Grouper Stocks of the Western Central Atlantic: The Need for Management and Management Needs

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ABSTRACT

Grouper stocks throughout much of the western central Atlantic are being heavily fished. An overview of the information on stocks in the region indicates that many are growth and/or recruitment overfished, and that management is essential to insure their continued commercial and recreational viability. Data necessary for effective management of grouper are identified, and the need for stock monitoring and assessment to be standardized and co-ordinated, on a regionwide basis, is emphasized.

KEYWORDS: grouper; fisheries management.

INTRODUCTION

The purpose of this paper is to focus the attention of biologists, fisheries managers, and public officials on the precarious state of grouper stocks in much of the western central Atlantic. In particular, I want to emphasize the need for standardizing and improving data collection protocols in the region, and also to identify the major data gaps precluding development of more effective management approaches. I have drawn together information widely dispersed in the scientific literature, unpublished reports, manuscripts, newsletters, and management plans to produce an overview of (1) the current status of stocks in the region, (2) the most pressing data needs for managing and monitoring stocks, and (3) the current approaches to management. While I have focused on grouper, many of the problems of resource status and use, monitoring, and managment are relevant to demersal (substrate-associated) fisheries resources, in general, throughout the region.

Grouper are of considerable commercial and recreational significance throughout the Caribbean, Bermuda, the Gulf of Mexico, Florida, and southeastern United States. They are also species of major ecological importance and of great aesthetic and scientific value. A total of 20 species is exploited, ranging in length from the giant jewfish (*Epinephelus itajara*) which may exceed 2 m to the creole fish, or barber (*Paranthias furcifer*), which barely reaches 0.3 m. (Table 1). Among the most economically valuable species are the red grouper (*E. morio*), followed by the gag (*Mycteroperca microlepis*) in northern continental areas, and the Nassau grouper (*E. striatus*), at least historically, and red hind (*E. guttatus*), among the islands of the region (Fischer, 1978; Mahon, 1987).

Table 1. Grouper species of commercial and/or recreational importance in the Western Central Atlantic.

Epinephelus adscensionis	rock hind
Epinephelus cruentatus	graysby **
Epinephelus drummondhayi	speckled hind
Epinephelus flavolimbatus	yellowedge grouper
Epinephelus fulvus	coney **
Epinephelus guttatus	red hind **
Epinephelus itajara	jewfish
Epinephelus morio	red grouper **
Epinephelus mystacinus	misty grouper
Epinephelus nigritus	Warsaw grouper
Epinephelus niveatus	snowy grouper
Epinephelus striatus	Nassau grouper *
Mycteroperca bonaci	black grouper **
Mycteroperca interstitialis	yellowmouth grouper
Mycteroperca microlepis	gag **
Mycteroperca phenax	scamp
Mycteroperca tigris	tiger grouper **
Mycteroperca venenosa	yellowfin grouper
Alphestes afer	mutton hamlet
Paranthias furcifer	creole fish

* and ** – evidence exists for female to male sex change
* – Carter *et al.*, (1994)
** – Shapiro, (1987)

Grouper species share a number of life-history characteristics believed to render them particularly vulnerable to human exploitation (Manooch, 1987; Ralston, 1987). They are carnivores, have a relatively long life-span, large size at sexual maturation, slow growth, and appear to be relatively easy to catch, being susceptible to a wide range of sizes and types of fishing gear. In particular, two characteristics may make them especially vulnerable. Many exhibit a sexual pattern incorporating adult sex change (female to male sex change, known as protogyny) making them more sensitive to fishing pressure than gonochore (non sex-changing) species (Bannerot, 1984; Bannerot *et al.*, 1987), under certain conditions. Also, some species spawn in large numbers at well-defined times and locations each year. Many of these spawning "aggregations" are thus easily located in both time and space and have been heavily fished.

STATUS OF GROUPER STOCKS

Information on the condition of grouper stocks (a stock is the part of a fish population which is under consideration for actual or potential use) in the region is patchy and largely incomplete. Few databases were initiated prior to the early 1970's, and even now much of what exists derives from a handful of the island nations of the region, and from southeastern United States and the eastern Gulf of Mexico.

The condition of a fishery may be monitored in a number of ways. Data on catch per some unit of effort, such as per fisherman day, trip, or gear hour, may be used to follow trends in catch over time in a standardized manner. Changes in catch composition (*i.e.*, relative numbers of different species comprising the catch), in the mean size of captured individuals, or in catches from spawning aggregations, also provide indications of the response of stocks to fishing pressure (Munro, 1983). Finally, formal stock assessments, although time-consuming and expensive to do, permit more rigorous assessments of actual and potential yield under a range of fishery conditions.

I have divided available information into five categories (Table 2): a. landings or catch per unit effort (CPUE); b. catch composition; c. mean size (length or weight); d. characteristics of spawning aggregations; and e. formal stock assessments (yield-per- recruit and spawning-stock-biomass per-recruit).

a. CPUE and Landings

Long-term landings and CPUE data are available from few locations. Moreover, since data on grouper species were originally combined, assessment by individual species in the early years of exploitation of a number of grouper stocks was not possible. This situation has improved and grouper are more frequently monitored on a species by species basis.

Data from Bermuda show an almost fourfold decline between 1975 and 1989 for reported landings of larger grouper species and a steady decline in CPUE (lbs. per trap haul) between 1975 and 1985, with a slight rise thereafter (Report of the Commission of Inquiry, Bermuda, 1991). Particularly striking have been the declines in reported weight landed of certain species, principally the yellowfin (*M. venenosa*), Nassau and tiger groupers (*M. tigris*), as much as 15-fold over the 6-year period between 1975 and 1981 (Bannerot *et al.*, 1987, Fig. 13.9).

In Puerto Rico, a six-fold decline (in weight) in reported grouper landings (all species combined) was reported between 1977 and 1989 following a steady increase as the fisheries of the island were developed during the mid-1970's (Sadovy and Figuerola, 1992, Fig. 1; unpubl. data; Fisheries Research Laboratory (FRL), CODREMAR, now the Department of Natural Resources - (DNR), Mayaguez, Puerto Rico). Since the number of fishermen in Puerto Rico is not believed to have declined markedly during this 12-year period, the picture

Table 2. Indications of stock status in grouper by species and by location

CRITERION	SPECIES	LOCATION
Reduction in landings and/or in CPUE	Grouper *	Bermuda, Puerto Rico, Martinique, Jamaica, Southeastern United States **
Decrease in percentage of total fish/grouper landings	Grouper *	Bermuda, Puerto Rico, Jamaica
	E. striatus	U.S. Virgin Islands, Puerto Rico
Decline in mean size or loss of larger individuals	*E. fulvus*	U.S. Virgin Islands
	E. guttatus	U.S. Virgin Islands, Jamaica
	E. striatus	Puerto Rico, Jamaica
	Grouper species *	Bermuda, Southeastern United States
Loss of, decline in, or other change in spawning aggregations	*E. striatus*	U.S. Virgin Islands, Belize, Caymans, Bermuda, Dominican Republic, Puerto Rico, Mexico
	E. guttatus	U.S. Virgin Islands, Bermuda, Puerto Rico
	M. microlepis *M. phenax*	Southeastern United States
Overfished stocks as indicated by stock assessment ***	*E. guttatus*	U.S. Virgin Islands, Puerto Rico
	E. striatus	U.S. Virgin Islands
	Grouper species *	Southeastern United States

* see text for details
** includes Atlantic and Gulf of Mexico

of consistently diminishing landings likely also reflects a decrease in CPUE. Particularly alarming have been the declines in landings of Nassau grouper in Puerto Rico and the U. S. Virgin Islands. In Puerto Rico, this species was once one of those most frequently landed (Suárez-Caabro, 1970), "A common and very important food-fish, reaching a weight of 50 pounds or more" (Evermann, 1900). Now it is essentially extinct for fisheries purposes (Bohnsack *et al.*, 1986). In Martinique, as in much of the Lesser Antilles, grouper comprise less than 10% of the demersal catch with three smaller species dominating: the coney, *E. fulvus*, the red hind, and the mutton hamlet, *Alphestes afer*. Species-specific trends in CPUE by depth across the island platform indicate that grouper biomass is severely reduced on the shelf (Gobert, 1994). In Jamaica, Munro (1983) reported that the mean catch rate of red hind in exploited areas was significantly less than that of unexploited areas. In general, grouper are found to contribute relatively less to landings in areas that are heavily exploited than in those which are lightly exploited (Appeldoorn *et al.*, 1987).

For a number of species taken off eastern and southern Florida and the states of North and South Carolina, United States, catch by weight and by number, as well as CPUE, declined during the 1970's and 1980's. The most affected species have been the Nassau, black, snowy, and warsaw (*E. nigritus*) groupers, and the speckled hind, as well as the red grouper in southern Florida. Data indicate that scamp, *M. phenax*, and gag, speckled hind, *E. drummondhayi*, and snowy grouper, *E. niveatus*, can quickly become depleted by heavy unregulated fishing activity (Huntsman and Dixon, 1975; Moore and Labisky, 1984; Bohnsack, unpubl. ms.; Plan Development Team - National Marine Fisheries Service (NMFS) Beaufort, North Carolina - Report, South Atlantic Reef Fish Snapper-Grouper Assessment (SARSGA), October, 1990).

The most seriously impacted species appears to be the jewfish, which in southeastern United States is heavily overfished. Evidence of overfishing in both recreational and commercial sectors include comments from divers and dive boat operators who report declining numbers (Amendment 2 February, 1990, Fisheries Managment Plan for Reef Fish of the Gulf of Mexico Fisheries Management Council (FMP-GMFMC), 1981).

These data consistently indicate that rapid, heavy declines have occurred in landings and CPUE for many, if not most, grouper species following unregulated exploitation of stocks, assuming that landings trends reflect population levels.

b. Catch Composition

Grouper exhibit another classic fisheries response to heavy fishing pressure; a change in catch composition from larger to smaller individuals and/or species over time. Catch composition data indicate that over the last 13 years the proportion of the total reported landings (in pounds) from the commercial

fishery of Puerto Rico (all reef fish included) comprising grouper species has dropped from 16% to 7% (1977-1989) (unpubl. data. FRL-CODREMAR-DNR; Matos and Sadovy, 1990). A similar decline (48% to 19%) over a 14-year period (1975-1989) was reported from Bermuda.

Grouper landings in Bermuda have exhibited a marked differential loss (by weight) of some of the larger species, such as the Nassau grouper (16% - <1%), and gag (14% - 2%), moderate losses of hinds (34% - 21%), a relative increase in the percentage of smaller grouper being taken, such as the coney and barber (4% - 52%) (Report of the Commission of Inquiry, Bermuda, 1991). Smith (1971) reported that the small size of the red hind rendered it of minor commercial importance in Bermuda prior to the 1970's, but that its abundance made it useful as bait for larger species; it is many years since the red hind was taken solely for bait in Bermuda. Grouper species that were once common in the markets of Jamaica are now rare (Milton Haughton, Jamaica, pers. comm.). In southeastern United States shifts in catch composition to less desirable species in both commercial and recreational fisheries, especially loss of the largest predators, have been noted (SARSGA, 1990). Since grouper species are among the largest of the multispecies fishery components, it is not surprising that they are among the first to be affected by fishing activity.

Overall, data indicate declines in both absolute and relative terms of exploited grouper species, with a shift in the proportion of grouper landed from predominantly larger to predominantly smaller individuals and species over time.

c. Trends in Size

Fishing activity tends to select for larger/heavier individuals of a species. For this reason changes in mean fish size over time can provide indications of species' responses to exploitation.

Analysis of size-frequency data of the red hind from St. Thomas indicates a gradual, but consistent, decline in mean size between 1984 and 1988 with a complete loss of the largest size classes over this period (Bohnsack *et al.*, 1986; Beets and Friedlander, 1992). A similar progressive decline in size was recorded for the coney in St. Croix between 1984 and 1989 (Beets and Friedlander, 1994). In Jamaica, differential loss of larger red hind and Nassau grouper were noted from more heavily exploited areas (Munro, 1983). Over the last decade, commercial samples of the once abundant Nassau grouper from Puerto Rico have been scarce and have consistently fallen almost exclusively within the immature size range (*i.e.*, < 450 mm standard length) (unpubl. data FRL-CODREMAR-DNR).

Analysis of weight data from the 1970's and into the 1980's from Florida and the Carolinas show a progressive decline in mean weight for most species in both headboat (boats that charge on a per person, or per 'head', basis) and

commercial fisheries of gag, scamp, warsaw, and snowy groupers and in the speckled hind. Data on gag from the Carolina headboat fishery recorded that, while in 1973 virtually no fish were less than 800 mm in total length, by 1988, 97% of fish taken were less than this in size (SARSGA, 1990).

d. Spawning Aggregations

Species which assemble in large numbers to spawn at known times and locations are particularly vulnerable to heavy fishing activity. Several grouper species in the region are known to aggregate for spawning. Such aggregations have been reported for the Nassau grouper, the red hind, and the yellowfin grouper (Smith, 1972; Burnett-Herkes, 1975; Olsen and LaPlace, 1979; Colin *et al.*, 1987; Carter, 1988; Beets and Friedlander, 1992; Colin, in press). One has recently been reported for the tiger grouper in eastern Puerto Rico, and aggregating behavior appears likely for the gag and scamp (Gilmore,1994), as well as for the black grouper (Carter *et al.*, 1994). Reports from heavily fished aggregations indicate declining catches, and, in some cases, declining mean sizes and progressively female-biased sex ratios over time (Carter *et al.*, 1994; Beets and Friedlander, 1992; Sadovy, Rosario and Roman unpubl. data; Grant Gilmore, pers. comm.; Jack Ward, pers. comm.). Whether these changes result directly from fishing pressure on the aggregations, or simply reflect pressure on stocks in the area throughout the year, or perhaps some combination, is not known. However, Carter *et al.* , (1994) showed that an exploited aggregation in Belize yielded smaller individuals than either an unexploited aggregation or an exploited population during the non-reproductive period.

Particularly hard hit have been the Nassau grouper aggregations. Several, with a history of heavy fishing in Puerto Rico and St. Thomas (Olsen and LaPlace, 1979; Carlos Cumpiano, CODREMAR, pers. comm.; Beets and Friedlander, 1992), have now completely disappeared, at least from their original locations. It is not known whether disturbed aggregations develop elsewhere de novo, although this has never been reported. Catches from long-fished spawning aggregations in the Cayman Islands and in Belize have exhibited particularly marked declines during the 1980's (Carter *et al.*,1994; Bush and Ebanks-Petrie, 1994). Reduced catches from grouper aggregations in the Dominican Republic led, recently, to protection of spawning Serranidae on the north coast, and prohibition of fishing at spawning sites (Colin, 1988).

In Mexico, an aggregation at Mahahual was fished by hook and line since the 1950's but numbers apparently declined sharply following introduction, in the late 1960's, of spearguns (Aguilar-Perera and Sosa-Cordero, 1994). The use of spearguns on aggregating grouper appears to be a very efficient technique. For example, many thousands of pounds of tiger grouper were reported taken by a couple of divers on just one day of an aggregation lying in about 120 ft of

water off Puerto Rico (Ishmael Rivas, pers. comm.); tiger grouper may be particularly susceptible to spear fishing because of their curiosity toward divers (Appeldoorn *et al.*, 1987).

e. Stock Assessment

Assessment of stock status at current levels of fishing mortality, and age, or size, at which individuals of a species enter (recruit into) the fishery, have been predominantly made using yield-per-recruit (Y/R) (Beverton and Holt, 1957), and spawning-stock-biomass-per-recruit (SSB/R) (Goodyear, 1989) models. These models enable the fishery manager to establish what would happen to stock yield (*i.e.*, catch), or spawning stock biomass (*i.e.* , reproductive potential of a stock), at different levels of fishing mortality (death in fish stock caused by fishing), or at different sizes of recruitment into the fishery.

The models allow fisheries managers to establish the recruitment age (and hence size) and level of fishing mortality likely to produce the theoretical maximum sustainable yield (the largest average catch, or yield, that can continuously be taken from a stock under existing environmental conditions) of the stock. If fishing mortality is greater than this theoretical level, or fish enter the fishery at too small a size, then yield will decline and overfishing will occur.

Overfishing may take one of two basic forms. Growth overfishing occurs when fish are caught before they have had an adequate chance to grow. More severe is recruitment overfishing, when fishing reduces adult numbers to a level which greatly decreases egg production and hence increases the chance for recruitment failure (*i.e.*, not enough juveniles will be produced to replace the adult population (Plan Development Team (PDT), 1990)).

In the Caribbean, a recent yield-per-recruit analysis of red hind from western Puerto Rico and St. Thomas showed that, in both cases, stocks are growth overfished (Sadovy and Figuerola, 1992). By the late 1970's, Nassau grouper were found to be likely overfished in the U. S. Virgin Islands, and underexploited off northwestern Cuba (Baisre and Páez, 1981).

From the eastern Gulf of Mexico, Moe (1969) reported declining stocks of red grouper between 1965 and 1968 following 15 years of fluctuating or increasing catch, and expressed concern that management would be necessary if yield continued to decline despite increasing fishing effort (see also analyses by Blanco *et al.*, 1980; Contreras *et al.*, 1994 and Burton, 1994 on red grouper).

For gag, scamp, snowy, and black groupers, and the speckled hind, in southeastern United States, stock assessments conducted in the early 1980's showed that if the age (and hence size) at which individuals first enter the fishery (recruitment age) could be kept moderately elevated, then yield-per-recruit would stay high regardless of how great fishing mortality should become (Huntsman *et al.*, 1983; Matheson and Huntsman, 1984; Manooch and Mason, 1987). However, age (and size) of recruitment has not

remained high and stocks have rapidly declined. For gag, speckled hind, and snowy grouper, for example, mean size captured in 1985 equalled the minimum size considered necessary to produce a reasonable yield-per-recruit (Huntsman and Willis, 1989; SARSGA, 1990).

Recent assessments of red grouper and jewfish from the Gulf of Mexico indicate that spawning stock biomass per recruit for both species may be below the theoretical minimum necessary for maintaining stocks (Goodyear 1988; Amendments 1 and 2, 1990, FMP-GMFMC, 1981). Similar stock assessments of speckled hind, gag, scamp, snowy, black, red and Warsaw groupers from the south Atlantic indicate that some stocks, especially Warsaw grouper, are also recruitment overfished (SARSGA, 1990; Huntsman *et al.*, 1994).

With few exceptions, therefore, stock assessments indicate that both growth and/or recruitment overfishing is occurring for many species at a number of locations. This is, in part, because age (or size) of recruitment into the fishery has not been kept sufficiently high to manage yield appropriately under the conditions of the fishery or insufficient adults remain to replenish stocks. Management measures need to be effected, improved or enforced, depending on location, to regulate fishing mortality, or size of recruitment into the fishery.

DATA NEEDS

Stock monitoring and effective management are impossible without knowledge of the biology, status, and exploitation levels of the species to be managed, as well as the socio-economics of resource users. Significant gaps in our knowledge of grouper biology, stock characteristics, and exploitation levels undermine stock monitoring and management. More attention must be given to the following five areas:

a. Landings, CPUE, Catch Composition and Size Frequencies of Exploited Stocks The recording of landings, fishing effort (the total fishing gear in use for a specified period of time) catch composition, and individual size and weight data, on a long-term basis, is necessary for any fishery monitoring program. While these data are essentially simple to collect, care is needed to ensure that they are adequately and consistently recorded, and are appropriate for stock monitoring and management. For example, effort and size frequency data should specify gear type, including mesh size for traps or nets, because of the influence of gear on the data collected (see Munro, 1983). Units of fishing effort should be specified (*e.g.*, catch per trap haul, per hook hour, per fishing trip, etc), as should the sector of the fishery being monitored *i.e.*, commercial or recreational. When catch composition is recorded, any data biases should be noted, such as the possible undersampling of small individuals which may have been discarded prior to landing. When subsamples are taken from complete catches, it should be

determined whether large, small, or rare species tend to be preferentially measured (Bohnsack *et al.*, 1986), and whether subsamples are taken randomly. Furthermore, data collection should aim to sample all principal gears used (for grouper these would be hook and line, fish trap, and speargun), ideally for all seasons, and in all principal fishing areas; modifications in gear use not only influence the nature of the data collected, they also reflect user response to changes in the condition of a fishery.

Data collection should incorporate lengths and weights (units of length and weight - whole or gutted - and precision of measurement should be specified), and length-weight and length-length (*i.e.*, standard length to fork length/total length) relationships should be established. This enables comparison between data sets which have been collected in different ways. Data on size distribution by sex should also be collected whenever possible, although for grouper this may be difficult using gross inspection of gonads outside the spawning season. However, if examined carefully, ripe individuals taken at spawning aggregations may be sexed.

Collection of data on lengths, weights, and sex of ripe individuals does not require sophisticated equipment or extensive training of personnel. Nonetheless, if standardized and well documented, such information provides an essential database which may be used for comparative purposes both over time and between geographic locations. Because many stocks are likely shared by many of the nations of the western central Atlantic (Mahon, 1987), standardized and compatible data collection programs over as wide a geographic area as possible would greatly assist our understanding of stocks on a regionwide basis.

b. Reproduction

A better understanding of grouper reproductive biology would greatly facilitate stock management. In particular, among those species that assemble to reproduce, we need to know whether most annual reproduction occurs exclusively at the spawning aggregations. If so, and there is no evidence to the contrary, then the limited number of known aggregation sites that have been identified (Colin *et al.*, 1987; Beets and Friedlander, 1992; Sadovy *et al.*, in press) suggest that these aggregations are of critical importance to stocks in much of the region. Moreover, since individuals of a number of species are known, from mark-recapture studies, to be able to move over considerable distances, it is not unlikely that each aggregation site services individuals from extensive areas. For example, red hind may move at least 18 km, through water of at least 194 m to reach an offshore bank in western Puerto Rico (Sadovy, Figuerola and Roman, submitted ms.). Individual Nassau grouper have been reported to travel as far as 110 km (Colin, in press) to a spawning site in the Bahamas, and an individual Nassau grouper was recorded to move a distance of

240 km between spawning areas in Belize waters (Carter *et al.*, 1994). An individual gag was found to have moved 621 km, during a possible spawning migration, off southeastern United States (van Sant *et al.*, 1994). We need to know the geographic locations and durations of significant aggregations. For example, despite the presence of exploitable stocks of red hind in the islands of the Lesser Antilles, no aggregations are known for this species in much of the eastern Caribbean. Duration of spawning activity each year may be extremely brief. In the red hind, for example, all annual spawning activity at two spawning locations in Puerto Rico, in different years, was recorded to occur over no more than two weeks (Sadovy *et al.*, in press; Sadovy, Rosario and Roman, unpubl. data). Given the apparent importance of spawning aggregations, we need to know how aggregation fishing is likely to affect courtship or spawning behavior (see also discussion in symposium summary). Data recorded from aggregation sites need to be specific regarding date, location, and fishing gear, and should be collected on a long-term basis.

Relatively little is known for many species concerning the minimum size of sexual maturation relative to size of entry into the fishery. This information is necessary to determine the proportion of the catch which is composed of juveniles. If this proportion is too high, then management measures must aim to reduce it. Information is also needed on the relationship between fecundity and body size, the male to female sex ratio, and on the size of sex change, if this occurs. Sex change has been confirmed for less than half of the groupers of Table 1, and certainly not all grouper are exclusively hermaphroditic (Sadovy and Colin, 1990). Mode of reproduction (*i.e.*, hermaphroditism versus gonochorism) (Sadovy and Shapiro, 1987) must be established to determine the possible impact on stocks of fishing activity (Bannerot *et al.*, 1987), as well as their response to management measures. For example, fishing activity can result in a reduction of mean individual size, thus reducing the number of males, since males are generally larger than females in protogynous species. If male availability is a limiting factor for successful reproduction, and if sex change is controlled by age (or size) rather than by some socially-mediated factor, then a heavily fished stock may not be able to compensate for the differential removal of the larger males. If, on the other hand, sex change is behaviorally induced, then a decline in males may be compensated for by increased numbers of females changing sex. However, this could result in a decline in mean female size leading to a reduction in stock egg production. Until more is known of reproductive dynamics, the response of grouper populations to exploitation and management cannot be fully evaluated.

c. Recruitment

It is not known to what extent grouper recruit (in this context "recruitment" refers to the settlement of planktonic larvae onto the substrate) locally or from

larvae originating from up-stream and/or off-island locations. This information is essential for establishing the necessary geographic extent of monitoring and management initiatives. The fact that some grouper spawn in large concentrations and are known to be able to migrate over substantial distances to reach aggregation sites, indicates that adults move across international boundaries where platforms are shared by more than one nation. This latter has obvious management implications.

Assuming a larval life of between 3 weeks and 2 months (Colin *et al.*, 1987) for grouper species, spawning aggregations in one location may well supply recruits well downstream, on different geological platforms, depending on prevailing currents. Colin *et al.* (1987) for example, proposed that, given the current patterns off southwestern Puerto Rico and in the western Caribbean, larvae from spawning areas in this location could potentially reach at least to Hispaniola, Jamaica, Cuba, Turks and Caicos Islands, and the southeastern Bahamas. However, on the Puerto Rico and Virgin Island geological platform area, anecdotal information suggests the likelihood that local recruitment is of some importance: there appears to be an association between local declines in catches of the Nassau grouper over this platform and loss of local spawning aggregations; the losses of both being most marked for Puerto Rico to the west, and least for the British Virgin Islands to the east (pers. obs.). It has been suggested for gag off southeastern United States, that a single stock may be involved, indicating the need for a uniform monitoring and management strategy in that area (van Sant *et al.*, 1994). Powles (1977) hypothesized that grouper might be recruited to southeastern United States from the Gulf of Mexico. It is thus important for stock management to establish the extent to which local stocks are self-recruiting, and to what extent they depend on larvae generated at aggregation sites upstream. Collection of landings and other data in a standardized and co-ordinated manner throughout the region, combined with genetic studies to distinguish different populations, would be needed to address some of these important issues (Appeldoorn *et al.*, 1987).

Little is known of the characteristics of critical juvenile habitat for the majority of grouper species, nor of their principal settlement periods. Juvenile Nassau grouper are reported from grass beds, jewfish from mangrove areas, red hind from shallow rocky, rubble and sandy areas (pers. obs.), and gag from estuarine areas (Mullaney,1994.). Hence, juveniles of several species depend on shallow, nearshore habitats which are those most susceptible to coastal human activity. Nonetheless, for many species, little or nothing is known of juvenile habitats. If critical juvenile habitat is being impacted then management of adults may be of little consequence for the condition of local stocks.

d. Stock Assessment

Biological data on exploited stocks are necessary to determine growth,

longevity, mortality, and other parameters used in formal stock assessment. Unfortunately, these data are difficult and/or extremely expensive to collect, especially on a regular basis, and, for many small, understaffed, and underfunded fisheries divisions, may be impossible to obtain.

For these reasons, small fisheries divisions may have to rely, at least partly, on population parameters established elsewhere and corrected for local conditions, rely on relatively simple methods for stock assessment (Pauly, 1980), or use appropriate length data in length-frequency analyses (the use of data on fish lengths to determine growth parameters) such as ELEFAN (Pauly, 1987) to produce the necessary information (Caddy, 1986; Beets *et al.*, 1994). However, for the larger, slow-growing, long-lived species of grouper, the use of length-frequency techniques may be limited because of considerable size variation at different ages. Finally, it needs to be established whether standard stock assessment models, originally developed for temperate, gonochore, species, can be effectively applied to tropical, hermaphroditic species. For example, adult sex ratios are assumed to be 1:1 for spawning stock biomass per recruit analysis. This ratio may not apply to species of grouper that transform from female to male during their lifetime because of the frequent female bias to the sex ratio (Goodyear, 1989). Yield-per-recruit models deal with sexes-lumped data; the impact of sex-specific differences in age and size distributions, associated with sex change, on the estimation of the population parameters used in these models, has yet to be evaluated (Sadovy and Figuerola, 1992).

e. Socio-economic Factors

A knowledge of local social and economic factors associated with the fishery would assist assessment of the possible impact of management options on the different resource user groups. It would also facilitate the improvement of data collection program design.

MANAGEMENT AND CURRENT MANAGEMENT MEASURES

By November 1990, four classes of management measures were in effect specifically to manage grouper stocks in the region: minimum size (weight or length), protection of spawning aggregations, quota/bag limits, total harvest ban (Table 3). These measures are summarized below. Not included are broader measures, such as marine reserves or prohibition of spearguns or traps, which would also impact these stocks, nor included are a number of harsher measures presently under consideration in Amendment 4 of the South Atlantic Fisheries Management Council (SAFMC News Release, Nov. 7, 1990).

a. Minimum Size of Capture

The most widespread management measure currently utilized is minimum capture size (for grouper this ranges from 12" and 20" TL, depending on species

Table 3. Management measures in effect November 1990, by species and location.

SPECIES	LOCATION	MANAGEMENT MEASURE* 1	2	3	4
E. striatus	U.S. Virgin Islands	Xf			
	Puerto Rico	Xf			
E. guttatus	U.S. Virgin Islands		Xf		
E. striatus	Dominican Republic		X		
E. striatus	Cayman Islands		X		
E. striatus / *M. venenosa*	Bahamas	X			
Grouper species **	Bermuda	X		X	
E. guttatus	Bermuda		X		
E. itajara	Florida				Xf_{SA}^{s}
E. itajara	Florida				Xf
Grouper species **	Florida	Xf_{SA}^{s}		Xs	
Grouper species **	Gulf of Mexico	Xf_{GU}		Xf_{GU}	

* 1 = minimum size; 2 = protection of spawning aggregations; 3 = quota/bag limits; 4 = total harvest ban
f = federal; SA = South Atlantic Fishery Management Council; s = state waters (regulations for Gulf states water not included

** see text or references cited for details

and jurisdiction; minimum weight of 3 lbs. for the yellowfin and Nassau groupers in the Bahamas) (Amendments 1 and 2, 1990, FMP-GMFMC, 1981; Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region, 1983 and its Amendment 2, 1990; Florida State Law; Luckhurst, 1990). The effectiveness of minimum size restrictions depends on two critical factors; adherence to the law and survivorship of released, undersized, individuals (Waters and Huntsman, 1986), the latter a variable yet to be fully evaluated; survivorship is generally believed to be low for released grouper species, in particular for those taken from deep water which exhibit pronounced stomach eversion on surfacing. Imperfect survival of released fish reduces the expected increase in yield-per-recruit resulting from size limit regulations. Moreover, the effectiveness of minimum size limits for protogynous (female to male sex changing) species under conditions of high fishing mortality are not known (Huntsman and Waters, 1987).

Recent evaluation of the impact of minimum size regulations implemented in the early 1980's, in Florida, indicated that there was little obvious increase in sizes recorded from subsequent landings of Nassau and black grouper (Bohnsack, unpubl. ms.). Whether this is due to lack of compliance to, or enforcement of, the law, or the inappropriateness of minimum size limits for grouper management is not known.

b. Protection of Spawning Aggregations

Seasonal and/or areal closures are designed to protect stocks which may be particularly vulnerable to fishing pressure at specific times and/or locations, such as during spawning periods. Such closures also reduce fishing mortality on the spawning stock.

Aggregations in Bermuda and in the Dominican Republic are protected from all fishing activity. In the Cayman Islands, aggregation fishing is permitted but access is restricted to local residents and hook and line fishing. In St. Thomas, U. S. Virgin Islands, no fishing at all is permitted over the three month period identified as the red hind spawning season (Dec. 1 - Feb. 28) at a location lying in federal waters south of the island. A similar measure has been proposed for a red hind spawning area in federal waters off western Puerto Rico (Sadovy, Rosario and Roman, unpubl. data).

There is much support, from both theoretical and practical standpoints, for the protection of aggregations (Bohnsack, 1989; Beets and Friedlander, 1992; Sadovy and Figuerola, 1992). However, the extent to which protection of aggregations, in the absence of additional management measures, is likely to protect the spawning stock cannot yet be fully evaluated.

c. Catch Quotas

Establishment of catch quotas requires sound knowledge of fishing effort and catch and of mortality rates of released individuals. This information is

often difficult to obtain, and limits hence difficult to establish, monitor, and enforce. Bag limits have been implemented in Bermuda and in some U. S. mainland waters for a number of recreational and commercial fishery species. The effectiveness of bag limits for the management of grouper is not known.

d. Total Harvest Ban

This measure aims to protect individual species believed to be severely overfished. A total ban on harvest has been implemented for only one species, the jewfish, in U. S. federal waters of the Gulf and South Atlantic, and in Florida state waters. This measure has also been proposed for a number of other species (speckled hind, warsaw, Nassau, snowy, misty, and yellowedge groupers) in southeastern United States, as a result of recent stock analyses (SAFMC News Release - Nov. 7, 1990).

SUMMARY

Information on the status of grouper stocks in the tropical western Atlantic provides undeniable testimony of the vulnerability of grouper species to anything but low levels of fishing effort, in the absence of regulation. For almost all stocks assessed, there have been sharp declines in mean size and weight, reduced landings and CPUE, and loss of, or alarming reductions in, spawning aggregations, all classic indications of overfishing. Hence, many stocks in both continental and island areas are growth and/or recruitment overfished. More stringent management measures, and their enforcement, are badly needed. At the very least, spawning aggregations should be protected, monitoring programs implemented or refined, and management options evaluated. Some species have been more heavily impacted than others. Nassau grouper, for example, have shown particularly dramatic declines in both mainland United States and island areas, and many spawning aggregations have been so badly depleted that the species may be considered extinct for fisheries purposes in a number of locations. The largest of the grouper species, the warsaw grouper and jewfish, have also been heavily impacted, and have declined markedly off mainland United States. As larger grouper have disappeared from landings, smaller individuals and species have come to comprise an increasingly greater proportion of the catch.

Considerable data are required to better understand and manage grouper stocks. Data collection programs necessary to monitor these resources must be long-term and well-planned, and should be standardized over as wide a geographic area as possible because of the possibility of shared stocks over extensive regions. Socio-economic data also need to be collected to determine the possible impact of management measures on various resource user groups. A number of biological questions, particularly those regarding recruitment and reproduction, need to be addressed. Much of this information is relatively simple to collect, with the appropriate planning and training of personnel.

Nonetheless, many island nations of the Caribbean are extremely limited in their capacity to evaluate and research their own resources, having to deal with considerable shortages of funding and personnel, combined with the intrinsic difficulties of monitoring artisanal fisheries. Moreover, the low natural productivity of the island platform areas and the relatively limited economic value of individual components of multispecies fisheries, result in low priority for fisheries funding, little or no law enforcement, and little interest from local legislators (Kimmel and Appeldoorn, in press). Many nations do not even have a national policy regarding their fishery stocks, which frustrates attempts to assign priorities to resource use and management.

One option for the protection of grouper, in particular, and reef stocks, in general, may be marine fishery reserves (areas set aside for no consumptive usage) (PDT, 1990). Carefully located, such reserves would, among other things, serve to protect spawning stock biomass and recruitment, maintain population age structure and the balance of natural communities, insure against growth overfishing and management failure, and provide undisturbed underwater park areas for public enjoyment (PDT, 1990), of particular importance for tourism development. Indeed, marine fishery reserves may be the only realistic solution to managing multispecies fisheries, given the lack of enforcement and the limitations of stock monitoring, assessment and management capabilities regionwide. Another option to be explored is mariculture (Tucker, 1994). While only in the very earliest stages of development, concerning the technical details of grouper culture, mariculture holds some promise for the future. It will not, however, substitute for stock management if we wish to continue exploiting natural populations.

Finally, while the focus of this paper has been grouper, many of the comments concerning use and management of fisheries resources apply to other components of the fishery. There clearly and urgently needs to be a change in perception regarding the exploitation of marine resources. Management must to be seen to be an integral component of sustainable resource use. Communication between fisheries officers and those in government responsible for caretaking public resources must improve. There is now no longer any excuse for proposing or promoting the development of marine fisheries resources without a scientific database on which such development must be founded. The lessons learned from past failures following poorly-planned attempts to "develop" must not be forgotten.

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Aspects of the Ecology and Reproduction of Nassau Grouper, *Epinephelus striatus*, Off the Coast of Belize, Central America

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ABSTRACT

Aspects of the life history of Nassau grouper, *Epinephelus striatus*, from Belize in the western Caribbean are described, including food habits, movements, protogyny, sexual maturation, seasonality, periodicity of spawning, fecundity, and population sex ratios. Additional information is provided on the potential effect overfishing spawning aggregations has on future reproductive potential of the population.

Gonad structure and ontogenetic development patterns are described and evidence for sex—reversal is given. Seasonal variation in the percentage of sexually active fishes indicate the majority of fishes aggregated and spawned along the shelf edge at the reef promontories around the full moon in December and January. A comparison of sex ratios and length frequency distribution among three sites indicates that there is a marked increase in the number of females relative to males at heavily fished sites, as well as a significant decrease in the size of both sexes relative to the general population outside of the spawning banks and at pristine spawning aggregation sites.

Spawning of Nassau grouper is discussed in relationship to environmental conditions (*e.g.*, reef geomorphology, temperature, photoperiod, current, etc.). Finally food habits of Nassau grouper are described and related to foraging strategy and daily patterns of movement.

KEYWORDS: Belize, ecology, protogyny, reefs, reproduction, serranidae, Nassau grouper.

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CONTENTS

SECTION A: PEER REVIEWED PAPERS

GULF AND CARIBBEAN FISHERIES – GENERAL

STOCK ASSESSMENTS AND TROPHIC STUDIES

SYMPOSIUM ON THE BIOLOGY AND MANAGEMENT OF GULF AND CARIBBEAN GROUPERS