SE Florida Off-Shore Fish Assemblage Trends (1999-2008)

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Abstract

Analysis of the last ten years of REEF sighting and density estimates for off-shore SE Florida reef fish assemblages in comparison to the last three years average indicates that overall reef fish sighting frequencies have declined by 18% and fish density estimates have declined by six percent. Fish sightings calculations are more acutely in decline in the Jupiter to Miami reef corridor (-21%) in comparison to Key Largo (-14%) and the Dry Tortugas (-16%). All three areas show declines in both sighting frequency and density estimates. Analysis of fish sighting trends using 28 indicator species organized into eleven eco-niche off-shore reef habitats show decline in every group. Thirteen of the 28 indicator species have a sighting frequency decline greater than 30%. Similarly, the data when organized into one of the three trophic levels show decline in all groupings as well. The lower two trophic levels (-20%) have twice the rate of decline as the higher top predator group (-10%).

Introduction

Florida's off-shore reefs are the home to over 500 different species of fish comprising at least 84 different fish families. Each species of fish is a potential indicator of the reef health because the reef food web depends on, benefits from, and participates in the reef fish food chain. The reef ecosystem is a complex interaction of reef fish inhabitants and benthic organisms such as scleractinian corals, sponges, algae, gorgonians, and sea grasses. Full understanding of the complex interaction of all of the reef organisms is nearly impossible, but tracking select species of representative fish can offer insight into the entire reef ecology since they reflect the overall health the reef system in which they live.

The focus of this report is to review the fish assemblage data from the last 10 years, report trends of off-shore reef fish sighting data and density estimates for three years for related but different areas of SE Florida. These study areas include the highly developed and populated Jupiter-Miami corridor, the much smaller, but populated Key Largo area, and the remote Dry Tortugas islands. The fish sighting and density data will also be evaluated for trends using a group of eleven eco-niche reef habitat as well as a broad three group trophic level assessment. The scope of this assessment will be based on a comparison of the last three years of fish sighting and density data in contrast to the last ten years. Data will be standardized using basic statistical techniques. The raw data used in this assessment will consist of fish sighting and density data as reported to the Reef Environmental and Education Foundation (REEF) by volunteer divers for the period 1999 through 2008. Only expert level REEF fish data (levels 4 and 5) was used to minimize identification errors and maximize observational effectiveness of divers conducting the REEF Roving Diver Technique (RDT) surveys. The data was further

qualified by selecting 28 representative fish species which are commonly found on SE Florida off-shore reefs.

The goal of this assessment is to identify the overall trends (increase or decrease) in sighting frequency and density as well as trends for each species. Trend data will also be arrayed by the three major areas (Jupiter-Miami, Key Largo, and Dry Tortugas), three major trophic levels (Herbivores, Omnivores, and Carnivores) as well as eleven niches that represent the major reef habitats. The working hypothesis is that fish assemblages in the Dry Tortugas should be more stable due to minimal human interactions such as fishing, boating, pollution, habitat loss and other practices such as the aquarium trade. A second hypothesis assumes that declines in species sightings and densities should be most acute at the top of the trophic pyramid (sharks, groupers, and snappers) where fishing is most intense.

Background

The off-shore coral reef tracts extend for approximately 309 miles in SE Florida. The study area begins in the north at Jupiter inlet in Palm Beach County and extend southward along the coast lines of Broward County, Miami-Dade County, and Monroe County which is home to the collective islands of the Florida Keys, and a remote group of islands known as the Dry Tortugas. The reef tract runs south from Jupiter to Miami for 85 miles and then it arcs south-west 225 miles through the Biscayne National Park, Key Largo, Islamorada, Marathon, Key West, the Marquesas Islands ending in the Dry Tortugas island group. Typically offshore reefs range in depth from 30 to 130 feet and they parallel the coast out to a distance of approximately three miles off-shore. In the Dry Tortugas, the reef structure is different and reefs ring small sandy islands or are situated on top of underwater ridges. The off-shore reefs are constantly bathed in the warm Gulf Stream current as it flows from the equatorial areas north to Labrador and Europe. This gives the entire area semi-tropical water temperatures allowing coral reefs, flora and fauna to extend beyond the typical limits of coral reefs.

The SE Florida reef tract is the largest off-shore reef system in the United States. It is home to a wide diversity of both benthic and fish species. It is the habitat of the protected Goliath Grouper (*Epinephelus itajara*) and the Nassau Grouper (*Epinephelus striatus*) as well as the recently protected Staghorn coral (*Acropora cervicornis*) and Elkhorn coral (*Acropora palmata).* Table 1 summarizes the REEF fishing sighting activities since 1996.

Table 1: REEF Reporting Summary 1996 - 2008

Location	Number of Species	Number of Fish Families	REEF Survey Sites	Total REEF Surveys	Expert REEF Surveys
Jupiter-Miami	486	84	325	6,496	2,593
Key Largo	402	75	97	7,998	2,916
Dry Tortugas	338	62	175	1,878	1,311
SE Florida Region	551	93	597	23,801	9,958

The REEF survey sites include sites include off-shore reef locations such as artificial reefs, inshore locations, and a few piers and bridge supports. The vast majority of the REEF sites are off-shore reef observational reporting. All REEF data is limited to dives within the normal recreational Scuba depth limit of 130 feet. The 28 species selected as an indicator panel for this assessment used fish that typically (but not exclusively) inhabit off-shore reefs. No data stratifications were attempted to control for marine protected areas, reef remediation zones, or park areas.

The 28 species used for this assessment were selected based upon three criteria. First, the species had to be present at all three locations and consistently sighted over a 10 year period. Second, the species indicator panel had to represent all trophic levels. Third, selected species primarily occupied one of eleven different reef micro-habitats habitats such as coral grazers, apex predators, minor carnivores, and planktivores.

Table 2 lists the 28 species selected for this assessment. The fish are clustered by reef feeding habitat which will be explained later in the report. The REEF Sighting Frequency Rank Number represents the rank order of sightings for that species for the combined three areas being assessed. The average Overall Sighting Frequency (SF%) signifies the probability that any species is likely to be observed. For example, the Caribbean Reef Shark (*Carcharinus perezii*), has a rank number of 210 and an overall sighting frequency of only 1.4%. Caribbean Reef Sharks are not a commonly encountered fish with barely one sighting in 100 dives. In fact there are 209 other fish species that are more likely to be observed when diving in the SE Florida area. In contrast, the Blue Tang (*Arcanthurus coeruleus*) has a rank number of 2 and an overall sighting frequency of 85%. This herbivorous species has one of the most consistently highest sighting frequencies. Table 2 shows that many of the 28 select panel of fish species have a Rank Number of 50 or less indicating common occurrence. Other fish with higher Rank Numbers were included in order to ensure that the panel of fish was as inclusive as possible for all reef communities and trophic levels. The Requiem (Carcharhinidae) and Carpet (Rhincodontidae) Sharks have always been relatively few in number by virtue of their apex position on the reef food (and possible over-fishing). Similarly, the Grouper-Seabass (Serranidae) family has been negatively impacted by intense sport and commercial fishing and habitat loss reducing their number. These factors result in larger Rank Numbers reflective of their lower abundance levels.

Table 2	REEF 1993 – 2008 Overall Sighting Frequency Rank Number Sighting Frequency					
Common Name	**Scientific Name**	**SF % Rank Number**	**Overall SF%**	**Jupiter-Miami SF%**	**Key Largo SF%**	**Dry Tortugas SF%**
Reef Shark	*Carcharhinus perezii*	210	1.4	1.7	1.7	0.6
Nurse Shark	*Ginglymostoma cirratum*	99	13.6	11.3	15.6	12.0
Great Barracuda	*Sphyraena barracuda*	23	53.5	28.7	73.3	47.5
Goliath Grouper	*Epinephelus itajara*	148	5.0	5.0	3.3	11.7
Gray Snapper	*Lutjanus griseus*	30	50.4	47.1	53.8	46.4
Schoolmaster	*Lutjanus apodus*	43	42.6	22.4	61.8	25.2
Black Grouper	*Mycteroperca bonaci*	58	34.2	9.2	50.0	44.6
Sergeant Major	*Abudefduf saxatilis*	5	76.9	75.8	82.7	56.5
Creole Wrasse	*Clepticus parrae*	49	40.1	37.5	41.4	42.8
Brown Chromis	*Chromis multilineata*	39	44.0	32.6	54.7	34.9
Graysby	*Cephalopholis cruentatus*	31	50.3	40.2	56.3	55.9
Harlequin Bass	*Serranus tigrinus*	33	49.3	40.5	60.0	32.0
Butter Hamlet	*Hypoplectrus unicolor*	36	47.1	44.7	41.9	75.6
Trumpetfish	*Aulostomus maculatus*	32	49.7	41.3	64.3	15.6
Orangespotted Filefish	*Cantherhines pullus*	76	24.0	35.5	19.7	6.8
Doctorfish	*Arcanthurus chirugus*	19	57.5	63.8	57.4	38.7
Blue Tang	*Arcanthurus coeruleus*	2	85	75.2	90.9	90.2
Stoplight Parrotfish	*Sparisoma viride*	4	77.7	65.3	86.3	80.3
Redband Parrotfish	*Sparisoma aurofrenatum*	10	71.1	67.3	72.5	76.6
Bridled Goby	*Coryphopterus glaucofraenum*	45	42.0	34.0	44.3	56.7
Spotted Goatfish	*Pseudupeneus maculatus*	17	60.5	65.8	59.0	50.5
French Grunt	*Haemulon flavolineatum*	7	74.1	74.5	78.3	55.9
Bluestripe Grunt	*Haemulon sciurus*	11	68.7	65.2	80.0	33.3
Porkfish	*Anisotremus virginicus*	6	74.2	84.5	71.7	53.6
Beaugregory	*Stegastes leucosticus*	59	33.9	32.6	31.9	46.5
Bicolor Damselfish	*Stegastes partitus*	3	77.9	67.4	85.6	78.3
Gray Angelfish	*Pomacanthus arculatus*	20	56.4	53.5	56.7	63.4
Queen Angelfish	*Holacanthus cilaris*	37	47.0	40.3	52.4	45.1

Results

Table 3 shows the overall Sighting Frequency Change and Density Change for all 28 indicator fish species. Change for the base line period of 1999 to 2008 was calculated by averaging 10 years of fish sighting frequency data or density estimation data and then calculating the respective standard deviation. An average was also calculated for the last three years (2006-2008) to indicate recent trends. The average for the three year data was subtracted from the average of the 10 year data and this sum was divided by the standard deviation. The resulting value (commonly referred in statistics as a Z score or normalized average) shows how distant the three year average is from the 10 year average. A positive number indicated an increase whereas a negative number indicates a decrease. The Z score was converted to a positive or negative percentile rank using a Z Score look-up table. Sighting Frequency or Density Estimations are then more intuitively understood and change estimates are easily compared from one species to another.

Table 3	Overall sighting Frequency and Density Estimate Percent Change			
Common Name	***Scientific Name***	**Overall Sighting % Change**	**Overall Density % Change**	**Remarks**
Reef Shark	*Carcharhinus perezii*	20%	-1 %	Largest sighting frequency increase.
Nurse Shark	*Ginglymostoma cirratum*	-13%	13%	
Great Barracuda	*Sphyraena barracuda*	-23%	-9%	
Goliath Grouper	*Epinephelus itajara*	13%	8%	Species protected in 1991. Largest combined increase.
Gray Snapper	*Lutjanus griseus*	-29%	-21%	Large combined decline.
Schoolmaster	*Lutjanus apodus*	-8%	16%	
Black Grouper	*Mycteroperca bonaci*	-16%	-10%	
Sergeant Major	*Abudefduf saxatilis*	-31%	-18%	Large sighting frequency decrease.
Creole Wrasse	*Clepticus parrae*	-20%	17%	
Brown Chromis	*Chromis multilineata*	-10%	0%	
Graysby	*Cephalopholis cruentatus*	-19%	-33%	Largest density decrease.
Harlequin Bass	*Serranus tigrinus*	-20%	-8%	
Butter Hamlet	*Hypoplectrus unicolor*	-28%	-25%	
Trumpetfish	*Aulostomus maculatus*	-34%	-25%	Large combined decline.
Orangespotted Filefish	*Cantherhines pullus*	-28%	-5%	
Doctorfish	*Arcanthurus chirurgus*	3%	29%	Largest density increase.
Blue Tang	*Arcanthurus coeruleus*	-38%	-28%	Largest combined decline.
Stoplight Parrotfish	*Sparisoma viride*	-24%	-23%	
Redband Parrotfish	*Sparisoma aurofrenatum*	-16%	-23%	
Bridled Goby	*Coryphopterus glaucofraenum*	-1%	3%	
Spotted Goatfish	*Pseudupeneus maculatus*	-7%	-10%	
French Grunt	*Haemulon flavolineatum*	-24%	15%	
Bluestripe Grunt	*Haemulon sciurus*	-25%	-10	
Porkfish	*Anisotremus virginicus*	-29%	-7%	
Beaugregory	*Stegastes leucosticus*	-21%	6%	
Bicolor Damselfish	*Stegastes partitus*	-22%	-16	
Gray Angelfish	*Pomacanthus arculatus*	-19%	-7	
Queen Angelfish	*Holacanthus cilaris*	--24%	5	
Percent Change	---	**-18%**	**-6%**	

Calculations using an un-weighted average for the 28 indicator species indicate that overall sighting frequencies have decline by 18% over the last three years. Density estimates have declined by 6% for the same period of time. Large decreases and increases are highlighted in Table 2. Large decreases in both sighting frequency and estimated density occurred in the following species --- Gray Snapper (*Lutjanus griseus)*, Trumpetfish (*Aulostomus maculatus*), and Blue Tang (*Arcanthurus coeruleus*. Notable are the large increase for the Doctorfish (*Arcanthurus chirurgus*) and modest gains for the Caribbean Reef Shark (*Carcharhinus perezii*). Also, the protected Goliath Grouper (*Epinephelus itajara)* experienced a moderate increases in both sighting frequency and estimated density.

Table 4 summarizes the sighting frequency changes for the three major comparison areas --- Jupiter to Miami, Key Largo, and the Dry Tortugas. In addition to the area averages, an ordinal count of increases, decreases, and no changes are included. Changes greater than 30% are highlighted with shading.

Table 4	**Sighting Frequency Changes by Indicator Species for Three Comparison Areas**			
Common Name	**Scientific Name**	**Jupiter---- Miami**	**Key Largo**	**Dry Tortugas**
Reef Shark	*Carcharhinus perezii*	31%	11%	19%
Nurse Shark	*Ginglymostoma cirratum*	-28%	-5%	-7%
Great Barracuda	*Sphyraena barracuda*	-34%	-12%	-24%
Goliath Grouper	*Epinephelus itajara*	26%	27%	-14%
Gray Snapper	*Lutjanus griseus*	-40%	-9%	-39%
Schoolmaster	*Lutjanus apodus*	-23%	2%	-4%
Black Grouper	*Mycteroperca bonaci*	-21%	-26%	-2%
Sergeant Major	*Abudefduf saxatilis*	-36%	-21%	-37%
Creole Wrasse	*Clepticus parrae*	-32%	10%	-38%
Brown Chromis	*Chromis multilineata*	-31%	-10%	10%
Graysby	*Cephalopholis cruentatus*	-33%	-11%	-14%
Harlequin Bass	*Serranus tigrinus*	-32%	-29%	1%
Butter Hamlet	*Hypoplectrus unicolor*	-33%	-17%	-34%
Trumpetfish	*Aulostomus maculatus*	-33%	-33%	-35%
Orangespotted Filefish	*Cantherhines pullus*	-25%	-35%	32%
Doctorfish	*Arcanthurus chirurgus*	17%	-8%	-1%
Blue Tang	*Arcanthurus coeruleus*	-38%	-36%	-40%
Stoplight Parrotfish	*Sparisoma viride*	-20%	-14%	-37%
Redband Parrotfish	*Sparisoma aurofrenatum*	-8%	-26%	-14%
Bridled Goby	*Coryphopterus glaucofraenum*	17%	-19%	0%
Spotted Goatfish	*Pseudupeneus maculatus*	-29%	-17%	24%
French Grunt	*Haemulon flavolineatum*	-15%	-19%	-38%
Bluestripe Grunt	*Haemulon sciurus*	-29%	-17%	-30%
Porkfish	*Anisotremus virginicus*	-34%	-16%	-36%
Beaugregory	*Stegastes leucosticus*	-27%	-14%	-21%
Bicolor Damselfish	*Stegastes partitus*	-37%	-26%	-2%
Gray Angelfish	*Pomacanthus arculatus*	2%	-21%	-37%
Queen Angelfish	*Holacanthus cilaris*	-35%	-6%	-32%
Percent Change	---	**-21%**	**-14%**	**-16%**
Increase Count	---	*5*	*4*	*5*
Decrease Count	---	*23*	*24*	*22*
No Change	---	*0*	*0*	*0*

Table 4 data shows that the Jupiter to Miami area has the largest overall decline in sighting frequencies with a 21% decrease. Declines out numbered increases by a factor of more than four to one. Fourteen of the 28 indicator species for the Jupiter – Miami area showed a decline of 30% or greater. Additionally, two species showed declines of 30% or greater in all three comparison areas --- Trumpetfish (*Aulostomus maculatus*) and Blue Tang (*Arcanthurus coeruleus*).

Table 5 summarizes the density estimate changes for the three major comparison areas --- Jupiter to Miami, Key Largo, and the Dry Tortugas. In addition to the area averages, an ordinal count of increases, decreases, and no changes are included. Changes of 30% or greater are shaded.

The Dry Tortugas showed the greatest overall decline in estimated density with an eight percent decrease. Declines for all three areas out numbered increases.

The preponderance of the data in Tables 2, 3 and 4 indicate that fish assemblages are in considerable decline across all comparison areas. Surprisingly, the Dry Tortugas despite its relative remoteness and less anthropogenic impacts is experiencing declines as well. Some of the declines are quite large, averaging between 30% and 40%.

Table 5	Density Estimate Changes by Indicator Species for Three Comparison Areas			
Common Name	**Scientific Name**	**Jupiter- Miami**	**Key Largo**	**Dry Tortugas**
Reef Shark	*Carcharhinus perezii*	-5%	-21%	33%
Nurse Shark	*Ginglymostoma cirratum*	14%	19%	5%
Great Barracuda	*Sphyraena barracuda*	-8%	4%	-23%
Goliath Grouper	*Epinephelus itajara*	20%	34%	-30%
Gray Snapper	*Lutjanus griseus*	0%	-26%	-37%
Schoolmaster	*Lutjanus apodus*	0%	28%	19%
Black Grouper	*Mycteroperca bonaci*	10%	-34%	-5%
Sergeant Major	*Abudefduf saxatilis*	-14%	0%	-40%
Creole Wrasse	*Clepticus parrae*	34%	18%	0%
Brown Chromis	*Chromis multilineata*	28%	-8%	-21%
Graysby	*Cephalopholis cruentatus*	-39%	-29%	-32%
Harlequin Bass	*Serranus tigrinus*	24%	-29%	-19%
Butter Hamlet	*Hypoplectrus unicolor*	-34%	-16%	-26%
Trumpetfish	*Aulostomus maculatus*	-39%	-9%	-23%
Orangespotted Filefish	*Cantherhines pullus*	-3%	-30%	19%
Doctorfish	*Arcanthurus chirurgus*	25%	30%	32%
Blue Tang	*Arcanthurus coeruleus*	-17%	-25%	-41%
Stoplight Parrotfish	*Sparisoma viride*	-34%	0%	-35%
Redband Parrotfish	*Sparisoma aurofrenatum*	-33%	-16%	-17%
Bridled Goby	*Coryphopterus glaucofraenum*	0%	10%	0%
Spotted Goatfish	*Pseudupeneus maculatus*	-16%	-32%	19%
French Grunt	*Haemulon flavolineatum*	0%	29%	17%
Bluestripe Grunt	*Haemulon sciurus*	-19%	9%	-20%
Porkfish	*Anisotremus virginicus*	-10%	-17%	6%
Beaugregory	*Stegastes leucosticus*	29%	-7%	-4%
Bicolor Damselfish	*Stegastes partitus*	-25%	-41%	19%
Gray Angelfish	*Pomacanthus arculatus*	4%	-10%	-15%
Queen Angelfish	*Holacanthus cilaris*	34%	-31%	12%
Percent Change	---	**-3%**	**-7%**	**-8%**
Increase Count	---	*10*	*9*	*10*
Decrease Count	---	*14*	*17*	*16*
No Change	---	*4*	*2*	*2*

Table 6 lists the 28 indicator species and the corresponding eco-niche category. The intent is to have two to four representative fish species for each of the common eleven habitats found on most off-shore reefs. Apex Predators are top predators that as adults have no natural predators on the reef other than humans. This group includes sharks (both Carcharhinidae and Rhincodontidae), the Great Barracuda (Sphyraenidae), and the Goliath Grouper (Serranidae). The Major Reef Piscivore group consists of large carnivores in the Grouper (Serranidae) and Snapper (Lutjanidae) families. The Water Column Planktivores are species that swim in the water column above the reef and feed primarily on Plankton. Smaller Reef Piscivores are reef dwelling carnivores that are approximately 6 to 24 inches in length and are in the Sea Bass (Serranidae) family.

Gorgonian Dwellers are species that inhabit the Gorgonian reef cover. Gorgonian Dwellers can be either a carnivore or omnivore. Algae Grazers are herbivorous fish that specialize in eating algae off of the reef. Coral Grazers specialize in nibbling at coral for algae or zooxanthellae, the symbiotic animal contained within the coral polyp. Detritivore are fish that eat by filtering the bottom sand material. Seagrass Grazers are members of the Grunt family and feed on mollusks and other inhabitants on sea grass beds adjacent to off-shore reefs. Typically these fish hunt at night and congregate on reef ledge during the day. Rubble Dwellers are fish that live and feed within the low relief rock and coral structures usually found on top of the reef. Poriferavores are fish that feed on sponges.

Table 6	**Indicator Species and Corresponding Eco-Niche Category**	
Common Name	**Scientific Name**	**Eco-Niche Level**
Reef Shark	*Carcharhinus perezii*	Apex Predator
Nurse Shark	*Ginglymostoma cirratum*	Apex Predator
Great Barracuda	*Sphyraena barracuda*	Apex Predator
Goliath Grouper	*Epinephelus itajara*	Apex Predator
Gray Snapper	*Lutjanus griseus*	Major Reef Piscivore
Schoolmaster	*Lutjanus apodus*	Major Reef Piscivore
Black Grouper	*Mycteroperca bonaci*	Major Reef Piscivore
Sergeant Major	*Abudefduf saxatilis*	Water Column Planktivore
Creole Wrasse	*Clepticus parrae*	Water Column Planktivore
Brown Chromis	*Chromis multilineata*	Water Column Planktivore
Graysby	*Cephalopholis cruentatus*	Smaller Reef Piscivore
Harlequin Bass	*Serranus tigrinus*	Smaller Reef Piscivore
Butter Hamlet	*Hypoplectrus unicolor*	Smaller Reef Piscivore
Trumpetfish	*Aulostomus maculatus*	Gorgonian Dweller
Orangespotted Filefish	*Cantherhines pullus*	Gorgonian Dweller
Doctorfish	*Arcanthurus chirurgus*	Algae Grazer
Blue Tang	*Arcanthurus coeruleus*	Algae Grazer
Stoplight Parrotfish	*Sparisoma viride*	Coral Grazer
Redband Parrotfish	*Sparisoma aurofrenatum*	Coral Grazer
Bridled Goby	*Coryphopterus glaucofraenum*	Detritivore
Spotted Goatfish	*Pseudupeneus maculatus*	Detritivore
French Grunt	*Haemulon flavolineatum*	Seagrass Grazer
Bluestripe Grunt	*Haemulon sciurus*	Seagrass Grazer
Porkfish	*Anisotremus virginicus*	Seagrass Grazer
Beaugregory	*Stegastes leucosticus*	Rubble Dweller
Bicolor Damselfish	*Stegastes partitus*	Rubble Dweller
Gray Angelfish	*Pomacanthus arculatus*	Poriferavore
Queen Angelfish	*Holacanthus cilaris*	Poriferavore

Table 7 summarizes the overall sighting frequency and density estimate for the eleven eco-niche categories. The categories Minor Piscivore, Gorgonian Dweller, and Coral Grazer have large combined decreases. Very modest increases in estimated density occur in the Apex Predator and Algae Grazer groupings. No sighting frequency increases were recorded for any of the eleven eco-niches. The largest sighting frequency and density change estimates are shaded.

Table 7	**Overall Sighting Frequency and Density Estimates by Eco-Niche Categories**		
Trophic Level	**Overall Sighting % Change**	**Overall Density % Change**	**Remarks**
Apex Predators	-1%	3%	
Major Piscivore	-18%	-5%	
Planktivore	-21%	0%	
Minor Piscivore	-22%	-22%	Combined Large Decline.
Gorgonian Dweller	-31%	-15%	Largest Sighting Decline. Combined Large Decline.
Algae Grazer	-18%	1%	
Coral Grazer	-20%	-23%	Largest Density Decline. Combined Large Decline
Detritvores	-4%	-3%	
Sea Grass Grazer	-26%	-1%	
Rubble Dweller	-21%	-5%	
Poriferavore	-22%	-1%	
Averages	**-18%**	**-6%**	

Table 8 shows the sighting frequency changes for each of the eleven eco-niche groupings for the three geographic comparison areas. The Jupiter – Miami area has three groupings with a decline of greater than 30% --- Planktivores, Minor Carnivores, and Rubble Dwellers. Both Key Largo and the Dry Tortugas have a sighting frequency decline in excess of 30% in the Gorgonian Dweller group. Decreases of 30% or more are shaded.

Table 8	**Sighting Frequency Percent Change by Eco-Niche Group**		
Eco-Niche Level	**Jupiter-Miami**	**Key Largo**	**Dry Tortugas**
Apex Predators	-1%	5%	-1%
Major Piscivore	-28%	-11%	-18%
Planktivore	-33%	-7%	-21%
Minor Piscivore	-33%	-19%	-22%
Gorgonian Dweller	-29%	-34%	-31%
Algae Grazer	-11%	-22%	-18%
Coral Grazer	-14%	-20%	-20%
Detrivores	-6%	-18%	-4%
Sea Grass Grazer	-26%	-17%	-26%
Rubble Dweller	-32%	-20%	-21%
Poriferavore	-17%	-14%	-22%
Averages	**-21%**	**-14%**	**-18%**

Almost all of the eco-niche categories in Table 8 show a double digit decline in sighting frequency for all three geographic areas. This wide spread decline in so many groups may be indicative of a large scale problem in the SE Florida off-shore reef system.

Table 9 reports on density estimate percent changes for each of the eleven eco-niche groupings. The Jupiter – Miami area's Coral Grazer Group has the only density estimate decline of greater than 30%. Overall density estimate declines are more pronounced in the Dry Tortugas and Key Largo areas. The eleven eco-niche density estimate summary point to three reef fish habitats that appear to be under considerable stress in all geographic areas. These reef habitats are: Minor Piscivores, Gorgonian Dwellers, and Coral Grazers.

Table 9	**Density Estimate Percent Change by Eco-Niche Group**		
Eco-Niche Level	**Jupiter-Miami**	**Key Largo**	**Dry Tortugas**
Apex Predators	5%	9	-7%
Major Piscivore	3%	-11%	-8%
Planktivore	16%	3%	-20%
Minor Piscivore	-16%	-25%	-26%
Gorgonian Dweller	-21%	-20%	-5%
Algae Grazer	4%	3%	-5%
Coral Grazer	-34%	-8%	-27%
Detrivores	-8%	-11%	10%
Sea Grass Grazer	-10%	7%	1%
Rubble Dweller	2%	-24%	8%
Poriferavore	19%	-21%	-15%
Averages	**-3%**	**-7%**	**-8%**

The eleven eco-niche groupings analysis technique is designed to maximize off-shore reef habitat representation. The seminal published paper for Caribbean reef fish diet was written by John Randall in 1967 after analyzing 5,526 specimens consisting of 212 species. Diet of most fish was varied. Randall concluded that feeding habits of reef fish tend to reflect an opportunistic strategy of survival so assignment of a species into one of the eleven eco-nice categories is a summary generalization based on predominant diet preferences and typical feeding location on SE Florida off-shore reefs.

Another approach to understanding the fish sighting frequency and density trends involves clustering the 28 indicator species using a trophic level ranking score. Fishbase.org, the world repository for scientific fish data jointly operated by the United Nations Food and Agriculture Organization and the European Commission, utilizes the Lindeman trophic ranking system. The Lindeman system is based on an adjusted stomach content model to classify species based on diet. The Lindeman scale is a five tier model. Most herbivorous eating fish species have a trophic level score in the low 2s. The degree of carnivorous feeding can increase the trophic level score for fish to a high of 4.5.

Table 10 lists the actual Lindeman trophic level score in the Fishbase database and a truncated score to facilitate summary analysis.

Table 10	Lindeman Trophic Level Ranking			
Common Name	**Scientific Name**	**Eco-niche Group**	**Fishbase.org Lindeman Trophic Level Ranking**	**Trophic Group Number**
Reef Shark	*Carcharhinus perezii*	Apex Predator	4.5	4
Great Barracuda	*Sphyraena barracuda*	Apex Predator	4.5	4
Black Grouper	*Mycteroperca bonaci*	Major Piscivore	4.5	4
Tumpetfish	*Aulostomus maculatus*	Gorgonian Dweller	4.44	4
Nurse Shark	*Ginglymostoma cirratum*	Apex Predator	4.3	4
Graysby	*Cephalopholis cruentatus*	Smaller Piscivore	4.16	4
Goliath Grouper	*Epinephelus itajara*	Apex Predator	4.0	4
Butter Hamlet	*Hypoplectrus unicolor*	Smaller Piscivore	3.97	3
Gray Snapper	*Lutjanus griseus*	Major Piscivore	3.88	3
Schoolmaster	*Lutjanus apodus*	Major Piscivore	3.76	3
Brown Chromis	*Chromis multilineata*	Planktivore	3.73	3
Creole Wrasse	*Clepticus parrae*	Planktinvore	3.68	3
Harlequin Bass	*Serranus tigrinus*	Minor Piscivore	3.5	3
Spotted Goatfish	*Pseudupeneus maculatus*	Detrititvore	3.47	3
Porkfish	*Anisotremus virginicus*	Seagrass Grazer	3.42	3
Bluestripe Grunt	*Haemulon sciurus*	Seagrass Grazer	3.41	3
French Grunt	*Haemulon flavolineatum*	Seagrass Grazer	3.35	3
Queen Angelfish	*Holacanthus cilaris*	Poriferavore	3.12	3
Gray Angelfish	*Pomacanthus arculatus*	Poriferavore	3.10	3
Beaugregory	*Stegastes leucosticus*	Rubble Dweller	3.06	3
Orangespotted Filefish	*Cantherhines pullus*	Gorgonian Dweller	2.90	2
Sergeant Major	*Abudefduf saxatilis*	Planktinvore	2.76	2
Bridled Goby	*Coryphopterus glaucofraenum*	Detrititvore	2.7	2
Doctorfish	*Arcanthurus chirurgus*	Algae Grazer	2.0	2
Blue Tang	*Arcanthurus coeruleus*	Algae Grazer	2.0	2
Stoplight Parrotfish	*Sparisoma viride*	Coral Grazer	2.0	2
Redband Parrotfish	*Sparisoma aurofrenatum*	Coral Grazer	2.0	2
Bicolor Damselfish	*Stegastes partitus*	Rubble Dweller	2.0	2

Table 11 reports on sighting frequency percent change for the overall trophic level group as well as for the three comparison areas. The single largest percent decline (-28%) is in the Jupiter – Miami area calculation for Trophic Group 3 (Omnivores). Overall the lower segments of the food chain represented by Trophic Group Number 2 and 3 are experiencing greater declines than are the species in Trophic Group 4, the top predators. Overall percent declines for Groups 2 and 3 are double the decline (-20% each) in comparison to Group 4 (-10%) species.

Table 11	**Trophic Level Sighting Frequency Changes By Geographic Area**				
Trophic Level Description	**Trophic Group Number**	**Jupiter-Miami SF% Change**	**Key Largo SF% Change**	**Dry Tortugas SF% Change**	**Overall Change in Trophic Group**
Apex & Major Piscivore	4	-13%	-7%	-11%	-10%
Omnivore	3	-28%	-13%	-21%	-20%
Algae & Zooplankton	2	-16%	-23%	-12%	-20%
Averages		**-21%**	**-14%**	**-16%**	

Survey Sampling

The analysis of such a diverse area such as SE Florida off-shore fish reef communities inherently contains data sampling limitations. The REEF data is the largest and most continuous sighting database in the region. The choice to utilize REEF expert surveyor observations (Level 4 and Level 5) is a trade-off decision between sample size and precision. The author believes that the use of the expert fish watching data ensures a high degree of confidence in the reporting as well as expertise in sighting fish assemblages in a variety of eco-niches on the reef.

Table 12 summarizes the total number of surveys and expert level surveys contained in the REEF database by year. The number of expert sightings varies by indicator species resulting in a sampling size calculation for each of the 28 indicator species. The sampling size is further complicated since the assessment covers a period of 10 years thereby making 280 different sample size values. In order to characterize the contribution of the Expert level fish survey activity, Table 11 is based upon the Queen Angelfish, a species that is common to all areas in moderate numbers.

Table 12 data shows that the Dry Tortugas area has the largest percentage of expert level surveys at 35%. However, the Dry Tortugas expert level and overall fish surveying data has a disproportionate smaller surveying total in comparison to the Jupiter-Miami or Key Largo areas. This difference is probably due the area's relative remoteness.

Table 12	**REEF Database Sample Size Summary 1999-2008 for Queen Angelfish**					
	Jupiter – Miami		**Key Largo**		**Dry Tortugas**	
Year	*Total Surveys*	*Expert Surveys*	*Total Surveys*	*Expert Surveys*	*Total Surveys*	*Expert Surveys*
2008	401	131	287	49	92	32
2007	540	134	666	142	37	7
2006	776	216	450	132	176	50
2005	435	95	561	113	148	38
2004	614	150	687	97	164	69
2003	1095	303	997	233	234	127
2002	1000	174	1492	366	252	115
2001	746	89	726	99	476	132
2000	324	71	447	61	88	35
1999	348	14	442	116	112	22
Totals	6279	1377	6755	1408	1779	627
Expert Surveys 10 Year Average By Area		**22%**		**21%**		**35%**

The Reef Expert sighting data was adjusted for few select years when there was no expert level reporting (Levels 4 and 5) on specific indicator species. In those instances, REEF reporting at Levels 1-3 was utilized if there were any positive observations. This adjustment took place for the 1999 Goliath Grouper sighting data in the Jupiter-Miami area. An adjustment was also made in the Caribbean Reef Shark statistics for 1999 in the Jupiter-Miami and Key Largo areas and for 2000 in the Key Largo area. Other species in the Apex Predator group, the Great Barracuda and the Nurse Shark, did not require any adjustment as well as any of the other indicator species. These adjustments have a bias effect that slightly increases the 10 year base period.

Table 13 summarizes the expert level sample sizes for each of the 28 indicator species by area. Years in which the sample size is less than 30 are noted in the remarks column. The 1999 data for the Jupiter-Miami area has many occurrences of less than 30 expert fish survey reporting. The data for the Dry Tortugas area is similar. Both 1999 and 2007 have many occurrences of less than 30 expert fish survey reporting. The problem of consistently gathering fish sighting information on off-shore reefs is a difficult undertaking as volunteer interests change year to year and grant funding for fish abundance surveys varies. Unfortunately, other smaller fish sighting data collections may exist but there is no central database or clearinghouse in the State of Florida to supplement or challenge the REEF data.

Table 13	Expert Level Reporting Summary by Indicator Species and Area					
	Jupiter-Miami		Key Largo		Dry Tortugas	
Species	*Min-Max # of Observ. Range*	*Year with Observation < 30*	*Min-Max # of Observ. Range*	*Year with Observation < 30*	*Min-Max # of Observ Range*	*Year with Observation < 30*
Reef Shark	4-30	99 thru 07	1-08	99 thru 08	0 -8	99 thru 08
Nurse Shark	35-143	---	34-245	08	4-73	99-00 05 thru 08
Great Barracuda	10-197	99	39-404	---	6-125	00 & 07-08
Goliath Grouper	5-41	99 thru 03 05 thru 07	1-28	99 thru 08	1-46	99 Thru 01 04 thru 08
Gray Snapper	22-416	99	67-329	---	4-190	06 thru 08
Schoolmaster	13-141	99	45-368	---	2-96	99-00 05 & 07-08
Black Grouper	4-55	99 thru 02	33-402	---	16-227	99, 07-08
Sergeant Major	24-556	99	85-455	---	2-197	99, 07-08
Creole Wrasse	14-284	99	42-279	---	28-177	99, 07
Brown Chromis	11-280	99	44-452	---	12-146	99, 00, 07
Graysby	14-312	99	36-483	---	27-200	07
Harlequin Bass	14-298	99	37-509	---	17-94	99, 05 Thru 07
Butter Hamlet	18-372	99	30-289	---	27-308	07
Trumpetfish	14-327	99	32-373	---	3-49	99-00, 04-08
Orangespotted Filefish	15-304	99	6-143	00 & 08	1-22	99 thru 08
Doctorfish	22-459	99	34-465	---	14-151	99, 05, 07
Blue Tang	23-521	99	50-610	---	26-319	07
Stoplight Parrotfish	21-445	99	43-526	---	11-304	07
Redband Parrotfish	22-544	99	45-575	---	31-205	---
Bridled Goby	17-369	99	33-443	---	20-243	99, 07
Spotted Goatfish	14-505	99	34-520	---	20-174	99
French Grunt	23-527	99	45-364	---	3-189	99-00, 07-08
Bluestripe Grunt	23-498	99	56-418	---	2-119	99, 04-05, 07-08
Porkfish	24-585	99	44-316	---	5-186	99, 07-08
Beaugregory	17-224	99	25-270	08	11-180	99, 07
Bicolor Damselfish	20-500	99	68-601	---	33-295	---
Gray Angelfish	16-385	99	37-349	---	17-218	07
Queen Angelfish	14-303	99	49-366	---	7-132	99, 07

Other methodological limitations include the bias of volunteer REEF surveyors conducting their fish abundance and density observations in the warmer months with calmer seas. Table 14 summarizes the number of Expert Level REEF fish surveys for the Bluehead Wrasse in 2008. The Dry Tortugas has all of its expert level reporting exclusively occurring in the months of May, June, and July. The Key Largo area has 77% of its expert level reporting occurring in the warmer months of April through September. The Jupiter-Miami area has a warm weather bias as well with 60% of the surveys being conducted in the months April through September.

Table 14: Expert Level Surveyor Activity By Month and By Region*

	Jupiter - Miami			*Key Largo*			*Dry Tortugas*		
Month	**N**	**Expert**	**%**	**N**	**Expert**	**%**	**N**	**Expert**	**%**
Jan	11	7	3%	5	3	4%	0	0	0%
Feb	16	8	3%	5	2	3%	0	0	0%
Mar	16	13	5%	5	2	3%	0	0	0%
April	17	14	5%	28	17	25%	0	0	0%
May	10	9	3%	22	2	3%	45	43	50%
June	18	14	5%	93	8	13%	30	27	31%
July	155	80	31%	34	3	4%	16	16	19%
Aug	34	23	9%	51	20	29%	1	0	0%
Sept	25	17	7%	5	2	3%	0	0	0%
Oct	7	6	2%	25	0	0%	0	0	0%
Nov	29	18	7%	1	0	0%	0	0	0%
Dec	63	51	20%	8	8	13%	0	0	0%
% Total			100%			100%			100%

Another sampling bias in the data is a lack of control over the sampling area selection. The decision to select a dive site concern presumably favors sights with abundant fish assemblage since most REEF fish surveys are conducted by volunteer divers diving on reefs for relaxation and enjoyment. This type of diving would likely favor locations wherein there may be mooring buoys, minimized dive boat run times to reduce fuel costs and transit times, and shallower depths for safety and greater dive times.

A vast majority of REEF fish surveys are conducted during daylight, so the reporting of abundance and density of fish on off-shore reefs is limited to that portion of the day.

Lastly, the Optimal Foraging Theory needs to be recognized. Compartmentalization of any species into one eco-system niche or food foraging strategy is overly simplistic. Successful animals adapt and are opportunistic feeders. Thus, a large panel of indicator species is preferable to a few “silver bullets” or “canaries in a coal mine”. While the choice of indicator species and number of indicators may be questioned, the use of the

panel does address the need to explain the complex by using a manageable number of indicators as discrete variables.

While all of the above mentioned limitations are factors in estimating absolute off-shore reef fish abundance and density estimates, the comparison of the REEF data over a 10 year period in three adjoining areas is suitable to identify basic trends since the biases are held relatively constant over the sample period.

Conclusions

The three year average decline of 18% in sighting frequency and the 6% decline in fish density estimates for the SE Florida region taken as a whole is a major concern. The apparent declines in the Dry Tortugas area along with the declines in the other two comparison areas (Miami-Jupiter and Key Largo) are indicative of a regional problem that does not appear to correspond with local anthropogenic activities including population density. The decline of the bottom two trophic levels in comparison to the top predator trophic group suggests that off-shore reef communities may be experiencing stress that has not been reported widely.

This assessment suggests that large scale declines may be underway at various habitat levels on SE Florida's off-shore reefs. These changes may have gone largely un-noticed because of a lack of reliable baseline data. Daniel Pauley of the University of British Colombia has coined the term "Shifting Baseline Syndrome" to explain the often overlooked changes occurring in nature. The problem for natural resource managers, scientists, and naturalists is that there is a lack of information to accurately characterize the conditions of a past eco-system. The tendency is to view the relative near-term past as the baseline period to measure change. The question for consideration involving the SE Florida off-shore reef systems is when did change really begin to occur and how much possible decline has already taken place.

Future Research

- Evaluate other fish abundance or density estimates collected throughout SE Florida to corroborate the conclusion in this assessment.
- Investigate the cause of major species sighting frequency and density estimate declines reported in Tables 3, 4 and 5.
- Assess the 28 indicator species model and modify accordingly in order to gain better understanding of off-shore reef fish assemblages.
- Develop a standardized data collection protocol requirement for all future reef species assessment in the state of Florida to insure the data is comparable and portable.
- Establish a central clearinghouse in the state of Florida for all databases to ease accessibility to the information.

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The author acknowledges the pioneering work that Reef Environmental and Education Foundation (REEF) undertook in 1993 by developing and continuously operating the largest reef fish sighting program in the world. This grass roots effort coupled with

volunteer citizen naturalists has done more to document the conditions of SE Florida's reefs than any other single project or study. This assessment would not have been possible without the REEF data.

Bibliography

DeLoach, Ned. Reef Fish Behavior: Florida Caribbean Bahamas. New World Publications, Jacksonville, FL (1999).

Froese R. and D. Pauley. 2008 Edition Fishbase. Worldwide Web Electronic Publication www.fishbase.org (version 12/2008).

Humann Paul and Ned DeLoach. Reef Fish Identification: Florida Caribbean Bahamas. New World Publications, Jacksonville, FL (2002).

Lindeman, Raymond. The Trophic-Dynamic Aspect of Ecology. Ecology October 1942.

Pala, Victor. Victory at Sea. Smithsonian Magazine 39:6 (46-55). New York, NY (2009)

Randall, John. Food Habits of Reef Fishes of the West Indies. Stud. Trop. Oceanogr. 5:665-847. Hawaii Institute of Marine Biology University of Hawaii and Bernice P. Bishop Museum, Honolulu, Hi. (1967)

Reef Environmental and Research Foundation Volunteer Survey Project Database. Worldwide Web Electronic Publication www.reef.org (December 2008).