Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session Number 22

Are the Coral Reef Finfish Fisheries of South Florida Sustainable?

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Abstract.- We used population abundance and size structure data from fishery-independent (visual census) and fishery-dependent (creel surveys) monitoring programs from the Florida Keys and Biscayne National Park to estimate stock mortality rates and current reproductive potentials of the seven most commonly harvested reef fishes. Numerous indicators revealed these reef fishes are currently experiencing unsustainable rates of exploitation. Annual growth in recreational fishing effort compounds this problem. If healthy reefs are Florida's future, exploitation of reef fish stocks must be reduced. Fishery management actions were evaluated that could possibly reduce fishing mortality and increase reproduction potential sufficiently to achieve sustainable stock conditions. Results indicated that, when using only traditional management approaches such as increased minimum harvest sizes or decreased bag limits, rather radical changes will be needed to achieve sustainable stock conditions, and any improvements may be negated by continual increases in fishing effort over relatively short time horizons. We conclude that, in addition to traditional fishery management controls, contemporary measures such as placing a portion of the population under spatial protection will likely be needed to achieve long-term sustainability of Florida's coral reef finfish fisheries.

Keywords: Florida, coral reefs, overfishing, sustainable fisheries

Introduction

The Florida Keys coral reef ecosystem, including Biscayne National Park, is inhabited by more than 400 fish species and supports multibillion-dollar fishing and tourism industries. Over recent decades, reef fish populations have declined owing to a variety of human-related stressors, most notably fishing and habitat alterations (Bohnsack and Ault 1996; Ault et al. 1998, 2005a). These fishes are intensively exploited (Ault et al. 1998, 2001, 2005b) by a rapidly growing human population and recreational fishing fleet (**Fig. 1**). Biscayne National Park (BNP) is in the process of developing plans to guide resource management decisions for the Park over the next 15-20 years that will contribute to conservation of fish species and their habitats, and sustain a tradition of quality fishing experiences for generations to come. The strategy for fisheries management is being developed cooperatively by BNP and the Florida Fish and Wildlife Conservation Commission (FWC), with input from members of government agencies, area universities, and the public. Fishery management concerns for reef fishes in south Florida are two-fold: (1) declines in the abundance of fish; and, (2) loss of quality fishing opportunities.

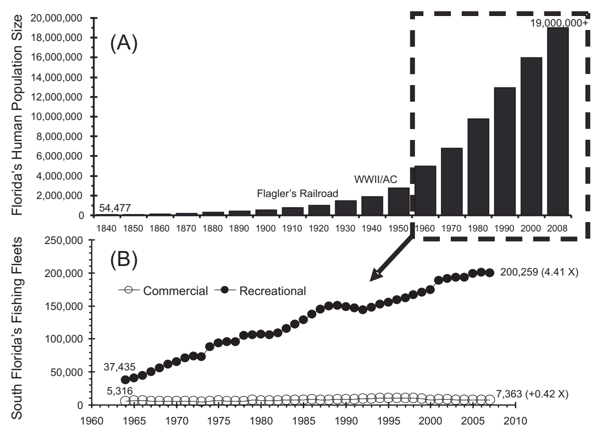

Figure 1.- Growth of south Florida: (A) human population (1840-2008); and, (B) fishing fleets (1964-2007).

To mitigate reef fishery declines, the South Atlantic Fishery Management Council in 1983 and the Florida Marine Fishery Commission in 1984 began establishing minimum size, season, and bag limit restrictions on a number of reef fish species. The current size and bag limit regulations for reef fishes in south Florida have been in place since the late 1990s (www.myfwc.com/marine/regulation.htm).

However, the most recent assessments suggest that majority of snapper-grouper species are currently fished at unsustainable levels (Ault et al. 2005b).

To assist in the BNP management processes, in this paper we assessed the sustainability of key reef fish stocks in BNP in relation to the Florida Keys, Once exploitation levels were identified, we evaluated potential benefits of more restrictive size and/or bag limits in terms of their efficacy to achieve sustainable populations and meet regional resource management goals.

Methods

Data Sources.- Two principal data sources were used, fishery-independent and fishery-dependent. Fishery- independent data were visual census surveys of reef fish species abundance and size structure for the Florida Keys ecosystem, including Biscayne National Park, for the period 2000-2004 (Bohnsack et al. 1999; Ault et al. 2001, 2005b). Fishery-dependent data were creel census surveys conducted in BNP for exploited species abundance and size structure for the two time periods, 1995-1998 and 2000-2004 (Ault et al. 2007).

Sustainability Analysis.- The principal stock assessment indicator variable we used to quantify sustainability status was average length ($\bar{L}$) of the exploited part of the population, the interval between the minimum size/age of first capture (L_c/a_c) and the maximum size/age (L_λ/a_λ) observed in the stock. For exploited species, $\bar{L}$ directly reflects the rate of total instantaneous mortality through alterations of the population size structure (Beverton & Holt 1957; Ehrhardt and Ault 1992; Quinn & Deriso 1999).

Estimates of average length were obtained from length composition data derived from the fishery-independent and -dependent data following the procedure described in Ault et al. (2005b, 2008). Using estimates of $\bar{L}$, total instantaneous mortality rate *Z* was estimated using the method of Ehrhardt and Ault (1992) and an iterative numerical algorithm (computer program LBAR, FAO 2003). Life history parameters for maximum age, growth and maturity for the reef fish species considered are given in Ault *et al.* (1998, 2005*b*). Additionally, we evaluated the two major components of *Z*, namely fishing mortality rate *F* and natural mortality rate *M*. In this process, we estimated *M* from lifespan, and *F* was estimated by subtracting *M* from *Z* (Ault *et al*. 1998).

A numerical cohort-structured model (Ault et al. 1998, 2008) was used to compute several fishery management reference points of stock status, or "*sustainability benchmarks*", including yield-per-recruit (YPR), spawning potential ratio (SPR), and limit control rules. Spawning potential ratio (SPR) is a management benchmark that measures a stock's potential to produce yields on a sustainable basis, and is computed as the ratio of current SSB relative to that of an unexploited stock. Benchmarks used to evaluate sustainable exploitation as a limit control rule were: F_{msy} (F generating maximum sustainable yield, MSY); B_{msy} (population biomass at MSY); and SPR (spawning potential ratio). We defined F = M as a proxy for F_{msy} (Quinn and Deriso 1999).

Bag & Size Limit Analysis.- We used the BNP creel census data to facilitate evaluation of bag limits. Catch and effort data were computed in terms of landings per angler-trip (i.e., number of fish landed and kept per person-trip). Current bag limits were evaluated in terms of percentages of trips that caught more than specific amounts of fish per person.

To evaluate potential gains in population benchmarks through increases in the minimum size of first capture, we conducted a "eumetric" fishing analysis (*inter alia* Beverton & Holt, 1957) for each key reef fish species. This analysis identifies the optimum combination of minimum size of first capture L_c given a particular fishing mortality rate F that results in maximal yields in weight and/or numbers of fish.

Results

Estimates of $\bar{L}$ from BNP creel data for seven principal exploited reef fishes were consistent between the 1995-1998 and 2000-2004 time periods (**Table 1**). The estimates of $\bar{L}$ from the latter time period were consistent between the BNP creel and Florida Keys visual census (**Fig.** 2). A substantial proportion of fishes observed in the creel census were smaller than the minimum legal size (**Table 1**). These undersized fish were not included in the computation of $\bar{L}$.

These data, together with the known life history parameters for each of these species, were then used to calculate estimates of current fishing mortality rates, stock biomass, SPR and YPR for each of the key reef fish species. Values of the F/F_{msy} ratio plotted against the B/B_{msy} ratio (**Fig. 3**) suggest all seven species are being subjected to unsustainable rates of exploitation (F-ratio >1, B-ratio <1; Ault et al. 2008).

We evaluated creel census catches to determine the closeness of catch rates to current bag limits (**Table 2**). The majority of the hook-and-line trips caught none of the key reef fishes, and only a small fraction of these trips ever reached the current bag limit. The only exception was for hogfish taken by spearfishers, who reached the bag limit on about 10% of the trips.

Given that we found that all seven of the key species are currently being subjected to unsustainable rates of exploitation, we evaluated the potential impact (in terms of SPR and YPR) of changing the size limits. For these analyses, we assumed that current estimated fishing mortality rates would continue unabated at their most recent levels, and then we increased the minimum size limit to the apparent optimal (i.e., eumetric) level.

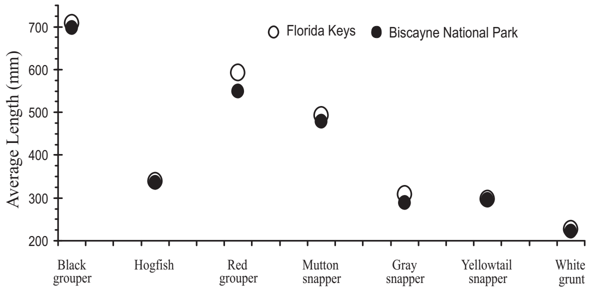

Figure 2.- Average size in the exploited phase for 7 reef fish species in the Florida Keys and BNP.

Summary results of these analyses for the "eumetric" minimum harvest size are given in **Table** 3. The changes in size correspond to a 2-3 fold increase in the age of first capture for most species. This increase in size/age is projected to favorably increase SPR for all stocks to above the 30% SPR federal standard for sustainability.

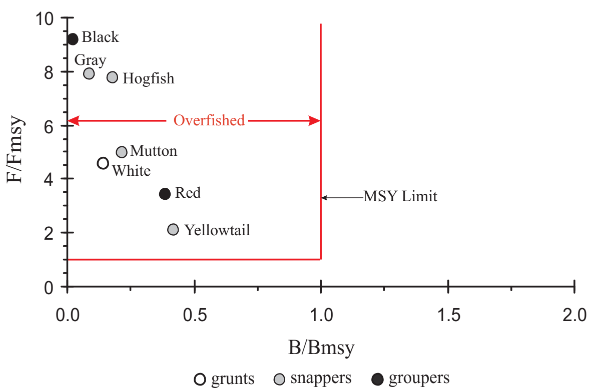

Figure 3.- Plot of F/Fmsy ratio against B/Bmsy ratio for 7 key reef fish species in the Florida Keys-BNP coral reef ecosystem for the years 2000-2004.

The time required for reaching the new equilibrium following implementation of a size change varies among the species, but could be a decade or longer for groupers (**Fig.5**).

Discussion

There has been a continuous long-term increase in registered recreational boats and fishing effort coupled with human population growth in South Florida. In the last 15 years, the recreational fleet has increased from about 140 thousand registered vessels to over 200 thousand (**Fig. 1**) and there is nothing to suggest that recreational fishing effort will not continue to increase into the future within the park and the greater south Florida area. Unless some additional restrictions are placed on the recreational fishery, fishing mortality rates for all of the species are likely to continue to increase into the future.

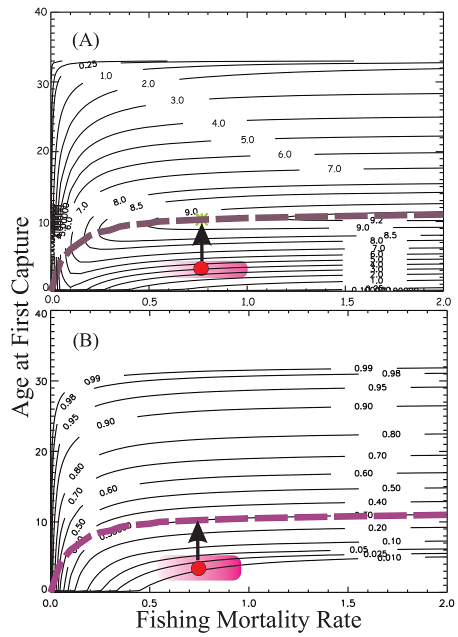

Figure 4.- Black grouper isopleths for: (A) yield-per-recruit in weight (Yw/R); and (B) spawning biomass-per-recruit (SSB/R). Current estimated *F* is shown in the shaded area of each panel, and the arrows denote required changes in size to reach the eumetric line (dashed).

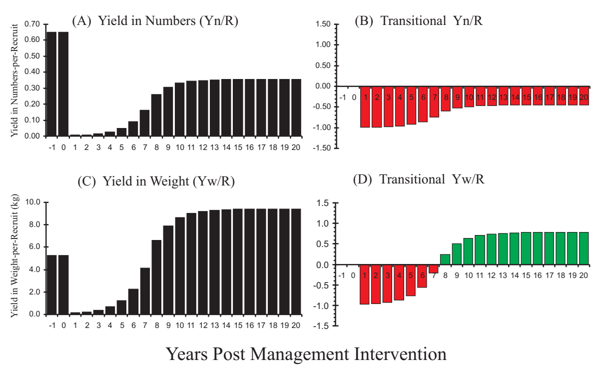

Figure 5.- Transitional dynamics and difference from initial equilibrium for Florida Keys black grouper: (A-B) yield in numbers-per-recruit; and, (C-D) yield in weight-per-recruit, after a eumetric size-limit change.

All seven species analyzed in this study were found to have fishing mortality rates that exceed those which are generally considered sustainable for healthy fish populations. While there has been an apparent stabilization of effective fishing mortality over the past decade, perhaps in response to the various management controls, none of the BNP (or Florida Keys) reef fish populations equaled or exceeded the minimum 30% spawning potential ratio (SPR) standard generally accepted as necessary for a sustainable fishery stock.

Even though the average number of fish landed per fishing trip for all of the species analyzed was found to be very low, we found a reduction in bag limit may, in some cases, reduce fishing mortality rates. In cases where catch rates are principally low (e.g., black and red grouper, and mutton snapper), reductions in bag limits would have little apparent effect, or would close the fishery. Our analysis suggests that a reduction in bag limits alone will not be sufficient to allow stocks to recover.

On the other hand, increasing the minimum size of first capture could lead to demonstrable increases in yield and in stock spawning potential. The important point suggested by our analyses is that a dramatic increase in the size at first capture is required to move stock spawning levels above those considered minimum for sustainability. This would, *de facto*, make the entire fishery a closed area for several years following the change (**Fig. 5**).This is particularly true for black grouper, hogfish, mutton snapper, gray snapper, and white grunt.

With either increases in minimum size or decreases in bag limits there will undoubtedly be an unintended increase in catch-and-release mortality incurred as both undersized fish and fish in excess of the allowable bag are released. This topic has been thoroughly reviewed by Bartholomew and Bohnsack (2005), who reported that catch-and-release mortalities ranged between 10 and 90% for over 200 species studied. For reef fishes targeted in BNP, release mortality rates would likely average from 10 to 30% from catch-and-release fishing.

Studies as early as Beverton and Holt (1957) and many others (Quinn and Deriso 1999) have shown that the ratio of natural mortality to growth rate of a species can provide a good indication of the rate at which species will recover when exploitation rates are reduced. All the reef fishes analyzed have relatively low M/K values. Unfortunately, this suggests that even if the necessary size were instituted immediately, stocks would not likely reach a sustainable status for at least 10 years.

In this paper we have only considered traditional management tools as the means of ensuring the sustainability of exploited reef fish stocks. While increased size limits have shown some promise, we believe that the only long-term solution will eventually involve multiple control methods including traditional approaches such as limiting the amount of fishing effort and/or restricting sizes to be captured, combined with more contemporary approaches like placing a portion of the population under spatial protection to ensure long-term resource sustainability.

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Table 1.- Biscayne National Park creel survey estimates of average size in the exploited phase, $\bar{L}$, and 95% confidence intervals (CI) for seven principal reef fishes for two time periods. Also reported is the percentage of measured fish (n) below the minimum legal size for the period 2000-2004; n/a denotes no legal size limit.

Species	L_c (mm)	2000-2004 n	2000-2004 $\bar{L}$ (95% CI) (mm)	2000-2004 Undersized (%)	1995-1998 n	1995-1998 $\bar{L}$ (95% CI) (mm)
Black grouper (*Mycteroperca bonaci*)	600	13	697 (648, 748)	23.5	31	691 (671, 710)
Red grouper (*Epinephelus morio*)	500	53	549 (537, 562)	29.3	64	535 (527, 543)
Mutton snapper (*Lutjanus analis*)	400	81	478 (462, 494)	36.7	48	499 (471, 527)
Gray snapper (*L. griseus*)	250	891	288 (286, 291)	13.7	979	292 (289, 294)
Yellowtail snapper (*Ocyurus chrysurus*)	250	644	296 (293, 299)	6.3	385	287 (284, 290)
Hogfish (*Lachnolaimus maximus*)	300	487	336 (333, 340)	21.7	492	347 (343, 352)
White grunt (*Haemulon plumieri*)	170	1126	221 (220, 223)	n/a	1878	217 (216, 218)

Table 2.- Bag limits (number of fish per person-day) for seven exploited species and the percentage of sampled trips in the Biscayne National Park creel survey that landed specified numbers of fish per person. Sampled trips are the number of boat trips using the specified gear that fished within habitats where a given species is found.

Species	Principal Gear	Sampled Trips	Bag Limit	Percentage (%) of Trips Landing: >0 fish	≥1 fish	≥2 fish	≥5 fish	≥10 fish
Black grouper	Hook-line	1089	2	1.4	0.4	0.0	0.0	0.0
Red grouper	Hook-line	1089	5	5.2	0.9	0.4	0.1	0.0
Mutton snapper	Hook-line	1661	10	5.5	1.7	0.3	0.1	0.0
Gray snapper	Hook-line	1661	5	18.7	10.1	5.1	0.3	0.0
Yellowtail snapper	Hook-line	1089	10	15.3	8.6	5.2	1.7	0.4
Hogfish	Spear	169	5	81.7	60.4	36.7	9.5	0.0
White grunt	Hook-line	1089	none	18.9	14.1	9.3	3.2	0.6

Table 3.- Comparison of the estimated spawning potential ratio (SPR) at the current legal minimum size with the projected SPR at the minimum size corresponding to a eumetric fishing strategy for seven reef fish species. Also given are maximum age (a_λ), age at sexual maturity (a_m), and age at minimum capture size (a_c).

Species	a_λ (y)	a_m (y)	Current min Size (mm FL)	Current a_c (y)	Current SPR (%)	Eumetric min Size (mm FL)	Eumetric a_c (y)	Eumetric SPR (%)
Black grouper	33	5.2	610	3.4	0.8	1078	10.0	31.2
Red grouper	29	4.3	508	5.4	17.7	648	8.8	35.7
Mutton snapper	29	2.0	406	3.7	8.4	703	10.0	38.0
Gray snapper	28	2.0	254	2.3	3.1	545	9.5	35.4
Yellowtail snapper	14	1.3	254	2.4	14.1	292	4.3	46.5
Hogfish	23	0.8	305	3.3	6.7	569	10.5	44.2
White grunt	18	1.6	170	1.5	4.9	378	6.5	39.4