The Case of the Disappearing Grouper: *Epinephelus striatus*, the Nassau Grouper, in the Caribbean and Western Atlantic

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ABSTRACT

The Nassau grouper, *Epinephelus striatus*, was once a species of considerable commercial significance in the Caribbean and western Atlantic. Over the last two decades, however, annual landings have declined sharply in many areas, and the species is now effectively extinct commercially in Bermuda, Puerto Rico, and the U. S. Virgin Islands. Of particular concern are the declines in, or losses of, fully one fifth of spawning aggregations. Because these likely represent the total yearly reproductive output of participating individuals, their disappearance or disturbance will inevitably influence future recruitment and fishery yield. The apparent vulnerability of this species to heavy exploitation is believed to result from a combination of its biology (*i.e.*, long life, slow growth, etc.), large size of sexual maturation relative to other components of multispecies fisheries, its aggregating habit and its susceptibility to fish traps and the speargun. Recommendations are made for the protection of spawning biomass through the management of aggregations, and for reducing growth overfishing through the introduction of marine reserves. Biological and fishery information necessary to monitor, manage and restore stocks is identified.

KEY WORDS: Nassau grouper, fisheries management.

INTRODUCTION

The Nassau grouper, *Epinephelus striatus*, is distributed throughout the islands of the western Atlantic, including Bermuda, in southern Florida and along the coasts of central and northern South America (Smith, 1971). Adults are reef dwellers and the young are common in shallow seagrass beds. Individuals live for 20 years, attaining sexual maturity at approximately 500 mm FL (1.87 kg) and more than five years of age (Claro *et al.*, 1990; Sadovy and Colin, unpubl. ms; Bush, pers. comm.). The Nassau grouper typically spawn in large aggregations over one to two weeks each year, during December and January in the the Caribbean, and during summer months in Bermuda. Aggregation sites are generally consistent in location from year to year, and are characteristically found in the vicinity of the shelf break (Burnett-Herkes, 1975;

Colin *et al.*, 1987; Colin, 1992). Spawning outside of the aggregation has not been recorded. The sexual pattern of this species has yet to be confirmed although, unlike its western Atlantic congeners, sexual development clearly involves males which develop directly from a juvenile bisexual phase and do not derive from adult females by sex change (Sadovy and Colin, unpubl. ms.).

The Nassau grouper is the most important commercial grouper in the islands of the region (Fisher, 1978; Randall, 1983; Appeldoorn *et al.*, 1987). In some areas it is also recreationally significant. This species is probably best known for the formation of spectacular spawning aggregations, numbering many thousands, or tens of thousands of individuals. In 1992, a mere 20 years after the first account of an aggregation located in Bimini, Bahamas (Smith, 1972), the Nassau grouper has the dubious distinction of being a candidate for the United States Endangered Species List, and is also being considered for protected species status in Bermuda.

Declines in commercial and recreational catches, as well as in landings from aggregations, raise concerns that the Nassau grouper could become locally or commercially extinct in the western Atlantic. The aim of this paper was to assemble information and anecdotal accounts to document trends in landings and to focus attention on the need to manage this species. I explore the factors that may be responsible for the declines noted, discuss monitoring and research needs, and identify management options.

METHODS

I reviewed scientific literature and recreational and commercial landings information, examined size-frequency data, and summarized management measures in effect. Fish size is presented as mm Fork Length (= Total Length). Where conversion from Standard Length (SL) to Fork Length (FL) was necessary, I used the equation: FL = 28.11 + 1.23 SL (Sadovy and Colin, unpubl. ms). Anecdotal information solicited from fishermen, biologists, and resource managers was particularly important for providing a perspective on years preceding the initiation of monitoring programs.

RESULTS

On-going data collection programs generally began in the 1970's, with the exception of Cuba which has landings records from 1959. Information from aggregation landings has been sporadically collected through short-term studies or surveys, or is anecdotal. Results are presented alphabetically by country.

Bahamas

Long-term commercial or recreational data on Nassau grouper landings were unavailable although landings of combined grouper species were initiated in the 1970's and the Nassau grouper is the principal grouper species taken

(presently about 70% of the grouper catch; Ronald Thompson, pers. comm.). At least twenty traditional spawning areas are currently fished in the Bahamas, although data on the history and current condition of most were not available (Dept. of Fisheries, Bahamas Government - DFBG). Aggregations are typically fished by handline and trap, with spear guns more frequently used in recent years resulting in user conflicts (DFBG).

The first published *in situ* observation of mass spawning in Nassau grouper identified an aggregation of possibly 100,000 individuals at Cat Cay in Bimini, with reported catches on the order of 35,000 to 40,000 fish during 1970 (Smith, 1972). An aggregation still forms intermittently (*i.e.,* not every year) in the Bimini area although no recent information regarding its size or production was available (Charlie Weech, pers. comm.). Another site off eastern Andros Island, has been exploited since the 1960s and is heavily fished today with hookah, traps, handlines and spears (Brian Kaykuk, pers. comm.). At Long Island fish traps are used by a small number of local fishermen to collect grouper. At one site in southern Long Island, known to local fishermen since before 1900, catches have declined in recent years from several thousand to less than 100 fish. It was estimated that during the winter season of 1988-89 almost every *E. striatus* appearing at one site (about 100 fish) was eventually taken by fishermen (Colin, 1992). Aggregation sites reported in the Bahamas are located at Cat Island (1), the Berry Islands (4), Bimini (1), Andros (5), New Providence (1), Ragged Island (1), Cay Sal (1), Exuma (1), Eleuthera (4), Long Island (3), and Ackins (1) (DFBG).

Nassau grouper stocks are believed to be in good condition in the Bahamas (Ronald Thompson, pers. comm.). Approximately 40% of the total annual grouper landings for 1991 (total = 400,000 kg) were taken during aggregation months (December, January and February) indicating the significance of aggregation fishing for annual landings (DFBG). Minimum size regulations prohibit the taking of undersize (<1.36 kg - 3 lbs.) Nassau grouper.

Belize

No published long-term data on commercial landings were available for review, although *E. striatus* is the principal grouper species landed. It is the most valuable finfish in Belize, comprising >30% of annual marine finfish landings. Between 1984 and 1991, landings of this species dropped from 90,900 to 21,000 kg (Stephanie Auil, pers. comm.). Most annual landings come from aggregations. Until 1986 the handline was the principal fishing gear and in recent years antillean fish traps have been introduced (Stephanie Auil, pers. comm.).

At least six spawning sites are known (Carter, 1989; Carter *et al.*, 1994). One large aggregation at Cay Glory has been fished since the 1920's. By the 1950's activity at this site had intensified with 600 fishermen landing

>45,500 kg annually. The aggregation was termed "astonishing" in terms of number of fishes in a 1966 publication (Craig, 1966). By 1986, however, only a few dozen fishermen visited this bank landing 13,600 kg (Carter, 1986). Other aggregations have also been heavily fished. One site at Rocky Point, Ambergris Cay, was fished intensively by local fishermen. In the third year following its discovery, the fish failed to group and no aggregation has been located since within 30 miles of this area (Carter, 1989). The mean length of fish from the heavily exploited Cay Glory site was about 500 mm FL in 1984-6, and the sex ratio was notably female-biased. On the other hand, from a relatively unexploited site, Lighthouse reef atoll, discovered about a decade ago, mean fish size was larger at 615 mm FL and the sex ratio was closer to unity (Carter *et al.*, 1994). These authors suggested that heavy fishing on aggregations may reduce mean fish size and cause differential loss of males and management of this species is being recommemded.

Bermuda

Commercial grouper landings have declined in Bermuda according to records available since 1975 and despite an increase in effort over this period (Bannerot *et al.*, 1987). While all groupers have been affected, among those most severely reduced has been the Nassau grouper. Landings of this species declined from 29,100 kg in 1975 to approximately 1,800 kg in 1981, and from 16% of total grouper (all species) catch, by weight, in 1975 to <1% in 1989 (Bannerot *et al.*, 1987; Report of the Commission of Inquiry, Bermuda, 1991).

Commercial fishermen exploited concentrations of *E. striatus* in Bermuda for generations (Burnett-Herkes, 1975). Aggregations were known from the Challenger and Argus (=Plantagenet) banks. Three sites were fished until the mid-1970s (Burnett-Herkes, 1975) although no aggregations are known to have formed for at least a decade (Jack Ward, pers. comm.). Mean size sampled at offshore banks in the mid 1950s was approximately 620 mm FL (Bardach *et al.*, 1958) with considerably smaller individuals inshore. In recent years, only occasional juvenile Nassau have been seen inshore (Jack Ward, pers. comm.). Concern for the condition of this species has resulted in its evaluation for possible protected species status. Bag limits and minimum size restrictions (356 mm FL) are in effect for the Nassau grouper (Luckhurst, 1990).

Cayman Islands

Commercial landings data on Nassau grouper from the Cayman Islands do not exist although this species is known to have supported a small-scale fishery for many years. During the 1980's there were reports from local fishermen of declines in both number and size of grouper being harvested from aggregations (Bush and Ebanks-Petrie, 1994). Although five spawning sites are known, located at the eastern ends of the three Cayman Islands, aggregations do not

necessarily form at each site every year (Phillippe Bush, pers. comm.). Mean size of aggregating fish was 604 mm FL in 1978 and 610 mm FL in 1990 (Colin *et al.*, 1987; Bush and Ebanks-Petrie, 1994). Only handlining by residents is permitted at aggregation sites.

Cuba

Data on Nassau grouper commercial landings from each of four principal fishing zones, SE, SW, NW and NE (until 1976 the NE zone also included landings from the Bahamas), of the Cuban platform, showed that about 50% of the annual landings came from spawning aggregations. Grouper are almost exclusively fished by fish trap (Claro *et al.*, 1990). Total annual landings from all four regions combined declined from a mean of 2,768,000 kg in 1959-61 to 766,000 kg in 1981-85, despite an increase in fishing effort (Claro *et al.*, 1990). A large proportion of individuals harvested are juveniles (Claro *et al.*, 1990). Lee (1974) noted that juveniles were fished heavily and that adults were removed from aggregations prior to spawning. Claro *et al.* (1990) concluded that the resource is overfished and requires management.

Dominican Republic

No commercial landings data on Nassau grouper were available. An aggregation close to Punta Rusia on the north coast, discovered in the early 1980s and then intensively fished, did not form recently and may have disappeared (Colin, 1992). A Presidential decree was introduced in the 1980's prohibiting the fishing of Serranidae during the spawning season as well as the trading of fishes with eggs. A second decree prohibiting fishing of *Epinephelus* at a site of mass spawning on the north coast is in effect (Colin, 1988).

Florida

Commercial landings data, available from 1986 onwards, record only the occasional Nassau grouper over many thousands of trips sampled (Robert Müller, pers. comm.). Data on recreational landings were available from two different databases; headboat (a boat used by recreational fishermen who pay individually, by the "head") logbook surveys (National Marine Fisheries Service - NMFS) off Florida Keys, and recreational creel surveys off Biscayne National Park (BNP). Based on the assumption that landings trends reflect population levels, these data indicate that Nassau grouper have comprised a progressively smaller proportion of landings since the late 1970s, dropping from 10% of the catch in 1979, to 1-2% of the catch in the mid- to late 1980's in both the Florida Keys and BNP (Bohnsack, 1991). During the early 1980s, numbers landed per trip also declined markedly in both areas, from approximately 0.18 fish per trip to 0.01-0.03 fish per trip by the mid-1980's (Bohnsack, 1991).

Despite its current low abundance, evidence indicates that, until about the 1960's, relative and absolute abundance of Nassau grouper were high in southern Florida (Bohnsack, unpubl. ms). This species was still of minor sport and commercial importance in the Florida Keys in the early 1960s (Moe, 1963). Longley and Hildebrand (1941) found that the species was "common in the Keys", and Starck (1968) reported that Nassau grouper "may be found during virtually every dive or collection in the proper areas" off Alligator Reef, Florida Keys. No spawning aggregations of Nassau grouper have been recorded from Florida waters although individuals within the mature size range, averaging 4-7 kg, were taken in a trap survey off southeastern Florida Keys in the winter months of 1979-80 (Taylor and McMichael, 1983).

Length-frequency data on recreational landings in BNP, taken before the implementation of a minimum size limit of 457 mm FL (18 inches) in 1985, show that the majority (76%) of fish taken were sexually immature (Bohnsack, unpubl. ms). The minimum size limit increased to 508 mm (20") in 1990, and all harvest of Nassau grouper was prohibited in 1992.

Honduras

Published data on Nassau grouper commercial landings were not available. A spawning site was discovered in the Bay Islands (Guanaja) in 1988. It was subsequently heavily fished with speargun, handline, and fish trap. Landings increased from an initial 4,500 kg in early 1988 to 13,600 kg in 1988-89 and 1990-91 spawning seasons. Visual counts during the 1990-91 season produced estimates of 500 aggregating fish, compared to approximately 10,000 similarly assessed the previous year. Few mature Nassau grouper are now seen on reefs where previously they were abundant (Fine, 1992).

Jamaica

Data on the commercial landings of Nassau grouper were not available. A 1971-72 survey using fish trap and handline caught mature Nassau grouper on offshore oceanic banks with a mean size of 570 mm FL. Inshore, only immature individuals were sampled (Thompson and Munro, 1978). This species was considered to be underexploited at the time of the survey. By 1989, however, grouper species, including the Nassau grouper, once common in the markets had become rare (Milton Haughton, pers. comm.). Spawning aggregations have not been reported from Jamaican waters.

Martinique

Large species of grouper are now rare in the catches of artisanal fishermen in Martinique (Gobert, , a). However, prior to a recent increase in the use of fish traps, larger species of grouper, including the Nassau, were commonly taken (Gobert, 1996). Aggregations of grouper in local waters have reportedly never

been known to fishermen interviewed in a recent survey of the fishing community (Gobert, 1994).

Mexico

Commercial landings data on Nassau grouper were unavailable. There are at least seven documented aggregation sites in Quintana Roo on the eastern Yucatan Peninsula, including Majahual and Xahuaxhol (Aguilar-Perera, 1994). The Majahual aggregation is best known and has been fished by local fishermen since 1910-1920. The site attained commercial importance in the 1950-60's when it was fished by handline and produced 40,000-60,000 kg annually. At the end of the 1960s the introduction of the speargun apparently resulted in declining landings. In 1990 federal authorities applied an existing law prohibiting the use of speargun at coastal sites. Subsequently, gill nets were introduced and used as barrier nets, trapping the fish as they arrived at aggregation sites. Mean sizes taken at both Majahual and Xahuaxhol by gill net during the 1990-1991 spawning season were between 580-600 mm FL (Sosa-Cordero and Cardenas-Vidal, 1996).

Netherlands Antilles

Data from prior to 1950 indicate that the Nassau grouper was once abundant around these islands. As a result of intensive spearfishing during the 1960-70s, however, grouper populations declined considerably and the Nassau grouper is no longer common (Nagelkerken, 1981).

Puerto Rico

Reporting on the first U. S. survey of the fishery resources of Puerto Rico, Evermann (1900) wrote that the Nassau grouper was "A common and very important food fish, reaching a weight of 50 lbs. (22.7 kg) or more." In 1970, the Nassau grouper was reported as the fourth most commonly landed of all the shallowwater species of the artisanal fishery of Puerto Rico (Suárez-Caabro, 1970). The species is now considered to be effectively extinct for fishery purposes (Bohnsack *et al.*, 1986) with only about a thousand kg reported annually in recent years (Fisheries Research Laboratory (FRL), Puerto Rico Dept. Natural Resources, unpubl. data). Biologists recall seeing abundant Nassau grouper up until the early 1970s (Miguel Rolón, pers. comm.) Fishermen report two spawning aggregations that were fished until the late 1970's off southern PR (Hector Vega, pers. comm.). A third aggregation off southwestern Puerto Rico was fished until the early 1970's (Carlos Cumpiano, pers. comm.). An intensively exploited aggregation off the island of Mona, eastern Puerto Rico, has also disappeared (Colin, 1982).

Length-frequency data collected for federal (NMFS) programs by FRL personnel between 1986 and 1990 show not only that very few individuals of

this species are now taken, but also that most are sexually immature (Figure 1 - FRL, unpubl. data). During this five year period only 236 Nassau were sampled out of aproximately 100,000 fishes measured. The taking of Nassau grouper was prohibited in federal waters of the U.S. Caribbean (Perto Rico and the U.S. Virgin Islands) in 1990.

St. Vincent and the Grenadines

Although Nassau grouper are landed in these islands, no spawning aggregation sties are known and no landings data were available (John Neilson, pers. comm.).

Virgin Islands (VI)

The Nassau grouper was once an abundant and valuable food fish and a common component of handline and trap catches from shallow reefs of the United States VI (Brownell and Rainey, 1971). Several spawning aggregations were exploited around these islands. During the 1970's, fishing pressure on aggregations increased dramatically. From 1968-1976 a threefold increase in the number of small boats was observed during peak aggregation periods and fishing was by handline. By the early 1980's, 10-15 boats were present daily each hauling several strings of 6-15 traps (Olsen and LaPlace, 1979; Beets and Friedlander, 1992). In St. Thomas, reductions in landings from 14,460 kg to 4,930 kg, and a 76% decline in CPUE (kg/boat) were recorded between the 1974-5 and 1975-6 spawning seasons. Fishermen had noted that between 1966 and 1974, aggregation catches of 1000 kg per day were frequent (Olsen and LaPlace, 1979). By the 1980's, however, aggregations had disappeared completely from south of St. Thomas and from Lang Bank, St. Croix. Additional aggregation sites have been reported from the outer platform of St. Thomas and north and south of the British VI (Beets and Friedlander, 1992), although their current condition could not be determined. These aggregations are believed to be lightly fished (Jim Beets, pers. comm.).

Length-frequency data collected in St. Thomas between 1974-1977 showed that the mean length of aggregating fish approximated 680 mm FL (Olsen and LaPlace, 1979). Length-frequency data from the commercial fishery from St. Thomas/St. John (mean = 550 mm FL; N=73) for 1985 (Bohnsack *et al.*, 1986), and from St. Croix for 1985-1989 combined (mean = 448 mm FL; N=115) (Figure 1) indicate that the majority of individuals taken in recent years were juveniles.

Venezuela

Despite the common occurrence of *E. striatus* off the Los Roques Islands, neither fishermen nor local scientists were aware of any spawning aggregations in the area (Fernando Cervignon, Juan Posada, pers. comm.).

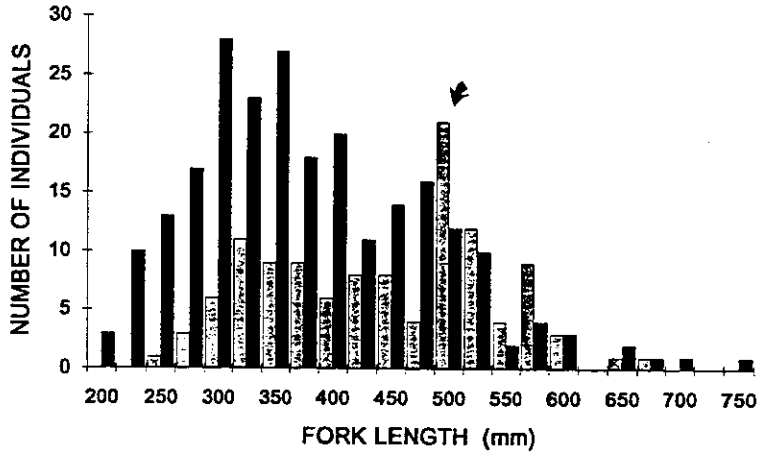

Figure 1. Size-frequency distributions of Nassau grouper from Puerto Rico for data collected between 1986 and 1990, inclusive (black bars, N=236), (Puerto Rico Dept. of Natural Resources, Fisheries Research Laboratory), and St. Croix for data collected between 1985 and 1989, inclusive (stippled bars, N=115) (Division of Fish and Wildlife), during National Marine Fisheries Service (NOAA, U. S. Dept. of Commerce) fisheries monitoring programs. Arrow indicates approximate size of sexual maturation.

Table 1. Summary of data indicating status of Nassau grouper spawning aggregations in the Caribbean and western Atlantic. Aggregations for which recent information on status is unavailable are not included (see text and Figure 1 for more details and data sources).

COUNTRY	LOCATION	STATUS
BAHAMAS	Andros Island	Heavily exploited
BAHAMAS	Long Island	Declines noted
BAHAMAS	Cat Cay/Bimini	Active but intermittent
BELIZE	Cay Glory	Threefold decline over thirty years
BELIZE	Lighthouse Reef	Active
BELIZE	Ambergris Point	Disappeared
BERMUDA	Three sites	Disappeared
CAYMAN ISLANDS	Three sites	Recent declines
SE CUBA	Cabo Cruz	Declining landings
NW CUBA	Cayo Cuano	Declining landings
NW CUBA	San Carlos	Declining landings
DOMINICAN REPUBLIC	Punta Rusia	Possibly disappeared
HONDURAS	Bay Islands	Fiftyfold decline over three years
MEXICO	Majahual	Declines since the 1970s
MEXICO	Xahuaxhol	Active
PUERTO RICO	Mona Island	Disappeared
PUERTO RICO	S and SW coasts	Disappeared 1970-80s
U.S.V.I	St. Thomas	Disappeared in 1980s
U.S.V.I.	St. Croix	Disappeared in 1970s

DISCUSSION

There can be no doubt as to the response of the Nassau grouper populations (stocks) to heavy fishing pressure, despite the general scarcity of long-term databases on the fisheries of the western Atlantic. Declines have been noted in many areas in both absolute terms and relative to other grouper species. At least one fifth of documented aggregations have apparently disappeared over the last two decades, very probably the direct result of heavy exploitation. Declines in fish numbesr and/or mean fish size have been noted in many other aggregations throughout the geographic range of this species (Table 1, Figure 2). In some areas, annual harvests consist almost exclusively of juveniles.

Local stocks and aggregations apparently sustained light fishing pressure from early in the twentieth century until the 1950-60s. At this time, fishing activity began to intensify and, in the ensuing two decades, the fishing industry gradually adopted and incorporated new fishing technology: motorized vessels, refrigeration, wire fish traps, and the speargun. From most accounts, declines in

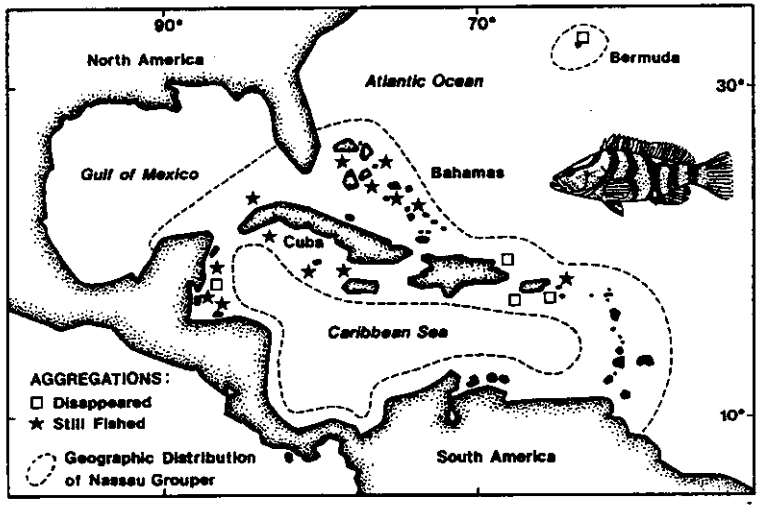

Figure 2. Locations of known spawning aggregation sites and geographic distribution of the Nassau grouper (dashed line). Each symbol may denote more than one site in the general area indicated (see text and Table 1 for more details): black star = actively fished site; white star = known site at which Nassau grouper are no longer known to aggregate.

landings of Nassau grouper began in the 1960-70s. Aggregation sites encountered in the 1980s rapidly diminished within a few years of discovery, often shortly following the introduction of speargun or fish trap.

Reported declines in landings were more striking in some areas than in others. As local aggregations disappeared from Puerto Rico, Bermuda and the U. S. Virgin Islands, for example, so too did annual landings diminish to such an extent that this once abundant species is now extinct for fisheries purposes in these areas. Such trends could indicate that the stocks of these islands are more heavily exploited than elsewhere, which seems unlikely, or that they are essentially self-recruiting, with local stocks dependent largely on local aggregations. This is almost surely the case for Bermuda. Self-recruitment has also been proposed for the stocks of the Cayman Islands because of local water circulation patterns (Colin *et al.*, 1987).

It is also possible that recruitment from off-island to these islands, with their narrow insular platforms, is sporadic and variable compared to recruitment to more extensive platform areas. This would imply that island stocks may be more vulnerable to heavy fishing pressures that those located, for example, along the coastline of central America or on the insular platforms of the Bahamas. Studies aimed at distinguishing populations are needed to resolve the question as to what extent local stocks depend on local aggregations. Such research would also help establish the vulnerability of local stocks to local fishing pressure, and to establish what management or restoration strategies would be appropriate, and on what geographic scale.

Why is the Nassau grouper apparently so vulnerable to anything other than light levels of exploitation? In part, its response is a consequence of its biology, *i.e.*, long-lived, slow to reach asymptotic (mean maximum) size, and at a high trophic level (Manooch, 1987; Ralston, 1987). In particular, its large size at sexual maturation (1.87 kg) relative to most other components of the shallow water reef fisheries in many areas means that juveniles are commonly taken by most types of traditional fishing gear (Gobert, 1996), and that growth overfishing is inevitable. In the small-scale fishery of Puerto Rico, for example, the average weight of fish sampled in NMFS surveys was approximately 0.3 kg (Matos, 1992), far smaller than the size of sexual maturation of the Nassau grouper. As a result, management measures such as minimum mesh sizes on fish traps, or minimum size capture limits, intended to avoid capture of juvenile Nassaus, would not be realistic management approaches. This is because, on the one hand, mesh sizes large enough to avoid retention of juvenile Nassaus would retain little else, and on the other, the return of undersize juveniles to the water is generally of little benefit to grouper species since substantial post-release mortality is believed to occur. Other options to reduce growth overfishing, such as the establishment of marine reserves, would need to be considered.

Probably of most significance, however, in the declines of this species, is its

reproductive strategy of forming mass aggregations for spawning. Most demersal species become progressively harder to catch as their numbers decline because their densities decrease. The aggregating behavior of the Nassau grouper, however, means that even if only few adults remain, if these continue to aggregate to spawn they may still be fished at aggregation sites with a similar efficiency as before. In fisheries terms, 'catchability' does not decline in concert with population size.

Since it is likely that a substantial proportion of, if not all, annual reproduction takes place at aggregations, aggregation fishing is a matter for special concern. Not only are ripe individuals removed from aggregations before they have spawned, but it is also likely that intensive fishing over spawning aggregations reduces genetic diversity and disrupts reproductive behavior, further reducing spawning potential (Bannerot *et al.*, 1987; Bohnsack, 1989; Smith *et al.*, 1991; Colin, 1992). Moreover, the relatively small number of aggregations described (<60) and the distance traveled by some fishes to reach such sites (>100 km, Colin 1992), suggest the possibility that the number of suitable aggregation areas in the region may be limited.

As we learn more about the biology of grouper species, and as technology becomes more sophisticated, it will become ever easier to locate heretofore undiscovered spawning sites. Given their apparent importance, the significance of aggregation fishing in annual landings in several locations (*e.g.* Belize, Bahamas and Cuba), and the difficulties of managing non-spawning individuals through either size or gear restrictions, the answer to the question of whether the Nassau grouper could become commercially extinct in the region must clearly be yes. Indeed this has already happened in several locations (*e.g.*, Bermuda and Puerto Rico). Whether populations of this species could disappear completely from some areas is open to conjecture but seems possible under certain conditions (*e.g.*, small islands with little recruitment from off-island).

Many of the biological characteristics that make the Nassau grouper vulnerable to heavy exploitation are not unique to this species. Indeed it is the current status of a number of grouper species worldwide that reaffirms the need for concern over landing trends of Nassau grouper in the western Atlantic. For example, in Australia the black cod, *Epinephelus damelii*, is classified as "potentially threatened" (one of the only Australian marine finfish species to be so categorized) because of its depletion through spearfishing. It is protected in New South Wales, along with two congenerics, *E. malabaricus* and *E. lanceolatus* (Pollard *et al.*, 1990). In the Pacific, aggregations and local stocks of several species of grouper have become severely depleted through intensive commercial exploitation, often after the introduction of spearfishing. In Palau this led to recommendations to ban the fishing of species known to form spawning aggregations (Johannes, 1991). In the Mediterranean, *Epinephelus guaza* is considered to be in depleted condition due to a combination of

commercial fishing, spearfishing and pollution, and protective measures for this species exist in several areas (Harmelin and Robert, 1992). Finally, in Puerto Rico concern has been expressed over exploitation patterns on a recently discovered aggregation of tiger grouper, *Mycteroperca tigris* (Sadovy *et al.*, in press).

Several recommendations concerning management, monitoring, and research initiatives for Nassau grouper stocks are pertinent:

1. *Management* — Stocks of the Nassau grouper should be managed to maintain adequate reproductive (spawning stock) biomass and, hence, to sustain recruitment. Serious consideration should be given to the protection of spawning aggregations, at a minimum by prohibiting spearguns and fish traps, and permitting only low levels of, if any, exploitation. The introduction of marine reserves in critical areas also needs to be considered as a management option to address the problem of growth overfishing.

2. *Monitoring* — There is a paucity of data regionwide for tracking stock history and assessing stock status. Aggregation catches and annual landings (both recreational and commercial), including CPUE, sex ratios, and fish sizes should be collected (Sadovy, 1994). To obtain a longer term perspective on the history of the fishery, interviews with long-established fishermen are valuable (*e.g.*, Johannes, 1981; Gobert, 1994). Aggregation catches should be monitored annually using standardized techniques to permit inter-year and regional comparisons of fish sizes and sex ratios (Sadovy, 1994). Care should be taken in establishing the status of aggregations since these do not all necessarily form annually without fail even at healthy aggregation sites (*e.g.*, Cayman Islands, Bahamas).

3. *Research* — It is important that stocks be delineated to identify stock boundaries and to establish to what extent local stocks may be self-recruiting. Only thereby can biologically-meaningful monitoring programs and management units be established. Evaluation of the potential impact of fishing on aggregation spawning is a particularly critical question (Bannerot *et al.* 1987; Shapiro, 1987; Sadovy, 1994).

There is still the belief by many that fisheries resources are so abundant regionwide that they could not possibly be overfished, let alone disappear locally. I believe that the case of the Nassau grouper provides an important lesson by showing us just how inherently vulnerable certain species are to anything other than light levels of fishing pressure. Species like the Nassau grouper clearly are particularly susceptible to heavy exploitation. Given the extent of fishing pressure on this species in many locations, and the likely consequences of aggregation fishing, protection through aggregation protection and the introduction of marine reserves should be high on any management agenda.

ACKNOWLEDGMENTS

I am extremely grateful to all those who have shared their knowledge of Nassau grouper with me. Other than those personal communications I have already acknowledged, I wish also to thank Scott Bannerot, Jim Bohnsack, René Buesa, Lew Bullock, John Fine, Daniel Matos, Steve Meyers, George Mitcheson, Eloy Sosa Cordero, Miguel Rolón, Ronald Thompson, and especially the Caribbean Fishery Management Council (National Marine Fisheries Service, NOAA, U. S. Dept. of Commerce) for assistance and support. Special recognition goes to Gene Huntsman for organizing the Endangered Marine Finfish session at the 1992 American Fisheries Society annual meeting which provided the stimulus for the preparation of this paper. Figure 2 was prepared by Bonny Bower-Dennis.

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