# The influence of spear fishing on species composition and size of groupers on patch reefs in the upper Florida Keys

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Groupers are an important fishery resource throughout tropical and subtropical regions of the world (Heemstra and Randall, 1993). Dependent and independent fishery surveys of grouper populations in south Florida and the Caribbean have shown drastic declines in populations, most likely due to intense fishing pressure (Sadovy, 1994; Bohnsack et al., 1994). Combined grouper species landings by weight have declined in the Florida Keys by more than half since the mid 1980's (Bohnsack et al., 1994).

Fishermen tend to target the larger fish in a population, with the result that a decrease in the density, average size, and relative abundance of exploited species is inevitable (Bohnsack, 1982; Russ, 1985; Plan Development Team (PDT), 1990; Roberts and Polunin, 1991). Grouper populations are especially sensitive to fishing pressure, exhibiting reductions in density and average size, as well as shifts in species composition between sites that are fished and those that are unfished (Russ, 1985). For example, the mean weight of three species of grouper was found to be significantly greater in unfished than in fished sites in the Red Sea (Roberts and Polunin, 1993). Similarly, the density and biomass of groupers was significantly greater in sites protected from fishing than in sites unprotected in the Philippines (Russ and Alcala, 1989). Craik (1981) found that a commercially important grouper (*Plectropomus leopardus*) on the Great Barrier Reef had a higher mean size at an unfished reef than at a fished reef. Russ (1985) and Craik (1981) observed that larger individuals of a grouper species were abundant only at unfished reefs. Sluka et al. (1997) showed that the biomass, average size, and reproduction (the total number of eggs produced per hectare) of Nassau grouper, *Epinephelus striatus*, was significantly greater inside a marine fishery reserve than outside. Many studies have attributed a change in the relative abundance of grouper species to fishing pressure (Goeden, 1982; Bohnsack, 1982; Russ, 1985; Watson and Ormond, 1994; Sluka, 1995).

In the Florida Keys there has been a history of management measures that have affected fishing pressure on groupers. In 1980, the state of Florida banned fish traps in its waters (<3 nautical miles), and in 1992 the United States government banned fish traps in federal waters of the Florida Keys (>3 nautical miles to the 150 fathom depth contour). During this study, there was a bag limit of five fish and a minimum size limit of 51 cm (20 in.) for six grouper species (red grouper, *Epinephelus morio*, black grouper, *Mycteroperca bonaci*, yellowmouth grouper, *M. interstitialis*, gag, *M. microlepis*, scamp, *M. phenax*, and yellowfin grouper, *M. venenosa*). Harvest of two species (jewfish, *E. itajara*, in 1990 and Nassau grouper, *E. striatus*, in 1991) has been prohibited in the south Atlantic waters of the United States. Reefs within Key Largo National Marine Sanctuary (KLNMS) and John Pennekamp Coral Reef State Park (JPCRSP) have been protected from spear fishing since 1960. Since the time of this study, the entire Florida Keys has come under the management of the Florida Keys National Marine Sanctuary.

One of the results of the previous management scheme is that the upper Florida Keys can be divided into two areas: one area protected from spear fishing and the other unprotected from spear fishing. It is assumed that the intensity of hook-and-line fishing is similar inside and outside of KLNMS and JPCRSP. Thus the goal of this study was to examine the influence of spear fishing on the size and species composition of groupers in the upper Florida Keys and to discuss potential implications for the management of these populations. These population parameters were

Manuscript accepted 19 August 1997.
Fishery Bulletin 96:388–392 (1998).

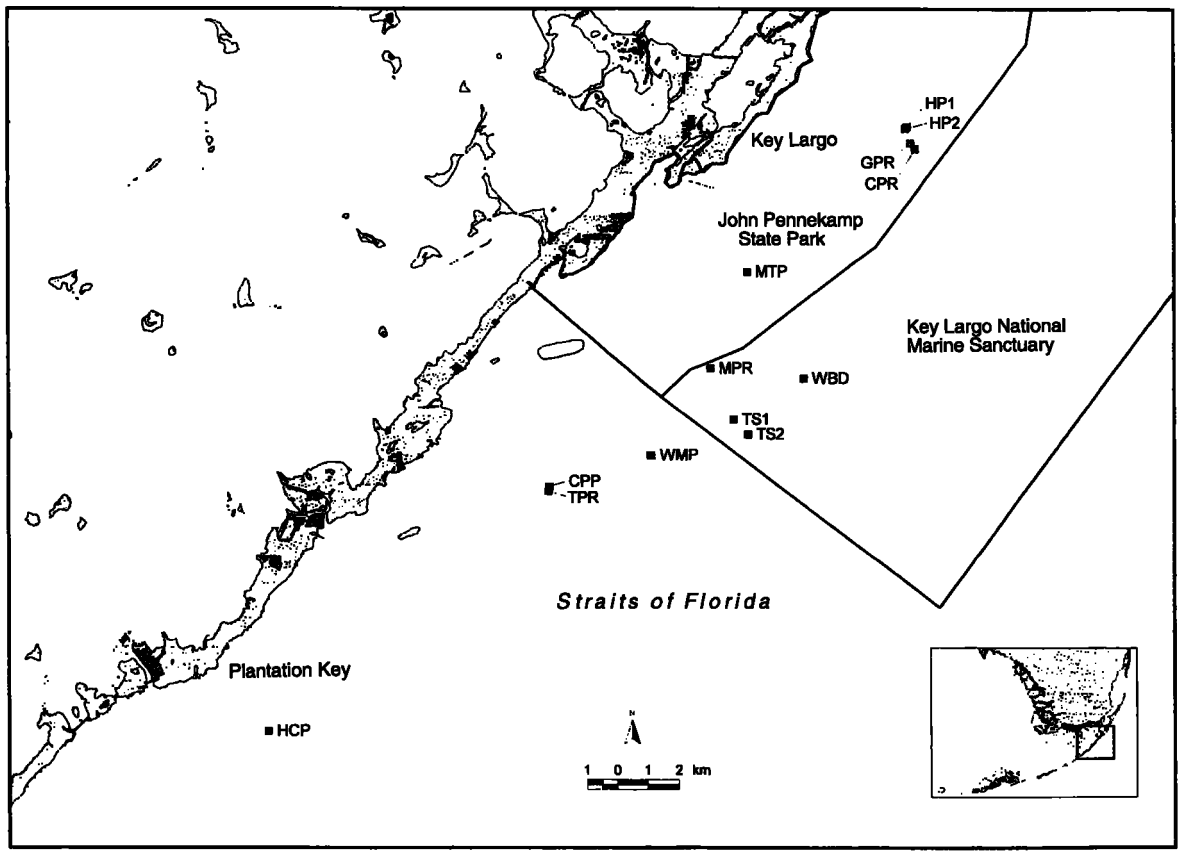


**Figure 1**
Map showing survey sites located in the upper Florida Keys.

expected to differ between sites under differing fishing intensities owing to the biology of the species, their site-attached nature, and the susceptibility of these species to fishing pressure.

## Materials and methods

Sampling on four patch (shallow-water, small) reefs occurred in February 1992, April 1993, September 1993, January 1994, April 1994, and September 1994. Nine additional patch reefs were sampled in September 1994. A total of 13 patch reef sites were sampled (Fig. 1). There were no significant seasonal differences in the size distribution of all grouper species combined at these sites (Sluka and Sullivan, 1996). Thus, data from all seasons were combined for analyses.

Researchers were trained to estimate lengths of fish consistently and accurately using methods outlined in Bell et al. (1985). Observers had approximately five minutes to estimate the length of a series of fish models of varying lengths. The length of each model was recorded in one of five categories: <5 cm, 5–15 cm, 16–25 cm, 26–35 cm, and >35 cm. The frequency distribution of estimated model lengths was compared to the known distribution by using a chi-square test. The bias of each observer was determined as either consistently underestimating or overestimating the size of the fish models. The information on biases was given to each observer. The observer then repeated the length estimation procedure until there was no significant difference between the observed and expected distributions ($P>0.05$). Observers were found to be competent for length estimation after 2–3 trials.

At four of the sites (MPR, TS1, TS2, and HCP), transect lines of 20 m or 25 m in length were used to sample the number, species, and length of groupers. The transect lines were laid in representative portions of each patch reef. The transect line was searched 6 m out from each side for a total width of 12 m (width by visual estimation). Within each transect all groupers were enumerated and their length category and species recorded on underwater paper. Observers using SCUBA searched throughout the width of the transect, examining all crevices, caves, and holes. At the other nine sites, observers sampled the entire patch reef. Patch reef size was not quantified at these sites; thus density could not

be compared between protected sites and those unprotected from spear fishing.

It was hypothesized that spear fishermen were targeting some species more than others owing to their larger size. Targeted species were assumed to be red grouper, black grouper, scamp, and gag. The latter two species were rare, constituting <14% of individuals observed by site. Nassau grouper were assumed to be a nontargeted species because of the ban on harvest. Differences in the relative abundance of targeted grouper were assessed with a $t$-test on the arcsine-transformed percentage of the total number of grouper observed at a site. Individual sites were the replicates for the analysis.

It was also hypothesized that the average size of targeted species would be significantly different between protected sites and those unprotected from spear fishing. A nested ANOVA was used to test this hypothesis, with the main factor being protection level (spear fished or protected) and sites nested within protection level. The mid points of size categories were used as an estimate of the individual sizes of sampled fish. Thus, for this analysis, individual fish sizes were the replicates. A value of 40 cm was used for individuals in the >35 cm category. This results in a conservative analysis because many of the fish in this category were much larger than 40 cm (R. Sluka, personal observation).

## Results

There was no significant influence of spear fishing on the relative abundance of targeted grouper species ($t$=0.658, $P$>0.55). Targeted species constituted an average of 65% ($n$=9) and 71% ($n$=4) on protected and unprotected sites, respectively. Nontargeted species (graysby, *Epinephelus cruentatus*, coney, *E. fulvus*, rock hind, *E. adscensionis*, red hind, *E. guttatus*, and Nassau grouper, *E. striatus*) constituted on average 35% and 29% of the total number of individuals on protected and unprotected sites, respectively. Nassau grouper constituted a greater proportion of the individuals observed at protected (15%) than at unprotected (2%) sites. These values were statistically different ($t$=2.46, $P$<0.05).

Patch reefs protected from spear fishing had a significantly greater size of targeted individuals than did unprotected patch reefs ($F_{1,211}$=3.874, $P$=0.05). The mean size (+/– 1 SE) of targeted grouper species on protected patch reefs was 29.3 (0.7) cm, whereas the mean size of targeted species on unprotected sites was 26.0 (0.8) cm. There was also a significant difference among sites nested within protection levels ($F_{11,211}$=5.151, $P$<0.001).

## Discussion

In this study, spear fishing appears to primarily influence the average size of groupers. Sites in which spear fishing was not allowed had grouper assemblages that were characterized by larger-size individuals. This result is similar to those found in studies examining the effects of hook-and-line fishing, where fishermen target the larger individuals in a population and thus decrease the average size of a fish species (Roberts and Polunin, 1991). Overall, grouper species composition was not significantly influenced by the presence or absence of spear fishing; targeted species were similarly abundant on protected and unprotected patch reefs. Sluka and Sullivan (1996) have shown that grouper species, such as black grouper, red grouper, and Nassau grouper, are more abundant, but smaller, on inshore patch reefs than on offshore bank reefs of the upper Florida Keys. It is likely that species such as these are recruiting inshore before they move offshore (Ross and Moser, 1995). Nassau grouper, however, were more abundant on patch reefs protected from spear fishing than on unprotected patch reefs. Although there is a ban on harvesting these species, spear fishermen may still collect individuals. It is important to examine how effective the ban on harvesting this species is in the Florida Keys.

Offshore bank reef sites in the upper Florida Keys protected from spear fishing had snappers (Lutjanidae) and grunts (Haemulidae) of larger size and greater abundance than did a lower Keys site subjected to spear fishing (Bohnsack, 1982). Clark et al. (1989) found similar results when sites inside Looe Key National Marine Sanctuary (lower Florida Keys) were compared before and after protection from spear fishing. The present study did not examine differences in abundance between protection levels. However, it is expected that there would be no significant differences in abundance between these sites; this result is due to the nature of both spear fishing and grouper growth and reproductive characteristics. Spear fishing targets the largest fish in an assemblage but only accounts for a small percentage of the total fishing effort (PDT, 1990). For example, spear fishing accounted for 10.5% of the total recreational fishing catch in Biscayne National Park.[1] Thus the magnitude of the selection pressure is likely much less than that from hook-and-line fishing because of

[1] Tilmant, J. T., and R. Stone. 1984. Reef fish harvest trends, Biscayne National Park, Dade County Florida. Unpublished report presented to the 1984 stock assessment workshop. Southeast Fisheries Center, National Marine Fisheries Service, Miami, Florida, 26 p.

the smaller number of spear fishermen. However, the lower number of spear fishermen may exert a more directed selectional effect on grouper species because they can be highly selective for the largest individuals.

The growth and reproductive characteristics of groupers render these species especially susceptible to overfishing (Bannerot et al., 1987; Shapiro, 1987; Huntsman and Schaaf, 1994). Groupers that are targeted by fishing grow slowly to a large maximum size (Manooch, 1987). The removal of larger individuals leaves behind smaller individuals to spawn. Over many generations, this can result in a decrease in the size and age at sexual maturity (Ricker, 1981) and also decrease the average size of the population (Roberts and Polunin, 1991). Many grouper species are protogynous hermaphrodites, changing sex from females to males later in life (Shapiro, 1987). Larger groupers are generally males, and at intensive fishing levels, the number of males in the population can be drastically reduced. If too many males are removed, sperm are reduced for reproduction (Bannerot et al., 1987). If sperm are reduced, protogynous stocks are more vulnerable to overfishing than are gonochoristic stocks (Huntsman and Schaaf, 1994). Species that are protogynous may experience a drastic reduction in reproductive capacity, even at moderate levels of fishing (Huntsman and Schaaf, 1994). However, there may be mechanisms by which the population can compensate for a changing sex ratio in the presence of overfishing (Claro et al., 1990; Huntsman and Schaaf, 1994). Huntsman and Schaaf (1994) showed that these types of compensation mechanisms can reduce the detrimental impacts of fishing pressure on protogynous species. In addition to protogyny, the reproductive behavior of groupers may increase their susceptibility to overfishing. Many species of grouper aggregate to spawn during one or two months of the year (Smith, 1972; Shapiro, 1987; Claro et al., 1990). These spawning aggregations are subject to intense fishing pressure (Olsen and LaPlace, 1978, Claro et al., 1990; Sadovy, 1994). In many parts of the Caribbean, aggregations have disappeared as a result of overfishing (Sadovy, 1994). Sluka et al. (1997) showed that reproduction (the total number of eggs produced per hectare) was six times greater in a marine fishery reserve in the central Bahamas than in the surrounding unprotected region.

It is concluded that the ban on spear fishing in the upper Florida Keys has significantly benefitted the size distribution of groupers. However, it appears that a ban on spear fishing alone has not resulted in recovering population levels of grouper in this region. Bohnsack et al. (1994) has clearly shown a decline in commercially and recreationally targeted grouper landings throughout the Florida Keys. Sluka and Sullivan (1996) have shown that the offshore grouper assemblage over shallow bank reefs of the upper Florida Keys is dominated numerically by graysby (88%), a small, nontargeted species. Densities of targeted species are low compared with regions where fishing was prohibited or had not yet taken place (Sluka and Reichenbach, 1996; Sluka et al., 1997).

It is recommended that marine fishery reserves be considered as a management measure because of their success in other regions and because of a strong theoretical basis (PDT, 1990). Grouper assemblages inside marine fishery reserves are more dense, of greater average size, and produce greater numbers of eggs per hectare than in similar, unfished sites (Bohnsack, 1982; Russ and Alcala, 1989, Roberts and Polunin, 1993; Watson and Ormond, 1994; Sluka et al.,1997). Although management measures, such as bans on spear fishing, have some beneficial effects, the available evidence suggests that the establishment of marine fishery reserves is the most successful method for restoring and conserving grouper assemblages.

## Acknowledgments

The authors would like to thank the staff of the National Undersea Research Program Florida Keys Program for logistical support. Fieldwork was assisted by M. Chiappone, T. Potts, G. Meester, and J. Levy. Figure 1 was prepared by R. Wright. This research was funded by NOAA's National Undersea Research Program under NURC/UNCW grant UNCW-9420 to K.M. Sullivan and was conducted in the Florida Keys under National Marine Sanctuary Permit 93-27. Support was also obtained from University of Miami (Department of Biology) and The Nature Conservancy's Florida Keys Initiative and Caribbean program. Research was conducted as part of a doctoral dissertation completed by R. Sluka at the University of Miami. This manuscript benefitted significantly from readings by J. Bohnsack, S. Bolden, N. Ehrhardt, J. Prince, C. R. Robins, and three anonymous reviewers.

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