

Biological Services Program

FWS/OBS-80/59
FEBRUARY 1981



PROCEEDINGS
U.S. FISH AND
WILDLIFE SERVICE
WORKSHOP

**COASTAL
ECOSYSTEMS**
OF THE SOUTHEASTERN
UNITED STATES

Fish and Wildlife Service

U.S. Department of the Interior

RECREATIONAL IMPACTS ON CORAL REEF

FISH POPULATIONS

James T. Tilmant
Biscayne National Monument
U.S. Park Service
P. O. Box 1369
Homestead, Florida 33030

ABSTRACT

The impact of recreational activities is being documented through the study of selected coral patch reefs and through the analysis of recreational fish harvest data within Biscayne National Monument, Florida. Four buoyed, frequently used, coral patch reefs have been intensively studied and compared to four similar unmarked control reefs. Approximately 3,500 persons/year have used the buoyed reefs studied. The most frequent recreational activities on these reefs were snorkeling and spearfishing. Visual species/time reef fish surveys have revealed a total of 214 fish species on the reefs studied. Similarity of the fish populations on buoyed and control reefs has ranged from 73 to 87%. Significant alteration of overall reef fish populations by present levels of recreational activities has not been evident. Parkwide, approximately 12,000 sportfishing parties/year used the Monument's reefs. None of the most frequently harvested species have shown continuous long-term declines in catch rate. However, grouper catches declined during 1979. Size class data for harvested fish indicate population age class structures have remained stable. Changes in catch rate appeared to be more closely related to total number of fishermen than to change in rela-

tive abundance of fish as determined by underwater survey.

INTRODUCTION

Florida's coral reef ecosystem is heavily subjected to a wide array of recreational activities and human uses. The fact that they are the only fully developed tropical coral reefs bordering the continental United States attracts thousands of people each year to snorkel and scuba dive. The reefs are heavily utilized for sport and commercial fishery harvest and are subjected to constant pleasure boating activities. The reef popularity is both national and local. Most local boat owners make numerous trips a year to the reefs for diving activities.

Concern for possible impact of human activity on Florida's coral reefs was documented several years ago during a coral reef workshop held at the University of Miami (October 1974). Since that first workshop, the need for research on man's impact and natural stresses has become even more urgent. Recent documentation of man-induced damages to reefs include boat anchor damage (Davis 1977), damage to coral by divers (Dustan 1977a), shipwreck damage (Dustan 1977a), and removal of live marine specimens in large numbers for aquarist trade (Jaap and Wheaton 1975). Stresses from within the reef's ecosystem, such as algal destruction of coral, hermodice predation, reduced reef vitality, and coral "shut down" reactions have also been recognized (Antonius 1977, Dustan 1977b).

In response to these concerns and to assure that the National Park Service is providing the management actions needed to properly protect the coral reefs within

their trust, intensive studies of the coral reefs and their associated resources have been conducted at Biscayne National Monument during the past 4 years. These studies have included both intensive underwater investigations of the coral reefs and an assessment of organisms harvested, both sport and commercially, from the coral reef ecosystem.

It is the intent of this paper to synthesize some of the results of these two approaches in an evaluation of overall impacts of recreational activities on reef fish populations. Other aspects of our studies of the coral reefs including coral damage, studies of the reef algal communities, and observations of selected macro-invertebrates have been reported elsewhere (Tilmant et al. 1979).

Biscayne National Monument is located in the southern part of Dade County, Florida. It consists of the waters of the south end of Biscayne Bay and northern Card Sound, a northern extension of the Florida Keys, and offshore waters and coral reefs out to the 10-fathom (18-m) depth contour (Figure 1). The coral reefs occurring within the monument comprise the approximate northern limit of well-developed reef growth along the United States Coast. The Monument's reefs are a part of the coral tract that extends from Miami 360 km to the south and west terminating at the Dry Tortugas in the extreme southeastern Gulf of Mexico. The Florida reefs have been described as a bank reef system (Davis 1928) and are formed upon a broad shallow water coastal platform.

Within the area of Biscayne National Monument, the outer reefs form a discontinuous elongated barrier located approximately 7 km offshore of the keys. The outer reefs rise to within 1 m of the surface and are characterized by the corals Diploria clivosa, D.

labyrinthiformis, Montastrea annularis, and Acropora cervicornis. Numerous living coral patch reefs occur between the outer reefs and the keys. These patch reefs are separated by beds of turtle grass (Thalassia testudinum) and water depth averages 6-9 m. The patch reefs generally range from 50 to 400 m in diameter and rise to within a few meters of the surface. On the patch reefs, stony coral growth is dominated by head and encrusting forms such as Montastrea annularis, M. cavernosa, Colpophyllia natans, Siderastrea siderea, and Diploria clivosa. The low-growing branching corals of the genus Porites are also common. Larger branching forms such as Acropora cervicornis and A. palmata are restricted in their occurrence. Alcyonaria grow profusely between the coral heads on the upper reef surface. Much of the reef surface and coral skeletons are covered with the hydrozoan Millepora.

METHODS

Conventional creel census techniques were employed to determine the number of reef fish species that are being harvested by sport fishermen. Fishermen returning from Park waters were interviewed at the Convoy Point boat launching ramp (Figure 1), the major access point to Biscayne National Monument. Data recorded during fishermen interviews included size of party, residence, trip hours, hours fished, area fished, species and number caught, and number of each species released. The number and species harvested was verified by the person obtaining the interview. General parkwide surveys, by boat and air, have provided data on the proportion of visitors participating in various recreational activities and enabled estimates of

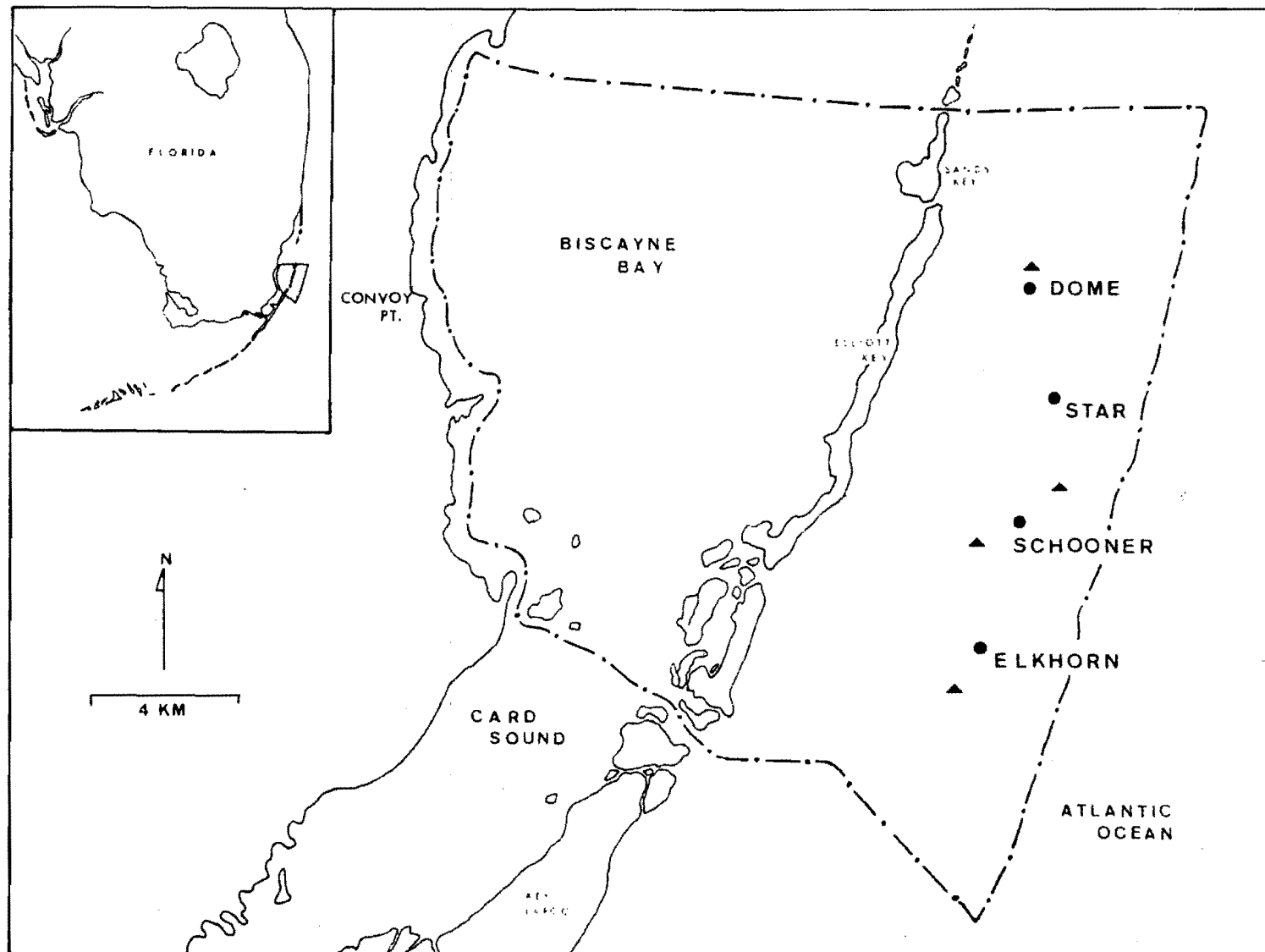


Figure 1. Biscayne National Monument, Dade County, Florida. Broken line represents the monument boundary. Location of experimental (buoyed) reefs is indicated as black circles. Black triangles represent location of control reefs.

total fishing effort and harvest from the interview samples.

Evaluation of the condition of the fishery has been based on the analysis of catch-per-unit of effort for successful fishermen and size class data of fish harvested. Size classes for selected species have been obtained by measuring fork-length, to the nearest centimeter, of a representative sample of fish in the catches observed.

Underwater observations of reef fish populations have been conducted on eight coral reefs representative of typical lagoonal patch reefs found within the Monument (Figure 1). Four of these reefs have been marked with mooring buoys and are described in a visitor brochure. By virtue of their ease of location and advertisement, these four reefs receive heavier visitor use and are considered to be experimental reefs.

The remaining four reefs were selected on the basis of their similarity in topographic relief and community structure to each of the experimental buoyed reefs and were left unmarked. These unmarked reefs are considered controls for the purpose of the study. It is believed that significant differences between communities of experimental buoyed reefs and control reefs reflect ecological impact from recreational use.

The amount of use the selected study reefs received was monitored by boat patrols designated for this purpose and by incidental observations by park staff whenever they were in the vicinity of a study reef. Patrols designated to monitor study reef use were conducted from early morning until late evening on weekends when maximum park use occurred. During such patrols, continued surveillance over all study reefs was maintained and all boat use of buoyed and control reefs was noted.

Data recorded include type of activity (snorkeling, diving, fishing), boat registration number, time of day, and number of persons per boat. The proportion of park visitors using the buoyed reefs was then determined from estimated total boat use of the park on the day patrolled. Incidental observations of the use of study reefs served to increase the total number of observations obtained per reef and provided proportional data in terms of relative frequency of use per observation.

Reef fish populations on the study reefs were assessed through a visual species/time random count technique described by Jones and Thompson (1978). This method involved assigning point values based on the amount of time required to first observe a given species during an established observation period. A series of repetitive observation periods then resulted in the most common species receiving the highest scores.

Although the species/time random count did not indicate actual numbers of individuals, it did provide a standard quantitative measure reflecting relative abundance of each species present that is comparable between study reefs. Differences in point values between buoyed reefs and their controls indicate possible impacts of recreational activity on the reef fish populations, and repeated periodic observations on the same reef might reveal seasonal changes and changes that may be attributed to various levels of visitor use.

Sixteen repetitive 50-minute counts were conducted on each study reef during each tri-annual sampling period of our study. These counts were divided equally between the outer and top reef areas yielding eight repetitive counts per reef zone. The P_k statistic of Gaufin et al. (1956) was used to

determine that eight repetitive counts could be expected to reveal 95.5% or more of the possible species diversity. Comparisons between buoyed and control reef pairs and temporal comparisons of individual reefs have been made using the Shannon-Weiner diversity function and evenness values of Pielou (1966), Bray-Curtis community similarity indices (Bray and Curtis 1975), and ANOVA (one-way and multiple cell two-way) statistical tests for significance.

RESULTS AND DISCUSSION

REEF FISH HARVEST

Visitor activity surveys revealed that approximately 19% of the annual boaters used the coral reefs for one or more recreational activities (Table 1). The estimated total number of boats (based on aerial and ramp count surveys) using the park during the past 4 years and the number of these boats using coral reef areas are shown in Table 2.

Overall, approximately 35% of the boaters visiting the Monument were participating in activities consumptive of the resources (i.e., fishing, lobstering, diving for conch, or spearfishing). This percentage is higher during the winter months when other recreational activities decline. Among the boats using the reef area, 67% were conducting activities consumptive of the resources (Table 3).

A total of 126 fish species were observed harvested by recreational fishermen (including divers taking fish, lobster, and conch). Catch rates for the major reef fish families harvested during the period 1976-1978 are shown in Table 4. The six most frequently harvested reef fish species have been white

grunt (Haemulon plumieri), grey snapper (Lutjanus griseus), yellow-tail snapper (Ocyurus chrysurus), hogfish (Lachnolaimus maximus), Nassau grouper (Epinephelus striatus), and black grouper (Mycteroperca bonaci). Trends in catch rate for these most frequently harvested reef species are graphed in Figure 2.

It is evident from the catch-per-unit effort data that although catch rate varies seasonally, clearly declining trends have not been observed for most of the species being harvested. Two exceptions to this have been the bigeyes (Priacanthus spp.) and the black grouper. Although black grouper have declined in catch rate since 1978, overall catch rate for all groupers combined has not continually declined (Table 4). Bigeyes have never comprised more than 0.8% of the total catch and, therefore, the number of reported catches on which to evaluate catch rate has been limited. However, the annually lower catch rate for this species since 1976 indicates a decline in its population may be occurring.

There was a correlation between the total number of fishermen and resulting overall catch rates. During the period 1976 to 1978, the number of fishermen using park waters declined annually while catch rates generally increased. In 1979, reef use figures were higher than any of the previous 3 years (Table 2) and catch rates were the lowest we observed. These data indicate that present fish harvest is at or exceeding the maximum sustainable yield. Size class data obtained on several harvested species has not revealed declining trends (Table 5). A decline in size of species being harvested did not accompany the decline in catch rates observed from 1978 to 1979.

Table 1. Proportion of visitors using various park areas for recreational activities as determined by boater interviews (n = 5,254).

Park area	% of boaters
Biscayne bay	7.6
Islands and creeks	80.5
Reef zone	18.8
Gulf stream	13.0

Table 2. Estimated total number of boater visits to Biscayne National Monument and number of boaters visiting the park's coral reefs, 1976 - 1979.

Year	Total boats in park	Boats using reef zone
1976	57,250	10,900
1977	50,950	9,700
1978	46,800	8,900
1979	61,300	11,650

Table 3. Proportion of boaters using the coral reefs that participated in each recreational activity observed, Biscayne National Monument, Florida.

Activity	% of Boaters
Hook-line fishing	59.2
Snorkeling	10.2
SCUBA diving ^a	9.3
Spearfishing	8.3
Pleasure boating	7.2
Sailing	4.9
Waterskiing	0.7
Swimming	0.2
Photography	0.1

^a Does not include spearfishermen that were using SCUBA.

Table 4. Comparison of catch rates reported by sport fishermen for the major reef fish families, April 1976 - December 1979. The percent that each species is of total catch is shown in parentheses.^a

Family	Rate			
	1976	1977	1978	1979
Grunts	0.849 (35.0)	0.975 (26.9)	0.926 (26.3)	0.815 (30.5)
Snappers	0.506 (16.5)	0.668 (20.0)	0.552 (17.1)	0.614 (22.6)
Grouper	0.229 (6.4)	0.241 (7.0)	0.247 (7.1)	0.189 (5.9)
Wrass (hogfish)	0.407 (4.3)	0.450 (5.3)	0.437 (5.0)	0.349 (3.9)
Barracuda	0.248 (3.6)	0.210 (2.1)	0.190 (2.3)	0.247 (3.1)
Jacks	0.321 (2.1)	0.232 (1.8)	0.267 (1.4)	0.238 (2.1)
Bigeye	0.698 (0.8)	0.547 (0.8)	0.366 (0.6)	0.116 (0.1)

^aCatch rate = Number of fish caught/man hour effort of fisherman successful in catching one or more fish of the family indicated.

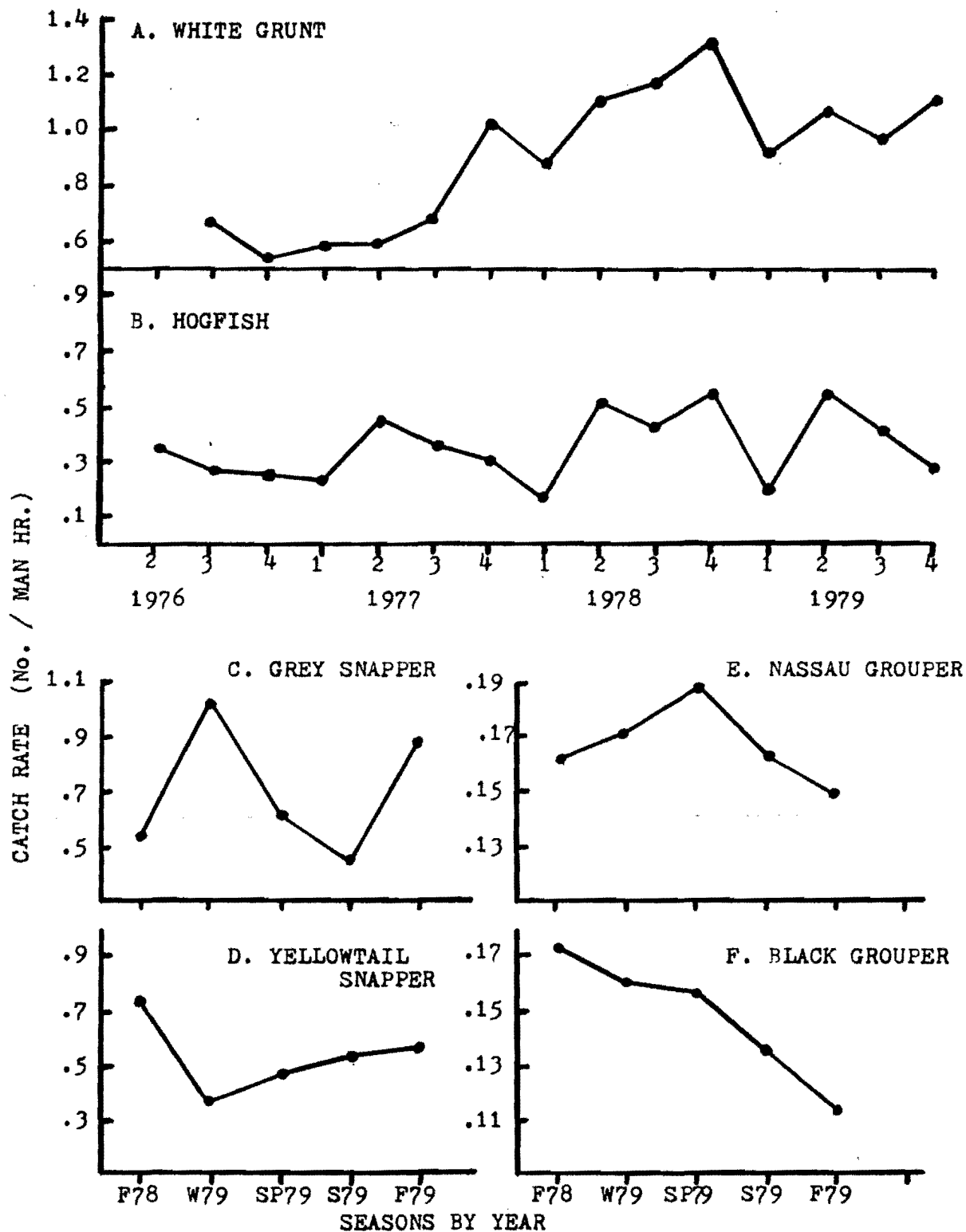


Figure 2. Changes in catch rate (Number caught/man hour effort) as reported by sport fishermen for the six most frequently harvested reef fish species, Biscayne National Monument, Dade County, Florida.

Table 5. Average size of the fish most frequently harvested from Biscayne National Monument reefs, July 1978 - December 1979.

Species	Mean size cm (standard deviation)					
	Sum 78	Fall 78	Wint 79	Spr 79	Sum 79	Fall 79
White grunt	22 (2)	22 (3)	22 (3)	34 (12)	23 (3)	23 (3)
Grey snapper	25 (6)	26 (8)	24 (5)	32 (5)	27 (7)	24 (5)
Yellowtail snapper	22 (2)	23 (4)	24 (6)	33 (8)	22 (5)	24 (4)
Hogfish	36 (9)	34 (8)	35 (10)	38 (11)	36 (9)	35 (10)
Nassau grouper	41 (8)	43 (6)	44 (12)	44 (8)	44 (7)	41 (7)
Black grouper	46 (5)	62 (17)	53 (28)	52 (12)	54 (18)	53 (14)

IMPACT AT SELECTED STUDY REEFS

Approximately 79% of the total use of the study reefs observed occurred on the buoyed reefs. The two largest reefs, Elkhorn and the Elkhorn control reef, received the heaviest amount of use. However, each of the buoyed reefs has received three or more times as much use as its corresponding control. Our observations have indicated that approximately 1.5 percent of the boaters using the park visit the buoyed experimental reefs. This represents a total annual use of from 850-900 boats (3,400-3,600 persons) on the specific reefs studied.

The most frequent recreational activities have been snorkeling and spearfishing (spearfishing is presently permitted under park fishing regulations). Approximately one third of the total recreational activity observed on the intensively studied reefs consisted of consumptive uses. This is less than the level of consumptive use on the reef tract as a whole. Approximately 70% of the consumptive use on the study reefs was spearfishing.

Underwater surveys of the reef fish populations on the patch reefs selected for study have revealed a total of 214 fish species. This exceeds the number of species reported by other investigators using the species/time random visual census on other Florida reefs. Jones and Thompson (1978) reported 146 species at a study site in the John Pennekamp Coral Reef Marine Sanctuary and 134 species at Dry Tortugas in 1975. Thompson and Schmidt recorded 137 species at the same stations at Dry Tortugas (Thompson and Schmidt 1977). Note, however, that the total number of counts over several seasons in the present study greatly exceeds the total counting time expended in these other studies.

Relative abundances of fish species were determined by accumulated point totals. Only one of the most frequently harvested fish species was found to be among the 20 most abundant species on the reef. However, this is not surprising because those species harvested by fishing generally comprise the upper level carnivores within the system and would not be expected to outnumber their prey.

In describing basic ecological conditions and assessing possible impacts of recreational activities, we have been concerned with both the number (richness) of fish species occurring on the study reefs and the relative abundance of individuals of those species. Changes in fish species richness (mean spp./count) observed during the study are shown in Figure 3. Fish abundance, as indicated by mean total point values per count, is shown in Figure 4. Seasonal changes in both species richness and fish abundance have been observed on all the reefs studied.

Total point values of abundance have fluctuated more markedly than number of species observed, but changes in abundance values have been more similar between buoyed and control reefs. Overall fluctuations in reef fish populations generally have followed a similar pattern on all the reefs. A decline in both the number of species present and the relative abundance of those species was noted on many of the study reefs during the spring of 1978. A similar decline was not evident during the spring of 1979. The spring of 1978 decline may be a result of unusually cold water temperatures during the 1977-78 winter months (Figure 3).

Two-way ANOVA tests have indicated a statistically significant difference in seasonal changes between buoyed and control reefs in five situations (Figures 3 and 4). Four of these instances involved

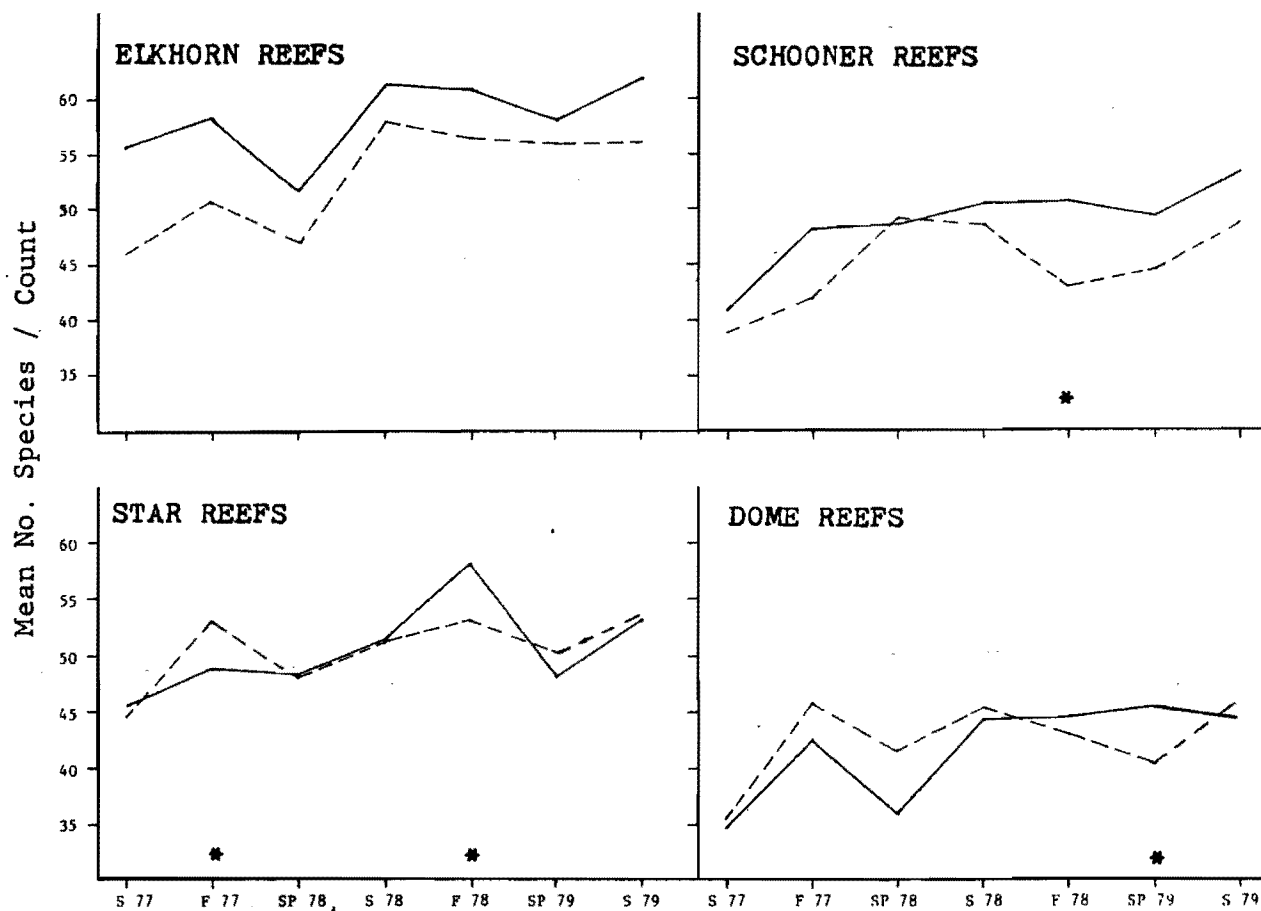


Figure 3. Mean number of fish species recorded/count on buoyed-control reef pairs, summer 1977 - summer 1979. Solid line represents buoyed reef. Broken line represents unmarked control reef. Standard error of the sample means were ± 3.0 species for all observations. A * represents significant difference ($P < 0.05$) in seasonal change between buoyed and control reefs.

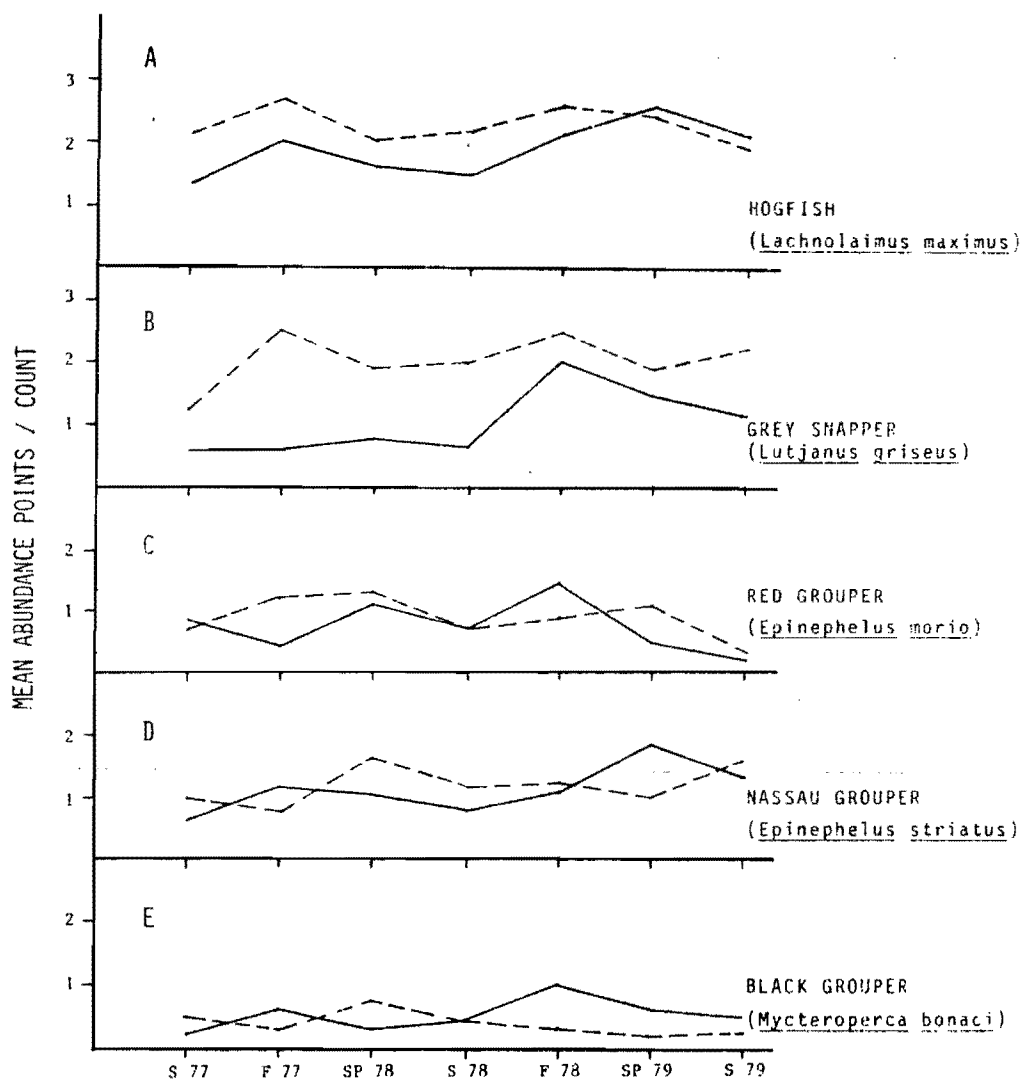


Figure 4. Mean point total/count for fish abundance observed on buoyed-control reef pairs, summer 1977 - summer 1979. Solid line represents unmarked control reef. Standard errors of the sample means were ± 10 points for all observations.

significant differences in both number of species and total fish abundance. In all but one of these circumstances (Star Reef in the Fall of 1977) the buoyed reef had either a greater increase or less decrease in species richness or fish abundance, or both, than its control.

Bray-Curtis indices have shown a relatively high similarity in species composition of fish populations (species occurring and their abundance) between each of the buoyed and control reef pairs. Although seasonal fluctuations have occurred in the populations, the community similarity indices in most cases have not greatly changed. This indicates a high similarity in species comprising the changes observed on both buoyed and control reefs.

None of the differences observed between buoyed and control reef pairs clearly indicate significant impact from human activity to the overall reef fish populations. As is evident from Figures 3 and 4, most marked differences in species richness or relative abundance between buoyed and control reefs have involved greater fish abundance and diversity on the buoyed reefs.

Spearfishing was identified as one of the most frequent activities on the buoyed reefs, so a comparison of the relative abundance of five frequently speared fish was made between buoyed and control reefs. This analysis indicates that the relative abundance of those species frequently speared has generally been lower on the more heavily used buoyed reefs. This difference has been most marked with hogfish and grey snapper between the Elkhorn reefs and Dome reefs. Differences in the abundance of groupers have not been as distinct, although for the majority of observation periods the control reefs supported a higher

group repopulation than the buoyed reefs.

In the John Pennekamp Coral Reef Marine Sanctuary, where spearfishing is prohibited, Jones and Thompson (1978) reported a higher relative abundance (mean abundance point value/count) for four of these five species (Table 6). Red grouper (*Epinephelus morio*) was not observed by Jones and Thompson but has been observed in low numbers in Biscayne National Monument. Further comparison of these species with observations from the Dry Tortugas, where spearfishing is also prohibited, revealed that all but the Nassau grouper had a higher relative abundance at the Tortugas.

Differences in reef structure may account for differences in abundance of these fish species. However, differences between heavily used and less used reefs within Biscayne National Monument, along with overall lower populations, indicate that spearfishing activities in Biscayne National Monument may be a factor in reducing the abundance of selected reef fish species.

Results of the 1977-79 underwater surveys do not indicate continued population declines in any of the frequently harvested fish species. No declines were noted during 1979 when fishing catch rates generally declined. Long-term abundance to catch rate comparisons of frequently harvested individual species are available for only white grunt and hogfish. In both instances, relative abundance observed has roughly followed catch rate. However, seasonal short-term variation in catch rate for these species is not reflected in abundance changes. The continued decline in catch rate observed for the bigeye did correlate with a continuous decline in relative abundance of this family observed on the reefs since summer 1977.

Table 6. Relative abundance of five fish species frequently speared in three south Florida reef areas.

Species	Mean abundance point value/count			
	Pennekamp 1975 ^a	Dry Tortugas 1975 ^a	1976 ^b	Biscayne NM 1977-78 ^c
Hogfish	2.8	3.3	3.2	1.9
Gray snapper	3.5	4.4	4.5	1.1
Red grouper	0.0	2.3	2.2	0.7
Nassau grouper	1.2	0.3	0.3	0.9
Black grouper	2.8	2.7	1.8	0.4

^a Jones and Thompson (1978).

^b Schmidt personal communication and as described in Thompson and Schmidt (1977).

^c Present study (July and August observations only).

CONCLUSIONS

The data obtained at Biscayne National Monument indicate that the present level of recreational activities and consumptive uses are not depleting the coral reef fish resources. The synthesis of data obtained through fisherman interview, and through underwater observation of fish populations, indicates that reef fish populations have generally remained stable even though catch rates have shown marked declines or increases during each year.

Change in fishermen catch rate has varied inversely with number of fishermen using Park waters. This correlation suggests that total annual harvest may remain relatively constant while the number of fishermen harvesting those fish fluctuates. Under such conditions, the park fishery must be considered to be near a maximum sustainable yield. Additional data are needed, during years when the number of fishermen remained constant, to determine long term stability at present harvest levels.

Comparisons to date between closely studied buoyed and control reef pairs have indicated a high degree of similarity in overall reef fish populations. Therefore, at present levels of activity it is believed that significant alteration to reef fish populations has not occurred. It is believed these data have provided a good baseline on which to evaluate other heavily used park reefs and on which to determine impacts of future reef use.

ACKNOWLEDGMENTS

Several persons at Biscayne National Monument assisted with portions of the field work. Fishermen

interviews were conducted by K. Jettmar, L. Forrester, and R. Skinner. G. P. Schmall, S. Andree, D. Morrison and R. D. Conant assisted in underwater fish surveys. G. Hendrix and G. E. Davis, Everglades National Park's Research Center, provided helpful review and comments during the study.

LITERATURE CITED

- Antonius, A. 1977. Coral mortality in reefs: a problem for science and management, pp. 617-623. In *Proceedings Third International Coral Reef Symposium*, Univ. Miami, Coral Gables, Florida. Vol. 1.
- Bray, J. R. and J. T. Curtis. 1975. An ordination of the upland forest communities of Southern Wisconsin. *Ecol. Monog.* 27: 325-349.
- Davis, G. E. 1977. Anchor damage to a coral reef on the coast of Florida. *Biol. Conserv.* 11: 29-34.
- Davis, W. M. 1928. The coral reef problem. *Amer. Geogr. Soc. Spec. Publ.* 9 as cited in: Smith, F. G. 1943. *Atlantic Reef Corals*. Univ. Miami Press. 164 pp.
- Dustan, P. 1977a. Besieged reefs of Florida's Keys. *Nat. Hist.* 86(4): 73-76.
- Dustan, P. 1977b. Vitality of reef coral populations off Key Largo, Florida: recruitment and mortality. *Environ. Geol.* 2: 51-58.
- Gauvin, A. R., E. K. Harris, and H. J. Walter. 1956. A statistical evaluation of stream bottom sampling data obtained from

- three standard samples. Ecology 37: 643-648.
- Jaap, W. C. and J. Wheaton. 1975. Observations on Florida reef coral treated with fish collecting chemicals. FDNR Mar. Res. Pub. No. 10. 18 p.
- Jones, R. S., and J. J. Thompson. 1978. Comparison of Florida reef fish assemblages using a rapid visual technique. Bull. Mar. Sci. 28(1): 159-172.
- Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13: 131-144.
- Thompson, J. J. and T. W. Schmidt. 1977. Validation of the species/time random count technique sampling fish assemblages at Dry Tortugas, pp. 283-288. In Proceedings Third International Coral Reef Symposium, Univ. Miami, Coral Gables, Florida. Vol. 1.
- Tilmant, J. T., G. P. Schmahl, and D. Morrison. 1979. An ecological assessment of Biscayne National Monument's coral reefs in relation to recreational use. Proceedings 2nd National Conference on Scientific Resources in the National Parks, San Francisco, California. 15pp.