Comparison of Two Techniques for Estimating Tilefish, Yellowedge Grouper, and Other Deepwater Fish Populations

Gary C. Matlock
Fisheries Division, Texas Parks and Wildlife Department
4200 Smith School Road, Austin, Texas 78744

Walter R. Nelson
Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA
75 Virginia Beach Drive, Miami, Florida 33149

Robert S. Jones
Marine Science Institute, University of Texas at Austin
P.O. Box 1267, Port Aransas, Texas 78373

Albert W. Green
Environment Assessment, Texas Parks and Wildlife Department
4200 Smith School Road, Austin, Texas 78744

Terry J. Cody
Coastal Fisheries Branch, Texas Parks and Wildlife Department
100 Navigational Circle, Rockport, Texas 78382

Elmer Gutherz
Mississippi Laboratory, National Marine Fisheries Service, NOAA
P.O. Drawer 1207, Pascagoula, Mississippi 39567

Jeff Doerzbacher
11505 Oak Branch Drive, Austin, Texas 78737

Abstract.–Tilefish *Lopholatilus chamaeleonticeps* and yellowedge grouper *Epinephelus flavolimbatus* are deepwater fishes and targets of a relatively recent bottom longline fishery in the Gulf of Mexico. They are long-lived, slow growing, have very limited movements and distribution, and are susceptible to longlines. However, population size and life-history parameter estimates are generally unknown for Gulf fish. This study compared two methods for estimating population sizes to determine the most cost-effective one for use on long-term fishery-independent stock assessments. Bottom longlines were used to deplete fish from a small area, and a regression of catch per effort on cumulative catch was used to estimate the area's population prior to fishing. The population was also estimated by counting fish burrows from a submersible and expanding the mean number per unit area by the study site's area after correcting for the number of occupied burrows. Longlines and submersibles provided significantly different estimates of tilefish populations, the only species for which estimates could be compared. Longline estimates were probably more accurate because errors in area estimation and double counting were evident in submersible data. Longlines were less expensive to operate ($5000 vs. $8000 per day) and they afforded collection of size, age, and sex data on each fish caught. These data were not available from the submersible. Longlines could be used more cost-effectively than submersibles in determining long-term population changes. However, direct observation of fish behavior was not available from longlines, but was from the submersible. Submersibles also provide data on habitat and gear assessment, including deployment, efficiency, bait predation, and potential catch loss during retrieval.

Manuscript accepted 1 August 1990.
Fishery Bulletin, U.S. 89:91–99 (1991).

Tilefish *Lopholatilus chamaeleonticeps* support an economically important bottom longline fishery in the Mid-Atlantic Bight (Grimes et al. 1980, Turner 1986), and are the focus of a developing longline fishery in the South Atlantic Bight and the Gulf of Mexico (Katz et al. 1983, Low et al. 1983). Impacts of this development in the Gulf are unknown because population sizes and life-history parameter estimates there are generally unknown. However, the potential for recruitment overfishing appears large even at relatively low fishing effort because of the fish's life history (Harris and Grossman 1985). The fish is long-lived, slow growing (Turner et al. 1983, Harris and Grossman 1985), has limited movement (Grimes et al. 1983, 1986), and is restricted to temperatures of 9–14°C (Grimes et al. 1986, Freeman and Turner 1977). Tilefish are burrowers, requiring a clay substrate that is soft enough to allow burrowing, but firm enough for maintenance of burrows that may exceed 1 m in diameter and 3 m in depth (Able et al. 1982, Grimes et al. 1986, Twichell et al. 1985). In the Gulf of Mexico this is a narrow geographic area along the outer edge of the continental shelf between depths of 229 and 411 m (Nelson and Carpenter

1968, Wolf and Rathjen 1974). For the above reasons, tilefish are susceptible to capture on longlines (Nelson and Carpenter 1968, Wolf and Rathjen 1974, Grimes et al. 1982, Cody et al. 1981) and overfishing (Harris and Grossman 1985).

Yellowedge grouper *Epinephelus flavolimbatus* are also a target of the developing Gulf longline commercial fishery (Prytherch 1983, Graham 1978). However, even less is known about the life history and populations of this species than of tilefish. They are apparently present in commercial concentrations off Texas in the 128–274 m depth zone (Nelson and Carpenter 1968). On only 90 trips in the Gulf in 1982 over 65,000 kg of yellowedge grouper were landed (Prytherch 1983). However, their frequent distribution around rock and coral formations may preclude sustained commercial catches because of gear loss (Graham 1978).

This study was conducted to contrast "fishing out" an area with bottom longlines to direct visual observations from a small research submersible as methods for determining population sizes of tilefish, yellowedge grouper, and other deepwater fishes. The impact of longline fishing on these populations within a limited area was also determined.

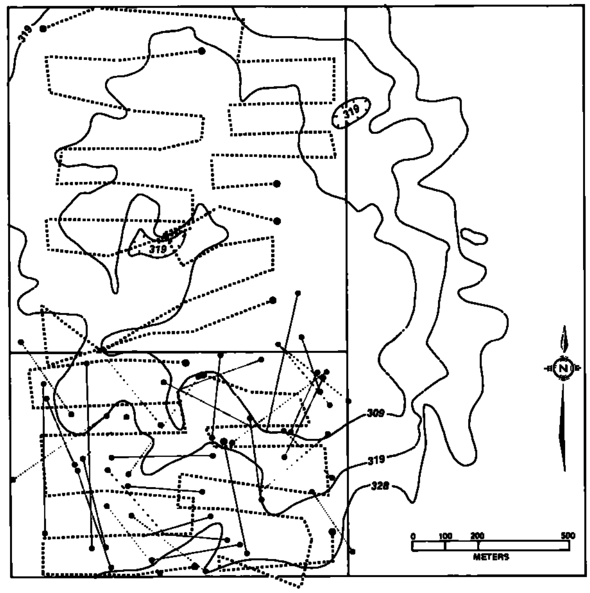

Figure 1
Tilefish study area (center point at 27°40.0′N lat. and 94°22.8′W long.) showing depth contours in meters, submersible transect tracks (dashed lines), and distribution of longline sets (solid lines) within the southern part of the study area. Chart represents one square nautical mile.

Materials and methods

Preliminary activities

In May 1984 the NOAA ship *Oregon II* spent 6 days surveying an area measuring 95 km east-to-west (94° 10′ long. to 95°00′W long.) between 183- and 457-m depths directly south of Galveston, Texas. Bottom configuration and acoustic signatures of fish were noted with a color-enhanced fathometer. Eleven bottom longline sets were made during each day to locate areas of high tilefish and yellowedge grouper catch rates (≥0.3 fish/100 hook-hours). Based on these preliminary cruises, specific sites were chosen for the submersible and longline studies described in this paper. Three days (10–13 September 1984) were spent by the *Oregon II* making detailed charts of each study site prior to the arrival of the submersible. Bathymetric charts of each site were developed using a depth sounder and Loran "C" plotter. These charts represented an area 2.6 km² (1 nmi²) and were contoured by 10-m depth intervals. The trackline interval used in mapping was about one track per 15 m. The charts were duplicated and copies were provided to the Harbor Branch Foundation's RV *Johnson* prior to the beginning of submersible and fishing activities. This allowed both vessels to track and plot the position of the submersible and location of longline sets precisely.

Study area

Tilefish A study area (1.9 × 1.1 km) was selected off the north Texas coast at 27°40.0′N lat. and 94°22.8′W long. (Fig. 1). The area was a broad ridge with a minimum depth of 304 m. Approximately 50% of the study area was less than 311 m in depth with the bottom dropping gradually away to 316–318 m at the northern part of the area, and 320–329 m in the southwestern part. The area was almost entirely covered with a soft sand-clay mixture, characteristic of tilefish habitat along the entire U. S. eastern coastline (Freeman and Turner 1977, Able et al. 1982, Twichell et al. 1985, Grimes et al. 1986). However, the substratum was less cohesive than in east coast tilefish grounds. A fin-stabilized metal rod, dropped from a height of 1.2 m by the submersible's manipulator arm, penetrated 80–100 cm in the gulf and 20–30 cm on east coast tilefish grounds (C.B. Grimes et al., NMFS Panama City Lab., unpubl. data for Mid-Atlantic Bight and South Atlantic off Florida).

Many of the burrows in the study area were dug at an oblique angle into the substratum or into a sloping face, instead of perpendicular as is characteristic of east coast tilefish on flat bottom (Able et al. 1982, Grimes et al. 1986). It was evident that the low cohesiveness of the sediment probably caused the frequently observed cave-ins and sloughing of sediment around the mouths of burrows. Extensive secondary bioerosion by galatheid crabs and other burrowers (similar to the mechanism described by Able et al. 1982 and Grimes et al. 1986) further weakens the structure, contributing to cave-ins of the burrow roofs dug at an angle. Consequently, large areas of up to 6 x 9m appeared to be plowed or cratered. It is not known if these broad areas were caused by one or several tilefish within each of the "plowed areas," or if one or more generations of tilefish were responsible.

Other tilefish burrows found in the study site were more like the typical "vertical" burrows known for these animals (Able et al. 1982, Grimes et al. 1986). Vertical burrows are apparently more stable than oblique ones, requiring less constant re- excavation. Some burrows that had become inactive were filled with sediment at the shaft entrance, but they showed evidence of recent bioerosion around their margins from secondary burrowers. There were also extensive areas that contained numerous depressions, apparently remains of old structures that were 1–2m across and 0.6–1.5m deep. Concentrations of 15–20 such depressions, 6–8 filled-in burrows, and 2–5 active burrows were common in the study area.

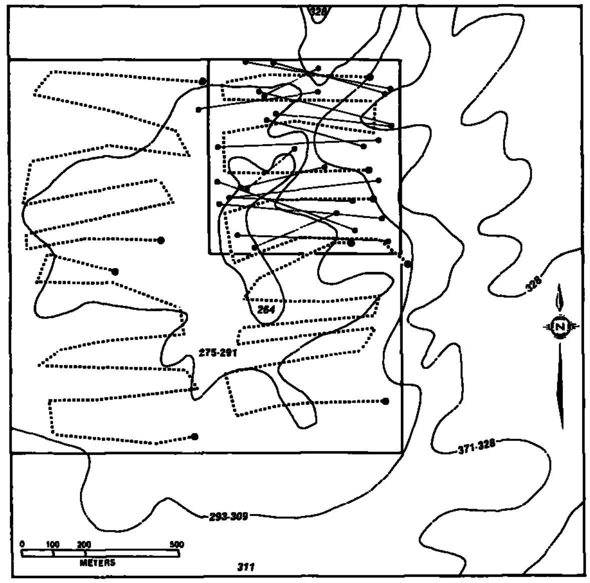

Figure 2
Yellowedge grouper study site (center point at 27°41.3′N lat. and 94°23.6′W long.) showing depth contours in meters, submersible transect tracks (dashed lines), and distribution of longline sets (solid lines) within the northeast part of the study area. Chart represents one square nautical mile.

Yellowedge grouper A study area (1.28 x 1.28km) slightly inshore of the tilefish site was selected at 27°41.3′N lat. and 94°23.6′W long. (Fig. 2). Depth ranged from 267m along a central ridge to 311m at the outer edge of the study area. The area was characterized by isolated boulders and scattered low rock ridges concentrated in depths of less than 283m. The bottom was comprised of a sand-clay mixture interspersed with rubble and shell. Patches of avalanche anemones (*Bolocera* sp.) and sea pens (*Penatula* sp.) were frequently attached in the vicinity of rubble and "hard bottom." Bottom temperature fluctuated little at the study site (12.0–12.9°C). Fishing activities were confined to a 640 x 640m (409,600 m^2) quadrant of the study area because time available was shortened by bad weather.

Study activities

Submersible observations Burrow and fish counts were made from the submersible *Johnson-Sea-Link* during morning. Accordian-type transects with randomly selected starting points and alternating 366 (east–west) and 91-m (north–south) legs (up to 2652m total distance per dive) were run with the submersible within 1m of the bottom and traveling at 1.9km/h. At the end of the east–west portions of each transect leg, the submersible would maintain position while the RV *Johnson* maneuvered directly above and recorded the position on a LORAN plot of the study area. Five transect dives were made on each of the study areas (Figs. 1, 2). Two of these transects were located completely within the portions of the tilefish area fished with longlines; one transect was completely within the fished portion of the grouper area.

The number of adult and juvenile burrows that were "filled-in" (denoting previous occupancy) or were "depressions" (characteristic of long-abandoned burrows that had been gradually filled in and smoothed over) were counted as inactive burrows. All others were counted as "active" (currently used by fish); only "active" burrow counts were used in estimating populations. Burrows within 7.3m on either side of the submersible in the tilefish area and 11.0m in the yellowedge grouper area were counted. These viewing distances were based on the range of visibility and viewing angles and were different in the two study areas because grouper and their burrows were generally larger than tilefish. So, grouper could be seen farther away than tilefish. All tilefish and yellowedge grouper seen were counted. All other fish seen were identified to species, if possible (names follow Robins et al. 1980), and these identifications were verified using photographic and video records made during each dive.

Occupancy of "active" burrows was estimated by observing tilefish diving into burrows and by observing "smoking" (sediment plumes extruded) burrows during each of three other dives. These "positive" sightings provided a minimum estimate of occupancy of the total number of active-looking burrows seen on each dive. Occupancy dives were not conducted in the yellowedge grouper site, because grouper were usually seen outside their burrows and only moved out of sight into burrows when the submersible approached.

Bottom longline fishing Intensive fishing activities were conducted with bottom longlines in a portion of each study area (Figs. 1, 2). In the tilefish area longline sets consisted of 100 No. 7 circle hooks on 4.6-cm gangions, attached to a 366-m long ground line with halibut line snaps. Weights were used at both ends of the longline to prevent movement of the line along the bottom. Longlines were baited with squid and fished during daylight only. Two lines were fished on a rotating basis, with sets being soaked for approximately 2 hours. A maximum of eight sets (800 hooks) were made per day. In the yellowedge grouper area "Kali" poles were used to reduce gear loss caused by hanging on large boulders. This gear consisted of 40 2.4-m long PVC pipes weighted at one end and buoyed at the other, with 5 hooks 20.3 cm apart on each pole separated vertically by about 0.5 m. One pole was clipped to a floating mainline every 9 m with a halibut line snap. The "Kali" lines had only the lower end of the PVC pipe and anchors touching bottom. The lines were set at randomly selected locations for approximately 2 hours, using squid for bait.

Upon retrieval of all longlines, number of hooks returned, number of baits returned, and catch by species were recorded. Catch-per-unit-effort (CPUE) was calculated for each set using number of hooks returned.

Data analysis

Population densities and sizes were estimated using the Leslie method modified by Braaten (Ricker 1975, p. 151) from longline catches of Cuban dogfish *Squalus cubensis*, gulf hake *Urophycis cirrata*, southern hake *U. floridana*, and tilefish in the longline-fished portion of the tilefish area; and barrelfish *Hyperoglyphe perciformis*, longspine scorpionfish *Pontinus longispinis*, southern hake, and yellowedge grouper in the longline-fished portion of the grouper area. A regression of CPUE (in number of fish/100 hook-hours) for each longline on adjusted (50% of each day's total catch) cumulative daily catch was calculated using least squares regression weighted by the inverse of variance in daily CPUE (SAS 1982). The cumulative catch was adjusted to reduce bias that can result from using the cumulative catch at the start or end of each fishing period (Braaten 1969). The X-axis intercept was the population estimate ($\hat{N}$) for the area fished. Associated 95% confidence intervals were calculated following Sokal and Rohlf (1981, p. 498). Catchability coefficients (for species caught on longlines with significant regressions) were equal to the slopes of the regressions (Ricker 1975, p. 150). The assumptions of this technique include constant catchability, geographically closed (within the study area) population (i.e. no recruitment or emigration), no natural mortality, and constant fishing effort (Ricker 1975).

Data from the submersible were used to estimate tilefish and yellowedge grouper populations ($\hat{N}$) within the area fished with longlines (fished) and the remaining portion of the study area (unfished). There were two transects made in the fished portion, and three transects in the unfished portion of the tilefish study area. There was one transect made completely in the fished portion, and four transects in the unfished portion of the yellowedge grouper study area. These populations were estimated as the product of the mean number of burrows or fish per km^2, the percent burrow occupancy (for tilefish only), and the total km^2 in the study area. The mean number of burrows or fish per km^2 ($\pm$ 1 SE) was estimated for each transect and each area using the mean and variance equations for the delta-distribution (Pennington 1983, 1986) after transforming the density data along each leg of each transect to natural logarithm. Differences in mean densities were tested using the t-test (Sokal and Rohlf 1981). Occupancy was estimated as the mean percent ($\pm$ 1 SE) from three dives using the "smoking" burrow data discussed previously using the ratio estimator (Cochran 1977). The variance of the population estimates ($\hat{N}$) based on burrow counts was calculated as the variance of a product (burrows/km^2 $\times$ percent occupancy; Goodman 1960). Differences in the population estimates resulting from the longlines and submersibles were tested using the t-test (Cochran 1977, Sokal and Rohlf 1981) and variances associated with the population estimates.

Results

Fish data from longlines and submersibles provided significantly different estimates of tilefish populations. Population estimates for yellowedge grouper could not be made from the longline data because it did not yield a significant regression (Table 1). The number of tilefish (with 95% confidence intervals in parentheses) in the

Table 1

Population estimates and 95% confidence intervals (CI) for fishes caught on longlines and observed during submersible dives on the tilefish and grouper study areas off Galveston, Texas during September 1984. Longline estimates for fishes other than tilefish and yellowedge grouper were made only for species with significant relationships between catch-per-unit-effort and cumulative catch (Ricker 1975). Submersible estimates were based on expansions of mean burrows or fish per unit area seen on one and two transects in the grouper and tilefish study sites, respectively, to the total fished area (836,067 m^2).

	Longline						Submersible		
Species	No. of days	Y-intercept (± 1 SE)	Slope (± 1 SE)	R^2	F	N (95% CI)	No. of transects	N (95% CI) based on burrows	N (95% CI) based on fish seen
Tilefish site									
Tilefish	7	4.026 ± 0.835	−0.050 ± 0.012	0.382	18.574**	81 (39–128)	2	446(364–522)[a]	134(121–147)
Cuban dogfish	7	5.410 ± 1.190	−0.084 ± 0.020	0.371	17.677**	65 (24–108)			
Gulf hake	7	0.491 ± 0.330	−0.005 ± 0.010	0.007	0.209NS				
Southern hake	7	1.874 ± 0.501	−0.043 ± 0.013	0.260	10.554**	43(−27–121)			
Grouper site									
Yellowedge grouper	3	0.914 ± 0.383	−0.030 ± 0.020	0.140	2.277NS		1	150(105–195)	150(118–182)
Southern hake	3	3.445 ± 1.154	−0.052 ± 0.020	0.320	6.587*	66 (9–170)			
Longspine scorpionfish	3	0.995 ± 0.287	−0.013 ± 0.013	0.066	0.983NS				
Barrelfish	3	1.713 ± 0.705	−0.027 ± 0.017	0.157	2.605NS				

[a] Mean percent occupancy of burrows was 35.6 ± 16.8 (95% CI).

fished portion of the study area was 81 (39–128) based on longline catches; the estimate from submersible data was 134 (121–147) based on observed fish (Table 1). These estimates were significantly different from each other ($t = 4.939$, df = 29, $P<0.05$). The estimated number of tilefish based on burrow counts (446, 364–522) was four to five times higher than either of the fish-based estimates. The estimated number of yellowedge grouper in the fished portion of the grouper area was 150 (118–182) fish based on submersible grouper data and 150 (105–195) based on burrow data (Table 1). Again, no comparable estimate was made from longline data.

The estimated number of tilefish seen per unit area was significantly ($t = 3.621$, df = 51, $P<0.05$) greater (about 30%) in the fished area than in the unfished portion of the study area. There were also significantly ($t = 5.899$, df = 42, $P<0.05$) more yellowedge grouper (about 68%) seen in the fished area than in the unfished area (Table 2). This same pattern was apparent in the burrow data for tilefish ($t = 3.737$, df = 51, $P<0.05$) and yellowedge grouper ($t = 6.381$, df = 42, $P<0.05$). In the unfished portion of the grouper study area, the mean number of yellowedge grouper burrows seen per km^2 (70, 95% CI = 62–78) was less than 50% of the mean number of yellowedge grouper seen (170, 95% CI = 154–186) (Table 2). However, the number of burrows seen in the tilefish study area in both the fished and unfished portions exceeded the number of tilefish seen by about 10 to 20 times.

Estimates using submersible data could not be made for southern hake, gulf hake, Cuban dogfish, longspine scorpionfish, and barrelfish since they were generally not seen from the submersible. However, longlines caught 322 of these fishes during the 12,000–13,000 hook-hours of fishing on the tilefish and grouper study areas. Longline catch rates declined through time for southern hake in both study areas and Cuban dogfish caught in the tilefish study area, but no significant change in catch rates was detected for gulf hake in the tilefish study area or longspine scorpionfish or barrelfish in the grouper study area. Therefore, population estimates and 95% confidence intervals were only made for southern hake and Cuban dogfish; 43 (−27–121) and 65 (24–108) fish, respectively, in the tilefish study area and 66 (9–170) southern hake in the grouper study area (Table 1). More species were seen from the submersible than were caught on longlines (Table 3), but more population estimates could be made from longline data than from submersible data.

Table 2

Mean number of tilefish and yellowedge grouper and burrows of each species seen per km² on transects by a submersible in areas fished with longlines (study sites) and adjacent areas. Mean number of tilefish burrows seen was multiplied by mean percent occupancy (0.36 ± 0.16) to estimate number of tilefish and grouper. Width of each transect was 14.6 and 22.0 m for tilefish and grouper areas, respectively. The number of transect legs (n) is indicated for each transect.

	Tilefish						Yellowedge grouper					
			Fish		Burrows				Fish		Burrows	
Area	Transect	n	$\bar{x}$	SE	$\bar{x}$	SE	Transect	n	$\bar{x}$	SE	$\bar{x}$	SE
Fished with longlines	A	11	109	24	1500	80	F	11	370	30	370	50
	B	13	150	29	1400	80						
	Pooled	24	134	13	1500	40						
Adjacent (unfished)	C	7	12	5	900	300	G	11	70	9	60	8
	D	11	109	19	900	40	H	11	300	30	120	20
	E	11	150	19	3400	70	I	11	100	20	50	9
	Pooled	29	100	7	1700	60	Pooled	33	170	8	70	4
Pooled		53	117	3	1600	30		44	220	7	140	6

Discussion

Longlines appear to be a more cost-effective means of monitoring fish population changes than submersibles. However, longlines kill all the collected fish whereas submersibles do not. More data can be collected on each caught fish at a lower cost with longlines than with a submersible. Size, age, and sex data could be collected from longline catches at a cost of about $5000 per day (in 1984 U.S. dollars), while none of these data were available from the submersible even though it cost about $8000 per day to operate. Additionally, the tilefish population based on burrow data from the submersible may have been overestimated because (1) "active" burrows were overestimated, (2) width of each burrow-count transect was underestimated, and (3) double counting occurred when transects crossed or came close to crossing. The number of tilefish estimated from tilefish seen was about 50% larger than the estimate based on longlines, and was about four times less than the estimate based on burrow counts. The number of burrows may be more a reflection of population size prior to exploitation if this area was heavily fished prior to our study.

Table 3

List of species caught on longlines and seen from submersible in the tilefish and grouper study areas. An X indicates presence; blank indicates absence.

Common name	Scientific name	Longline	Submersible
Tilefish	*Lopholatilus chamaeleonticeps*	x	x
Yellowedge grouper	*Epinephelus flavolimbatus*	x	x
Southern hake	*Urophycis floridana*	x	x
Gulf hake	*Urophycis cirrata*	x	
Cuban dogfish	*Squalus cubensis*	x	x
Longspine scorpionfish	*Pontinus longspinus*	x	x
Barrelfish	*Hyperoglyphe perciformis*	x	x
Night shark	*Carcharhinus signatus*	x	
Chain dogfish	*Scyliorhinus retifer*	x	x
Chub mackerel	*Scomber japonicus*	x	
Snowy grouper	*Epinephelus niveatus*	x	x
Beardfish	*Polymixia lowei*	x	x
Moray	*Gymnothorax kolpos*	x	x
Conger eel	*Conger oceanicus*		x
Argentines	*Argentine* sp.		x
Shortnose greeneye	*Chlorophthalmus agassizi*		x
Reticulate goosefish	*Lophiodes reticulatus*		x
Red hake	*Urophycis chuss*		x
Buckler dory	*Zenopsis conchifera*		x
Slimehead	*Gephroberyx darwini*		x
Deepbody boarfish	*Antigonia capros*		x
Longspine snipefish	*Macrorhamphosus scolopax*		x
Longtail bass	*Hemanthias leptus*		x
Yellowfin bass	*Anthias nicholsi*		x
Bladefin bass	*Jeboehlkia gladifer*		x
	Polylepion n sp.		x
Flatheads	*Bembrops* sp.		x
Scorpionfish	*Scorpanenodes* sp.		x

Tilefish populations were probably underestimated using longline data. But the amount of bias is unknown. Capture probabilities were not constant, and this usually leads to underestimates (White et al. 1982). Recruitment and emigration rates are unknown, but were probably low. If they occurred, recruitment must have been less than emigration because the populations were depleted in the study area. As recommended by Ricker (1975), our fishing effort was concentrated into "a rather short period of time" to minimize the effects of violating this assumption and that of no natural mortality.

The grouper population based on submersible fish data may have been overestimated because the estimated number of fish exceeded the estimated number of burrows and double counting of fish probably occurred. On one dive, the same fish (based on a scar on the lower jaw) was seen four different times.

Additional research is needed to determine the impacts of each of the above factors on fish population estimates based on counts made from submersibles. Future burrow counts should include all burrows, not just apparently active ones. Transect width should be accurately measured by counting burrows only within the range of a fixed physical extension from the submersible. Occupancy rates for tilefish and yellowedge grouper should be determined in randomly selected areas at night when they are most likely to be in their burrows.

Although no significant relationship between CPUE and cumulative catch was found for grouper, a more intensive effort should be made before discounting this technique. Additional longline collections over a longer period for yellowedge grouper are needed to determine if using the Leslie method is feasible.

Longlines can potentially impact stocks of tilefish. The population estimate of tilefish in the study area (39–128) and the catch made by the intensive fishing effort (79) indicate that from 62 to 100% of the fish were taken out of the area by an effort of approximately 6000 hook-hours, which is a 1.5–2 day effort by a commercial longliner (Prytherch 1983). Catch rates in the northern Gulf of Mexico in 1982 averaged 1–6 fish per 100 hook-hours (Prytherch 1983). Based on the estimated population size within the area, the initial catch rates indicate that the longline effectively catches all fish out of an area that is at least 12 m wide. Some fish are attracted from greater distances (Grimes et al. 1982), and some near the longline are not caught. But the number removed from the population is equal to the length of the longline × a width of 12 m × fish density.

Estimates of the total portion of the Gulf of Mexico inhabited by tilefish have not been developed, but the optimal areas are limited by depth, temperature, and bottom type (Grimes et al. 1980, 1986; Grossman et al. 1985). This, combined with slow growth rate, longevity, and low natural mortality (Turner et al. 1983, Harris and Grossman 1985), indicate that overfishing could easily take place if substantial effort is expended in tilefish habitat. This is especially true in light of the susceptibility to mass mortalities caused by sudden temperature reductions (Hachey 1955). Data from South Carolina tilefish habitat show a substantial decline in catch rate and mean size over a 4–5 year period with low to moderate effort (Low et al. 1983). Further, the number of tilefish burrows per km^2 in the Middle and South Atlantic Bights in the early 1980s was 241 and 125, respectively (Able et al. 1987). These estimates are much lower than the 1600 burrows per km^2 in the Gulf of Mexico estimated in this study.

More extensive longline studies of yellowedge grouper catches are required to assess the effect of longlines on these populations. The population estimate of yellowedge grouper in the yellowedge study site from fishing activities was not significant, but the best estimate (26 animals) from the non-significant regression may be realistic. The regression indicated that similar fractions of the yellowedge grouper population (40%) would be caught at similar levels of effort as compared with tilefish, and similar impacts from the longline fishery might be expected. However, the results may not be analagous because different gear were used in the two areas.

While the association with hard substrate and high relief was expected for yellowedge and other groupers, the burrowing habits were not expected. A detailed description of grouper habitat and burrow characteristics have been provided by Jones et al. (1989). The finding that this species also inhabits burrows was especially significant. If this were the only habitat, it would limit their distribution and increase their susceptibility to fishing once they are located. However, this species is also associated with rock and reef habitat typical of other grouper species. This diversity of habitat should enhance the survivability of the species overall, but it makes a part of the population more susceptible to longline fishing.

The uneven distribution of tilefish and yellowedge grouper between fished and unfished areas was also unexpected. Reasons for the differential distribution are not apparent. But the effects of depth, temperature, and bottom type on the fish were probably involved.

This study demonstrates the need for additional research to estimate population sizes and life-history parameters for deepwater Gulf fishes to quantify the amount of fishing they can support. Routine monitoring of these populations could be accomplished with longlines fished during August through October. Limited data on tilefish and yellowedge grouper have been collected with bottom longlines by the National Marine Fisheries Service since 1968 (Table 4). However, the data are insufficient to identify trends.

Table 4

Mean catch (no./100 hook-hours) ± 95% confidence interval of tilefish and yellowedge grouper on NMFS bottom longline sets each month, 1968–84, in the area bounded by 27°37′–27°50′ lat. and 93°32′–95°21′ long. Numbers in parentheses indicate numbers of sets. Blanks indicate no data collected.

Species	Year	Jan.	Feb.	May	Aug.	Sep.	Oct.	Nov.
Tilefish	1968	9.5 ± 12.2 (8)						
	1973			20.8 ± 6.9			6.8 ± 5.2 (14)	
	1975							2.1 ± 6.2 (3)
	1976				7.1 ± 4.1 (8)			
	1977		9.1 ± 9.3 (6)		10.0 ± 12.9 (4)			
	1983				6.1 ± 3.4 (7)			
	1984			6.9 ± 8.0 (9)		3.1 ± 1.3 (57)		
Yellowedge grouper	1968	5.5 ± 8.3 (11)						
	1973			18.4 (1)			0.7 ± 1.2 (8)	
	1975							0.0 (1)
	1976				2.5 ± 6.0 (3)			
	1977		0.0 ± 0.0 (3)					
	1981					0.0 ± 0.0 (2)		
	1983				3.7 ± 6.7 (8)			
	1984			1.2 ± 2.1 (6)		2.1 ± 1.3 (16)		

Natural and fishing mortality estimates, growth rates, population structure, distribution throughout all life stages, and weight landed should be determined and used in population simulation models to assist managers in protecting these resources from overfishing. A fishery-independent sampling program using longlines is recommended for monitoring the status of tilefish, hake, barrelfish, longspine scorpionfish, Cuban dogfish, and possibly yellowedge grouper populations. This is a more appropriate source of fish for mortality estimates than are commercial landings (Low et al. 1983, Winters and Wheeler 1985) and can yield reliable population size estimates if catchability coefficients are known.

Acknowledgments

Funding for submersible activities involved in this project was provided by the NOAA Office of Undersea Research. The Harbor Branch Oceanographic Institute participated on a cost-sharing basis. Support for the fishing activities and the NOAA Ship *Oregon II* was provided by the National Marine Fisheries Service. We would like to thank Captain Bill Abney and the crew of the RV *Johnson* for their dedication and long hours, and submersible pilots Tim Askew, Marshall Flake, Don Liberatore, Steve Hall, and the submersible support crew for the *Johnson-Sea-Link* for doing whatever was necessary to accomplish mission objectives. We would also like to thank Captain Gunnar Gudmundsson and the crew of the NOAA Ship *Oregon II* for their support and, especially, G. Michael Russell for serving as field party chief to insure accomplishment of planned fishing activities. Thanks are also extended to Art Crowe and Maury Osborn of the Texas Parks and Wildlife Department for their help in baiting hooks and collecting data. Suggestions from two anonymous reviewers were very helpful in improving the content of the manuscript.

Citations

Able, K.W., C.B. Grimes, R.A. Cooper, and J.R. Uzmann
1982 Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps* in Hudson Submarine Canyon. Environ. Biol. Fishes 7:199–205.

Able, K.W., D.C. Twichell, C.B. Grimes, and R.S. Jones
1987 Sidescan Sonar as a tool for detection of demersal fish habitats. Fish. Bull., U.S. 85:725–736.

Braaten, D.O.
1969 Robustness of the DeLury population estimator. J. Fish. Res. Board Can. 26:339–355.

Cochran, W.G.
1977 Sampling techniques. John Wiley, NY, 428 p.

Cody, T.J., B.E. Fuls, G.C. Matlock, and C.E. Bryan
1981 Assessment of bottom longline fishing off the central Texas coast, a completion report. Tex. Parks Wildl. Dep., Coast. Fish. Branch, Manage. Data Ser. 22, Austin, 51 p.

Freeman, B.L., and S.C. Turner
1977 Biological and fisheries data on tilefish, *Lopholatilus chamaeleonticeps*, Goode and Bean. Tech. Rep. 5, Sandy Hook Lab., Northeast Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Highlands, NJ 07732, 41 p.

Goodman, L.A.
1960 On the exact variance of products. J. Am. Stat. Assoc. 55:708–713.

Graham, G.
1978 Preliminary progress report: Bottom longline investigations. Unpubl. manuscr., Sea Grant Coll. Prog., Tex. A&M Univ., College Station, 30 p.

Grimes, C.B., K.W. Able, and S.C. Turner
1980 A preliminary analysis of the tilefish, *Lopholatilus chamaeleonticeps*, fishery in the Mid-Atlantic Bight. Mar. Fish. Rev. 42(11):13–18.
1982 Direct observation from a submersible vessel of commercial longlines for tilefish. Trans. Am. Fish. Soc. 111:94–98.

Grimes, C.B., S.C. Turner, and K.W. Able
1983 A technique for tagging deepwater fish. Fish. Bull., U.S. 81:663–666.

Grimes, C.B., K.W. Able, and R.S. Jones
1986 Tilefish *Lopholatilus chamaeleonticeps*, habitat, behavior, and community structure in Mid-Atlantic and southern New England waters. Environ. Biol. Fishes 15(4):273–292.

Grossman, G.D., M.J. Harris, and J.E. Hightower
1985 The relationship between tilefish, *Lopholatilus chamaeleonticeps*, abundance and sediment composition off Georgia. Fish. Bull., U.S. 83:443–447.

Hachey, H.B.
1955 Water replacements and their significance to fishery. Pap. Mar. Biol. Oceanogr., Deep-Sea Res. Suppl. to Vol. 3, p. 68–73.

Harris, M.J., and G.D. Grossman
1985 Growth, mortality, and age composition of a lightly exploited tilefish substock off Georgia. Trans. Am. Fish. Soc. 114:837–847.

Jones, R.S., E.J. Gutherz, W.R. Nelson, and G.C. Matlock
1989 Burrow utilization by yellowedge grouper, *Epinephelus flavolimbatus*, in the northwestern Gulf of Mexoci. Environ. Biol. Fishes 26:277–284.

Katz, S.J., C.B. Grimes, and K.W. Able
1983 Delineation of tilefish, *Lopholatilus chamaeleonticeps*, stocks along the United States east coast and in the Gulf of Mexico. Fish. Bull., U.S. 81:41–50.

Low, R.A., G.F. Ulrich, and F. Blum
1983 Tilefish off South Carolina and Georgia. Mar. Fish. Rev. 45(4-6):16–26.

Nelson, W.R., and J.S. Carpenter
1968 Bottom longline explorations in the Gulf of Mexico. Commer. Fish. Rev. 30(10):57–62.

Pennington, M.
1983 Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281–286.
1986 Some statistical techniques for estimating abundance indices from trawl surveys. Fish. Bull., U.S. 84:519–525.

Prytherch, H.F.
1983 A descriptive survey of the bottom longline fishery in the Gulf of Mexico. NOAA Tech. Memo. NMFS-SEFC-122, Southeast Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Miami, FL 33149, 33 p.

Ricker, W.E.
1975 Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191, 382 p.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott
1980 A list of common and scientific names of fishes from the United States and Canada. Spec. Publ. 12, Am. Fish. Soc., Bethesda, MD, 174 p.

SAS Institute, Inc.
1982 SAS user's guide: Statistics, version 5 edition. SAS Inst., Inc., Cary, NC, 965 p.

Sokal, R.R., and F.J. Rohlf
1981 Biometry, 2d ed. W.H. Freeman, San Francisco, 776 p.

Turner, S.C.
1986 Population dynamics of and the impact of fishing on tilefish, *Lopholatilus chamaeleonticeps*, in the Middle Atlantic-Southern New England region during the 1970's and early 1980's. Ph.D. diss., Rutgers Univ., New Brunswick, NJ, 289 p.

Turner, S.C., C.B. Grimes, and K.W. Able
1983 Growth, mortality, and age/size structure of the fisheries for tilefish, *Lopholatilus chamaeleonticeps*, in the Middle Atlantic–Southern New England region. Fish. Bull., U.S. 81:751–763.

Twichell, D.C., C.B. Grimes, R.S. Jones, and K.W. Able
1985 The role of erosion by fish in shaping topography around Hudson Submarine Canyon. J. Sediment. Petrol. 55:712–719.

White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis
1982 Capture-recapture and removal methods for sampling closed populations. LA-8787-NERP, Los Alamos Natl. Lab., Los Alamos, NM, 235 p.

Winters, G.H., and J.P. Wheeler
1985 Interaction between stock area, stock abundance, and catchability coefficient. Can. J. Fish. Aquat. Sci. 42:989–998.

Wolf, R.S., and W.F. Rathjen
1974 Exploratory fishing activities of the UNDP/FAO Caribbean Fishery Development Project, 1965–1971: A summary. Mar. Fish. Rev. 36(9):1–8.