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GROWTH, MORTALITY, AND YIELD OF SOUTHERN FLOUNDER IN TEXAS

The Texas saltwater fishery harvests many species of fish intentionally and as by-catch in bays and the adjacent Gulf of Mexico. Among the fishes caught are two bothids, southern flounder (*Paralichthys lethostigma*) and Gulf flounder (*P. albigutta*). However, southern flounder account for most of the flounder catch and almost all of the landings. The directed fishery is prosecuted by sport and commercial fishermen using hook and line, gigs, gill and trammel nets (prohibited September 1988), and trotlines primarily in Texas bays. Harvested fish are used primarily as table fare. About 250,000 to 500,000 kg worth about $1 million are landed annually (ex-vessel value if all fish landed by sport and commercial fishermen were sold for food). Most of these fish are females. The shrimp fishery unintentionally catches another 10 million juvenile (<1 year old) fish in the bays, almost all of which are discarded (Matlock 1982).

The life cycle of southern flounder is generally known, but few of the life history parameters have been quantified. Stokes (1977) conducted a 21-month study in the Aransas Bay system during 1974 and 1975. He found that southern flounder spawn in the Gulf of Mexico during late fall and winter (Nov–Mar) when about 2 years old (about 300 mm TL). Peak spawning probably occurs in December. Larvae are carried by currents into estuaries where they apparently remain until reaching sexual maturity when they migrate back to the Gulf. Males apparently complete their Gulfward migration sooner than females. Fish reach about 25 mm TL by February, and males grow slower than females. Males reach about half the size of females (320 mm vs. 620 mm TL). The longevity of southern flounder is unknown, but females probably live at least 9 years (based on monthly length frequency modes in Stokes 1977).

Most of the flounder harvest in Texas was essentially unregulated until 1988. The 305 mm (TL) minimum size limit applicable to the directed commercial fishery for many years was extended to sport-caught fish in September 1988, and a 20-fish bag (40-fish possession) limit was also imposed (Anonymous 1990). The use of all nets except cast nets, minnow seines, and shrimp trawls was prohibited in Texas salt waters in September 1988. Additional time and area closures for shrimp trawls were imposed in 1990. The effects of these regulations on yield in the directed fishery have not been quantified.

The objective of this study was to estimate growth and mortality rates and determine the minimum size limit and fishing mortality that would produce the maximum yield from southern flounder escaping the shrimp fishery.

MATERIALS AND METHODS

Data collected from southern flounder tagged during the Texas Parks and Wildlife Department's (TPWD) routine sampling of fish populations in Texas bays and recaptured during November 1975 through November 1990 were used to estimate the von Bertalanffy growth equation's parameters. The total length (TL) to the nearest mm at tagging was measured at the time of release by TPWD and the TL and date of recapture were provided by the sport or commercial fishermen reporting the recapture (Marwitz 1989). Further details of data collection are contained in Osburn *et al.* (1979) and Doerzbacher *et al.* (1988). Only fish with lengths reported at release and recapture and with recapture dates reported were used in the analysis. These data were analyzed using the Fishery Science Applications System (Saila *et al.*

1988) and Fabens' (1965) iterated least squares method for estimating K and L_∞ (average maximum TL) in the von Bertalanffy growth equation:

$$L_r = L_m + (L_\infty - L_m)\,[1 - \exp(-Kd)]$$

where L = total length (mm) at release (r) or marking (m);
t = time (days);
K = Brody's growth coefficient (per day); and
d = time elapsed between r and m.

Before analysis, the data were screened following the procedures of Doerzbacher *et al.* (1988). Ten flounder with reported data resulting in growth rates equal to or greater than 1 mm/day or equal to or less than -1 mm/day were excluded. Data from 94 fish were used to estimate daily K and L_∞. Estimates of daily K were annualized by multiplying by 365 days.

Annual instantaneous natural mortality (M) was estimated using the relationship between M, the growth parameters, and mean environmental temperature (Pauly 1979). Mean annual water temperature (23.7 C) was determined using data in Doerzbacher *et al.* (1988). M was also estimated using the relationship between total annual instantaneous mortality (Z) and maximum age developed by Hoenig (1983). In Hoenig's equation, Z approximates M because his regression was based on 134 lightly exploited species.

Annual instantaneous fishing mortality (F) occurring before the 1988 limits was estimated using tagging and recapture data form Marwitz (1989), the sport reporting rate for recaptured tagged flounder (31%), tagging mortality and tag loss rates of 20% each, and Ricker's (1975) equations for converting exploitation rate into F (p. 11). No estimate for the reporting of recaptured tagged fish by commercial fishermen was available, so the sport rate was used for all fishermen. Tag mortality and loss rates for southern flounder are unknown so values for other species were used to determine a "best estimate" for flounder. The optimum combination of minimum size limit and F that produced the maximum yield per recruit was determined using the Beverton-Holt yield equation and Saila *et al.* (1988). Lengths were converted to weights were necessary using Log W = $-5.260 + 3.125$ Log TL (Harrington *et al.* 1979).

RESULTS

Southern flounder reach an average maximum total length (L_∞) of 631 mm TL; K was 0.0009585 (daily) or 0.350 (annual). The mean daily growth rate ($\pm$1 SD) for the 94 fish recaptured during November 1975 through December 1990 was 0.21 mm/day ($\pm$0.30) for fish 249 to 552 mm long at tagging (Table 1). Of the 94 fish, 22 had mean daily growth rates ($\leq$0 mm/day), and most (16 of 22 fish) of these fish were free <90 days.

Southern flounder (larger than 249 mm TL) in Texas experience an annual instantaneous total mortality (Z) of at least 0.75. The estimates for M using Pauly (1979) were 0.35 and 0.44 using Hoenig (1983). F was at least 0.40. A total of 2,463 southern flounder were tagged in Texas bays during November 1975 through December 1988; 153 tagged fish were reported recaptured (116 by sport fishermen, 30 by commercial fishermen, and 7 by unknown fishermen). The mean annual reported recapture rate was 6.2%. When adjusted for non-reporting of tags and tag loss and tagging mortality, the annual exploitation rate (u) of 0.33 becomes an F of 0.40.

The maximum yield per recruit (about 614 g) can be achieved with a minimum size limit of about 453 mm (3.6 years old) and F>3.0 (Fig. 1). The current minimum size limit (305 mm) and F (0.40) are producing about 400 g per recruit or about 36% of the yield that could be achieved if the minimum size limit were increased to 453 mm (assuming the 305 mm size limit is now being followed),

Table 1. Size, time free, and mean daily growth rates of 94 southern flounder tagged in Texas bays and recaptured by sport and commercial fishermen during November 1975 and December 1990 with length at tagging and recapture and date of recapture reported to TPWD and used to estimate parameters in the von Bertalanffy growth equation. Ten fish with mean growth rates >1 mm/day or < – 1 mm/day were not included in analyses.

	Size (mm TL)			Days free			Growth (mm/day)		
Event	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Tagging	249-552	365	62						
Recapture	254-610	413	74	1-1113	206	176	– 0.78-0.86	0.21	0.30

and F were increased to at least 1.0.

DISCUSSION

Southern flounder currently experience fishing mortality similar to that normally associated with slot limits now used in freshwater fisheries management, especially for black basses (*Micropterus* spp.), to produce "quality" or "trophy" fisheries. Slot limits are designed to reduce the number of young or small fish by allowing a limited harvest below some minimum size and above some maximum size but no harvest between the two sizes (*i.e.* within the slot). Competition among individuals in the remaining population, mostly females in the case of bass, for the available food is thus reduced and growth is increased. Critical to the success of slot limits is limiting the harvest of small fish to insure adequate recruitment of sexually mature fish an adequate opportunity for spawning before harvest. The indirect mortality of juvenile southern flounder (90–250 mm TL) by bay shrimpers reduces the number of sexually immature fish, especially males. No legal harvest is allowed in the directed fishery until fish reach 305 mm. Thus, there is effectively a slot limit of about 250 to 305 mm within which almost no harvest is allowed. Fishing mortality below 250 mm is effectively unmanaged, and not included in this study. Above 305 mm F is limited by the sport bag limit and gear prohibitions. Perhaps the prohibition of shrimp trawling in nursery areas of Texas bays to be effective September 1991 will help limit the mortality of small flounder. Additional research is needed to quantify the effects of by-catch mortality.

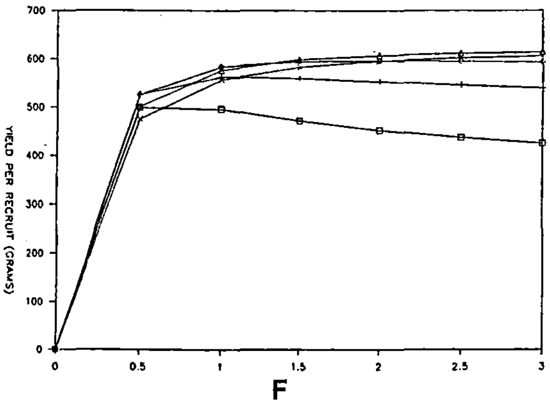

Figure 1. Maximum yield per recruit (g) of southern flounder with minimum size limits corresponding to 1.89 (□), 2.5 (+), 3 (◇), 3.6 (Δ), or 4 (X) years of age at annual instantaneous fishing mortality rates (F) ranging from 0 to 3. The age at recruitment to the stock is 1.89 years.

The estimates of growth for southern flounder appear reasonable. The estimate of L_∞ using length frequencies of fish caught in Texas bays in trammel nets during October 1977 through April 1980 was 595 mm (Matlock 1985). The largest southern flounder caught in the Aransas Bay system during 1974 and 1975 with seines, trawls, gigs, and gill nets was 620 mm TL (Stokes 1977). Estimates of L represent the average maximum size reached by a species; therefore, L_∞ should generally be less than the known maximum size. The largest known fish in Texas is 80 mm larger than the estimated L_∞. The Texas record flounder is a

711 mm fish caught in 1976 (Anonymous 1989). Since growth appears to be accurately estimated, the estimate for M (about 0.4) is also reasonable, at least as an upper limit. Fish could not die naturally at a much faster rate and still reach 9 years of age or older.

The estimate for current F (0.40) is probably an underestimate. The estimate assumes 20% tagging mortality and tag loss, but it does not include any illegally harvested fish, or mortality of fish below the minimum size limit released by fishermen. It also assumes the same reporting rate of recaptured tagged fish by commercial fishermen as for sport fishermen. But, several commercial fishermen openly stated during the 1980's that they did not report any tagged fish to TPWD because of distrust for the agency. The result of each of these inadequacies is that F is underestimated by an unknown amount. As a result, the current yield per recruit is probably between about 400 g (the maximum yield at $F = 0.4$) and 500 g (the maximum yield at any F for $t_c = 1.89$ years). Regardless of the true value of F, the yield could be increased in the southern flounder fishery by increasing the minimum size limit from the current 305 mm (12 inches) up to 450 mm (17.7 inches). However, increasing the current size limit almost 50% may be difficult to achieve. The mean size of southern flounder currently landed by sport fishermen is about 360 mm or 14 inches (Maddux *et al.* 1989). Changing the minimum size limit from 305 to 450 mm would eliminate almost all of the current landings for about 2 years or until the fish not harvested reached the new minimum size. Perhaps a gradual increase in the minimum size limit might be more palatable.

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