decline to the level of ecosystem instability. A few management strategies should be adopted regardless of approach. Spawning aggregation protection should be implemented for maintenence of local population abundance and avoidance of severe changes in species composition. Marine fisheries reserves not only allow for recovery of fish assemblages in overharvested locations, but also allow for collection of comparative data useful for sound assessment.

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Magnitude and Composition of Undersized Grouper Bycatch

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ABSTRACT

The bycatch of undersized fish less than 508 mm total length or fish discarded by fishermen as undersize grouper (gag, *Mycteroperca microlepis* and red grouper, *Epinephelus morio*) was established as a percentage of the daily grouper catch from the commercial hook-and-line fishery off northwest Florida in April and July, 1996. The proportion of undersized grouper catch ranged from 7.9 to 76.1% (overall total 35.7% and mean daily 28.0%) in April and from 40.9 to 87.2% (overall total 62.2% and mean daily 63.2%) in July. The undersized grouper size and age ranges were for gag, 391 to 520 mm total length (2 to 4 years of age) and for red grouper, 381 to 485 mm total length (4 to 7 years of age). Reproductive condition of the undersized grouper was 100% immature female for gag, and 63.5% immature female, 23.1% spawning female, 3.8% immature male, 5.8% spawning male, and 5.8% unknown for red grouper.

KEY WORDS: Grouper, bycatch, age, reproduction, Florida

INTRODUCTION

The gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) are reef-dwelling seabass (Serranidae) that inhabit temperate to tropical waters of the western Atlantic Ocean and the Gulf of Mexico. The gag is a protogynous hermaphrodite (McErlean and Smith, 1964), and the red grouper a protogynous hermaphrodite without precise correlation between size and sexual succession (Moe, 1969). Both species are common along shallow reef tracts as well as shelf break areas in depths of only a few meters to near 150 m (Bullock and Smith, 1991). The total fishery landings of gag in the United States range from 1.5 and 3 million kg per year (Schirripa and Goodyear, 1994; J. Bennett, NMFS, Miami FL, pers. comm.). Red grouper contributed about 3.4 million kg annually in the Gulf of Mexico (based on 1989 commercial landings) which represents about two-thirds of the total grouper commercial catch. The recreational harvest of red grouper is about 1.2 million kg per year (about 700,000 fish) and represents about 29% of the total grouper harvest by weight

(Goodyear and Schirripa, 1991).

The Florida Marine Fisheries Commission and the Gulf of Mexico Fishery Management Council established a 20-inch (508 mm) total length (TL) minimum size for gag and red grouper in 1990. This size limit and other regulations may have contributed to a 70% decline (by number) in the recreational harvest and 21% decline in the commercial landings. But significant numbers of red grouper are caught and released below the minimum size, and the discard (release) mortality has been reported to be high (Goodyear and Schirripa, 1991). The Reef Fish Stock Assessment Panel (RFAP, 1991) reported that release mortality was probably between 30% and 50%. However, tag recapture data and in site observation indicated that potential survival rate of grouper caught deeper than 44 m was too low (<33%) for the 50.8 cm (20 inches) size to be effective in increasing yield (Wilson and Burns, 1994). A high level of release coupled with high mortality could result in a high undocumented loss of the resource.

We present in this report preliminary results of our investigation of the undersized grouper discard (release), hereafter called bycatch, from the northwest Florida commercial hook-and-line fishery. Fish less than the 508 mm total length size limit and discarded or discarded by fishermen as undersized were considered bycatch. The main goals of this investigation were: 1) to determine the level of by-catch, 2) to identify the grouper species composition, and 3) to compare the bycatch to the contemporary legal catch and examine the differences between the two groups. Since the difference between the bycatch and the legal catch is based on a "knife-edge" selection, information is needed on the overlap of the two groups. Comparisons are presented on the catch composition traits of size, age and maturity.

MATERIAL AND METHODS

The grouper bycatch was examined from commercial hook-and-line fishery operations conducted during April and July, 1996. The fishery operations were monitored on boats fishing 80 to 100 km southeast of Panama City, Florida. Most vessels fished depths from 24 to 82 meters to avoid high concentrations of undersized grouper. Catch information (total grouper catch, number of legal and bycatch grouper and water depth) was recorded daily. The bycatch was collected, placed on ice, and sent to the National Marine Fisheries Service, Panama City Laboratory for processing. In the laboratory, fish processing consisted of measuring fish to the nearest millimeter total length (TL), removal of sagittal otoliths for age determination, and removal of gonads for reproductive condition determination. Catch data on bycatch, total catch and water depth was evaluated using the general linear model in SAS (SAS, 1988). In this report, "ln" is the natural logarithm of a number.

Age determination through otolith analysis followed the methods of Johnson *et al.*, 1993. The direct proportional method of Lea (1910) was used for backcalculation of total ength at annulus completion (BCLTL). Comparisons between catches used the Student's t-test. Reproductive condition was determined microscopically and confirmed histologically following the criteria of Wallace and Selman (1981) and West (1990). Briefly, female maturation stages 1 and 2 (primary growth and cortical alveoli formation) were considered immature and stages 3 to 5 (vitellogenesis, hydration and spent) were considered spawning condition. Male maturation description followed Moe (1969). Immature means sexually inactive.

Comparisons of the bycatch age and reproduction information were made between the bycatch and the 1996 legal catch information collected from Panama City commercial and recreational landings (February through July) using the aforementioned methods. Commeercial landings were sampled randomly with respect to size from dockside landings.

RESULTS AND DISCUSSION

The grouper bycatch (155 gag and 52 red grouper) represented a substantial component of the total sampled hook-and-line catch in water depths 24 to 82m (Table 1). The bycatch species composition was 75% gag and 25% red grouper. The undersized grouper catch ranged from 7.9 to 76.1% (overall total 35.7% and mean daily 28.0%) and from 40.9 to 87.2% (overall total 62.2% and mean daily 63.2%) of the grouper catches sampled in April and July, respectively. The observed length ranges were similar for gag (391 to 520 mm) and red grouper (381 to 485 mm), but the red grouper age range (4 to 7 years) was broader than the age range for gag (2 to 4 years). The 1993 year class dominated the undersized gag catch (96.1%), while the 1991 year class was predominant in the undersized red grouper catch (63.5%) (Table 2). The reproductive condition of the undersized gag was 100% immature female, but varied for undersized red grouper. The red grouper reproductive conditions were 63.5% immature female, 23.1% spawning female, 3.8% immature male, 5.8% spawning male and 3.8% immature unknown. The spawning female length range was 381 to 453 mm (mean 417.3 mm).

Daily catch of undersized grouper was negatively related to maximum water depth [ln Catch (number of fish) = 16.75-3.40 (ln Depth in m), $r^2 = 0.442$, $F_{(11)} = 7.91$, $p = 0.0184$]. The proportion of undersized grouper in the total daily grouper catch also had a significant negative relation to maximum water depth [ln Proportion = 6.48-1.87 (ln Depth in m), $r^2 = 0.455$, $F_{(10)} = 8.46$, $p = 0.017$].

The legal catch samples collected were 404 gag and 154 red grouper. The legal minimum size limit for these groupers was 508 mm TL, some undersized fish (9.9% gag and 9.7% red grouper) were landed as legal (Table 3). The size

Table 1. Commercial hook-and-line catch by day for trips where data was collected on undersized gag and red grouper (bycatch) from northwest Florida during April and July, 1996.

Month/Day	# Fish Total catch[1]	Bycatch[2]	Depth range fished (m)	Percent bycatch of total catch
4/8	38	3	64-81	7.9
4/10[3]	81	34	57-65	42.0
4/11	49	16	47-53	32.7
4/12	40	9	62-72	22.5
4/17	160	32	38-67	20.0
4/19	113	86	43-44	76.1
4/20	58	17	34-47	29.3
4/21	15	3	69-75	20.0
4/22	12	2	24-81	18.2
7/20	39	34	42-60	87.2
7/21	44	27	41-48	61.4
7/22	44	18	79-82	40.9
Total April	566	202	24-81	35.7
Total July	127	79	41-82	62.2

[1] Total catch is number of all gag and red grouper caught.

[2] Bycatch is number of gag and red grouper less than 508 mm total length or discarded by commercial fisherman as undersized

[3] Catches of two days combined.

Table 2. Age and length distribution of bycatch of gag and red grouper caught in the commercial fishery off northwest Florida during April and July, 1996.[1]

Species	Month	Age in years	Year class	Number of fish	Total length[3] Mean	Range
Gag	April	4[2]	1992	1	520.0	520
		3	1993	96	450.9	391-490
		2	1994	2	401.0	400-402
	July	3	1993	53	456.5	403-501
		2	1994	3	423.7	395-467
Red Grouper	April	7	1989	2	450.0	430-470
		6	1990	12	455.5	401-485
		5	1991	29	439.5	381-476
		4	1992	5	418.2	395-460
	July	5	1991	4	423.3	410-437

[1] Bycatch is gag and red grouper less than 508 mm total length and/or discarded by commercial fishermen as undersized.

[2] One fish discarded by commercial fisherman as undersized.

[3] Total length in millimeters

and age range of the legal catch for gag was 384 to 1227 mm TL (2 to 18 yrs) and for red grouper was 482 to 840 mm TL (5 to 14 years).

Reproductive condition of the legal groupers (239 gag and 139 red grouper collected February to August, 1996) was 70.2% immature female, 25.6% spawning female, 0.9% immature males, and 1.9% spawning males and 1.4% unknown for gag, and 53.1% immature female, 31.5% spawning female, 12.3% immature male, and 2.3% spawning male, and 0.8% unknown for red grouper. The ratios of immature females to spawning females for red grouper comparing bycatch (2.8:1) and legal catch (1.7:1) were not statistically different (X^2 = 1.4870, d.f. = 1, $0.3 > p > 0.2$).

The following observations can be made from grouper catches examined in this study:

i) A high level of bycatch exists in the hook-and-line fishery. Bycatch in waters deeper than 44 m, the depth of the majority of our samples (72% of both species) were collected, would be subject to high mortality (Wilson and Burns 1996).

ii) The dominance of the 1993 year class in the gag bycatch and the catch of legal sized fish is not unexpected, as this was predicted in 1994 by the alternating high and low years of abundance phenomenon (even number years-low and odd number years high) that was presented by Johnson and Koenig (In press). Their observations were based on year class strength of juveniles in estuarine seagrass beds and the resulting legal catch composition in later years for the northwest Florida area. The dominance of the 1993 year class in the catch (legal and bycatch) reflects the higher than average abundance of this year class. Information from local fishing captains indicated that this year (1996) had a larger than usual bycatch, but for the last several years the bycatch has been high compared to the previous decade. Additionally, the bycatch has been occurring in deeper water, mainly from 33 to 46m, but up to 130m..

iii) The size at annulus completion, BCTL, was significantly different between the bycatch and the legal catch (Tables 4 and 5) for all annuli that were shared by both groups for both gag and red grouper (Student's t-test, $p < 0.001$, Cochran option). The results of the backcalculation comparisons indicate that the bycatch grew slower than the legal catch for both gag and red grouper. This finding preliminarily supports the contention of Goodyear (1996) that large minimum sizes may cause the fishery to harvest the faster-growing component of each year class, thus could cause genetic selection for slow growth, depending on the heritability of growth. This selection may be occurring on the fish in shallower waters as those from deeper water (< 44 m) are probably subject to high release mortality.

iv) The spawning component of the red grouper bycatch (23.1% female and 5.8% male), if subject to mortality, may represent significant loss to the population's reproductive potential as size limit does not completely protect the sizes of fish that are actively reproducing. The use of size limits to lower mortality of fish until maturation may be inadequate for red grouper and potentially useless for gag. If a major proportion of the bycatch is subject to high release mortality, the benefits of minimum size limits to future yields may be negated, while providing no current fishing gain. Additionally, the use of size limits may have a detrimental genetic effect on the populations. Other approaches to conservation, such as refuges and seasonal closures to protect spawning aggregations during spawning season, may provide more suitable protection for these groupers. Since undersize fish are present in the legal catch, high levels of bycatch occur in the fishery in deep waters and the size limit does not completely protect the red grouper spawning, consideration should be given to landing quotas without size limits.

There are several advantages of minimum size limits for reef fish management: (1) the total weight harvested from a cohort may be maximized; (2) the minimum size can equal or exceed the age of sexual maturity thus maximizing the total long term yield; and (3) it has administrative appeal, as size limits are easy to enforce at sites of landings. However, there are disadvantages to size limits: (1) reef fish gear are not perfectly size selective and fish smaller than the limit are often brought to the surface; (2) fish are lost due to fishing trauma (pressure-induced trauma, et al.); and (3) size limits impact some fishery sectors more heavily than others, thus affecting fair distribution of the resource to user groups (Huntsman and Manooch, 1978), (4) size limits may cause harvesting of the faster growing fish of a year class and result in genetic selection for slower growth (Goodyear 1996). Huntsman and Waters (1987) reviewed the dilemma that minimum size limits pose to grouper management. They stated "size limits for those species with relatively small Ps (probability that undersized fish would survive if caught and released) and for the protogynous species (apparently all groupers and some porgies), may not allow adequate reproduction if fish mortality becomes very high." Small size limits would result in killing large fractions of the population before they spawn. The results of our investigation highlights the above dilemma in that the hook-and-line fishery produces high levels of grouper bycatch (7.9 to 87.2%) and that some of the red grouper bycatch are in spawning condition (23.1% female and 5.8% male).

Table 3. Age and total length distribution of samples collected from the legal grouper landings at Panama City, Florida, 1996.[1]

Species	Age (year)	Year class	Number of fish	Total length Mean	Range
Gag	2	1994	2	504.5	499-510
	3	1993	127	536.6	384-672
	4	1992	90	614.2	485-720
	5	1991	53	728.7	601-865
	6	1990	29	805.0	500-945
	7	1989	80	874.6	655-1010
	9	1987	6	1056.0	1020-1113
	10	1986	1	1006.0	1006
	11	1985	10	1100.8	993-1175
	13	1983	2	1175.0	1155-1195
	14	1982	1	955.0	955
	15	1981	1	1200.0	1200
	16	1980	1	1227.0	1227
	18	1978	1	1200.0	1200
Red Grouper	5	1991	21	515.5	492-612
	6	1990	49	568.1	482-942
	7	1989	46	600.1	505-705
	8	1988	17	660.3	523-758
	9	1987	11	702.0	573-775
	10	1986	7	693.1	532-786
	11	1985	1	822.0	822
	13	1983	1	840.0	840
	14	1982	1	835.0	835

[1] Legal indicates fish landed as commercial legal size. Minimum size limit is 508 mm total length. Not all fish landed as legal were 508 mm total length or greater. Total length in millimeters.

Table 4. Backcalculated mean total length at annulus completion for gag from northwest Florida, 1996.

	Bycatch			Legal catch		
Annulus	No. of annuli[2]	Mean[3]	Weighted mean	No. of annuli	Mean	Weighted mean
1	155	300.8	263.7	399	333.7	315.7
2	153	367.2	364.7	397	420.2	433.6
3	57	444.5	444.5	271	511.2	539.6
4				182	636.0	649.1
5				129	730.4	738.8
6				100	807.8	817.5
7				20		925.7
8				20	1010.1	981.5
9				14	955.7	1016.0
10				13	1064.7	1060.9
11				3		1080.3
12				3	1166.9	1166.9
13				2		1135.6
14				2	1156.1	1160.0
15				1	1201.7	1201.7

[1] Method of backcalculation was the direct proportional method of Lea, 1910. Number of fish used from bycatch was 155 and from legal catch was 399. Total length is in millimeters.

[2] Number of annuli is the number of annuli used to compile the weighted mean total length in mm at completion of annulus.

[3] Mean total length in mm at completion of most recent annulus before capture.

Table 5. Backcalculated mean total length at annulus completion for red grouper from northwest Florida during April and July, 1996.

	Bycatch			Legal Catch		
Annulus	No. of Annuli[2]	Mean[3]	Weighted Mean	# of annuli	Mean	Weighted Mean
1	52		157.1	153		185.1
2	52		263.4	153		320.3
3	52	348.5	332.9	153		408.0
4	47	395.7	386.7	153	455.7	474.4
5	19	419.5	416.3	129	523.2	534.8
6	2	421.2	421.2	81	561.5	576.4
7				36	632.6	637.7
8				20	676.1	676.1
9				9	687.8	707.8
10				3	812.7	777.2
11				2		783.9
12				2	819.3	803.7
13				1	806.9	806.9

[1] Method of backcalculation was the direct proportional method of Lea, 1910. Number of fish sampled from the bycatch was 52 and from legal catch w as 153. Total length is in millimeters.

[2] Number of annuli is the number of annuli used to compile the weighted mean total length in mm at completion of annulus.

[3] Mean total length in mm at completion of most recent annulus before capture.

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Explotación de los Serránidos en el Sureste del Golfo de México: Evolución y Situación Actual.

Groupers Exploitation on the Southest Gulf of Mexico: History and Present.

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RESUMEN

Aunada a la explotación del pulpo, la captura de serránidos en el sureste del Golfo de México constituye la base de la actividad pesquera de Yucatán. De 1980 a 1995 este recurso representó entre 19% y 38% de la captura total en dicha entidad. A nivel nacional Yucatán figura como el principal productor de meros. Entre 1980 y 1992 este estado aportó del 88% al 96% de las capturas mexicanas. Esta pesquería se caracteriza por su explotación de tipo secuencial y su aspecto multiespecífico. Este recurso, compartido entre las flotas artesanal y tecnificada nacionales y la flota de altura cubana, es explotado en la amplia plataforma continental que se extiende al norte y oeste de la Península de Yucatán (Banco de Campeche). Las operaciones de las pesquerías de escamas de ambos países inciden principalmente en al menos 15 especies de serránidos de los géneros *Epinephelus* y *Mycteroperca*; el mero americano *Epinephelus morio*, representa la especie con mayor volumen de captura. Aunque la población de esta especie, no ha alcanzado el estado de sobre explotación, el Gobierno mexicano decidió elaborar normas oficiales de ordenación de la pesquería de mero. Las diferentes estratégicas de regulación propuestas para el manejo de este recurso son presentadas y analizadas.

PALABRAS CLAVES: Banco de Campeche, Golfo de México, mero, ordenación, pesquería

ABSTRACT

Groupers and octopus from the Southest Gulf of Mexico are the major components of comercial fisheries from the state of Yucatan. Grouper landings represented 19% to 38% of the total marine production for the state between 1980 and 1995. Yucatan was the leading state in grouper catches between 1980 and 1992 with 88% and 96% of the mexican groupers total production. Sequential explotation and multi-species aspect characterize this fishery. This resource is fished both by mexican inshore and offshore fleets and cuban fishing

Proceedings of the

FORTY-NINTH ANNUAL

Gulf and Caribbean Fisheries Institute

CHRIST CHURCH, BARBADOS NOVEMBER 1996

Library of Congress Catalog Card Number 52-33786

Edited by

R. LeRoy Creswell

Associate Editors

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FORT PIERCE, FLORIDA 1997