12	12	12	12	***142***
13	BNP: IGW TRUST	2	2										31	30	30	16				8		12	6	***133***
14	BNP: BALL BUOY	2	2										19	56	31	16				8	12	12	6	***160***
	Total BNP			***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***187***	***297***	***282***	***81***	***126***	***0***	***0***	***143***	***60***	***145***	***115***	***1436***
	Upper Keys (FKNMS) and John Pennekamp Coral reef State Park (JPSP)																							
15	TURTLE REEF	3	3															16		12		12	6	***46***
16	BASIN HILL - OPEN	3	3														28	12	12	12	12		9	***85***
17	BASIN HILL - CLOSED	8	8														29	12	12	12	12		9	***86***
18	BASIN HILL - OPEN (NEW)	3	3																12	12	12		9	***45***
19	CARYSFORT REEF	3	7		3	10			6									16	9	24	11	15	9	***103***
20	CARYSFORT SOUTH REEF	3	7																	12	13	9	9	***43***
21	GARDEN COVE	3	3																	12		12	12	***36***
22	THE ELBOW	3	7		9	10													15	12	12	12	12	***82***
23	KEY LARGO DRY ROCKS	3	7			9												4	10			12	9	***44***
24	GRECIAN ROCKS	3	7			16														12		12	9	***49***
25	MOSQUITO BANK - OPEN	3	3														24	12	12	12	12		12	***84***
26	MOSQUITO BANK - OPEN (NEW)	3	3																12	12	12		12	***48***
27	MOSQUITO BANK - CLOSED	8	8														24	11	12	12	12		12	***83***
28	FRENCH REEF	3	7			11	18	14								21		14	20		12	11	9	***130***
29	WHITE BANK	3	3			8														7				***15***
30	MOLASSES REEF	3	7	4	35	52	53	29	63	52	12	9	6			64		14	32	12	12	12	6	***467***
31	TRIANGLES	1	3																			11	6	***17***
32	PICKLES REEF	1	3																	22		11	6	***39***
33	CONCH REEF	1	6													6			10	12	12	12	9	***61***
34	DAVIS REEF	1	7																9		12	12	6	***39***
35	CROCKER REEF	1	3																30			12	8	***50***
	Total Upper Keys (FKNMS) and JPSP			***4***	***47***	***116***	***71***	***43***	***69***	***52***	***12***	***9***	***6***	***0***	***0***	***91***	***105***	***111***	***207***	***209***	***156***	***165***	***179***	***1652***
	Middle Keys (FKNMS)																							
36	HEN AND CHICKENS	1	7																	12		12	12	***36***
37	CHEECA ROCKS	1	7																			19	12	***31***
38	ALLIGATOR REEF	1	6				12													20		12	9	***53***
39	TENNESSEE REEF (RESEARCH)	1	8																	13		28	9	***50***
40	TENNESSEE REEF (FISHED)	1	1																	21		29	6	***56***
41	COFFIN PATCH	1	7																			12	12	***24***
42	WEST TURTLE SHOAL	1	1																			12	12	***24***
43	DELTA SHOAL	1	1						12							6			12			12	12	***54***
44	SOMBRERO KEY	1	6				11		43							7		12	12			12	12	***109***
	Total Middle Keys (FKNMS)			***0***	***0***	***0***	***23***	***0***	***55***	***0***	***0***	***0***	***0***	***0***	***0***	***13***	***0***	***12***	***24***	***66***	***0***	***148***	***96***	***437***

Table 1 (cont.)

Geog. Posit.	Site	Pre-Protection Level	Post-Protection Level	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	***Total***
													Number of Point Samples											
	Lower Keys (FKNMS)																							
45	NO NAME REEF	1	1																	9				***9***
46	LOOE KEY - EAST	3	7															3			12	12	12	***39***
47	LOOE KEY - WEST	3	7															3	28		13	12	12	***68***
48	LOOE KEY - OTHER	3	7	9	98	87	95	426	101	66	13	24	30			95	25	18		12				***1099***
49	LOOE KEY RESEARCH	1	8																			14	12	***26***
50	BIG PINE SHOAL	1	1																			12	9	***21***
51	NEWFOUND HARBOR KEY (SPA E)	1	7															16				13	9	***38***
52	NEWFOUND HARBOR KEY (SPA W)	1	7			6												4				12	12	***34***
53	NEWFOUND HARBOR KEY (FISHED)	1	1															16				12	9	***37***
54	AMERICAN SHOAL	1	1																	20		12	12	***44***
55	MARYLAND SHOAL	1	1																				12	***12***
56	PELICAN SHOAL	1	1																	10			12	***22***
57	EASTERN SAMBO	1	8															19		8	12	12	28	***79***
58	MIDDLE SAMBO	1	1															20		9	12	12	24	***77***
59	WESTERN SAMBO - EAST	1	7															19		21	12	21	24	***97***
60	15-13 SAMBOS	1	7																			12	12	***24***
61	12-12 SAMBOS	1	1																			12	15	***27***
62	14 SAMBOS	1	7																			12	12	***24***
63	PETE'S PINNACLE	1	1																			12	12	***24***
64	WESTERN SAMBO - WEST	1	7															18		40	12	21	24	***115***
65	EASTERN DRY ROCKS	1	7																	12		12	13	***37***
66	EASTERN DRY ROCKS (FISHED)	1	1																			12	12	***24***
67	ROCK KEY	1	7																	12	12	12	13	***49***
68	MARKER 56	1	7																	19		12	17	***48***
69	KEY WEST (INSHORE FISHED)	1	1																	8				***8***
70	KEY WEST (WESTERN FISHED)	1	1																				12	***12***
71	KEY WEST (EASTERN FISHED)	1	1																	8		12	14	***34***
72	ANNE'S ANCHORAGE	1	7																			12	15	***27***
73	DOUG'S DEN	1	1																			12	12	***24***
74	SAND KEY	1	6																12	23	12	12	12	***71***
75	WESTERN DRY ROCKS	1	1																			12	12	***24***
	Total Lower Keys (FKNMS)			***9***	***98***	***93***	***95***	***426***	***101***	***66***	***13***	***24***	***30***	***0***	***0***	***95***	***25***	***136***	***40***	***211***	***97***	***321***	***394***	***2274***
	Marquesas Keys (FKNMS)																							
76	COSGROVE SHOAL	1	1																11	22				***33***
77	MARQUESAS ROCKS	1	1																	9				***9***
78	28 FOOT SHOAL	1	1																	12				***12***
79	DEVIL'S REEF	1	1																			8		***8***
	Total Marquesa Keys (FKNMS)			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	***11***	***43***		***8***		***62***
	Total FKNMS, BNP, JPSP			***13***	***145***	***209***	***189***	***505***	***229***	***124***	***33***	***73***	***263***	***318***	***282***	***280***	***256***	***259***	***282***	***672***	***325***	***787***	***791***	***6035***

Table 1 (cont.)

Geog Posit.	Site	Pre-Protection Level	Post-Protection Level	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total
													Number of Point Samples											
Tortugas Area (FKNMS) and Dry Tortugas National Park (DTNP)																								
Inside DTNP																								
80	PULASKI SHOAL	5	5																14	11	12	24		*61*
81	TEXAS ROCK	5	5																11		12	14		*37*
82	LOGGERHEAD KEY	5	5																21		12	10	12	*55*
83	LONG KEY (BIRD KEY)	5	5																28	12	12	22	12	*86*
84	TWIN PEAKS	5	5																10					*10*
85	LITTLE AFRICA	5	5																26		12	13		*51*
86	REPLENISHMENT ZONE	5	5																8					*8*
87	WHITE SHOAL	5	5																14		12	31		*57*
88	MARKER H	5	5																			4		*4*
89	MAVRO VETRANIC	5	5																			9		*9*
90	GUY'S GROTTO	5	5																			12		*12*
91	DAVE'S FINAL FRONTIER	5	5																				12	*12*
92	JOE'S CRACK	5	5																					*0*
93	GEORGE'S GORGE	5	5																					*0*
94	FRENCH WRECK	5	5																					*0*
	Total Inside DTNP			***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***132***	***23***	***72***	***139***	***36***	***402***
Outside DTNP (FKNMS)																								
95	TORTUGAS BANK (PINNACLES)	1	1																12	9				*21*
96	JOE'S HUMP	1	1																16		16			*32*
97	HANGOVER REEF	1	1																12					*12*
98	8 FATHOM ROCK	1	1																			8		*8*
99	BLACK CORAL ROCK	1	1																			8		*8*
100	HUMP 1	1	1																			5		*5*
101	CROSBY'S HUMP	1	1																		12	7		*19*
102	HUMP 2	1	1																			3		*3*
103	TORTUGAS FLAT	1	1																			5		*5*
104	GARY'S ANCHOR	1	1																			6		*6*
105	HUMP 3	1	1																			6		*6*
106	CECILY'S SITE	1	1																			3	6	*9*
107	LITTLE BANK	1	1																			8		*8*
108	SHERWOOD FOREST	1	1																			8	6	*14*
109	FANTOM REEF	1	1																				10	*10*
110	GEORGE'S ROCK	1	1																				10	*10*
111	RALPH'S RIDGE	1	1																				12	*12*
112	POTT'S PEAK	1	1																				12	*12*
113	TORTUGAS BANK SITE11	1	1																				6	*6*
114	TORTUGAS BANK SITE18	1	1																				6	*6*
115	TORTUGAS BANK SITE25	1	1																				6	*6*
116	TORTUGAS BANK SITE51	1	1																				6	*6*
117	TORTUGAS PARK SITE52	1	1																				6	*6*
118	TORTUGAS PARK SITE82	1	1																				6	*6*
	Total Outside DTNP (FKNMS)			***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***40***	***9***	***28***	***67***	***92***	***236***
	Total Tortugas Area (FKNMS) and DTNP			***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***172***	***32***	***100***	***206***	***128***	***638***
	Total All Sites			***13***	***145***	***209***	***189***	***65***	***229***	***124***	***33***	***73***	***263***	***318***	***282***	***280***	***26***	***29***	***46***	***704***	***425***	***993***	***919***	***6673***

Table 2. Summary of protection levels spatially applied to extractive activities in the Florida Keys. Protection levels range from a low of 1 to 8, the highest.

PL 1. Open access under regional regulations. This is the lowest level of protection and encompasses the largest area. It includes all areas under current state and federal fisheries and resource regulations. These include general size limits, bag limits, and gear restrictions established by Florida and the South Atlantic Fishery Management Council for the region. These area are open to commercial and recreational fishing for spearfishing, lobster diving and fishing, hook-and-line fishing, tropical fish collecting, etc.

PL 2. No marine life collecting. Biscayne National Park. All other extractive activities permitted under regional regulations.

PL 3. No spearfishing. Florida waters in the Upper Keys have banned spearfishing since the 1960s.

PL 4. No spearfishing or marine life collecting. These are historically protected areas that include John Pennekamp Coral Reef State Park and the former Key Largo National Marine Sanctuary since the 1960s. The former Looe Key National Marine Sanctuary (fore reef excluded, see PL5) was included in 1981. These area are open to commercial and recreational fishing with hook-and-line, and lobster fishing with traps or by diving.

PL 5. No spearfishing, lobster harvesting, collecting, or commercial fishing. This is the area inside of the Dry Tortugas National Park. Recreational hook-and-line fishing and 'no-take' diving are allowed. The Looe Key fore reef area is included due to the protection it received between 1981 and 1997 (it is now a SPA under PL 7).

PL 6. Catch-and-release fishing only. This includes four experimental "Sanctuary Protected Areas" [sic] which are 'no-take' except for catch-and-release troll fishing. All other take is prohibited. Skin and SCUBA diving are allowed. These areas are: Conch Reef (shallow), Alligator Reef, Sombrero Reef, and Sand Key.

PL 7. No extractive removals "no-take". This includes 19 Sanctuary Protected Areas (SPAs) and the Sambos Ecological Reserve (ER). No fishing or other taking are allowed. Skin and SCUBA diving are allowed.

PL 8. Permitted research only. No extractive activities and no skin or SCUBA diving allowed. In the FKNMS three of these zones are intended to examine the impacts of divers on reefs: Looe Key Research, Eastern Sambo, Tennessee Reef. One zone (Conch Reef, deep) is the site of the NURC Aquarius project. Two additional small, no entry, patch reef sites were established in 1992 in John Pennekamp Coral Reef State Park at Mosquito Banks and Basin Hill Shoals.

entry except for permitted research at Conch Reef, Tennessee, Looe Key Research, and Eastern Sambo Reefs.

Table 1 shows the classification changes for each sampled site by level of protection before and after 1 July 1997. Four reefs moved from level 1 to level 6 and were distributed in the upper (1), middle (2), and lower (1) Keys. Seven reefs moved from level 3 to level 7 protection; six in the upper and one in the lower Keys. Eleven reef sites moved from level 1 to level 7 protection; three in the middle Keys and eight in the lower Keys. Dry Tortugas National Park is classified at level 5 protection although the level of protection changed by prohibiting recreational lobster harvesting and later by prohibiting headboat fishing within Park boundaries.

Field Methods

Biological data on reef fish biodiversity were collected continuously since 1979 using visual methods by highly trained and experienced divers using open circuit SCUBA. Visual methods are ideal for assessing reef fishes in the Florida Keys because of prevailing good visibility and management concerns requiring the use of non-destructive assessment methods. Data were collected by a stationary diver centered in a randomly selected 7.5 m radius circular plot using a standard fishery-independent, stationary plot method (Bohnsack and Bannerot 1986). The plot method is non-destructive and provides reliable quantitative estimates of species composition, abundance (density per plot), frequency-of-occurrence, and individual size composition for the reef fish community. Management concerns required non-destructive sampling methods wherever possible. Reef sites were sampled from Miami through the Tortugas region.

At study sites, divers first recorded the species observed in five min within randomly selected 7.5 m radius circular plots. Then data were collected for each species on their abundance in the plot and the minimum, mean and maximum lengths of each species. Divers attempted to record all fish observed within each imaginary cylinder extending from the bottom to the limits of vertical visibility (usually the surface). Depth, bottom composition, and estimated percentage cover were recorded for each plot from the polar perspective of the centrally located observer. A ruler held out perpendicularly at the end of a meter stick aided in making size estimates by reducing apparent magnification errors. Obtaining accurate and precise visual estimates of fish length underwater requires well-trained and experienced observers because objects in water appear magnified and closer than their actual range (Bell et al. 1985; Bellwood and Alcala 1988, Harvey and Shortis 1996). To improve accuracy, divers continuously calibrated their length estimates using the 30 cm ruler and meter-stick. Divers with calibration sticks have been shown to obtain a mean accuracy of 86% for length estimates (St. John et al., 1990).

A rigorous sampling regime was used to avoid bias and prevent counting the same individuals more than once. Divers began each sample by facing in one direction and listing all species within the field of view inside the sample radius. When no new species were noted, new sectors were scanned by rotating in one direction. New species were listed as observed and rotations continued for five min. Several complete rotations were usually made for each plot. Divers periodically calibrated their estimates of the sample radius with the meter stick or fiberglass tape. Species with few individuals (e.g. angelfish, barracuda, hogfish) were counted and size estimated immediately. Species that were highly mobile and unlikely to remain in the area (e.g. sharks, carangids, *Clepticus parrai*) were tabulated when first observed and then ignored. Common species that were reliably always in the sample area (e.g. damselfish, wrasses, etc.) were initially listed only and later tabulated after the initial 5 min sample period when divers would make one 360° rotation for each species by working back up the list in reverse order of recording. This procedure eliminated potential bias in selecting to count a species when they were particularly abundant or obvious. The time required to record each sample averaged 15-20 min (range 5 - 30), depending on the plot.

Experimental Design

Sampling was conducted at inshore and offshore reef sites along the Florida reef tract from Miami to the Dry Tortugas (Fig. 2). Different areas of the reef track have had different levels of protection and different historical management policies (Table 2). Sampling has been concentrated in the spring and summer when sea conditions are generally calm and water conditions most suitable for visual sampling (Bohnsack and Bannerot 1986, Bohnsack et al., 1987). Actual sampling intensity has varied on a yearly basis as determined by weather, logistics, funding, scheduling, and personnel consideration. In recent years we have been investigating modifications in the survey design to increase the precision in the estimates.

This report describes baseline estimates of the abundance and size distributions of all observable reef fish populations based on samples taken continuously from 1979 to 30 June 1996, before the FKNMS FMP became effective. The years 1997 and 1998 are considered transition years following changes in management actions for the FKNMS. The experimental design was established to test factors in time and space. Time comparisons can be made at all sites before and after zoning changes (increased protection) became effective in 1997. Also, spatial comparisons can be made between sites with different levels of protection. The ultimate goal is to examine the effectiveness of different levels of management protection along the Keys. Eventually the effectiveness of different sized protected areas will be examined.

The null hypotheses is no change for specific parameters in space or over time. The geographical distribution, sizes, types, and numbers of protected areas in the FKNMS provide opportunities to evaluate types and sizes of zone protection. Zones provide different treatments in terms of the levels of protection and often include replicated sites of different size. Specific hypotheses and alternatives can then be tested to evaluate various levels and spatial scales of protection. In order for no-take marine reserves to be effective, for example, it is necessary (but not sufficient) to show that reserves increase spawning potential and protect biodiversity. Spawning potential can be increased by increasing abundance and size structure through differential mortality inside versus outside reserves.

Paired reef sites that differed in level of protection were selected for monitoring purposes. Where possible, the two sites were chosen to be in close proximity and as similar in terms of habitat structure and size as possible. Newly protected SPAs were approximately paired (where possible) with a level 1 or 2 protected site. SPAs are considered replicates because they are similar in size. Both SPAs and MER can be considered as "controls" for assessing impacts of fishing because they have minimum direct human extractive impacts even though we expect them to change over the short and intermediate term. Sites with different levels of fishing and other extractive activities can be considered "treatment" sites.

Analytical Methods

Statistical descriptions were made for each observed species showing mean, total and standard deviation of abundance; absolute, range, and percent frequency-of-

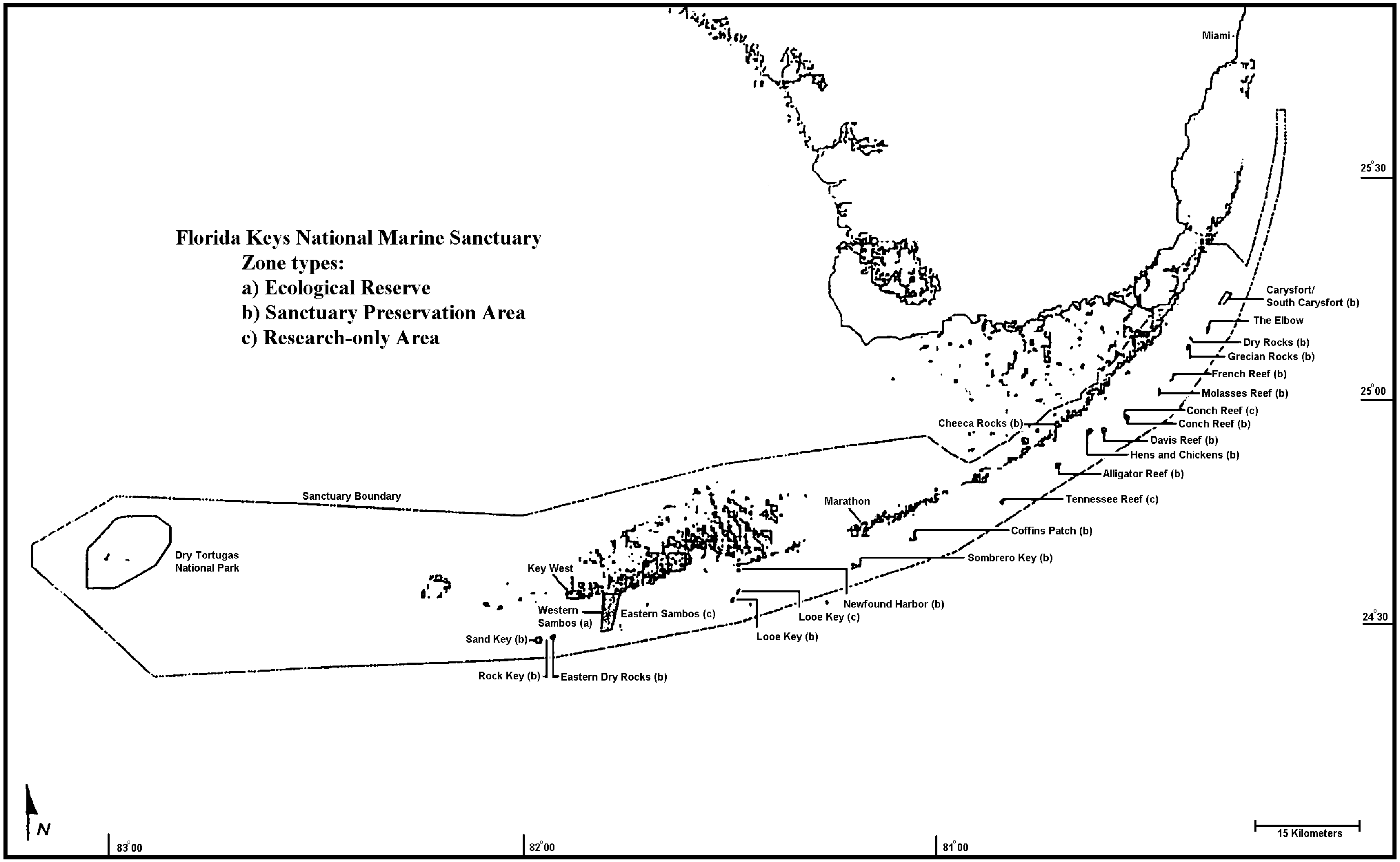


Figure 2. Location of reefs and no-take management zones in the Florida Keys National Marine Sanctuary. Source: Zone Performance Update: First Year Report 1998. Florida Keys National Marine Sanctuary.

occurrence; mean, minimum, and maximum length; and total biomass (Sokal and Rohlf 1981). Lengths of individual fish were converted into estimated biomass based on length-weight formulae developed and updated by Bohnsack and Harper (1988). Data summarized here are based on raw uncalibrated data. The power of the method is based in part on the large number of samples and reef sites included in the study. Maximum power and utilization of the visual survey data requires statistical intercalibration of the relative sampling efficiency of each diver (Ault et al. 1998) but is beyond the descriptive purpose of this report.

Community structure was evaluated in terms of species richness (total number of species) abundance, frequency-of-occurrence, individual size, and total biomass for observed species. Rank order total abundance and frequency were plotted for all samples. Confidence intervals for percent frequency were calculated according to Sokal and Rohlf (1981).

Spatial patterns among study sites were examined in terms of Bray-Curtis community similarity (Bray and Curtis 1957) using mean species abundance of 87 frequently occurring species. Flexible clustering (Beta = 0.25) was used and included 90 reef sites sampled from 1 January 1988 through 30 June 1997 (n = 3,679 samples). Data were not transformed or standardized. Species occurring in less than 2.5% of the total samples were excluded. Data collected before 1988 were excluded because they contained only a few study sites. No zero replacement was applied.

Species were classified into trophic categories according to primary adult feeding patterns based on published literature about each species or closely related species (e.g. Hiatt and Strasburg 1960, Randall 1967, Hobson 1974, Hobson and Chess 1976, Harmelin-Vivien 1981). Trophic structure was then examined in terms of total individuals and biomass for combined data and for different reef types in the four regions of the Keys.

Trends in annual mean density (number of individuals per sample) were examined for selected representative taxa. Annual mean density, 95% CI, and ± 1 SE were calculated for each species. These annual mean density values were then used to evaluate performance trends over the baseline study period (1979 - 1997). A performance band was plotted for each taxa showing the long-term annual mean density (± 95% CI). The same procedures were used to compare baseline performance for combined data from no-take sites with fished and Tortugas sites. Baseline performance for no-take and fished sites was based on 4 year of data collected immediately prior to implementation of the FKNMS FMP (1994-1997). Average performance bands for each category of reef site were projected for five years into the future as a prediction of future values assuming no change in performance.

Size data were analyzed separately for exploitable and non-exploitable phase fishes according to procedures developed by Ault et al. (1998) and Meester et al. (in press) where exploitable phase fishes were defined as individuals equal to or larger than the length at first capture (L').

RESULTS AND DISCUSSION

Sampling Summary

From 1979 through 1998 a total of 263 fish taxa from 54 families were observed from 118 sites in the Florida Keys from 6,673 visual stationary plot samples. A phylogenic listing and trophic classification of species observed during the study is shown in Table 3. Ten families that had over 10 identified species accounted for 59% of all observed fish taxa: Serranidae (32 species), Labridae (16), Gobiidae (14), Scaridae (14), Haemulidae

(13), Pomacentridae (13), Carangidae (12), Lutjanidae (11), Balistidae (11) and Clinidae (11).

A total of 118 reef sites were sampled through 1998. The distribution of sample effort by study site and year is shown in Table 1. Larger and fragmented reefs were divided into multiple sites (e.g. Carysfort, Looe Key, Newfound Harbor, and Western Sambo). Prior to 1987 most samples were collected from Molasses Reef in the Upper Keys and Looe Key Reef in the Lower Keys. Sampling in the Tortugas began in 1994. Sampling effort was most intense in recent years with over 650 samples being collected annually in 1995, 1997, and 1998.

Community Structure

Statistical descriptions of individual species and unidentified taxa for all 6,673 samples are provided in Table 4. Descriptive statistics include the total number of observed individuals; frequency and percent occurrence; abundance mean, standard deviation, and range; mean, minimum, and maximum observed length, and estimated total biomass for each species. Plots of rank order total abundance versus log abundance for all species and samples (Fig. 3) show a classic linear pattern of community structure characteristic of highly diverse ecosystems (Hubbell, 1979).

Rank order frequency-of-occurrence by species for all samples shows that most species rarely occur and that 95% confidence intervals are well defined (Fig. 4). Because the stationary plot technique provides large sample sizes, percent frequency becomes a useful statistic for detecting changes in frequency-of-occurrence. It should be especially sensitive and useful for detecting any increased occurrence of rare species.

The ten most abundant species accounted for 59% of all individuals observed (Table 4). These include in decreasing order: bluehead (*Thalassoma bifasciatum*, 188,037), bicolor damselfish (*Pomacentrus partitus*, 151,266), tomtate (*Haemulon aurolineatum*, 115,696), sergeant major (*Abudefduf saxatilis*, 68,357), striped parrotfish (*Scarus croicensis*, 45,114), yellowtail snapper (*Ocyurus chrysurus*, 43,967), bluestriped grunt (*H. sciurus*, 33,268), white grunt (*H. plumieri*, 31,577), masked goby (*Coryphopterus personatus*, 27,726), and French grunt (*H. flavolineatum*, 27,342).

Ten species had greater than 50% frequency-of-occurrence in plot samples (Table 4) and are listed below in decreasing order. The five species underlined were also among the ten most abundant species: <u>bluehead</u> (81.0%), redband parrotfish (*Sparisoma aurofrenatum*, 69.4%), blue tang (*Acanthurus coeruleus*, 67.7%), <u>striped parrotfish</u> (65.3%), stoplight parrotfish (*S. viride*, 62.8%), ocean surgeon (*A. bahianus*, 62.2%), <u>yellowtail snapper</u> (60.7%), yellowhead wrasse (*Halichoeres garnoti*, 55.0%), <u>French grunt</u> (52.0%), and <u>white grunt</u> (51.7%).

Ten species accounted for 55% of the total observed biomass (Table 4) and are listed below in decreasing order. The three species underlined were also among the ten most abundant species observed: tarpon (*Megalops atlanticus*, 8,869 kg), barracuda (*Sphyraena barracuda*, 7,641 kg), <u>yellowtail snapper</u> (6,253 kg), <u>bluestriped grunt</u> (4,556 kg), gray snapper (*Lutjanus griseus*, 4,287 kg), Bermuda chub (*Kyphosus sectatrix*, 3,392 kg), <u>tomtate</u> (3,205 kg), stoplight parrotfish (2,832 kg), smallmouth grunt (*H. chrysargyreum*, 2,755 kg), and yellow goatfish (*Mulloidichthys martinicus* 2,596 kg).

<u>Site Comparisons</u>

A dendogram shows the Bray-Curtis similarity analysis for 90 reef sites sampled between 1 January 1988 and 30 June 1997 (n = 3,679 samples) (Fig. 5). Reef sites clustered primarily between inshore patch

Table 3. Phylogenic listing of families and species observed in visual samples from the Florida Keys (1979-1998). Names are according to Robins et al. (1986, 1991) with the exception that Hypoplectrus species (denoted by #) which were all listed as H. unicolor in Robins et al. (1991) and are named. according to Stokes (1980). The species codes was derived from the first three and four letters, respectively, of the genus and trivial species name. Trophic level codes: B, browser; F, piscivore; H, herbivore; Ma, macroinvertivore; Mi, microinvertivore; P, planktivore. Predominate adult trophic mode indicated in bold.

FAMILY NAME	*Scientific name*	***Family common name***	Species common name	Trophic Level	Species Code
RHINCODONTIDAE		***Carpet sharks***			
	Ginglymostoma cirratum		nurse shark	**Ma**,F	GIN CIRR
CARCHARHINIDAE		***Requiem sharks***			
	Carcharhinus limbatus		blacktip shark	**F**	CAR LIMB
SPHYRNIDAE		***Hammerhead sharks***			
	Sphyrna lewini		scalloped hammerhead	**F**,Ma	SPH LEWI
	Sphyrna mokarran		great hammerhead	**F**,Ma	SPH MOKA
DASYATIDAE		***Stingrays***			
	Dasyatis americana		southern stingray	**Ma**	DAS AMER
UROLOPHIDAE		***Round stingrays***			
	Urolophus jamaicensis		yellow stingray	**Ma**,Mi	URO JAMA
MYLIOBATIDAE		***Eagle rays***			
	Aetobatus narinari		spotted eagle ray	**Ma**	AET NARI
MOBULIDAE		***Mantas***			
	Manta birostris		manta	**P**	MAN BIRO
ELOPIDAE		***Tarpons***			
	Megalops atlanticus		tarpon	**F**	MEG ATLA
MURAENIDAE		***Morays***			
	Gymnothorax funebris		green moray	**F**,Ma	GYM FUNE
	Gymnothorax miliaris		goldentail moray	**F**,Ma	GYM MILI
	Gymnothorax moringa		spotted moray	**F**	GYM MORI
	Gymnothorax saxicola		honeycomb moray	**F**,Ma	GYM SAXI
	Gymnothorax vicinus		purplemouth moray	**F**,Ma	GYM VICI

Table 3. (cont.)

FAMILY NAME	*Scientific name*	***Family common name***	Species common name	Trophic Level	Species Code
CLUPEIDAE		***Herrings***			
	Harengula jaguana		scaled sardine	**P**	HAR JAGU
	Jenkinsia lamprotaenia		dwarf herring	**P**	JEN LAMP
	Jenkinsia species		unknown herring	**P**	JEN SPE.
OGCOCEPHALIDAE		***Batfishes***			
	Ogcocephalus species		unknown batfish	**Ma**,F	OGC SPE.
EXOCETIDAE		***Flyingfishes***			
	Hemiramphus brasiliensis		ballyhoo	**F**	HEM BRAS
BELONIDAE		***Needlefishes***			
	Tylosurus crocodilus		houndfish	**F**	TYL CROC
ATHERINIDAE		***Silversides***			
	Atherinomorus stipes		hardhead silverside	**P**	ATH STIP
	Hypoatherina harringtonensis		reef silverside	**P**	HYP HARR
HOLOCENTRIDAE		***Squirrelfishes***			
	Holocentrus adscensionis		squirrelfish	**Ma**,Mi	HOL ADSC
	Holocentrus coruscus		reef squirrelfish	**Ma**,Mi	HOL CORU
	Holocentrus marianus		longjaw squirrelfish	**Ma**,Mi	HOL MARI
	Holocentrus rufus		longspine squirrelfish	**Ma**,Mi	HOL RUFU
	Holocentrus spe.		unidentified squirrelfish	**Ma**,Mi	HOL SPE.
	Holocentrus vexillarius		dusky squirrelfish	**Ma**,Mi	HOL VEXI
	Myripristis jacobus		blackbar soldierfish	**P**	MYR JACO
	Ostichthys trachypoma		bigeye soldierfish	**Mi**,P	OST TRAC
AULOSTOMIDAE		***Trumpetfishes***			
	Aulostomus maculatus		trumpetfish	**F**	AUL MACU
SCORPAENIDAE		***Scorpionfishes***			
	Scorpaena plumieri		spotted scorpion fish	**F**	SCO PLUM
FISTULARIIDAE		***Cornetfishes***			
	Fistularia tabacaria		bluespotted cornetfish	**F**	FIS TABA

Table 3. (cont.)

FAMILY NAME	Scientific name	Family common name	Species common name	Trophic Level	Species Code
CENTROPOMIDAE		***Snooks***			
	Centropomus undecimalis		common snook	**F**,Ma	CEN UNDE
SERRANIDAE		***Sea basses***			
	Diplectrum formosum		sand perch	**Ma**,Mi	DIP FORM
	Epinephelus adscensionis		rock hind	**Ma**,F	EPI ADSC
	Epinephelus cruentatus		graysby	**F**,Ma	EPI CRUE
	Epinephelus fulvus		coney	**F**,Ma	EPI FULV
	Epinephelus guttatus		red hind	**Ma**,F	EPI GUTT
	Epinephelus inermis		marbled grouper	**F**,Ma	EPI INER
	Epinephelus itajara		jewfish	**Ma**,F	EPI ITAJ
	Epinephelus morio		red grouper	**F**,Ma	EPI MORI
	Epinephelus striatus		Nassau grouper	**F**,Ma	EPI STRI
	Hypoplectrus chlorurus #		yellowtail hamlet	**Mi**	HYP CHLO
	Hypoplectrus gemma #		blue hamlet	**Mi**	HYP INDI
	Hypoplectrus guttavarius #		shy hamlet	**Mi**	HYP GEMM
	Hypoplectrus (hybrid) #		hybrid hamlet	**Mi**	HYP HYBR
	Hypoplectrus indigo #		indigo hamlet	**Mi**	HYP GUTT
	Hypoplectrus nigricans #		black hamlet	**Mi**	HYP NIGR
	Hypoplectrus puella #		barred hamlet	**Mi**	HYP PUEL
	Hypoplectrus sp. #		unidentified hamlet	**Mi**	HYP SPE.
	Hypoplectrus (tan) #		tan hamlet	**Mi**	HYP TANN
	Hypoplectrus unicolor #		butter hamlet	**Mi**	HYP UNIC
	Liopropoma eukrines		wrasse bass	**Ma**	LIO EUKR
	Mycteroperca bonaci		black grouper	**F**,Ma	MYC BONA
	Mycteroperca interstitialis		yellowmouth grouper	**F**,Ma	MYC INTE
	Mycteroperca microlepis		gag	**F**,Ma	MYC MICR
	Mycteroperca phenax		scamp	**F**,Ma	MYC PHEN
	Mycteroperca tigris		tiger grouper	**F**,Ma	MYC TIGR
	Mycteroperca venenosa		yellowfin grouper	**F**,Ma	MYC VENE
	Paranthias furcifer		creole-fish	**P**,F	PAR FURC
	Rypticus saponaceus		greater soapfish	**F**,Ma	RYP SAPO
	Serranus baldwini		lanternfish	**Mi**	SER BALD
	Serranus tabacarius		tobaccofish	**Mi**	SER TABA
	Serranus tigrinus		harlequin bass	**Mi**	SER TIGR
	Serranus tortugarum		chalk bass	**Mi**	SER TORT
PRIACANTHIDAE		***Bigeyes***			
	Priacanthus arenatus		bigeye	**F**,Ma,P	PRI AREN
	Priacanthus cruentatus		glasseye snapper	**Ma**,P	PRI CRUE
APOGONIDAE		***Cardinalfishes***			
	Apogon binotatus		barred cardinalfish	**P**	APO BINO
	Apogon pseudomaculatus		twospot cardinalfish	**P**	APO PSEU

Table 3. (cont.)

FAMILY NAME	*Scientific name*	***Family common name***	Species common name	Trophic Level	Species Code
MALACANTHIDAE		***Tilefishes***			
	Malacanthus plumieri		sand tilefish	**Mi**,Ma	MAL PLUM
ECHENEIDAE		***Remoras***			
	Echeneis naucrates		sharksucker	**F**,Ma	ECH NAUC
CARANGIDAE		***Jacks***			
	Alectis ciliaris		African pompano	**Ma**	ALE CILI
	Caranx bartholomaei		yellow jack	**F**	CAR BART
	Caranx crysos		blue runner	**F**	CAR CRYS
	Caranx hippos		crevalle jack	**F**	CAR HIPP
	Caranx latus		horse-eye jack	**F**,Ma	CAR LATU
	Caranx ruber		bar jack	**F**,Ma	CAR RUBE
	Caranx spe.		unidentified jack	**F**,Ma	CAR SPE.
	Decapterus macarellus		mackerel scad	**P**	DEC MACA
	Decapterus punctatus		round scad	**P**	DEC PUNC
	Elagatis bipinnulata		rainbow runner	**P**	ELA BIPI
	Seriola dumerili		greater amberjack	**F**	SER DUME
	Seriola rivoliana		almaco jack	**F**	SER RIVO
	Trachinotus falcatus		permit	**Ma**	TRA FALC
LUTJANIDAE		***Snappers***			
	Lutjanus analis		mutton snapper	**Ma**,F	LUT ANAL
	Lutjanus apodus		schoolmaster	**F**,Ma	LUT APOD
	Lutjanus buccanella		blackfin snapper	**F**,Ma	LUT BUCC
	Lutjanus cyanopterus		cubera snapper	**F**,Ma	LUT CYAN
	Lutjanus griseus		gray snapper	**F**,Ma	LUT GRIS
	Lutjanus jocu		dog snapper	**F**,Ma	LUT JOCU
	Lutjanus mahogoni		mahogany snapper	**F**,Ma	LUT MAHO
	Lutjanus spe.		unidentified snapper	**F**,Ma	LUT SPE.
	Lutjanus synagris		lane snapper	**Ma**,F	LUT SYNA
	Ocyurus chrysurus		yellowtail snapper	**F**,Ma,Mi,P	OCY CHRY
	Pristipomoides aquilonaris		wenchman	**F**,Ma,P	PRI AQUI
	Rhomboplites aurorubens		vermilion snapper	**P**,F	RHO AURO
GERREIDAE		***Mojarras***			
	Eucinostomus argenteus		spotfin mojarra	**Mi**,Ma	EUC ARGE
	Gerres cinereus		yellowfin mojarra	**Ma**,Mi	GER CINE

Table 3. (cont.)

FAMILY NAME	Scientific name	***Family common name***	Species common name	Trophic Level	Species Code
HAEMULIDAE		***Grunts***			
	Anisotremus surinamensis		black margate	**Ma**	ANI SURI
	Anisotremus virginicus		porkfish	**Ma**	ANI VIRG
	Haemulon album		margate	**Ma**	HAE ALBU
	Haemulon aurolineatum		tomtate	**Ma**	HAE AURO
	Haemulon carbonarium		caesar grunt	**Ma**	HAE CARB
	Haemulon chrysargyreum		smallmouth grunt	**Ma**	HAE CHRY
	Haemulon flavolineatum		French grunt	**Ma**	HAE FLAV
	Haemulon macrostomum		Spanish grunt	**Ma**	HAE MACR
	Haemulon melanurum		cottonwick	**Ma**	HAE MELA
	Haemulon parra		sailors choice	**Ma**	HAE PARR
	Haemulon plumieri		white grunt	**Ma**	HAE PLUM
	Haemulon sciurus		bluestriped grunt	**Ma**	HAE SCIU
	Haemulon sp.		unidentified grunt	**Ma**	HAE SPE.
	Haemulon striatum		striped grunt	**Ma**	HAE STRI
INERMIIDAE		***Bonnetmouths***			
	Inermia vittata		boga	**P**	INE VITT
SPARIDAE		***Porgies***			
	Archosargus probatocephalus		sheepshead	**Ma**	ARC PROB
	Archosargus rhomboidalis		sea bream	**H**	ARC RHOM
	Calamus bajonado		jolthead porgy	**Ma**	CAL BAJO
	Calamus calamus		saucereye porgy	**Ma**	CAL CALA
	Calamus penna		sheepshead porgy	**Ma**	CAL PENN
	Calamus proridens		littlehead porgy	**Ma**	CAL PROR
	Calamus spe.		unknown porgy	**Ma**	CAL SPE.
	Diplodus argenteus		silver porgy	**H**,B	DIP ARGE
	Diplodus holbrooki		spottail pinfish	**H**,B	DIP HOLB
	Lagodon rhomboides		pinfish	**B**,H	LAG RHOM
SCIAENIDAE		***Drums***			
	Equetus acuminatus		high-hat	**Ma**,Mi	EQU ACUM
	Equetus lanceolatus		jackknife-fish	**Ma**	EQU LANC
	Equetus punctatus		spotted drum	**Ma**	EQU PUNC
	Equetus umbrosus		cubbyu	**Mi**,Ma	EQU UMBR
	Odontoscion dentex		reef crocker	**Ma**	ODO DENT
MULLIDAE		***Goatfishes***			
	Mulloidichthys martinicus		yellow goatfish	**Mi**	MUL MART
	Pseudupeneus maculatus		spotted goatfish	**Mi**	PSE MACU

Table 3. (cont.)

FAMILY NAME	Scientific name	Family common name	Species common name	Trophic Level	Species Code
PEMPHERIDAE		***Sweepers***			
	Pempheris schomburgki		glassy sweeper	**P**,Mi	PEM SCHO
KYPHOSIDAE		***Sea chubs***			
	Kyphosus sectatrix		Bermuda chub	**H**	KYP SECT
EPHIPPIDAE		***Spadefishes***			
	Chaetodiperus faber		Atlantic spadefish	**Ma**	CHA FABE
CHAETODONTIDAE		***Butterflyfishes***			
	Chaetodon capistratus		foureye butterflyfish	**B**	CHA CAPI
	Chaetodon ocellatus		spotfin butterflyfish	**B**	CHA OCEL
	Chaetodon sedentarius		reef butterflyfish	**Mi**	CHA SEDE
	Chaetodon striatus		banded butterflyfish	**B**	CHA STRI
POMACANTHIDAE		***Angelfishes***			
	Centropye argi		cherubfish	**B**	CEN ARGI
	Holacanthus bermudensis		blue angelfish	**B**	HOL BERM
	Holacanthus ciliaris		queen angelfish	**B**	HOL CILI
	Holacanthus (bermudensis x ciliaris)		Townsend angelfish	**B**	HOL TOWN
	Holacanthus tricolor		rock beauty	**B**	HOL TRIC
	Pomacanthus arcuatus		gray angelfish	**B**	POM ARCU
	Pomacanthus paru		French angelfish	**B**	POM PARU
POMACENTRIDAE		***Damselfishes***			
	Abudefduf saxatilis		sergeant major	**P**	ABU SAXA
	Chromis cyanea		blue chromis	**P**	CHR CYAN
	Chromis enchrysurus		yellowtail reeffish	**P**	CHR ENCH
	Chromis insolata		sunshinefish	**P**	CHR INSO
	Chromis multilineata		brown chromis	**P**	CHR MULT
	Chromis scotti		purple reeffish	**P**	CHR SCOT
	Microspathodon chrysurus		yellowtail damselfish	**B**,H	MIC MICR
	Pomacentrus diencaeus		longfin damselfish	**H**	POM DIEN
	Pomacentrus fuscus		dusky damselfish	**H**	POM FUSC
	Pomacentrus leucostictus		beaugregory	**H**	POM LEUC
	Pomacentrus partitus		bicolor damselfish	**P**	POM PART
	Pomacentrus planifrons		three spot damselfish	**H**	POM PLAN
	Pomacentrus variabilis		cocoa damselfish	**H**	POM VARI
CIRRHITIDAE		***Hawkfishes***			
	Amblycirrhitus pinos		redspotted hawkfish	**Mi**	AMB PINO

Table 3. (cont.)

FAMILY NAME	Scientific name	**Family common name**	Species common name	Trophic Level	Species Code
SPHYRAENIDAE		**Barracudas**			
	Sphyraena barracuda		great barracuda	**F**,Ma	SPH BARR
	Sphyraena picudilla		southern sennet	**F**	SPH PICU
LABRIDAE		**Wrasses**			
	Bodianus pulchellus		spotfin hogfish	**Ma**,Mi	BOD PULC
	Bodianus rufus		Spanish hogfish	**Ma**,Mi	BOD RUFU
	Clepticus parrae		creole wrasse	**P**	CLE PARR
	Doratonotus megalepis		dwarf wrasse	**Mi**	DOR MEGA
	Halichoeres bivittatus		slippery dick	**Ma**,Mi	HAL BIVI
	Halichoeres cyanocephalus		yellowcheek wrasse	**Mi**,Ma	HAL CYAN
	Halichoeres garnoti		yellowhead wrasse	**Ma**,Mi	HAL GARN
	Halichoeres maculipinna		clown wrasse	**Mi**,Ma	HAL MACU
	Halichoeres pictus		rainbow wrasse	**P**	HAL PICT
	Halichoeres poeyi		blackear wrasse	**Mi**,Ma	HAL POEY
	Halichoeres radiatus		puddingwife	**Mi**,Ma	HAL RADI
	Hemipteronotus martinicensis		rosy razorfish	**Ma**,Mi	HEM MART
	Hemipteronotus novacula		pearly razorfish	**Ma**,Mi	HEM NOVA
	Hemipteronotus sp.		unidentified razonfish	**Ma**,Mi	HEM SPE.
	Hemipteronotus splendens		green razorfish	**Ma**,Mi	HEM SPLE
	Lachnolaimus maximus		hogfish	**Ma**	LAC MAXI
	Thalassoma bifasciatum		bluehead	**P**,Mi,Ma	THA BIFA
SCARIDAE		**Parrotfishes**			
	Cryptotomus roseus		bluelip parrotfish	**H**	CRY ROSE
	Nicholsina usta		emerald parrotfish	**B**	NIC USTA
	Scarus coelestinus		midnight parrotfish	**H**	SCA COEL
	Scarus coeruleus		blue parrotfish	**H**	SCA COER
	Scarus croicensis		striped parrotfish	**H**	SCA CROI
	Scarus guacamaia		rainbow parrotfish	**H**	SCA GUAC
	Scarus spe.		unidentified parrotfish	**H**	SCA SPE.
	Scarus taeniopterus		princess parrotfish	**H**	SCA TAEN
	Scarus vetula		queen parrotfish	**H**	SCA VETU
	Sparisoma atomarium		greenblotch parrotfish	**H**	SPA ATOM
	Sparisoma aurofrenatum		redband parrotfish	**H**	SPA AURO
	Sparisoma chrysopterum		redtail parrotfish	**H**	SPA CHRY
	Sparisoma radians		bucktooth parrotfish	**H**	SPA RADI
	Sparisoma rubripinne		redfin parrotfish	**H**	SPA RUBR
	Sparisoma spe.		unidentified parrotfish	**H**	SPA SPE.
	Sparisoma viride		stoplight parrotfish	**H**	SPA VIRI
OPISTOGNATHIDAE		**Jawfishes**			
	Opistognathus aurifrons		yellowhead jawfish	**P**	OPI AURI
	Opistognathus whitehursti		dusky jawfish	**P**	OPI WHIT

Table 3. (cont.)

FAMILY NAME	Scientific name	Family common name	Species common name	Trophic Level	Species Code
CLINIDAE		***Clinids***			
	Acanthemblemaria aspera		roughhead blenny	**P**	ACA ASPE
	Acanthemblemaria chaplini		papillose blenny	**P**	ACA CHAP
	Emblemaria pandionis		sailfin blenny	**H**	EMB PAND
	Hemiemblemaria simulus		wrasse blenny	**Mi**,P	HEM SIMU
	Labrisiomus nuchipinnis		hairy blenny	**H**	LAB NUCH
	Malacoctenus gilli		dusky blenny	**Mi**,P	MAL GILL
	Malacoctenus macrops		rosy blenny	**Mi**,P	MAL MACR
	Malacoctenus sp.		unidentified blenny	**Mi**,P	MAL SPE.
	Malacoctenus triangulatus		saddled blenny	**Mi**,P	MAL TRIA
	Malacoctenus versicolor		barfin blenny	**Mi**,P	MAL VERS
	Paraclinus marmoratus		marbled blenny	**P**,Mi	PAR MARM
	Paraclinus nigripinnis		blackfin goby	**P**,Mi	PAR NIGR
BLENNIIDAE		***Combtooth blennies***			
	Unidentified blenny		unidentified blenny	**H**	BLE SPE.
	Hypleurochilus bermudensis		barred blenny	**H**	HYP BERM
	Ophioblennius atlanticus		redlip blenny	**H**	OPH ATLA
	Scartella cristata		molly miller	**H**	SCA CRIS
CALLIONYMIDAE		***Dragonets***			
	Paradiplogrammus bairdi		lancer dragonet	**Ma**	PAR BAIR
GOBIIDAE		***Gobies***			
	Coryphopterus dicrus		colon goby	**H**	COR DICR
	Coryphopterus eidolon		pallid goby	**H**	COR EIDO
	Coryphopterus glaucofraenum		bridled goby	**H**	COR GLAU
	Coryphopterus personatus		masked goby	**P**	COR PERS
	Coryphopterus species		unknown goby	**H**,P	COR SPE.
	Gnatholepis thompsoni		goldspot goby	**H**	GNA THOM
	Gobiosoma evelynae		sharknose goby	**Mi**	GOB EVEL
	Gobiosoma macrodon		tiger goby	**Mi**	GOB MACR
	Gobiosoma oceanops		neon goby	**Mi**	GOB OCEA
	Gobiosoma randalli		yellownose goby	**Mi**	GOB RAND
	Goby-like fish		goby-like fish	**Mi**,H	GOB SPE.
	Ioglossus calliurus		blue goby	**P**	IOG CALL
	Ioglossus helenae		hovering goby	**P**	IOG HELE
	Microgobius carri		Seminole goby	**P**	MIC CARR
	Microgobius microlepis		banner goby	**H**	MIC CHRY

Table 3. (cont.)

FAMILY NAME	Scientific name	Family common name	Species common name	Trophic Level	Species Code
ACANTHURIDAE		**Surgeonfishes**			
	Acanthurus bahianus		ocean surgeon	**H**	ACA BAHI
	Acanthurus chirurgus		doctorfish	**H**	ACA CHIR
	Acanthurus coeruleus		blue tang	**H**	ACA COER
	Acanthurus spe.		unidentified Acanthurid	**H**	ACA SPE.
SCOMBRIDAE		**Mackerels/Tunas**			
	Scomberomorus cavalla		king mackerel	**F**,Ma	SCO CAVA
	Scomberomorus maculatus		Spanish mackerel	**F**,Ma	SCO MACU
	Scomberomorus regalis		cero	**F**,Ma	SCO REGA
BOTHIDAE		**Lefteye flounders**			
	Bothus lunatus		peacock flounder	**F**,Ma	BOT LUNA
	Bothus ocellatus		eyed flounder	**F**,Ma	BOT OCEL
BALISTIDAE		**Leatherjackets**			
	Aluterus monoceros		unicorn filefish	**H**	ALU MONO
	Aluterus schoepfi		orange filefish	**H**	ALU SCHO
	Aluterus scriptus		scrawled filefish	**H**,B	ALU SCRI
	Balistes capriscus		gray triggerfish	**Ma**	BAL CAPR
	Balistes vetula		queen triggerfish	**Ma**	BAL VETU
	Cantherhines macrocerus		whitespotted filefish	**B**,H	CAN MACR
	Cantherhines pullus		orangespotted filefish	**B**,H	CAN PULL
	Canthidermis sufflamen		ocean triggerfish	**Ma**,P	CAN SUFF
	Melichthys niger		black durgon	**P**	MEL NIGE
	Monacanthus hispidus		planehead filefish	**Mi**	MON HISP
	Monacanthus tuckeri		slender filefish	**Mi**	MON TUCK
OSTRACIIDAE		**Boxfishes**			
	Lactophrys bicaudalis		spotted trunkfish	**B**	LAC BICA
	Lactophrys polygonia		honeycomb cowfish	**B**	LAC POLY
	Lactophrys quadricornis		scrawled cowfish	**B**	LAC QUAD
	Lactophrys trigonius		trunkfish	**B**	LAC TRIG
	Lactophrys triqueter		smooth trunkfish	**B**	LAC TRIQ
TETRAODONTIDAE		**Puffers**			
	Canthigaster rostrata		sharpnose puffer	**H**,B,Mi	CAN ROST
	Chilomycterus antennatus		bridled burrfish	**Ma**	CHI ANTE
	Chilomycterus schoepfi		striped burrfish	**Ma**	CHI SCHO
	Diodon holocanthus		balloonfish	**Ma**	DIO HOLO
	Diodon hystrix		porcupinefish	**Ma**	DIO HYST
	Diodon species		unknown porcupinefish	**Ma**	DIO SPE.
	Sphoeroides spengleri		bandtail puffer	**Mi**,B	SPH SPEN
UNKNOWN		**Unknown**			
	Unidentified sp.		unidentified species		UNK SPE.

Table 4. Statistical summary by species of Florida Keys visual sampling, 1979 - 1998. Species are listed alphabetically by species code. Scientific names for codes are given in Table 1.

			SAMPLE FREQUENCY				SAMPLE ABUNDANCE RANGE		FISH LENGTH (cm)			BIOMASS (gms)
	Species Code	Total Indiv.	N	%	Mean Abund.	Stand. Dev.	High	Low	Mean	Min.	Max.	Total
1	ABU SAXA	68,357	2,969	44.49	9.923	29.62	550	0	9.7	1	15	2,267,284.2
2	ACA ASPE	14	6	0.09	0.002	0.08	5	0	2.9	2	3	2.5
3	ACA BAHI	20,710	4,147	62.15	3.006	6.41	220	0	11.1	1	38	891,588.5
4	ACA CHAP	7	7	0.10	0.001	0.03	1	0	2.4	2	4	2.6
5	ACA CHIR	5,541	1,585	23.75	0.804	3.21	120	0	14.3	1	38	616,922.8
6	ACA COER	19,744	4,520	67.74	2.866	12.38	450	0	14.2	1	40	2,196,928.4
7	ACA SPE.	1	1	0.01	<0.001	0.01	1	0	3	3	3	0.9
8	AET NARI	8	8	0.12	0.001	0.03	1	0	143.5	65	200	7,980.3
9	ALE CILI	20	5	0.07	0.003	0.12	8	0	42.7	9	100	92,785.1
10	ALU MONO	1	1	0.01	<0.001	0.01	1	0	14	14	14	45.1
11	ALU SCHO	32	24	0.36	0.005	0.09	3	0	31	7	60	11,590.6
12	ALU SCRI	318	253	3.79	0.046	0.26	6	0	40.4	12	75	221,722.4
13	AMB PINO	30	27	0.40	0.004	0.07	3	0	6.6	4	9	56.8
14	ANI SURI	124	80	1.20	0.018	0.22	8	0	32.1	12	53	118,636.6
15	ANI VIRG	3,446	1,399	20.97	0.500	2.35	110	0	14.4	1	40	526,032.7
16	APO BINO	1	1	0.01	<0.001	0.01	1	0	5	5	5	2.2
17	APO PSEU	2	1	0.01	<0.001	0.02	2	0	3	3	3	1.0
18	ARC PROB	5	5	0.07	0.001	0.03	1	0	29.4	18	48	4,814.7
19	ARC RHOM	166	21	0.31	0.024	0.86	60	0	16.4	10	30	19,699.4
20	ATH STIP	22,712	7	0.10	3.297	153.66	9812	0	3.3	2	6	10,691.8
21	AUL MACU	967	769	11.52	0.140	0.44	5	0	33.7	10	104	133,167.4
22	BAL CAPR	27	23	0.34	0.004	0.07	2	0	23.7	12	35	8,925.8
23	BAL VETU	47	41	0.61	0.007	0.09	3	0	27.2	14	40	29,259.8
24	BLE SPE.	11	10	0.15	0.002	0.04	2	0	5.3	3	12	34.1
25	BOD PULC	5	3	0.04	0.001	0.04	2	0	5.2	4	8	16.7
26	BOD RUFU	1,546	1,099	16.47	0.224	0.60	8	0	16.9	1	43	216,974.7
27	BOT LUNA	5	3	0.04	0.001	0.04	3	0	6.4	6	8	19.4
28	BOT OCEL	3	3	0.04	<0.001	0.02	1	0	9	6	12	41.0
29	CAL BAJO	116	94	1.41	0.017	0.16	4	0	28.5	8	50	90,786.8
30	CAL CALA	825	597	8.95	0.120	0.47	9	0	18.3	2	50	167,643.3
31	CAL PENN	4	3	0.04	0.001	0.03	2	0	24.3	23	25	1,509.7
32	CAL PROR	7	5	0.07	0.001	0.04	3	0	27.3	17	35	3,083.3
33	CAL SPE.	2	2	0.03	<0.001	0.02	1	0	28	18	38	1,280.8
34	CAN MACR	28	25	0.37	0.004	0.07	3	0	18.3	4	40	5,878.0
35	CAN PULL	225	199	2.98	0.033	0.20	3	0	11.6	3	25	10,769.5
36	CAN ROST	1,879	1,257	18.84	0.273	0.70	11	0	4.6	1	10	4,470.1
37	CAN SUFF	94	72	1.08	0.014	0.15	4	0	40	16	69	153,449.1
38	CAR BART	1,286	227	3.40	0.187	2.97	175	0	33.5	8	100	1,346,127.8
39	CAR CRYS	2,672	82	1.23	0.388	8.89	350	0	23.5	6	45	773,287.6
40	CAR HIPP	1	1	0.01	<0.001	0.01	1	0	75	75	75	6,944.5
41	CAR LATU	215	4	0.06	0.031	1.35	80	0	27	20	40	106,024.8
42	CAR LIMB	1	1	0.01	<0.001	0.01	1	0	152	152	152	22,092.0
43	CAR RUBE	16,631	1,486	22.27	2.414	13.21	500	0	15	2	70	1,655,218.3
44	CAR SPE.	1	1	0.01	<0.001	0.01	1	0	120	120	120	10,553.2
45	CEN ARGI	5	3	0.04	0.001	0.04	3	0	4.2	3	5	11.1
46	CEN UNDE	37	20	0.30	0.005	0.16	12	0	73.8	36	122	163,420.2
47	CHA CAPI	5,230	2,484	37.22	0.759	1.21	12	0	8.1	1	15	103,418.4
48	CHA FABE	398	66	0.99	0.058	1.39	75	0	32.2	8	50	469,194.9
49	CHA OCEL	2,033	1,186	17.77	0.295	0.74	12	0	10.6	3	20	81,980.1
50	CHA SEDE	793	469	7.03	0.115	0.52	17	0	8.7	2	15	19,491.4
51	CHA STRI	734	458	6.86	0.107	0.43	6	0	10.1	2	16	25,686.1
52	CHI ANTE	2	2	0.03	<0.001	0.02	1	0	18.5	18	19	430.9
53	CHI SCHO	2	2	0.03	<0.001	0.02	1	0	14.5	14	15	201.6
54	CHR CYAN	9,877	1,795	26.90	1.434	4.99	130	0	6.3	1	15	83,667.5
55	CHR ENCH	44	13	0.19	0.006	0.22	11	0	2.5	1	5	19.0
56	CHR INSO	52	16	0.24	0.008	0.22	13	0	5.9	2	10	437.3
57	CHR MULT	10,337	755	11.31	1.501	8.88	280	0	7.6	1	17	144,297.8
58	CHR SCOT	5,094	360	5.39	0.739	7.24	350	0	4.4	1	11	15,426.5
59	CLE PARR	13,355	495	7.42	1.939	14.44	500	0	11.1	1	30	503,242.4
60	COR DICR	430	227	3.40	0.062	0.46	13	0	3.1	1	6	202.0
61	COR EIDO	4	3	0.04	0.001	0.03	2	0	2.3	2	3	0.7
62	COR GLAU	6,549	1,653	24.77	0.951	3.09	100	0	3.1	1	8	3,239.2
63	COR PERS	27,726	620	9.29	4.025	26.55	800	0	2.4	1	6	6,205.7
64	COR SPE.	57	5	0.07	0.008	0.60	50	0	2.4	2	7	17.7

Table 4 (cont.)

	Species Code	Total Indiv.	SAMPLE FREQUENCY N	%	Mean Abund.	Stand. Dev.	SAMPLE ABUNDANCE RANGE High	Low	FISH LENGTH (cm) Mean	Min.	Max.	BIOMASS (gms) Total
65	CRY ROSE	315	83	1.24	0.046	0.58	23	0	4.5	2	11	2,847.6
66	DAS AMER	40	38	0.57	0.006	0.08	2	0	121	25	200	523,663.4
67	DEC MACA	91	3	0.04	0.013	0.88	70	0	12.5	2	14	2,272.1
68	DEC PUNC	236	4	0.06	0.034	2.05	150	0	10.4	7	17	3,937.9
69	DIO HOLO	46	45	0.67	0.007	0.08	2	0	15.7	11	23	5,716.8
70	DIO HYST	35	32	0.48	0.005	0.08	2	0	33.4	5	76	77,178.8
71	DIO SPE.	1	1	0.01	<0.001	0.01	1	0	10	10	10	100.6
72	DIP ARGE	15	3	0.04	0.002	0.16	13	0	12.1	8	17	561.3
73	DIP FORM	62	16	0.24	0.009	0.26	16	0	3.9	2	12	73.9
74	DIP HOLB	78	18	0.27	0.011	0.37	24	0	14.6	4	26	5,829.1
75	DOR MEGA	1	1	0.01	<0.001	0.01	1	0	4	4	4	0.9
76	ECH NAUC	105	98	1.47	0.015	0.13	3	0	13.1	4	61	5,579.1
77	ELA BIPI	10	4	0.06	0.001	0.06	4	0	23	15	30	1,550.8
78	EMB PAND	2	1	0.01	<0.001	0.02	2	0	8	7	8	8.3
79	EPI ADSC	42	40	0.60	0.006	0.08	2	0	21.6	7	35	9,326.8
80	EPI CRUE	1,790	1,296	19.42	0.260	0.70	23	0	15.9	3	40	148,966.9
81	EPI FULV	42	35	0.52	0.006	0.09	4	0	17.5	5	35	5,813.9
82	EPI GUTT	78	71	1.06	0.011	0.12	2	0	19.7	6	43	14,742.4
83	EPI INER	1	1	0.01	<0.001	0.01	1	0	24	24	24	186.1
84	EPI ITAJ	3	3	0.04	<0.001	0.02	1	0	135.3	6	200	320,814.3
85	EPI MORI	292	235	3.52	0.042	0.25	5	0	35.5	6	75	246,820.7
86	EPI STRI	55	51	0.76	0.008	0.10	2	0	41.6	13	70	82,293.1
87	EQU ACUM	239	101	1.51	0.035	0.52	29	0	9.1	1	17	3,050.7
88	EQU LANC	3	3	0.04	<0.001	0.02	1	0	3.7	2	5	0.8
89	EQU PUNC	34	29	0.43	0.005	0.09	4	0	11.4	1	24	1,283.4
90	EQU UMBR	31	19	0.28	0.004	0.14	10	0	9.5	3	15	473.3
91	EUC ARGE	1	1	0.01	<0.001	0.01	1	0	15	15	15	78.0
92	FIS TABA	1	1	0.01	<0.001	0.01	1	0	60	60	60	492.8
93	GER CINE	1,357	121	1.81	0.197	4.04	210	0	18.2	2	47	226,429.6
94	GIN CIRR	33	30	0.45	0.005	0.08	3	0	135.5	27	350	847,626.5
95	GNA THOM	1,263	410	6.14	0.183	1.09	29	0	3.5	1	7	792.0
96	GOB EVEL	2	2	0.03	<0.001	0.02	1	0	1.5	1	2	0.1
97	GOB MACR	3	1	0.01	<0.001	0.04	3	0	4	4	4	1.9
98	GOB OCEA	1,591	647	9.70	0.231	1.04	21	0	2.7	1	6	372.5
99	GOB RAND	1	1	0.01	<0.001	0.01	1	0	3	3	3	0.3
100	GOB SPE.	22	11	0.16	0.003	0.10	6	0	3.6	1	9	20.2
101	GYM FUNE	32	32	0.48	0.005	0.07	1	0	101.9	8	200	122,820.5
102	GYM MILI	26	24	0.36	0.004	0.07	2	0	32.5	19	60	2,587.7
103	GYM MORI	30	30	0.45	0.004	0.07	1	0	49.7	12	100	10,897.1
104	GYM SAXI	3	3	0.04	<0.001	0.02	1	0	39.7	30	50	385.0
105	GYM VICI	3	3	0.04	<0.001	0.02	1	0	50.7	16	90	1,673.0
106	HAE ALBU	64	19	0.28	0.009	0.34	25	0	19.6	4	60	23,899.3
107	HAE AURO	115,696	1,391	20.85	16.794	97.55	5000	0	9.2	1	30	3,205,014.1
108	HAE CARB	3,511	527	7.90	0.510	5.07	225	0	16.8	2	30	366,017.7
109	HAE CHRY	26,169	526	7.88	3.799	24.33	600	0	12.9	2	25	2,755,339.3
110	HAE FLAV	27,342	3,472	52.03	3.969	13.84	400	0	12.4	2	30	1,509,196.5
111	HAE MACR	865	425	6.37	0.126	1.42	100	0	18.9	2	53	288,376.2
112	HAE MELA	844	53	0.79	0.123	3.88	233	0	14.9	3	22	70,286.0
113	HAE PARR	1,179	250	3.75	0.171	2.13	94	0	20.1	4	45	225,747.2
114	HAE PLUM	31,577	3,450	51.70	4.584	15.89	500	0	12.3	1	40	1,955,794.3
115	HAE SCIU	33,268	2,593	38.86	4.829	18.35	450	0	17.4	1	40	4,556,407.8
116	HAE SPE.	22,572	132	1.98	3.277	114.53	9000	0	1.9	1	14	7,726.1
117	HAE STRI	837	37	0.55	0.121	2.50	95	0	11.3	3	25	33,364.9
118	HAL BIVI	22,235	3,161	47.37	3.228	7.16	100	0	6	1	18	78,608.1
119	HAL CYAN	13	10	0.15	0.002	0.06	3	0	7.5	3	15	120.0
120	HAL GARN	16,809	3,667	54.95	2.440	4.01	90	0	6.6	1	21	94,476.4
121	HAL MACU	12,726	2,913	43.65	1.847	3.60	75	0	6.1	1	25	49,045.2
122	HAL PICT	20	11	0.16	0.003	0.09	5	0	6.4	3	12	86.8
123	HAL POEY	140	54	0.81	0.020	0.38	25	0	7.2	3	14	809.7
124	HAL RADI	1,990	1,318	19.75	0.289	0.74	8	0	8.1	1	66	79,708.2
125	HAR JAGU	12,100	6	0.09	1.756	63.42	3000	0	5.5	3	8	33,376.9
126	HEM BRAS	656	14	0.21	0.095	3.43	175	0	16.9	7	30	58,060.0
127	HEM MART	243	24	0.36	0.035	1.25	79	0	5.9	2	30	2,164.7
128	HEM NOVA	17	9	0.13	0.002	0.09	6	0	6.1	5	10	50.4
129	HEM SIMU	37	9	0.13	0.005	0.32	26	0	3.5	3	8	46.8
130	HEM SPE.	161	5	0.07	0.023	1.11	60	0	2	1	5	48.0

Table 4 (cont.)

	Species Code	Total Indiv.	SAMPLE FREQUENCY N	SAMPLE FREQUENCY %	Mean Abund.	Stand. Dev.	SAMPLE ABUNDANCE RANGE High	SAMPLE ABUNDANCE RANGE Low	FISH LENGTH (cm) Mean	FISH LENGTH (cm) Min.	FISH LENGTH (cm) Max.	BIOMASS (gms) Total
131	HEM SPLE	391	101	1.51	0.057	0.85	34	0	7.1	2	15	2,117.1
132	HOL ADSC	1,075	361	5.41	0.156	2.13	150	0	19.9	8	35	222,562.3
133	HOL BERM	930	667	10.00	0.135	0.49	8	0	22.9	3	45	373,407.4
134	HOL CILI	676	544	8.15	0.098	0.41	16	0	17.9	3	45	156,588.4
135	HOL CORU	4	3	0.04	0.001	0.03	2	0	11	10	12	104.3
136	HOL MARI	15	11	0.16	0.002	0.06	2	0	16.4	12	25	1,861.5
137	HOL RUFU	814	356	5.33	0.118	0.73	24	0	17.6	4	35	97,152.2
138	HOL SPE.	1	1	0.01	<0.001	0.01	1	0	2	2	2	0.5
139	HOL TOWN	1	1	0.01	<0.001	0.01	1	0	15	15	15	82.1
140	HOL TRIC	1,884	1,265	18.96	0.273	0.68	8	0	12.2	1	25	137,522.3
141	HOL VEXI	85	40	0.60	0.012	0.26	17	0	13.9	7	22	7,749.5
142	HYP BERM	8	8	0.12	0.001	0.03	1	0	3.1	2	4	3.5
143	HYP CHLO	1	1	0.01	<0.001	0.01	1	0	9	9	9	2.0
144	HYP GEMM	757	494	7.40	0.110	0.54	21	0	7	3	14	5,471.0
145	HYP GUTT	10	8	0.12	0.001	0.05	3	0	7.1	4	10	73.2
146	HYP HARR	17,500	5	0.07	2.540	111.25	7000	0	2.7	1	4	5,687.9
147	HYP HYBR	1	1	0.01	<0.001	0.01	1	0	8	8	8	8.2
148	HYP INDI	29	27	0.40	0.004	0.07	2	0	9.4	5	15	498.4
149	HYP NIGR	90	80	1.20	0.013	0.13	3	0	6.9	3	15	642.1
150	HYP PUEL	307	258	3.87	0.045	0.25	4	0	6.9	3	14	2,276.7
151	HYP SPE.	4	4	0.06	0.001	0.02	1	0	10.5	7	13	90.2
152	HYP TANN	57	47	0.70	0.008	0.11	4	0	6.3	3	12	338.2
153	HYP UNIC	1,480	996	14.93	0.215	0.63	10	0	6.6	1	15	9,334.3
154	INE VITT	1,981	39	0.58	0.288	7.87	500	0	15.6	4	35	152,368.3
155	IOG CALL	278	60	0.90	0.040	0.62	29	0	4.4	1	10	375.1
156	IOG HELE	10	6	0.09	0.001	0.06	4	0	4.2	1	10	13.9
157	JEN LAMP	50	1	0.01	0.007	0.60	50	0	5	5	5	98.1
158	JEN SPE.	13,000	6	0.09	1.887	122.12	9999	0	1.5	1	5	1,916.9
159	KYP SECT	9,140	831	12.45	1.327	7.48	220	0	23.1	3	70	3,391,860.3
160	LAB NUCH	1	1	0.01	<0.001	0.01	1	0	7	7	7	4.2
161	LAC BICA	61	59	0.88	0.009	0.10	2	0	14.5	5	37	9,124.2
162	LAC MAXI	1,288	892	13.37	0.187	0.62	15	0	24.5	2	60	532,490.2
163	LAC POLY	9	9	0.13	0.001	0.04	1	0	22	13	35	2,116.0
164	LAC QUAD	67	65	0.97	0.010	0.10	2	0	23.5	10	40	16,688.1
165	LAC TRIG	14	13	0.19	0.002	0.05	2	0	16.5	7	37	2,425.6
166	LAC TRIQ	338	307	4.60	0.049	0.24	4	0	13.4	4	30	39,998.8
167	LAG RHOM	37	4	0.06	0.005	0.29	20	0	12.5	10	17	1,464.3
168	LIO EUKR	1	1	0.01	<0.001	0.01	1	0	8	8	8	8.2
169	LUT ANAL	230	186	2.79	0.033	0.24	10	0	44.5	6	85	434,726.6
170	LUT APOD	7,798	1,111	16.65	1.132	6.32	220	0	21.9	2	50	1,888,807.2
171	LUT BUCC	1	1	0.01	<0.001	0.01	1	0	4	4	4	1.3
172	LUT CYAN	4	3	0.04	0.001	0.03	2	0	41.8	39	46	5,682.4
173	LUT GRIS	19,510	1,612	24.16	2.832	14.33	508	0	22.3	4	60	4,286,995.0
174	LUT JOCU	100	62	0.93	0.015	0.20	8	0	33.5	4	90	113,247.5
175	LUT MAHO	1,243	334	5.01	0.180	1.52	47	0	25.1	1	60	395,949.9
176	LUT SPE.	3	2	0.03	<0.001	0.03	2	0	14	2	20	270.9
177	LUT SYNA	2,386	185	2.77	0.346	3.83	134	0	16.9	5	40	238,913.2
178	MAL GILL	6	2	0.03	0.001	0.05	4	0	4.7	4	6	8.2
179	MAL MACR	196	87	1.30	0.028	0.33	9	0	3.6	2	6	88.1
180	MAL PLUM	214	130	1.95	0.031	0.30	10	0	12.8	2	40	8,809.2
181	MAL SPE.	1	1	0.01	<0.001	0.01	1	0	5	5	5	1.1
182	MAL TRIA	449	244	3.66	0.065	0.58	33	0	4	1	8	312.1
183	MAL VERS	5	2	0.03	0.001	0.04	3	0	5	4	5	7.0
184	MAN BIRO	5	2	0.03	0.001	0.05	4	0	112	90	200	523,224.3
185	MEG ATLA	284	91	1.36	0.041	1.17	60	0	137.5	50	200	8,869,484.3
186	MEL NIGE	3	3	0.04	<0.001	0.02	1	0	30.7	28	32	1,756.6
187	MIC CARR	9	6	0.09	0.001	0.05	2	0	6.3	3	11	28.5
188	MIC CHRY	11,636	2,698	40.43	1.689	3.17	40	0	10.4	1	20	445,190.2
189	MIC MICR	3	2	0.03	<0.001	0.03	2	0	9.3	6	11	35.0
190	MON HISP	18	14	0.21	0.003	0.06	2	0	15.4	3	22	1,368.3
191	MON TUCK	38	32	0.48	0.006	0.09	3	0	6.3	3	9	250.9
192	MUL MART	10,351	974	14.60	1.503	8.71	380	0	21.9	3	45	2,595,961.4
193	MYC BONA	309	268	4.02	0.045	0.24	4	0	38.9	6	100	437,330.2
194	MYC INTE	3	3	0.04	<0.001	0.02	1	0	16.7	15	20	209.1
195	MYC MICR	22	20	0.30	0.003	0.06	2	0	36	10	90	30,298.1
196	MYC PHEN	45	30	0.45	0.007	0.12	6	0	27.4	4	50	19,266.8
197	MYC TIGR	2	2	0.03	<0.001	0.02	1	0	30	30	30	778.0
198	MYC VENE	3	3	0.04	<0.001	0.02	1	0	21.7	17	26	473.7

Table 4 (cont.)

			SAMPLE FREQUENCY				SAMPLE ABUNDANCE RANGE		FISH LENGTH (cm)			BIOMASS (gms)
	Species Code	Total Indiv.	N	%	Mean Abund.	Stand. Dev.	High	Low	Mean	Min.	Max.	Total
199	MYR JACO	45	21	0.31	0.007	0.17	9	0	13.8	10	27	3,495.6
200	NIC USTA	1	1	0.01	<0.001	0.01	1	0	6	6	6	2.2
201	OCY CHRY	43,967	4,051	60.71	6.382	34.67	2000	0	18.6	1	60	6,252,521.5
202	ODO DENT	1,192	357	5.35	0.173	1.89	80	0	10.6	4	24	18,538.0
203	OGC SPE.	1	1	0.01	<0.001	0.01	1	0	16	16	16	75.1
204	OPH ATLA	224	116	1.74	0.033	0.32	11	0	6.2	2	14	645.8
205	OPI AURI	921	224	3.36	0.134	1.08	31	0	6.2	2	10	2,447.4
206	OPI WHIT	1	1	0.01	<0.001	0.01	1	0	14	14	14	24.8
207	OST TRAC	2	2	0.03	<0.001	0.02	1	0	10	8	12	38.8
208	PAR BAIR	5	3	0.04	0.001	0.01	1	0	4	1	3	0.2
209	PAR FURC	103	5	0.07	0.015	0.90	70	0	10.6	6	20	2,217.3
210	PAR MARM	62	25	0.37	0.009	0.18	6	0	3.4	1	7	60.0
211	PAR NIGR	1	1	0.01	<0.001	0.01	1	0	4	4	4	0.6
212	PEM SCHO	4,924	214	3.21	0.715	11.97	650	0	7.6	1	20	49,269.3
213	POM ARCU	2,654	1,699	25.46	0.385	0.84	12	0	25.6	2	50	1,734,586.8
214	POM DIEN	1,295	372	5.57	0.188	1.07	29	0	7.7	1	13	20,087.5
215	POM FUSC	9,320	1,544	23.14	1.353	4.37	73	0	6	1	14	68,908.1
216	POM LEUC	2,614	954	14.30	0.379	1.56	35	0	4.7	1	12	9,166.8
217	POM PART	151,266	4,966	74.42	21.958	31.94	400	0	4.1	1	10	283,535.2
218	POM PARU	755	577	8.65	0.110	0.54	27	0	25.1	3	50	497,272.6
219	POM PLAN	19,204	2,599	38.95	2.788	7.30	120	0	6.6	1	15	181,824.6
220	POM VARI	5,259	1,694	25.39	0.763	2.20	40	0	5.4	1	14	25,523.7
221	PRI AQUI	3	1	0.01	<0.001	0.04	3	0	5	4	6	14.5
222	PRI AREN	20	11	0.16	0.003	0.12	9	0	23.3	8	35	5,402.0
223	PRI CRUE	78	48	0.72	0.011	0.20	10	0	14.9	7	25	11,021.4
224	PSE MACU	1,244	704	10.55	0.181	0.97	50	0	13.5	3	35	82,098.5
225	RHO AURO	3	1	0.01	<0.001	0.04	3	0	20	15	25	1,027.4
226	RYP SAPO	7	7	0.10	0.001	0.03	1	0	17.3	10	23	642.0
227	SCA COEL	1,376	398	5.96	0.200	1.91	75	0	38.2	6	91	1,779,889.7
228	SCA COER	983	516	7.73	0.143	0.97	42	0	29.1	3	75	757,273.9
229	SCA CRIS	40	21	0.31	0.006	0.12	10	0	4.5	1	7	48.9
230	SCA CROI	45,114	4,359	65.32	6.549	11.00	240	0	6.1	1	30	271,402.0
231	SCA GUAC	585	323	4.84	0.085	0.63	22	0	37.6	3	75	766,313.1
232	SCA SPE.	7	2	0.03	0.001	0.06	4	0	20.3	10	28	1,557.4
233	SCA TAEN	7,829	1,760	26.37	1.136	4.01	118	0	8.2	1	35	179,622.0
234	SCA VETU	2,531	1,328	19.90	0.367	0.99	18	0	24.4	2	60	937,976.5
235	SCO CAVA	4	4	0.06	0.001	0.02	1	0	80.5	45	120	23,811.0
236	SCO MACU	8	8	0.12	0.001	0.03	1	0	47.1	35	70	8,853.1
237	SCO PLUM	14	14	0.21	0.002	0.05	1	0	24.2	15	32	4,773.2
238	SCO REGA	191	138	2.07	0.028	0.27	10	0	44.2	15	100	168,879.3
239	SER BALD	66	43	0.64	0.010	0.14	5	0	4.5	2	8	94.1
240	SER DUME	9	7	0.10	0.001	0.04	2	0	95.6	35	183	179,367.9
241	SER RIVO	4	2	0.03	0.001	0.04	3	0	32	24	50	3,190.3
242	SER TABA	403	276	4.14	0.058	0.36	12	0	7.1	1	18	3,870.2
243	SER TIGR	1,914	1,293	19.38	0.278	0.69	8	0	6.8	1	18	11,620.2
244	SER TORT	151	20	0.30	0.022	0.61	29	0	4.7	1	10	321.7
245	SPA ATOM	1,612	411	6.16	0.234	1.41	36	0	4.3	1	12	2,181.2
246	SPA AURO	21,090	4,632	69.41	3.061	4.04	42	0	11.2	1	40	909,186.5
247	SPA CHRY	2,069	772	11.57	0.300	1.68	75	0	18.6	2	45	353,831.3
248	SPA RADI	589	156	2.34	0.085	1.07	52	0	6	1	23	4,345.2
249	SPA RUBR	3,135	1,252	18.76	0.455	1.75	40	0	22.6	2	70	1,013,156.5
250	SPA SPE.	2	2	0.03	0.000	0.02	1	0	16.5	5	28	385.3
251	SPA VIRI	12,574	4,193	62.84	1.825	2.51	35	0	17.4	1	50	2,831,744.8
252	SPH BARR	1,848	1,012	15.17	0.268	1.06	35	0	68.8	6	200	7,641,148.5
253	SPH LEWI	1	1	0.01	<0.001	0.01	1	0	190	190	190	45,748.2
254	SPH MOKA	1	1	0.01	<0.001	0.01	1	0	245	245	245	65,672.4
255	SPH PICU	55	1	0.01	0.008	0.66	55	0	40	38	42	18,989.3
256	SPH SPEN	32	30	0.45	0.005	0.07	2	0	9.8	3	16	849.5
257	SYN FOET	2	2	0.03	<0.001	0.02	1	0	13.5	10	17	48.2
258	SYN INTE	35	35	0.52	0.005	0.07	1	0	15.3	4	35	2,803.7
259	THA BIFA	188,037	5,402	80.95	27.295	43.59	800	0	4.9	1	16	258,589.9
260	TRA FALC	59	24	0.36	0.009	0.31	24	0	58.3	35	90	227,315.1
261	TYL CROC	54	15	0.22	0.008	0.30	19	0	54.6	30	75	79,721.6
262	UNK SPE.	6,563	11	0.16	0.953	45.19	3000	0	1.6	1	3	741.1
263	URO JAMA	158	153	2.29	0.023	0.15	2	0	30	10	50	46,644.6

NO. SAMPLES = 6,673
NO. SPECIES = 263
TOT.INDIVIDUALS = 1,241,270
TOT. BIOMASS (g) = 84,752,393.3 (some Biomass values are estimates)

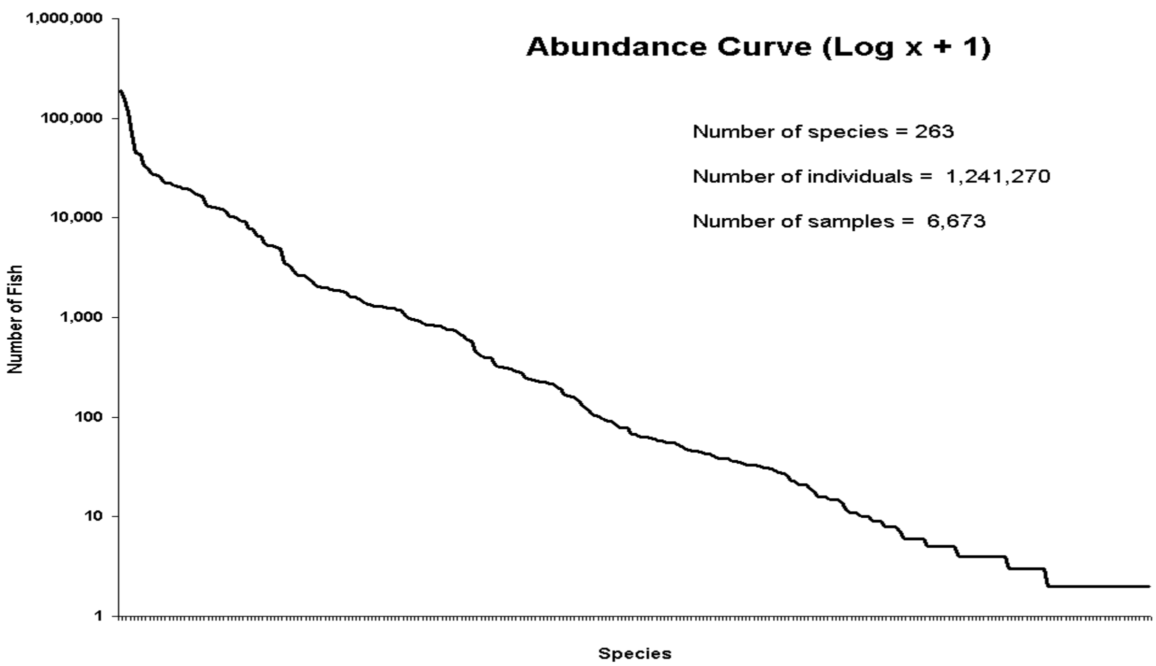


Figure 3. Rank order total log abundance for all species in 6,673 samples. Table 4 provides abundance data for individual species.

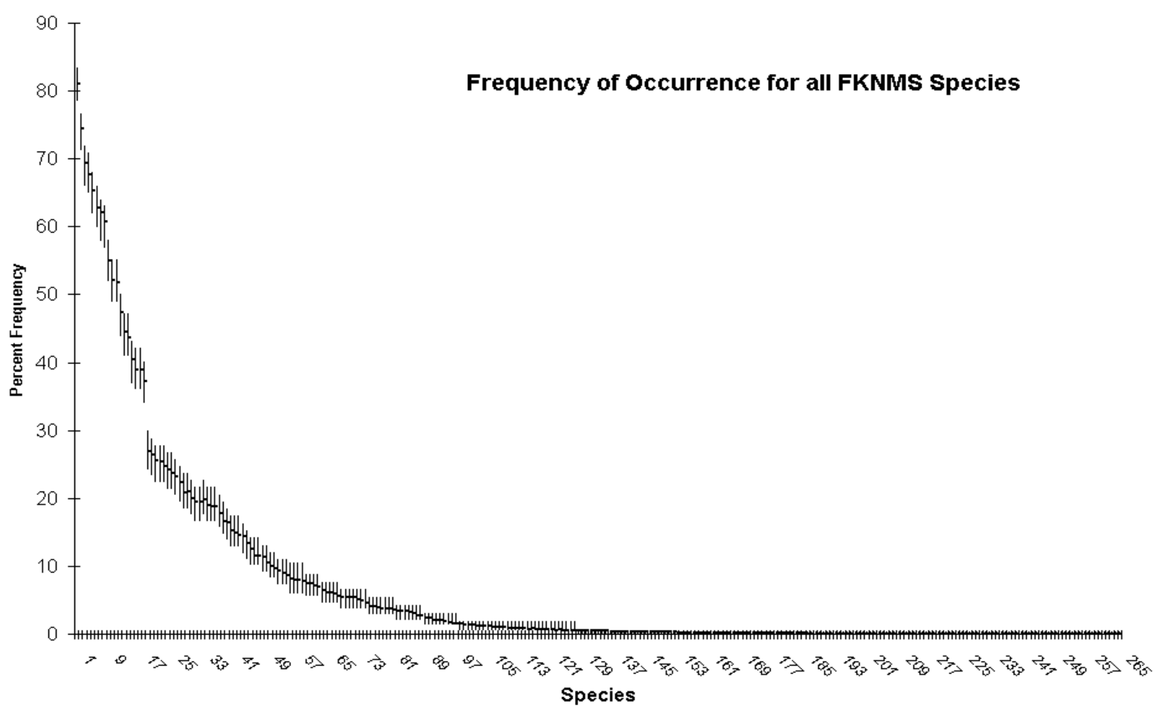


Figure 4. Rank order mean frequency-of-occurrence (± 95% C.I.) for all species in 6,673 samples. Table 4 shows frequency data for individual species.

reefs and offshore reefs irrespective of geographical region. Within offshore reefs, Tortugas deeper reefs were distinguished from sites in the rest of the Florida Keys. In the main Keys, offshore reefs clustered into high relief forereef and low relief hard bottom habitats. Within habitat types, reefs sites clustered primarily by geographical region (Fig 5.).

Trophic Structure

Each observed species was classified according to primary trophic level based on adult feeding patterns (Bohnsack et al. 1987, Table 1). Fishes were numerically dominated by planktivores (44 %), followed by macroinvertivores (26 %), herbivores (17 %), piscivores (8 %), microinvertivores (3 %), and browsers (1 %) (Fig. 6a). The pattern was quite different for biomass (Fig. 6b) in which piscivores (42%) dominated, followed by macroinvertivores (25%), herbivores (21%), planktivores (5%), browsers (4%), and microinvertivores (3%). The pattern of dominancy by predators is classic for coral reef fish communities (Talbot and Goldman 1973, Goldman and Talbot 1976).

Trophic classification was further analyzed according to region and reef type. In terms of numbers, the proportion of planktivores was higher at offshore reefs in all regions except the upper Keys (Fig. 7). The pattern for the upper Keys, however, may be anomalous because an unusual occurrence of large numbers of midwater planktivores occurred at one inshore reef and dominated the total numbers. The proportion of planktivores was lower in the middle Keys than in other regions. Macroinvertivores were especially abundant on inshore reefs in the lower Keys.

In terms of biomass, trophic structure across regions and reef types was remarkably consistent (Fig. 8). In all four regions biomass by reef type tended to be dominated by macroinvertivores and piscivores, followed by herbivores, browsers, planktivores, and macroinvertivores. Offshore reefs tended to have fewer browsers, but more planktivores and microinvertivores than mid-channel and inshore patch reefs.

Spatial Density Patterns

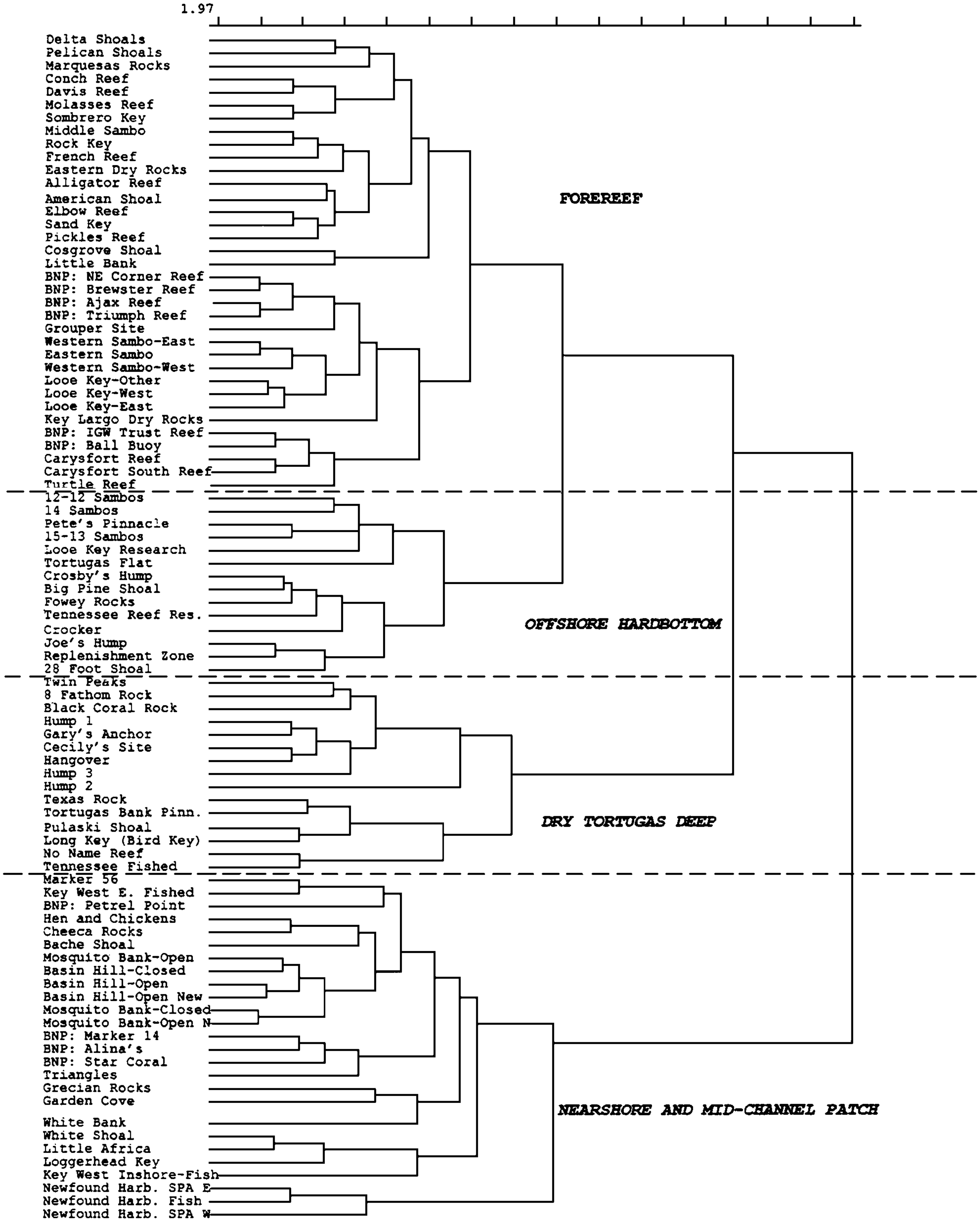
Spatial patterns of density (number of individuals observed per sample) can be determined for individual species using the database. Schmidt et al. (1999) plotted distributions for exploitable and non-exploitable phases of mutton snapper, gray snapper, yellowtail snapper, and red grouper in the Florida Keys and the Tortugas. In most cases relatively few exploitable phase individuals were observed. The highest occurrence of exploitable phase fishes tended to be in the Tortugas region, presumably because overall fishing mortality was lower. To avoid redundancy, these figures are not replicated here.

Density Trends

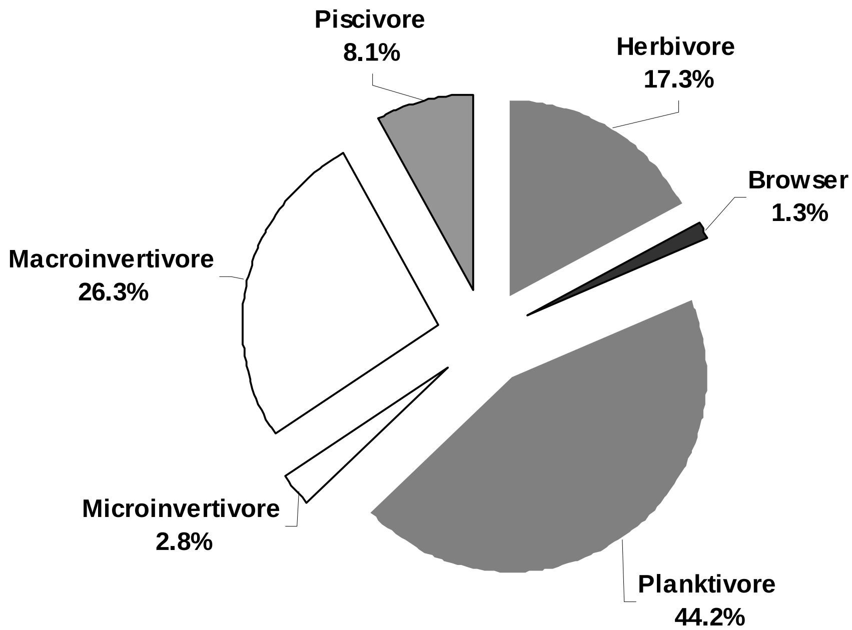
Density changes in number of individuals observed per sample were examined for selected species. Taxa selected with economic importance are gray snapper, yellowtail snapper, combined exploited grouper, and hogfish. Exploited grouper excluded graysby and coney. For comparison purposes, two taxa without direct economic importance were also analyzed in the same manner. Stoplight parrotfish represented a large species while striped parrotfish represented a small abundant species.

Four plots show trends for selected taxa: the first shows all data and the second includes only Tortugas data. Data from the rest of the Keys are included in the remaining two plots that show either sites that became no-take zones in 1997 or sites that continued to be fished. Trends showing all data should be interpreted cautiously because of variation in annual sample size and in the distribution of sites among regions (Table 1). The

Figure 5. Bray-Curtis similarity dendogram of 90 reef sites sampled between 1 January 1988 and 30 June 1997 (n = 3,679 samples). Major reef types for major groupings are noted. Transform = none, standardization = none, no zero replacement, and βeta = 0.25.



a)



b)

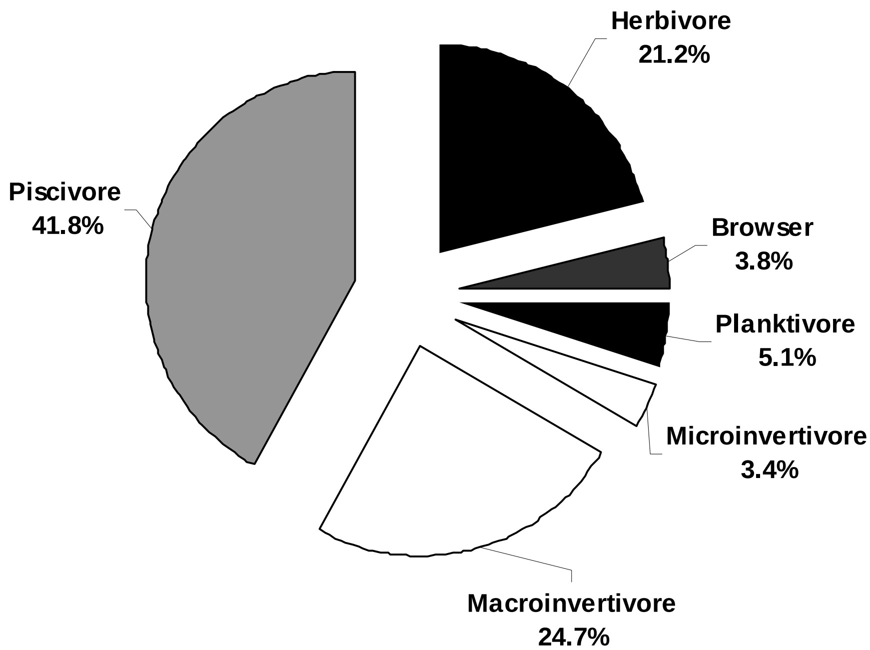


Figure 6. Mean trophic structure of reef fishes in the Florida Keys as percentage of total individuals (a) and biomass (b). N = 1,241,270 individuals, 6,673 samples, and 118 reef sites. Data were collected from 1979 - 98.

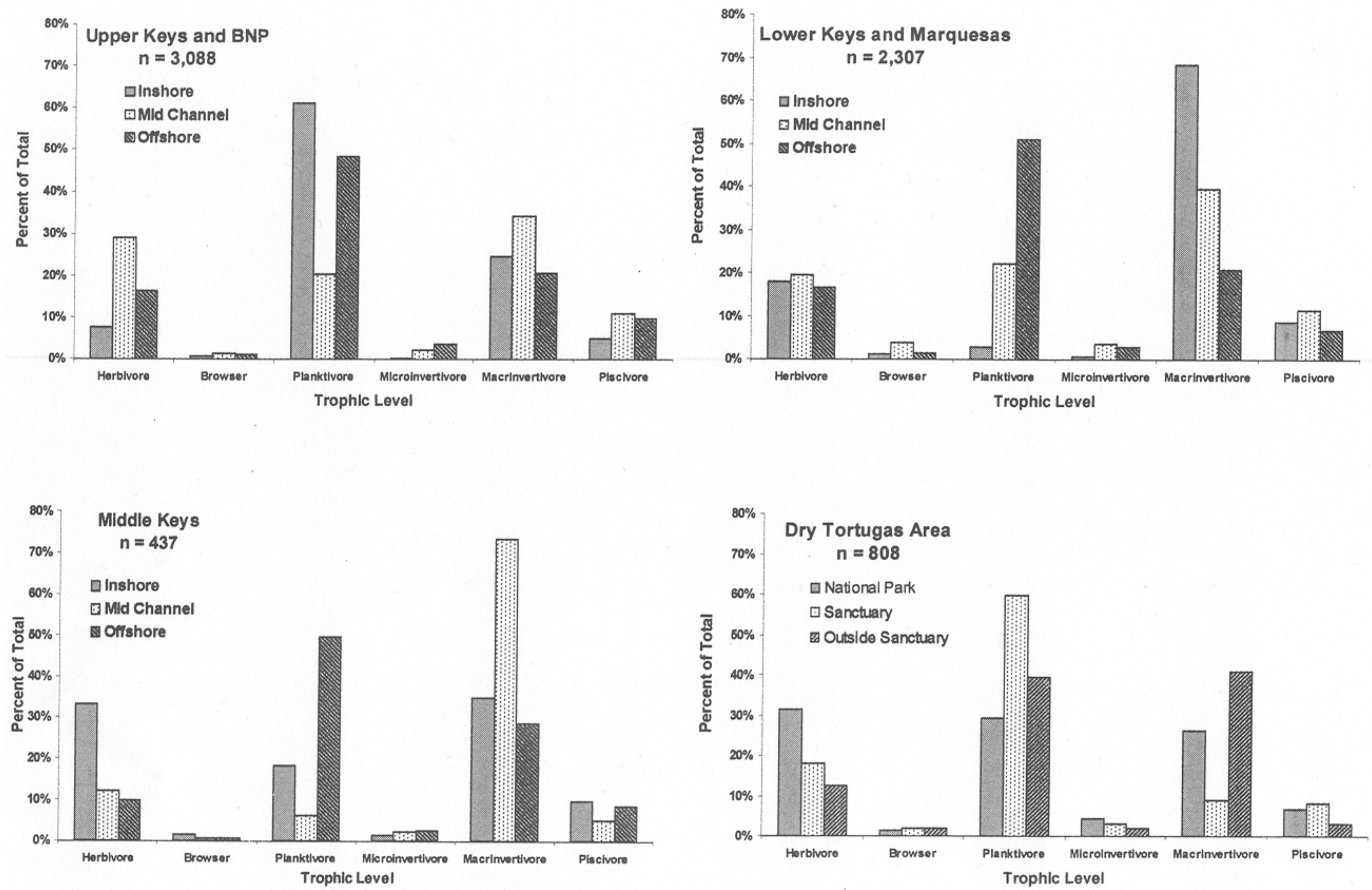


Figure 7. Reef fish trophic composition in numbers of individuals by reef type and region.

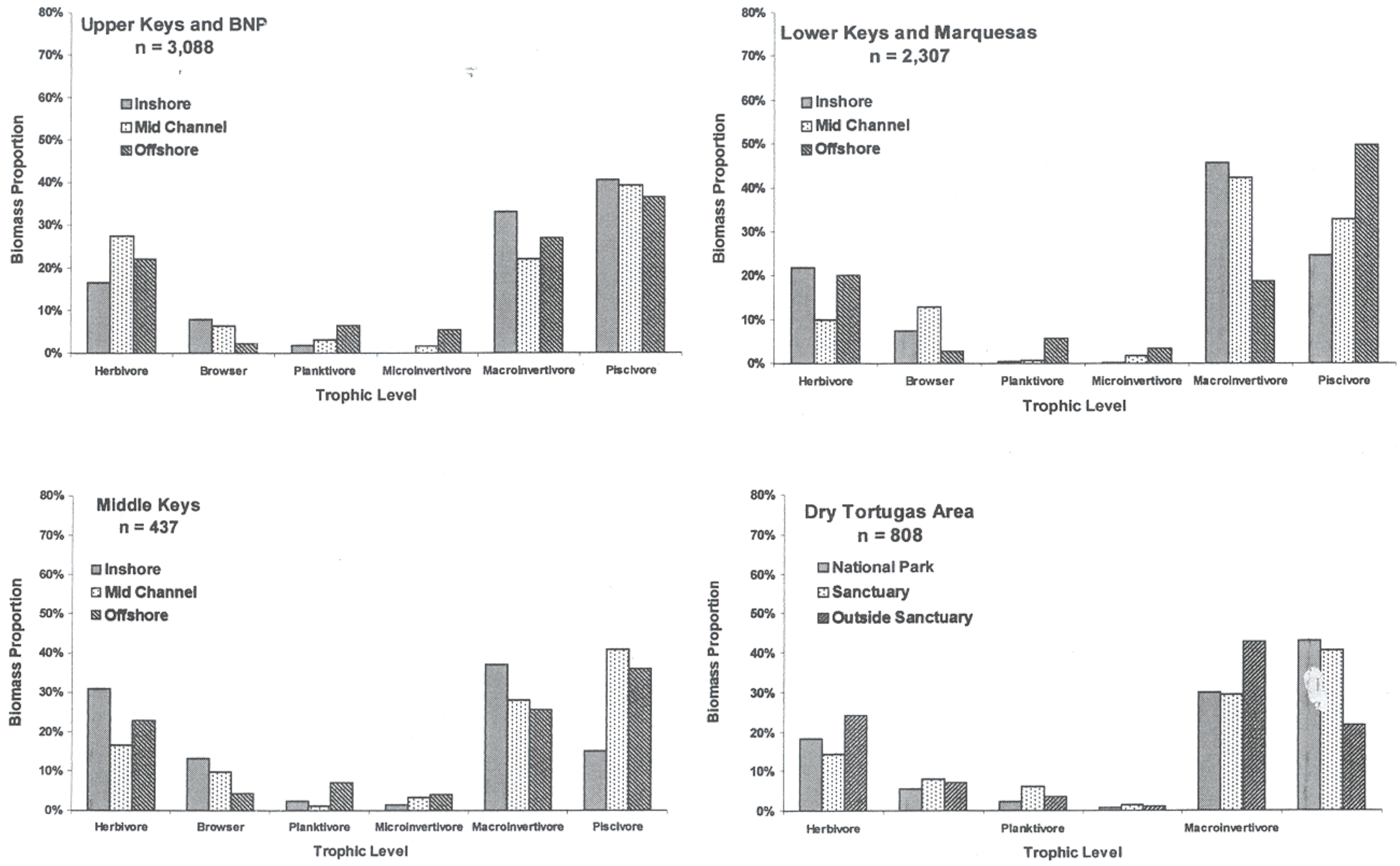


Figure 8. Reef fish trophic composition in biomass by reef type and region.

Tortugas region, for example, was not sampled until after 1994 while samples in 1979 through 1986 were primarily from Looe Key Reef and the Upper Keys. Also, changes in general regional fishery regulations may have influenced observed fish densities and sizes. In 1980, fish traps were banned in Florida waters. In 1983, fish traps were prohibited in federal waters less than 100 ft (30.5 m) deep by the SAFMC Snapper-Grouper Fishery Management Plan. In 1990, the SAFMC prohibited all fish traps in federal waters on the Atlantic side of the Florida Keys west to 83^{O} N Longitude as part of Amendment 4 to the Snapper-Grouper Plan. In December 1986, Florida established bag limits of 10 snapper and 5 grouper/angler/day.

Gray Snapper (*L. griseus*) (Fig. 9, Table 5)**.** Mean density (Fig. 9a) tended to decline through the early and middle 1980s before recovering somewhat in the early1990s. The high density and variance in1979 was most likely the result of a very small sample size (n = 2) collected only at Molasses Reef. Mean density at unfished sites (Fig. 9c) was slightly higher than at fished sites (Fig. 9d) during the baseline period, however, the 95% confidence intervals overlapped the fished sites. Mean density in the Tortugas (Fig. 9c) was similar to fished sites in the rest of the Keys. Changes in regional fishing regulations may have influenced observed densities. On July 1, 1985, Florida established a minimum size limit of 10" (25.4 cm) for state waters (< 3 nmi from land). In 1991, Amendment 4 of the SAFMC Snapper-Grouper Plan established a minimum size limit of 12 in (30.5 cm) for federal waters (> 3 nmi from land).

Yellowtail Snapper (*Ocyurus chrysurus*) (Fig. 10, Table 5)**.** Mean density (Fig. 10a) was reasonably consistent through the 1980s but tended to increase in the early 1990s. Mean density and confidence intervals were similar at unfished (Fig. 10c) and fished sites (Fig. 10d) during the baseline period. Mean densities in the Tortugas (Fig. 10b) was slightly lower than the rest of the Keys. Changes in regional fishing regulations may have influenced observed densities. Minimum size limits of 12" (30.5 cm) were established in federal waters (>3 nm from land) by the SAFMC in September 1983 and in Florida waters (< 3 nm from shore) in February 1990.

Combined Exploited Grouper (Serranidae) (Fig. 11, Table 5)**.** Because of low grouper density Keys-wide, data for the larger exploited species were combined for analysis. Graysby (*Epinephelus guttatus*) and coney (*E. fulvus*) were excluded because of their small maximum adult size. Mean grouper density **(**Fig. 11a) increased over the study period, perhaps in response to the prohibition in fish traps, the establishment of minimum size limits, and increased sampling in the Tortugas. Mean grouper density was similar and low at fished (Fig. 11d) and unfished (Fig. 11c) sites during the baseline period. Mean densities were much higher in the Tortugas (Fig. 11b) than in the rest of the Keys, an observation consistent with Bohnsack et al. (1994) who showed that grouper fishery landings were higher from the Tortugas region than the rest of the Keys.

Changes in regional fishing regulations may have influenced observed densities. In September 1983 minimum size limits of 12" (30.5 cm) were established for black grouper (*Mycteroperca bonaci*) by the SAFMC. On July 1, 1985, Florida established new minimum size limits of 18" (45.7 cm) for gag (*M. microlepis*), black (*M. bonaci*), red (*Epinephelus morio*), and yellowfin (*M. venenosa*) grouper. In February1990, Florida added or increased minimum size limits to 20" (50.8 cm) for scamp (*M. phenax*) and black, gag, red, yellowfin, and yellowmouth grouper (*M.*

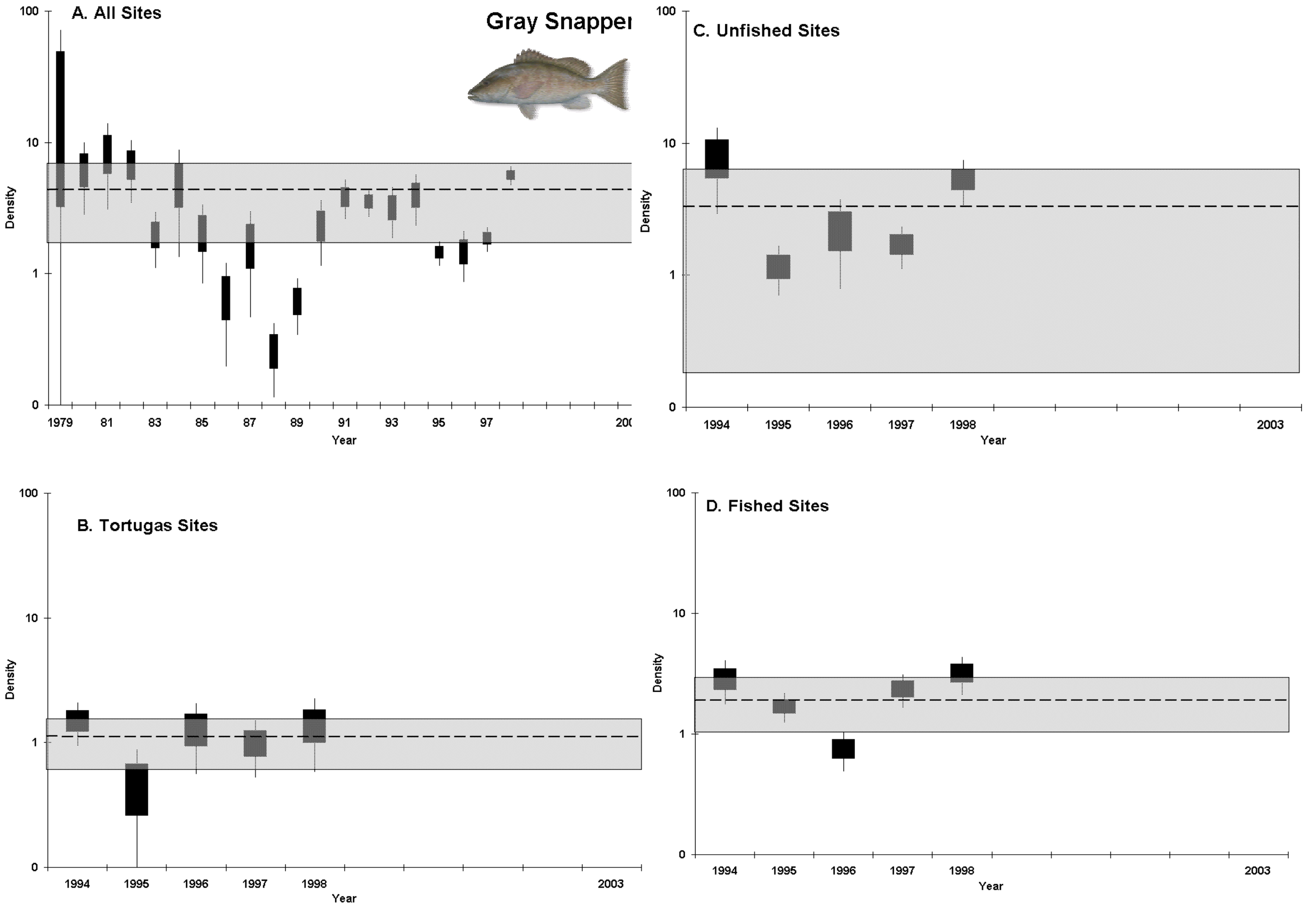


Figure 9. Changes in gray snapper mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean $\pm$ 95% CI. Bars show annual mean $\pm$ 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size.

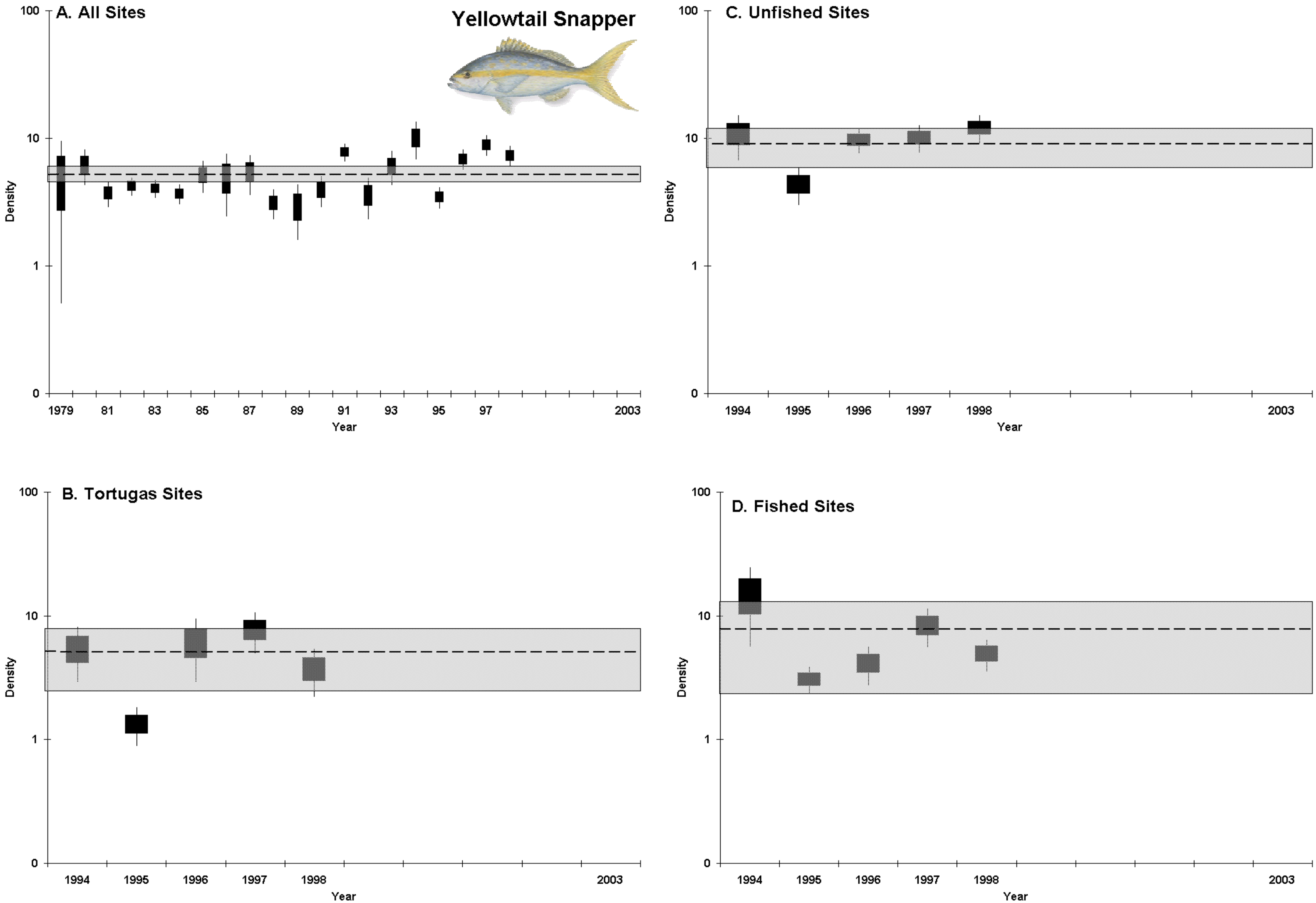


Figure 10. Changes in yellowtail snapper mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table1 shows annual sample size.

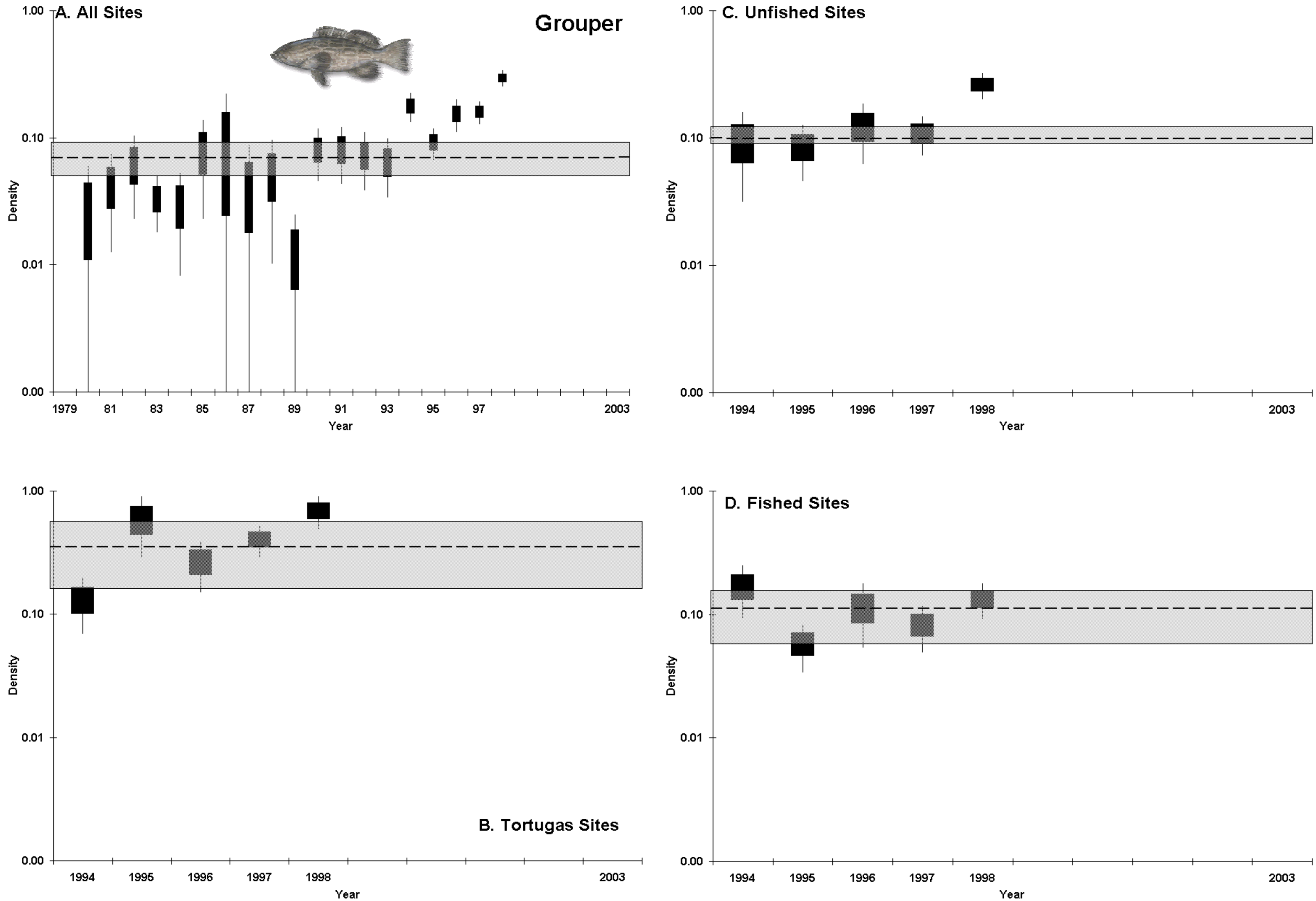


Figure 11. Changes in combined grouper mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size.

interstitalis).

Hogfish (*Lachnolaimus maximus)* (Fig. 12, Table 5)**.** Mean density (Fig. 12a) increased over the study period, perhaps in response to the prohibition of fish traps; the establishment of minimum 12" (30.5 cm) size limits by Florida in July 1994 and by the SAFMC in 1994; and the 5 fish daily bag limits by Florida in July, 1994. Mean hogfish density was higher in fished sites (Fig. 12d) than in unfished (Fig. 12c) sites during the baseline period. Mean densities in the Tortugas (Fig. 12b) were similar to fished sites in the rest of the Keys but had wider confidence intervals.

Stoplight Parrotfish (*Sparisoma viride*) (Fig. 13**,** Table 5)**.** Mean density (Fig. 13a) varied over the study period. Densities were low relative to the base period in 1998 in both fished (Fig. 13.d) and unfished (Fig. 13c) sites. Although larger individuals are occasionally landed, this species is medium sized and has little direct economic value. Thus, effects of no-take protection were expected to be minimal in terms of protection from direct exploitation. Average density of stoplight parrotfish was much lower in the Tortugas than in the rest of the Keys (Fig. 13b). This observation may be the result of the fact that sites in the Tortugas tended to be deeper than the rest of the Keys. Deeper sites have lower light levels and fewer algal food resources which may be reflected in lower parrotfish density.

Striped Parrotfish (*Scarus croicensis*) (Fig. 14, Table 5)**.** No-take protection is predicted to have no direct impact on this species because it is small, has no direct economic value, and would rarely be caught by fishing. Mean annual densities at fished (Fig. 14d) and unfished (Fig. 14c) sites were consistent. The fact that the high observed annual mean densities came from both fished and unfished sites in 1998 suggests that protection level was not responsible for the observed changes.

A comparison of fish density for exploited species at no-take sites and fished reference sites shows very similar patterns between species (Table 5). It is premature, however, to make conclusions about the impacts of no-take zones on reef fishes since only one full year of data are available following zoning changes in the FKNMS. It is encouraging, however, that after only one year of no-take protection, the annual mean densities of exploited species in no-take sites were the highest observed for yellowtail snapper, combined grouper, and hogfish and the second highest for gray snapper compared to the baseline period. In comparison, a similar uniform responses were not observed for these species at fished sites nor for two species examined without direct economic importance (striped and stoplight parrotfish). These patterns suggest that no-take protection is having some positive impact on density of exploited species. Despite the increased density of exploited grouper in no-take zones, grouper density was still much higher in the Tortugas than in the rest of the Keys. This difference suggests that a potential exists for a much greater response in the future.

Density of Size Phases

Trends in mean annual density of larger exploitable and smaller non-exploitable phase fishes were plotted for gray snapper, yellowtail snapper, combined grouper and hogfish. Because of relatively slow adult growth rates, changes in mean fish size were considered unlikely to change significantly after only one year protection.

Gray Snapper. Density of exploitable phase gray snapper (Fig. 15a) tended to decline slightly over the study period. The 95% confidence interval shows wide variation in density to very low values. The low density of exploitable sized gray snapper in 1998 and 1989 probably reflect intensive sampling in

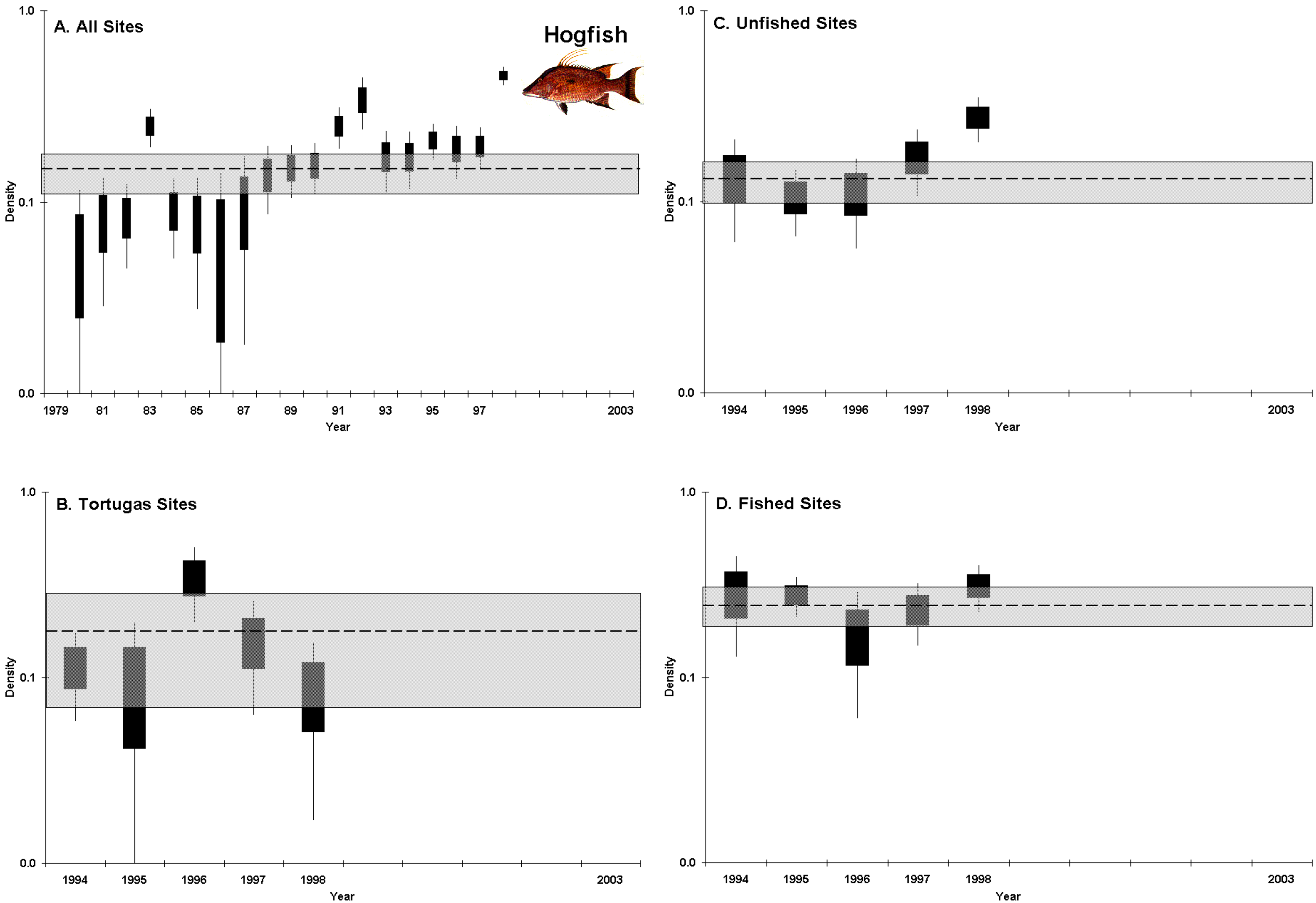


Figure 12. Changes in hogfish mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean $\pm$ 95% CI. Bars show annual mean $\pm$ 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size.

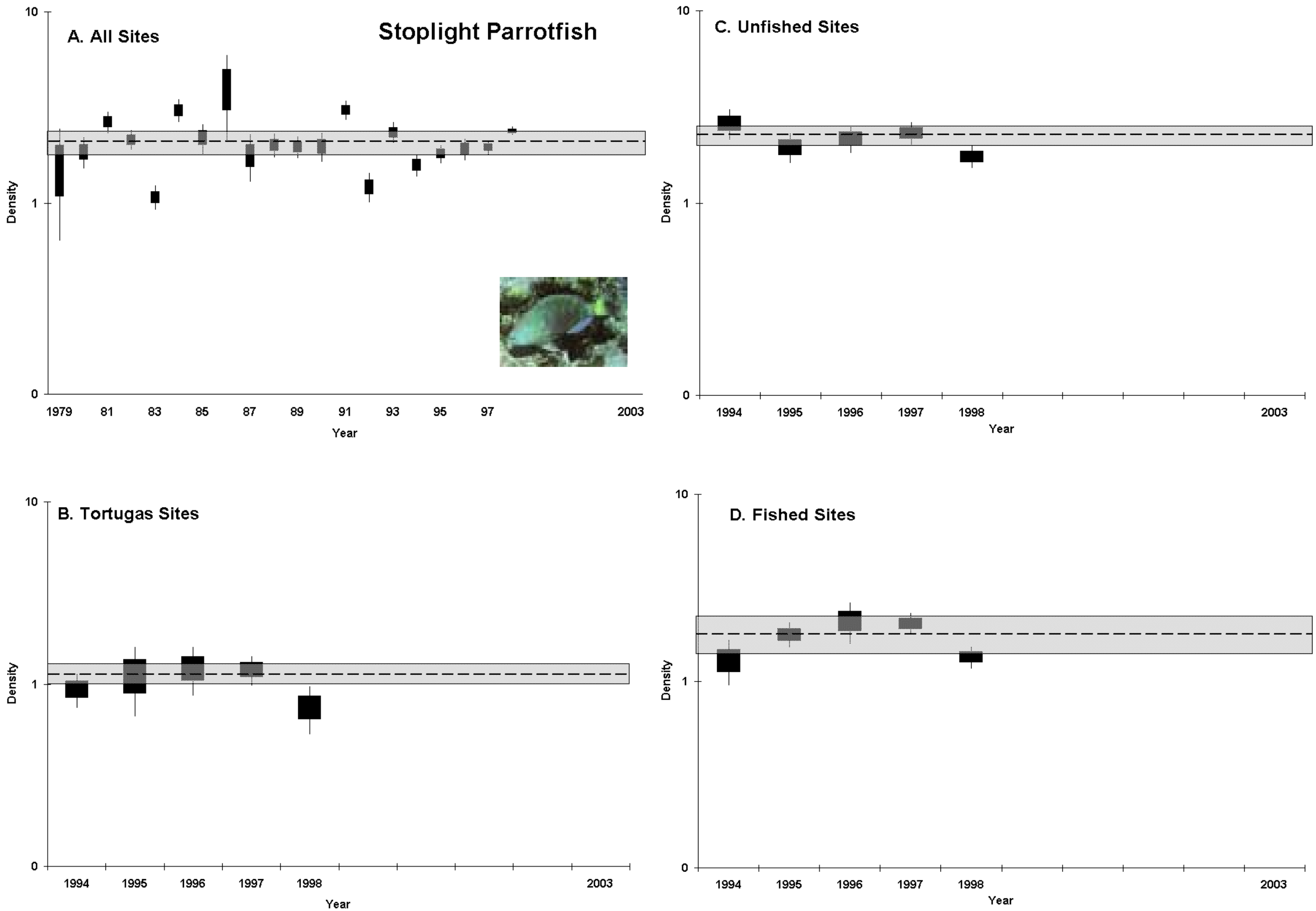


Figure 13. Changes in stoplight parrotfish mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size.

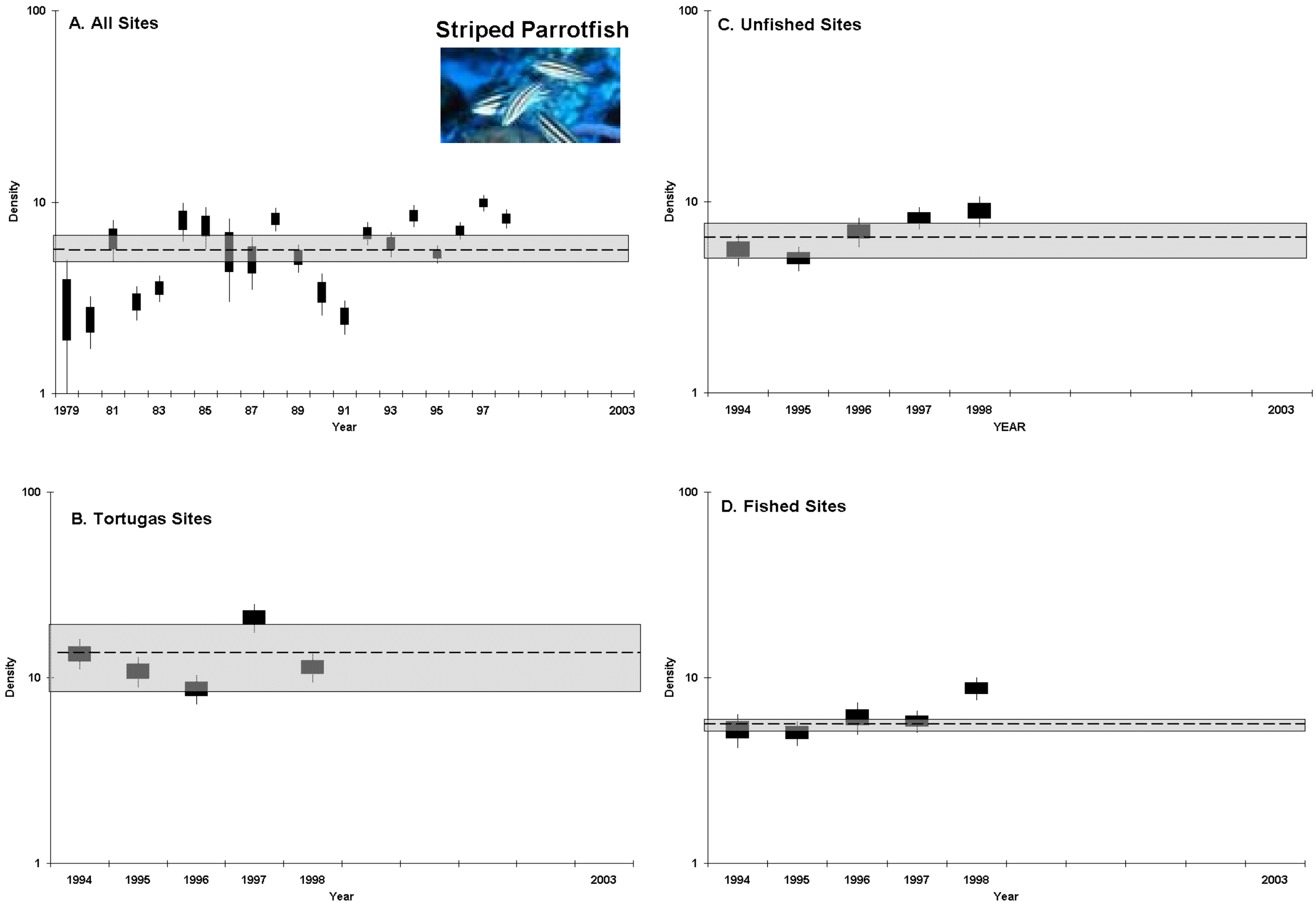


Figure 14. Changes in striped parrotfish mean density (total number of individuals per sample). (A) all sites; (B) Tortugas sites; (C) unfished sites with no-take protection beginning 1 July 1997; (D) fished sites excluding the Tortugas. Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997 in Fig A and for 1994 -1997 in Figs. B, C, and D. Shaded areas are projected beyond 1997 to show predicted performance ranges after 1997. Table 1 shows annual sample size.

Table 5. Summary statistics for selected species for Figures 9 - 14. SD = standard deviation; CI = confidence interval.

	Protection Level															
	Not Fished				Fished				Tortugas				All			
Species	Mean #	SD	Lower 95% CI	Upper 95% CI	Mean #	SD	Lower 95% CI	Upper 95% CI	Mean #	SD	Lower 95% CI	Upper 95% CI	Mean #	SD	Lower 95% CI	Upper 95% CI
Gray snapper	3.282	3.159	0.186	6.377	1.933	0.922	1.029	2.837	1.075	0.454	0.630	1.520	4.333	5.760	1.743	6.923
Yellowtail snapper	8.817	2.984	5.893	11.741	7.691	5.438	2.362	13.020	5.203	2.741	2.516	7.889	5.234	2.004	4.333	6.135
Combined grouper	0.104	0.017	0.087	0.120	0.107	0.048	0.060	0.154	0.351	0.197	0.159	0.544	0.072	0.049	0.050	0.094
Hogfish	0.132	0.030	0.102	0.161	0.244	0.053	0.192	0.295	0.180	0.117	0.066	0.294	0.147	0.084	0.109	0.184
Stoplight parrotfish	2.259	0.271	1.993	2.525	1.803	0.365	1.445	2.160	1.124	0.129	0.997	1.251	2.115	0.696	1.802	2.428
Striped parrotfish	6.482	1.409	5.102	7.863	5.570	0.501	5.079	6.061	13.568	5.444	8.233	18.903	5.659	2.243	4.651	6.668

Biscayne National Park at sites dominated by juveniles. Non-exploitable juvenile snapper (Fig. 15ab) showed a narrower confidence interval and cyclic pattern in density with two peaks of abundance in the early 1980s and 1990s. The density changes in the mid 1980s is highly correlated with a similar decline and recovery in commercial pink shrimp landings from the Tortugas (Nance and Patella 1989). This pattern may be a spurious correlation or may possibly reflect a period of poor recruitment in response to problems or changes in Florida Bay, a habitat used by both pink shrimp and gray snapper.

Yellowtail Snapper**.** Annual mean density of exploitable phase yellowtail snapper varied greatly over the study period (Fig. 16a) in comparisons to juveniles which were more consistent over time (Fig. 16b). Mean annual density of juveniles was an order of magnitude higher than adults.

Grouper. Annual mean densities of exploitable phase grouper were low and varied greatly over the study period (Fig. 17a) in comparisons to juveniles which were more consistent over time (Fig. 17b). Mean annual density of juveniles was an order of magnitude higher than adults.

Hogfish. Mean density of observed exploitable (Fig 18a) and non-exploitable hogfish (Fig. 18b) was low but has tended to increase over the study period most likely in response to the implementation of several conservation measures discussed earlier.

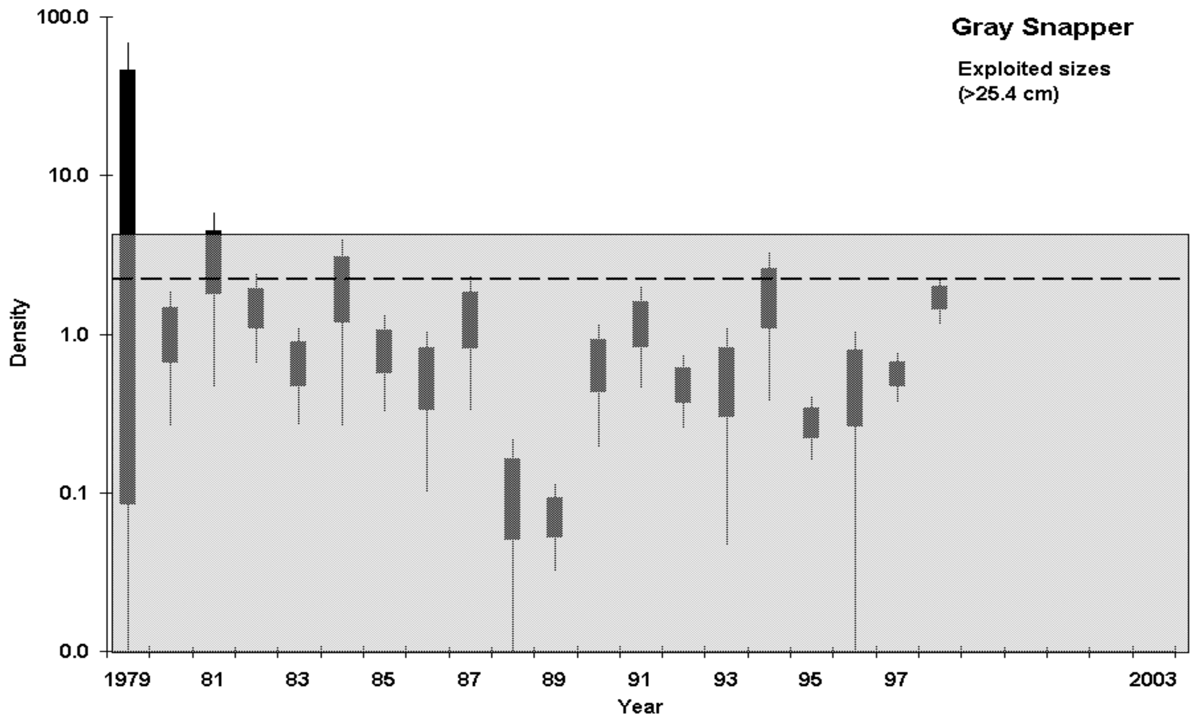
CONCLUSIONS

Fishery-independent visual sampling is a cost-effective method to obtain high precision spatial estimates and to non-destructively monitor reef fish biodiversity, abundance, and size trends in the Florida Keys. A 20 year data set, beginning in 1979, provides a basis for evaluating short and long term changes in the Florida Keys resulting from different management practices and environmental changes. Since only one full year of data are available following the establishment of no-take zones, it is premature to make conclusion about the impacts of marine reserves on reef fishes. It is encouraging, however, that after only one year of no-take protection, the annual mean densities of exploited species in no-take sites were the highest observed for yellowtail snapper, combined grouper, and hogfish and the second highest for gray snapper compared to the baseline period. In comparison, similar uniform responses were not observed for the same species at fished sites nor for two species without direct economic importance (striped and stoplight parrotfish). Over time, the average exploitable phase size of exploited species is expected to increase in no-take protect areas.

ACKNOWLEDGMENTS

We thank Dr. Nancy Thompson and the South Florida Ecosystem Restoration Program for providing funding to support field work between 1996 through 1999. Data were collected with cooperation and support from the Florida Keys National Marine Sanctuary, Biscayne National Park, John Pennekamp Coral Reef State Park, and Dry Tortugas National Park. Marine and Coastal Ecosystem Directorate of the U.S. Man and the Biosphere Program supported analysis of historical biological data. Funding for data collection was partially supported by the Biscayne National Park, the National Undersea Research Center (NURC), and the Coastal Ocean Program, NOAA. Cooperation in field work was provided the Florida Institute of Oceanography, Department of Navy, and Dry Tortugas National Park. Some point samples were provided by Scott Bannerot, Bill Hudson, Stacy Luthy, Helena Molina, John Ogden, Tom Rutledge, Otto Rutten, Joe Serafy, and Amy Woodhead. We thank Dr. Joseph Wahome for preparing Figure 5.

A)



B)

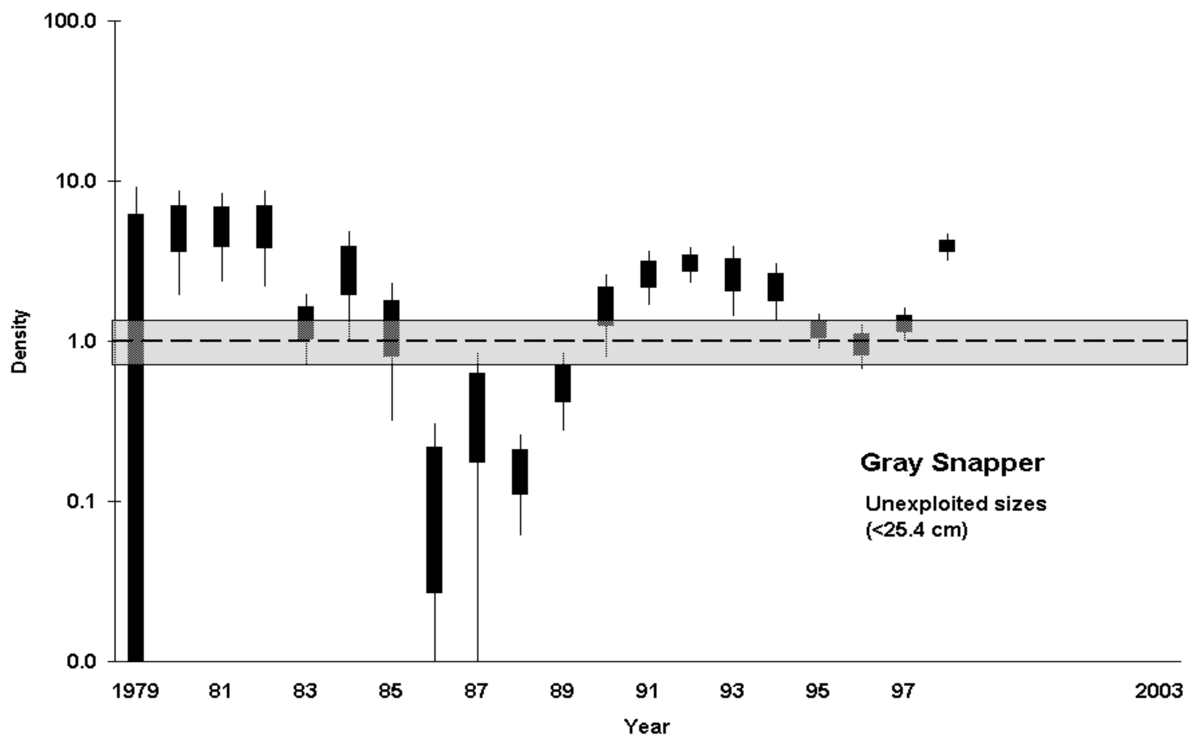
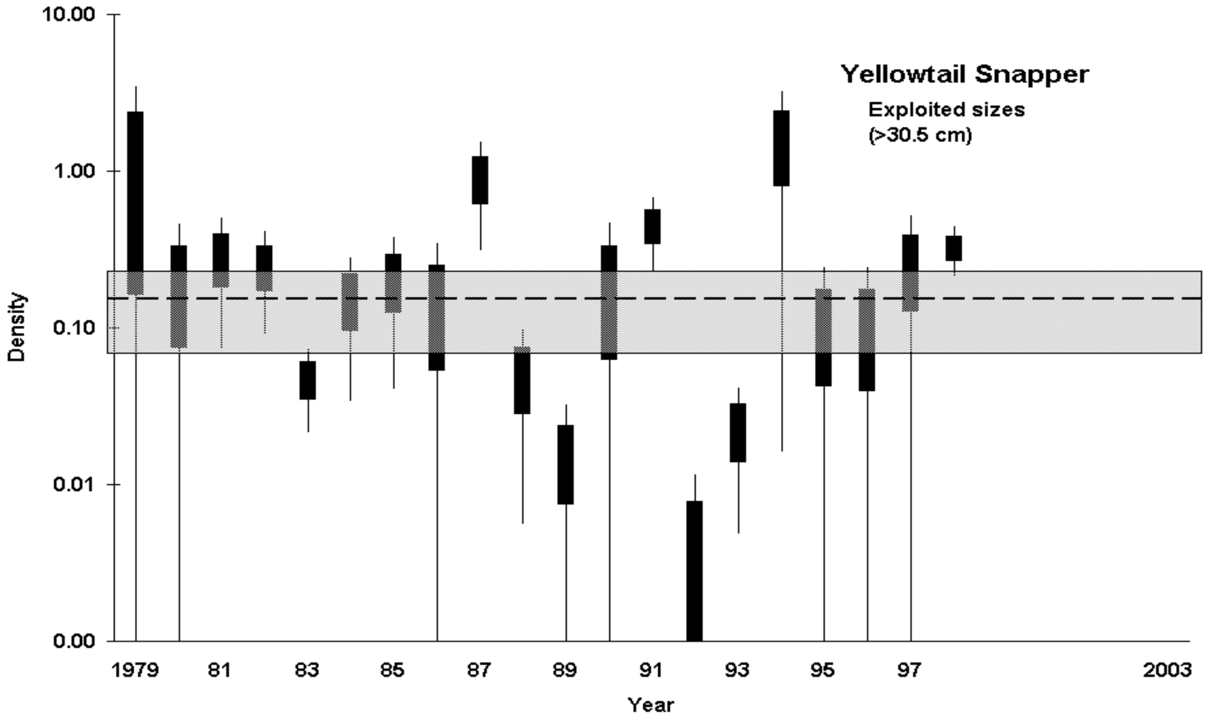


Figure15. Changes in gray snapper mean density (total number of individuals per sample) for (A) exploitable (≥25.4 cm FL) and (B) un-exploitable sizes (<25.4 cm FL) from all sites (1979-1998). Vertical lines show annual mean ±95% CI. Bars show annual mean ±1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Table 1 shows annual sample size.

A)



B)

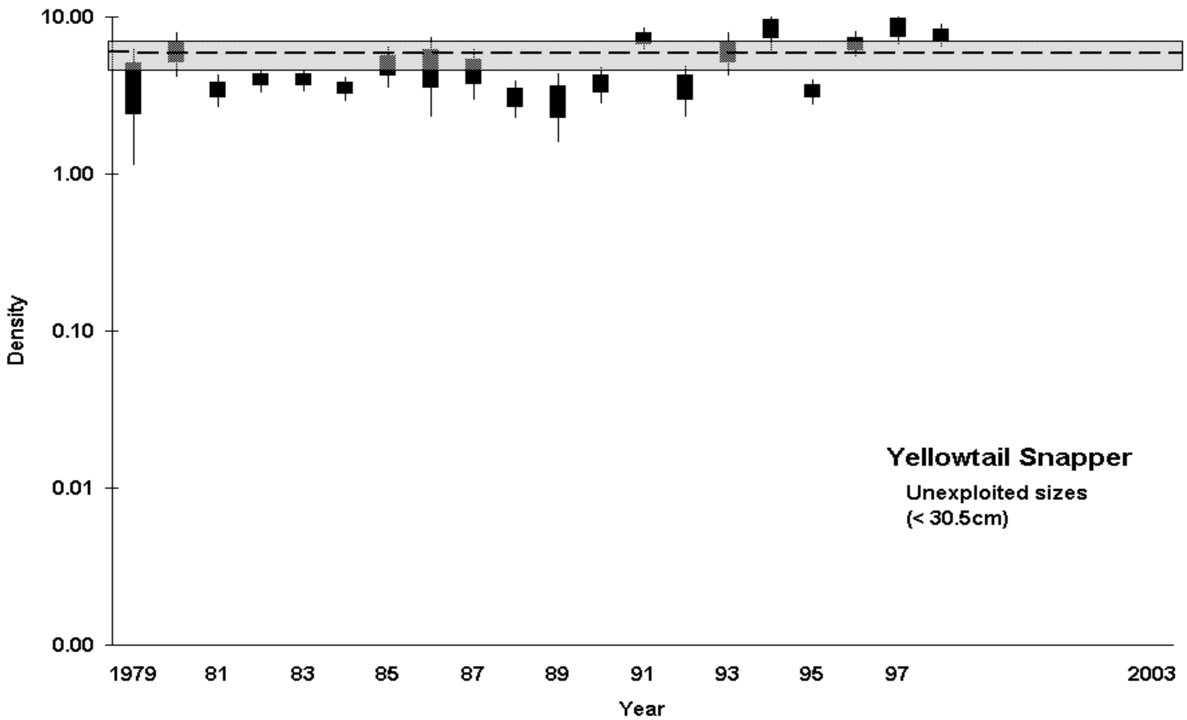
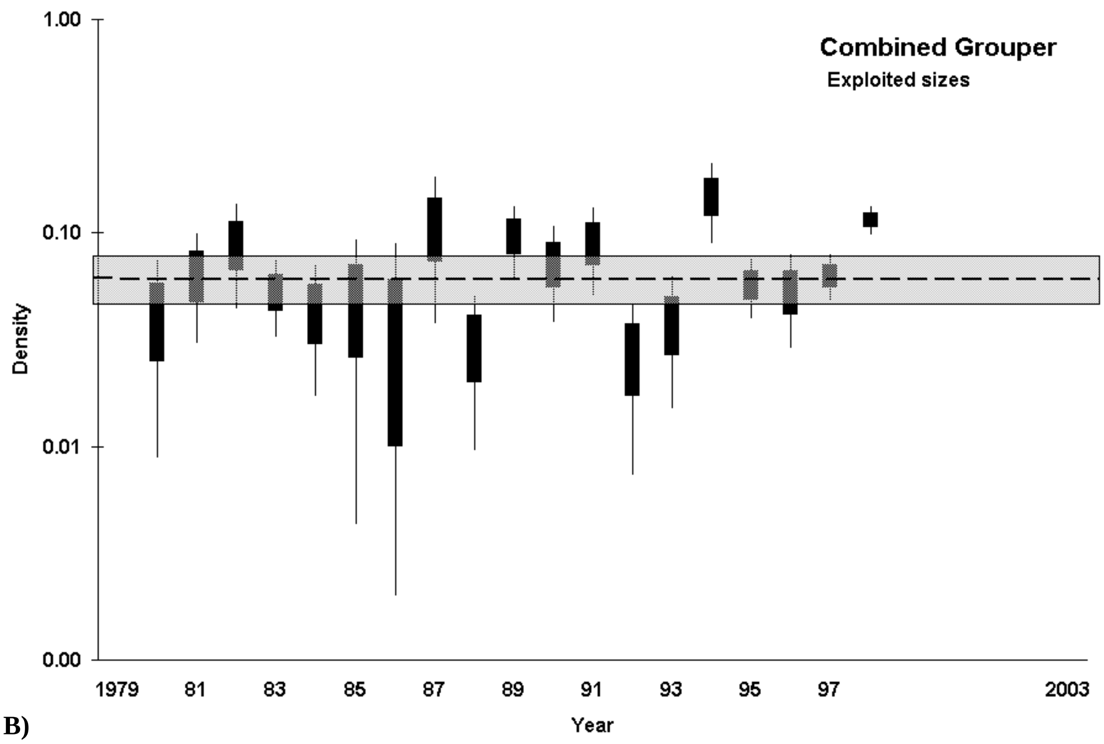


Figure16. Changes in yellowtail snapper mean density (total number of individuals per sample) for (A) exploitable sizes (≥30.5 cm FL) and (B) unexploitable sizes (< 30.5 cm FL) from all sites (1979 - 1998). Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance assuming no changes. Table 1 gives annual sample size.

A)



B)

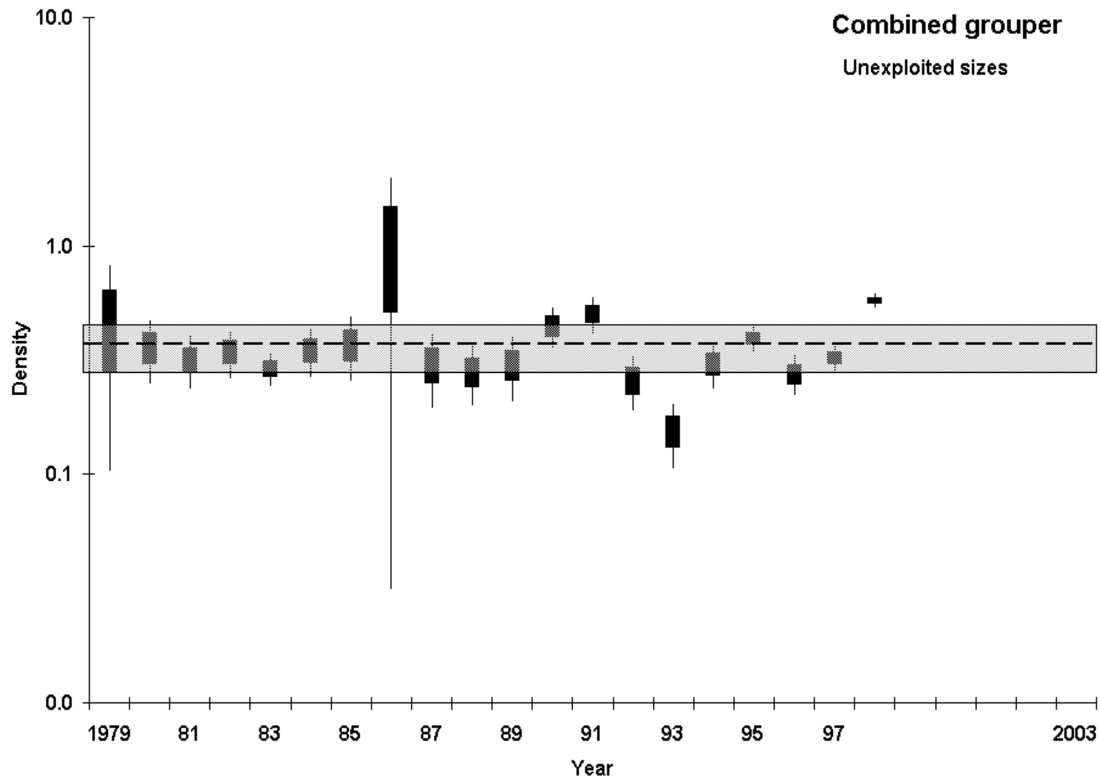
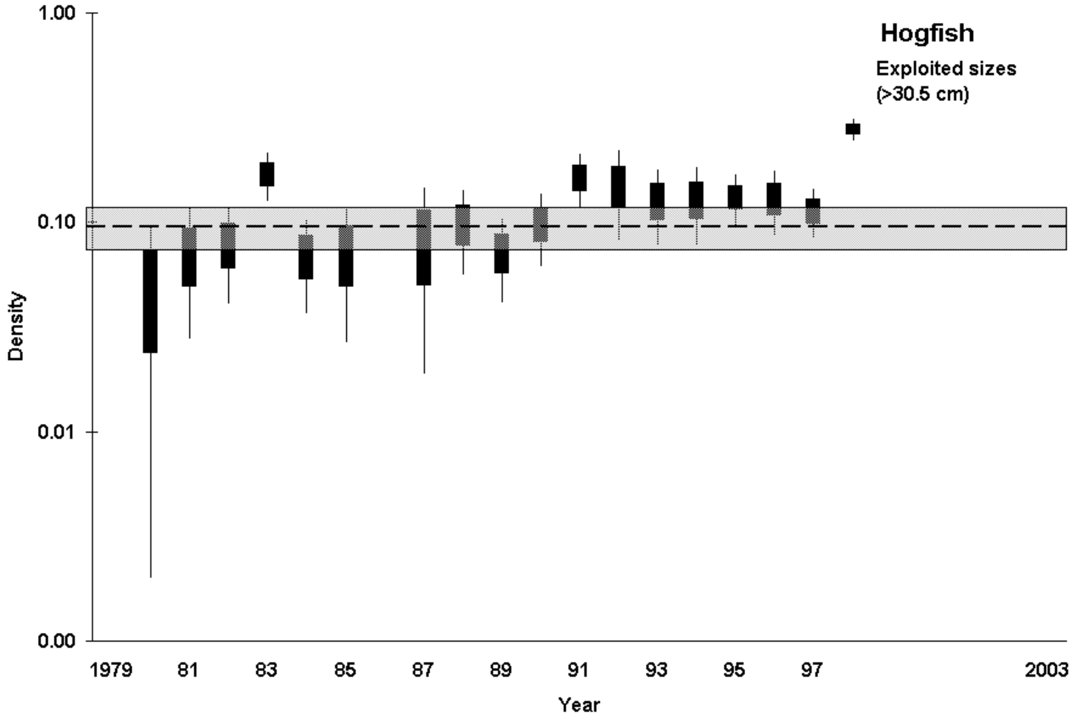


Figure17. Changes in combined grouper mean density (total number of individuals per sample) for (A) exploitable and (B) unexploitable sizes from all sites (1979-1998). Size at first capture varies between species. Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Table1 shows annual sample size.

A)



B)

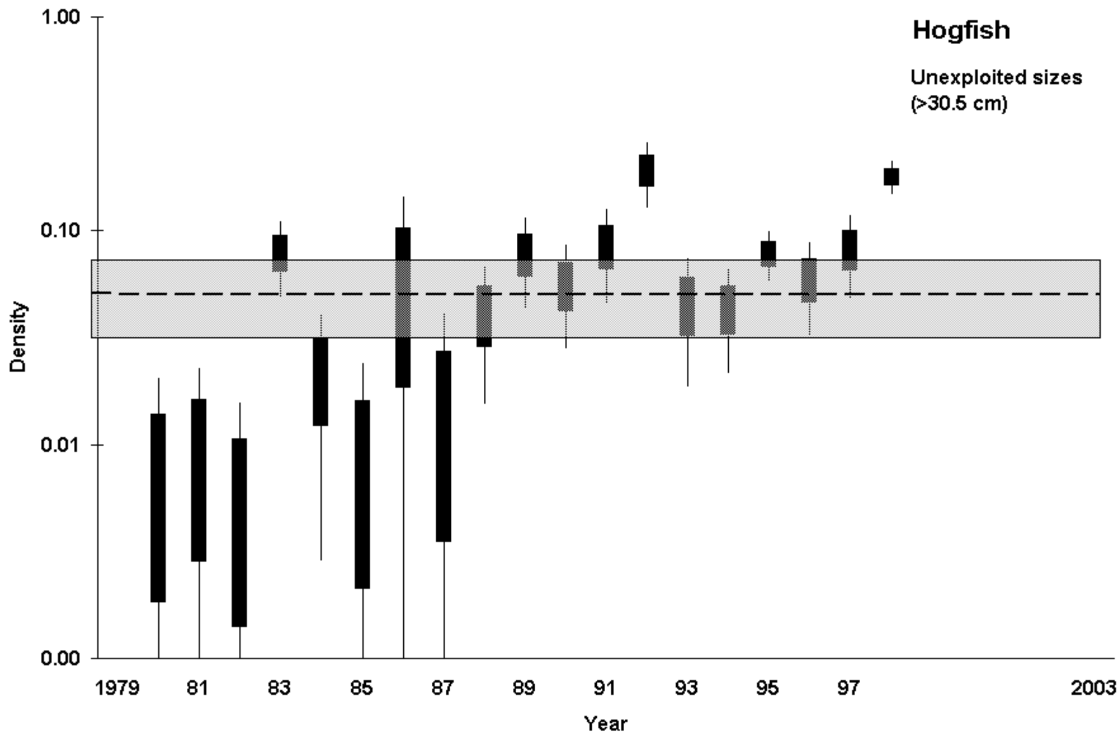


Figure18. Changes in hogfish mean density (total number of individuals per sample) for (A) exploitable sizes (≥ 30.5 cm FL) and (B) unexploitable sizes (< 30.5 cm FL) from all sites (1979 - 1998). Vertical lines show annual mean ± 95% CI. Bars show annual mean ± 1 SE. Shaded areas show 95% CI for annual means through 1997. Shaded areas are projected beyond 1997 to show predicted performance ranges assuming no changes. Table 1 gives annual sample size.

LITERATURE CITED

Ault, J.S., J.A. Bohnsack, and G. Meester. 1998. A retrospective (1979-1995) multispecies assessment of coral reef fish stocks in the Florida Keys. Fish. Bull., U.S. 96(3): 395-414.

Ault, J.S., J.A. Bohnsack, and G.A. Meester. 1997. Florida Keys National Marine Sanctuary: Retrospective (1979-1995) reef fish assessment and a case for protected marine areas. *In:* D.A. Hancock, D.C. Smith, A. Grant and J.P. Beumer (eds.). Developing and sustaining World Fisheries Resources: The State of Science and Management. World Fish. Congr. 2: 415-425.

Bannerot, S.P. 1990. Fish communities and fisheries biology. Pages 231-265 *in* Continental Shelf Associates, Inc. Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the South Florida area. U.S. Dept. Interior Minerals and Management Service OCS Study MMS 90-0019. 745 p.

Beets, J. 1993. Baseline data, 1988-1992, with emphasis on the impact of Hurricane Hugo. Chapter I *in* Long-term monitoring of fisheries in Virgin Islands National Park. U.S. Nat. Park Serv. Tech. Rep. VINP 1/93. 45 p.

Bell, J.D., G.J.S. Craik, D.A. Pollard, and B.C. Russell. 1985. Estimating length frequency distributions of large reef fish underwater. Coral Reefs 4:41-44.

Bellwood, D.R. and A.C. Alcala. 1988. The effect of minimum length specification on visual census estimates of density and biomass of coral reef fishes. Coral Reefs 7:23-27.

Bohnsack, J.A. 1982. The effects of piscivorous predator removal on coral reef fish community structure. Pages 258-267 *in* G.M. Cailliet and C.A. Simenstad (eds.). Gutshop ‘81: Fish Food Habits Studies. Proceedings of the Third Pacific Workshop. Washington Sea Grant. University of Washington, Seattle.

Bohnsack, J.A. 1995. Passive Assessment techniques for shallow water reef resources. Pages 17-21 *in* Proceedings of the 1987 SEAMAP Passive Gear Assessment Workshop at Mayaguez, Puerto Rico. NOAA Tech. Mem. NMFS-SEFSC-365. 177 p.

Bohnsack, J.A. 1996. Maintenance and recovery of fishery productivity. Chapter 11. Pages 283-313 *in* N.V.C. Polunin and C.M. Roberts (eds). Tropical Reef Fisheries. Fish and Fisheries Series 20. Chapman and Hall. London. 477 p.

Bohnsack, J.A. 1997. Consensus development and the use of marine reserves in the Florida Keys, U.S.A. Proc. 8th Int. Coral Reef Symp. 2: 1922-1930.

Bohnsack, J.A. 1998. Consensus development and the use of marine reserves in the Florida Keys National Marine Sanctuary. Pages 67-70. *in* D. Onysko and R. Usher (eds.). Protected areas in resource-based economies: Sustaining biodiversity & ecological integrity. 14th Annual General Meeting of the Canadian Council on Ecological Areas. 1995, Calgary, Alberta, Canada. 85 p.

Bohnsack, J.A. and J.S. Ault. 1996. Management strategies to conserve marine biodiversity. Oceanogr. 9: 73-82.

Bohnsack, J.A. and S.P. Bannerot. l983. A random point census technique for visually assessing coral reef fishes. Pages 5-7 *in* C.A. Barans and S.A. Bortone (eds.). The visual assessment of fish populations in the southeastern United States: l982 Workshop. South Carolina Sea Grant Consortium, Tech. Rep. l (SC-SG-TR-0l-83). 52 p.

Bohnsack, J.A., and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report NMFS 41: 1-15.

Bohnsack, J.A. and D.E. Harper. 1988. Length-weight relationships of selected marine reef fishes from southeastern United States and the Caribbean. NOAA Tech. Mem. NMFS-SEFC-215. 31 p.

Bohnsack, J.A., D.E. Harper and D.B. McClellan. 1994. Fisheries trends from Monroe County, Florida. Bull. Mar. Sci. 54: 982-1018.

Bohnsack, J.A., D.E. Harper, D.B. McClellan, D.L. Sutherland, and M.W. White. 1987. Resource survey of fishes within Looe Key National Marine Sanctuary. NOAA Tech. Mem. NOS MEMD 5: 1-108.

Bortone, S.A., R.W. Hastings, and J.L. Oglesby. 1986. Quantification of reef fish assemblages: A comparison of several *in situ* methods. Northeast Gulf Sci. 8(1): 1-22.

Bortone, S. and J. Bohnsack. 1991. Sampling and Studying Fish on Artificial Reefs. Chapter 7. Pages 39-51 *in* J.G. Halusky (ed.). Artificial Reef Research Diver's Handbook. Tech. Paper 63. Florida Sea Grant College Program. 198 p.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

Chiappone, M. and R. Sluka. 1996. Fish and Fisheries. Vol. 6. Site characterization for the Florida Keys National Marine Sanctuary and environs. Farley Court Publishers, Zenda, WI. 149 p.

Clark, J.R., B. Causey, and J.A. Bohnsack. 1989. Benefits from coral reef protection: Looe Key Reef, Florida. Coastal Zone '89: Proc. 6th Symp. Coastal Ocean Mgt 4: 3076-3086.

Continental Shelf Associates, Inc. 1990. Synthesis of available biological, geological, chemical, socioeconomic, and cultural resource information for the south Florida area. Phillips, N. and K. Larson (eds.) OCS Study MMS 90-0019. U.S. Department of the Interior, Minerals Management Service. Washington, DC: U.S. Government Printing Office. 657 p. + Appendices.

Goldman, B. and F. Talbot. 1976. Aspects of the ecology of coral reef fishes. Pages 125-154 *in* O.A. Jones and R. Endean (ed.), Biology and geology of coral reefs. Vol. 3, Biol. 2. Academic Press, N.Y. 435 p.

Harmelin-Vivien, M.L. 1981. Trophic relationships of reef fishes in Tulear (Madagascar). Oceanologica ACTA 4(3): 365-374.

Haitt, R.W. and D.W. Strasburg. 1960. Ecological relationships of the fish fauna on coral reefs of the Marshall Islands. Ecol. Monogr. 30: 65-127.

Harvey, E. and M. Shortis, 1996 A system for stereo-video measurement of sub-tidal organisms. MTS Journal 29:10-22.

Hobson, E.S. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fish. Bull. U.S. 72: 915-1031.

Hobson, E.S. and J.R. Chess. 1976. Trophic relationships among fishes and plankton in a lagoon at Enewetak Atoll, Marshall Islands. Fish. Bull. U.S. 74: 567-598.

Hoffmeister, J.E. 1974. Land from the sea, the geologic story of south Florida. University of Miami Press, Miami, FL 143 p.

Hubbell, S.P. 1979. Tree dispersion, abundance, and diversity in a tropical dry forest. Science 203: 1299-1309

Jaap, W.C. 1984. The ecology of the south Florida coral reefs: A community profile. U.S. Fish Wildl. Serv. FWS/OBS - 82/08. 138 p.

Lee, T.N., C. Rooth, E. Williams, M. McGowan, A.F. Szmant, M.E. Clarke. 1992. Influence of Florida Current, gyres and wind-driven circulation on transport of larvae and recruitment in the Florida Keys coral reefs. Continental Shelf Res. 12: 971-1002.

Lee, T.M., M.E. Clarke, E. Williams, A.F. Szmant, and T. Berger. 1994. Evolution of the Tortugas gyre and its influence on recruitment in the Florida Keys. Bull. Mar. Sci. 54: 621-646.

Limouzy-Paris, C., M.F. McGowan, W.J. Richards, J.P. Umaran, and S.S. Cha. 1994. Diversity of fish larvae in the Florida Keys: Results from SEFCAR. Bull. Mar. Sci. 54: 857-870.

Longley, W.J. and S.F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida; with observations on color, habits, and local distribution. Paps. Tortugas Lab. 34: 1-331. Carnegie Institution of Washington Publication Number 535.

McClellan, D.B. 1996. Aerial surveys for sea turtles, marine mammals, and vessel activity along the southeast Florida Coast, 1992-1996. NOAA Tech. Mem. NMFS-

SEFSC-390. 42 p.
McKenna, J.E., Jr. 1997. Influence of physical disturbance on the structure of coral reef fish assemblages in the Dry Tortugas. Carib. J. Sci. 33: 82-97.
Meester, G.A., J.S. Ault, and J.A. Bohnsack. (in press). Visual censussing and the extraction of average length as a biological indicator of stock health. Naturalista Sicil. Vol. (Suppl.): 205-222.
Nance, J.M. and F.J. Patella. 1989. Review of the Tortugas pink shrimp fishery from May 1987 to January 1989. NOAA Tech. Mem. SEFC-NMFS-238. 24 p.
Pattengill-Semmens, C.V. and B.X. Semmens. 1999. An analysis of fish survey data generated by non-expert volunteers in the Flower Garden Banks National Marine Sanctuary. Gulf of Mexico Sci. 1998 (2): 196-207.
PDT (Plan Development Team). 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. NOAA Tech. Mem. NMFS-SEFC-261. 45 p.
Randall, J.E. 1967. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. 5: 665-847.
Richards, W.J. and J.A. Bohnsack. 1990. The Caribbean Sea: A large marine ecosystem in crisis. pp. 44-53 *in*: K. Sherman, L.M. Alexander, and B.D. Gold (eds.). Large Marine Ecosystems: Patterns Processes and Yields. Am. Assoc. Adv. Sci. Washington, D.C. 242 p.
Robins, C.R. 1971. Distributional patterns of fishes from coastal and shallow waters of the tropical western Atlantic. F.A.O. Fisheries Rep. 71.2: 249-255.
Robins, C.R., G.C. Ray, J. Douglass, and R. Freund. 1986. A field guide to Atlantic coast fishes of North America. The Peterson Field Guide Series. Houghton Mifflin Co., Boston. 354 p.
Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, Fifth Edition, 1991. Amer. Fish. Soc., Spec. Pub. 20. 183 p.
Schmidt, T.W., J.S. Ault, and J.A. Bohnsack. 1999. Site characterization for the Dry Tortugas region: Fisheries and essential habitats. NOAA Tech. Mem. NMFS-SEFSC-428.
Schmitt, E.F. and K.M. Sullivan. 1996. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. Bull. Mar. Sci. 59: 404-416.
Shinn, E.A. 1963. Spur and groove formation on the Florida reef tract. J. Sediment. Petrol. 3(2): 291-115.
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. 530 p.
Sokal, R.R. and F.J. Rohlf. 1981. Biometry (2nd ed.). W.J. Freeman, San Francisco. 859 p.
Starck, W.A. 1968. A list of fishes of Alligator Reef, Florida with comments on the nature of the Florida reef fauna. Undersea Biol. 1:4-40.
Stokes, F.J. 1980. Handguide to the coral reef fishes of the Caribbean. Lippincott and Crowell, Publ., New York. 160 p.
St. John, J., G.R. Russ, and W. Gladstone. 1990. Accuracy and bias of visual estimates of numbers, size structure, and biomass of coral reef fish. Mar. Ecol. Prog. Ser. 64:253-262.
Talbot, F. and B. Goldman, B. 1973. A preliminary report on the diversity and feeding relationships of reef fishes of One Tree Island, Great Barrier Reef System. Pages 425-443 *in*: Proc. Symp. Coral and Coral Reefs 1969. Mar. Bio. Assoc. India.
Thayer, G.W. and A.J. Chester 1989. Distribution and abundance of fishes among basin and channel habitats in Florida Bay. Bull. Mar. Sci. 44(1): 200-219.
Thayer, G.W., D.R. Colby and W.F. Hettler. 1987. Utilization of the red mangrove prop root habitat by fishes in south Florida. Mar. Ecol Prog. Ser. 35: 25-38.

APPENDIX A: List of Abbreviations

BNP	Biscayne National Park
CI	Confidence Interval
DTNP	Dry Tortugas National Park
EEZ	Exclusive Economic Zone
ENP	Everglades National Park
FKNMS	Florida Keys National Marine Sanctuary
FMC	Fishery Management Council
GMFMC	Gulf of Mexico Fishery Management Council
JPSP	John Pennekamp Coral Reef State Park
MER	Marine Ecological Reserve
NURC	National Undersea Research Center
PDT	Plan Development Team (Snapper-Grouper Plan, SAFMC))
SAFMC	South Atlantic Fishery Management Council
SD	Standard Deviation
SE	Standard Error
SFERP	South Florida Ecosystem Restoration Program
USDOC	U.S. Department of Commerce.

Appendix B. Locations of sampled reef site in the FKNMS.

Reef Name	LATITUDE	LONGITUDE
12-12 SAMBOS	24-30.16 N	081-40.37 W
14 SAMBOS	24-29.61 N	081-42.82 W
15-13 SAMBOS	24-29.81 N	081-42.38 W
8 FATHOM ROCK	24-41.98 N	082-59.92 W
ALLIGATOR REEF	24-51.13 N	080-37.11 W
AMERICAN SHOAL	24-31.39 N	081-31.10 W
ANNE'S ANCHORAGE	24-33.03 N	081-42.85 W
BACHE SHOAL	25-29.20 N	080-09.00 W
BASIN HILL - CLOSED	25-12.99 N	080-17.21 W
BASIN HILL - OPEN	25-12.90 N	080-16.79 W
BASIN HILL - OPEN (NEW)	25-12.40 N	080-17.06 W
BIG PINE SHOAL	24-34.21 N	081-19.63 W
BLACK CORAL ROCK	24-41.95 N	083-00.12 W
BNP: AJAX REEF	25-23.70 N	080-07.90 W
BNP: ALINA'S	25-23.10 N	080-09.90 W
BNP: BALL BUOY	25-19.10 N	080-11.00 W
BNP: BREWSTER REEF	25-33.40 N	080-06.10 W
BNP: IGW TRUST	25-20.40 N	080-09.90 W
BNP: MARKER 14	25-27.80 N	080-10.10 W
BNP: NE CORNER REEF	25-37.60 N	080-05.50 W
BNP: PETREL POINT	25-24.70 N	080-11.20 W
BNP: STAR CORAL	25-24.60 N	080-09.10 W
BNP: TRIUMPH REEF	25-28.50 N	080-06.80 W
CARYSFORT REEF	25-13.49 N	080-12.70 W
CARYSFORT SOUTH REEF	25-12.66 N	080-13.20 W
CECILY'S SITE	24-40.43 N	083-01.29 W
CHEECA ROCKS	24-54.30 N	080-37.50 W
COFFIN PATCH	24-40.80 N	080-58.40 W
CONCH REEF	24-57.49 N	080-27.68 W
COSGROVE SHOAL	24-27.51 N	082-11.29 W
CROCKER REEF	24-54.49 N	080-31.51 W
CROSBY'S HUMP	24-32.63 N	082-56.92 W
DAVE'S FINAL FRONTIER	24-35.60 N	082-52.40 W
DAVIS REEF	24-55.36 N	080-30.34 W
DELTA SHOAL	24-37.94 N	081-05.38 W
DEVIL'S REEF	24-26.19 N	081-54.04 W
DOUG'S DEN	24-32.94 N	081-44.61 W
EASTERN DRY ROCKS (FISHED)	24-27.89 N	081-50.25 W
EASTERN DRY ROCKS	24-27.52 N	081-50.67 W
EASTERN SAMBO	24-29.48 N	081-39.84 W
THE ELBOW	25-08.69 N	080-15.53 W
FANTOM REEF	24-40.57 N	083-01.40 W
FOWEY ROCKS	25-35.20 N	080-05.53 W
FRENCH REEF	25-02.17 N	080-21.05 W
FRENCH WRECK	24-37.57 N	082-56.12 W
GARDEN COVE	25-09.27 N	080-17.29 W
GARY'S ANCHOR	24-40.70 N	083-03.83 W
GEORGE'S GORGE	24-39.50 N	082-48.80 W
GEORGE'S ROCK	24-39.62 N	083-00.34 W
GRECIAN ROCKS	25-06.71 N	080-18.18 W
GROUPER SITE	25-42.15 N	080-05.88 W
GUY'S GROTTO	24-37.50 N	082-49.80 W
HANGOVER REEF	24-39.39 N	083-01.92 W
HEN AND CHICKENS	24-55.36 N	080-32.90 W
HUMP 1	24-40.76 N	083-03.50 W
HUMP 2	24-40.76 N	083-03.05 W
HUMP 3	24-40.85 N	083-01.70 W
JOE'S CRACK	24-38.80 N	082-49.60 W
JOE'S HUMP	24-30.46 N	082-52.65 W

Appendix B (cont.)

KEY BISCAYNE SITE	25-39.50 N	080-05.60 W
KEY LARGO DRY ROCKS	25-07.40 N	080-17.85 W
KEY WEST (EASTERN FISHED)	24-33.25 N	081-40.88 W
KEY WEST (INSHORE FISHED)	24-32.15 N	081-47.90 W
KEY WEST (WESTERN FISHED)	24-32.62 N	081-46.56 W
LITTLE AFRICA	24-38.25 N	082-55.33 W
LITTLE BANK	24-43.05 N	082-59.52 W
LOGGERHEAD KEY	24-38.37 N	082-55.93 W
LONG KEY (BIRD KEY)	24-36.71 N	082-52.18 W
LOOE KEY - EAST	24-32.81 N	081-24.26 W
LOOE KEY - WEST	24-32.78 N	081-24.50 W
LOOE KEY - OTHER	24-33.00 N	081-24.00 W
LOOE KEY RESEARCH	24-34.09 N	081-23.11 W
MARKER 56	24-33.23 N	081-41.23 W
MARKER H	24-44.00 N	082-54.00 W
MARQUESAS ROCKS	24-27.53 N	082-12.39 W
MARYLAND SHOAL	24-30.53 N	081-34.42 W
MAVRO VETRANIC	24-42.32 N	082-46.95 W
MIDDLE SAMBO	24-29.27 N	081-40.53 W
MOLASSES REEF	25-00.72 N	080-22.60 W
MOSQUITO BANK - CLOSED	25-04.35 N	080-22.77 W
MOSQUITO BANK - OPEN	25-04.04 N	080-23.40 W
MOSQUITO BANK - OPEN (NEW)	25-04.16 N	080-22.54 W
NEWFOUND HARBOR KEY (FISHED)	24-37.16 N	081-22.87 W
NEWFOUND HARBOR KEY (SPA E)	24-36.90 N	081-23.64 W
NEWFOUND HARBOR KEY (SPA W)	24-36.90 N	081-23.73 W
NO NAME REEF	24-35.55 N	081-13.05 W
PELICAN SHOAL	24-30.10 N	081-37.90 W
PETE'S PINNACLE	24-29.06 N	081-45.41 W
PICKLES REEF	24-59.40 N	080-24.92 W
POTT'S PEAK	24-40.78 N	083-01.06 W
PULASKI SHOAL	24-41.78 N	082-46.23 W
RALPH'S RIDGE	24-40.65 N	083-01.23 W
REPLENISHMENT ZONE	24-28.82 N	082-48.24 W
ROCK KEY	24-27.24 N	081-51.43 W
SAND KEY	24-27.26 N	081-52.65 W
SHERWOOD FOREST	24-42.52 N	083-02.81 W
SOMBRERO KEY	24-37.68 N	081-06.60 W
TENNESSEE REEF (FISHED)	24-44.66 N	080-46.82 W
TENNESSEE REEF (RESEARCH)	24-45.93 N	080-45.39 W
TEXAS ROCK	24-40.87 N	082-53.06 W
TORTUGAS BANK (PINNACLES)	24-39.17 N	083-01.81 W
TORTUGAS BANK SITE11	24-40.20 N	083-03.70 W
TORTUGAS BANK SITE18	24-39.70 N	083-02.50 W
TORTUGAS BANK SITE25	24-37.60 N	083-04.00 W
TORTUGAS BANK SITE51	24-41.06 N	083-01.90 W
TORTUGAS FLAT	24-40.43 N	083-01.29 W
TORTUGAS PARK SITE52	24-38.20 N	082-56.20 W
TORTUGAS PARK SITE82	24-38.10 N	082-55.30 W
TRIANGLES	25-07.07 N	080-24.47 W
TURTLE REEF	25-17.03 N	080-12.36 W
28 FOOT SHOAL	24-25.30 N	082-25.30 W
TWIN PEAKS	24-37.98 N	082-58.01 W
WEST TURTLE SHOAL	24-41.86 N	080-58.17 W
WESTERN DRY ROCKS	24-26.68 N	081-55.57 W
WESTERN SAMBO - EAST	24-28.91 N	081-42.36 W
WESTERN SAMBO - WEST	24-28.86 N	081-42.74 W
WHITE BANK	25-02.38 N	080-22.28 W
WHITE SHOAL	24-38.46 N	082-53.91 W