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Declining Size at Age Among Red Snapper in the Northern Gulf of Mexico off Louisiana, USA: Recovery or Collapse?

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Abstract.—The red snapper, *Lutjanus campechanus*, is currently both overfished and undergoing overfishing in the Gulf of Mexico (GOM) waters adjacent to the southeastern United States. From October 1998 through May 2004, we sampled 6,159 red snapper landed at a commercial dock in Cameron, LA, for morphometric data and otoliths for age estimation. Despite the species' potential lifespan of more than 50 years, the harvest is almost totally dominated by individuals of ages 2–6 years. Over the course of our sampling we have observed striking, statistically significant decreases in mean total length (TL) at age for red snapper of ages 2–6 years. Density dependence theory tells us that, within a population of fishes that is increasing in numbers, a decrease in resources (food, habitat, etc.) per individual might be manifested in a compensatory decrease in growth rate. Thus, the declines in red snapper mean TL at age may be an expression of recovery of an overfished population. Conversely, the heavy commercial and recreational harvest of young red snapper in the northern GOM, many of them at the very minimum TL required for retention, may have resulted in an inadvertent selection for the survival of slow-growing individuals.

Introduction

The red snapper, *Lutjanus campechanus*, is currently both overfished (low biomass, *B*) and undergoing overfishing (excess fishing mortality, *F*) in the Gulf of Mexico (GOM) waters adjacent to the southeastern United States (SEDAR7 2005). As a consequence, the recreational and commercial fisheries for red snapper in these waters are among the most rigorously managed fisheries in the GOM. Both fisheries are variously regulated by the enforcement of size limits, trip or creel limits, seasonal closures, and quotas with the

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expectation of achieving a spawning potential ratio (SPR) of 30% and of allowing populations to recover.

Although the red snapper in the GOM has been recognized as a single, panmictic stock for assessment purposes, several studies have shown that local populations may be behaving differentially to the selective regimes, including extent of overfishing, they are experiencing. Indeed, demographic variations in population genetics (Camper et al. 1993; Gold et al. 1997, 2001; Gold and Saillant 2007, this volume; Saillant et al. 2003; Saillant and Gold 2004), growth rates (Fischer et al. 2004), and reproduction (Jackson et al. 2007, this volume) may have resulted, at least to a degree, from excessive reductions in the numbers of individuals in local populations of red snapper.

The efficacy of the management of red snapper might be perceived in changes in density dependent processes such as growth, survival, and reproduction over the span of several years. Such processes are compensatory if they vary in response to change in population density: population growth rate slows at high densities and population growth rate increases at low densities (Rose et al. 2001). Within a population of red snapper that is decreasing in numbers, an increase in resources (food, habitat, etc.) per individual might be manifested in an increase in growth rate. Conversely, intraspecific competition for limited resources within a red snapper population that is increasing in numbers might curtail growth of individuals. Any changes in growth rates would most likely be demonstrated during the period of fastest growth, up to age 10 years in red snapper (Wilson and Nieland 2001).

The commercial harvest of red snapper produces significant dockside revenue (>$11 million in 2005) (National Marine Fisheries Service 2007) and is among the most highly regulated (381 mm total length (TL) minimum size, 909 kg trip limit, 2.11 million kg annual quota) (Gulf of Mexico Fishery Management Council 2006) fisheries in the GOM. From 1998 to 1904 we sampled red snapper from the commercial harvest in the waters off the Louisiana coast. The primary objective of this research was to describe the age and size composition of the red snapper commercial harvest in the northern GOM (Nieland et al. 2007, this volume). However, these 6.5 years of data were subsequently applied to an investigation of possible changes in TL at age that may have resulted from the management strategies applied to the red snapper fisheries.

Methods

Red snapper was sampled opportunistically during commercial harvest seasons from October 1998 to May 2004, a period when between 34% and 64% of the total GOM harvest of red snapper was landed in Louisiana (National Marine Fisheries Service 2007). To assure broad seasonal coverage, we attempted to extend our sampling efforts to include as many monthly openings as was practicable. All of our sampling efforts were focused at a commercial dock in Cameron, Louisiana, where an important share of the total red snapper commercial harvest is landed. Our sample population was drawn from those catches that were available on the sampling days; randomization of specimens was attempted by simply selecting the next available individual from a moving conveyor belt.

Fork length (FL) in mm, eviscerated weight (EW) in kg, and gender (when apparent) were recorded for each specimen. The sagittal otoliths from each specimen were removed and placed in labeled envelopes; all undamaged, intact otoliths were subsequently weighed to the nearer 0.1 mg. Red snapper total length (TL) was estimated from FL with the equation TL = 1.073 (FL) + 3.56 (Wilson and Nieland 2001). As there were few significant changes to the commercial harvest regulations applied to red snapper during our sampling period, we assume that fishing tactics and fisherman behavior were reasonably constant throughout this period.

The left sagitta (in those few instances where the left sagitta was damaged or unavailable, the right sagitta was substituted) of each specimen was sectioned following the protocols described either in Cowan et al. (1995) or in Wilson and Nieland (2001). Opaque annuli were counted, and ages, plus year of birth or cohort, were estimated as described in Wilson and Nieland (2001). Mean TL at age was graphed and compared for specimens of ages 2–6 years by sample year. A sample year began in September and extended through May of the following year; no red snappers were sampled during June, July, and August, the presumed months of their most vigorous growth. This arrangement both ensures that all specimens included together in a sample year have experienced the previous summer's growth maximum and assumes minimal growth outside the summer months.

Mean TL at ages 2–6 years were compared both with a one factor analysis of variance (ANOVA) of log_{10} transformed TL by sample year and with a Tukey's Studentized Range (HSD) Test (SAS Institute, Inc. 2001). An alpha level of 0.05 was applied in all instances.

Results

Our sample population of 6,159 red snapper was drawn from the commercial harvest of the species off Louisiana during the 6.5 year period from October 1998 to May 2004. Among these 2,018 were males, 2,223 were females, and 1,918 were of unresolved gender (the fishes are landed in eviscerated condition). Total lengths (N = 6,159) ranged from 278 to 953 mm; however, due to the 15 in (381 mm) TL minimum size applied to the commercial fishery, only 237 specimens less than the regulatory minimum were sampled. The distribution of TL binned in 25 mm increments is distinctly unimodal with that mode seen at 400 mm (Figure 1). Fully 97.5% of all specimens were less than 700 mm TL. Red snapper ages (N = 6,077) ranged from 0 to 36 years, but the preponderance (97.3%) of these were ages 2–6 years, the modal age was 3 years, and only 20 specimens were 10 years or older (Figure 2).

Mean TL at age by sample year for red snapper ages 2–6 years are shown in Figure 3. Mean TL for 2 year old individuals, ranging from 407 to 430 mm, demonstrated little variation during the sampling period. Similarly, age 3 specimens, while perhaps showing slightly greater variation in mean TL, have remained in the 425–475 mm range. The variations and declines in mean TL evidenced in the 4, 5, and 6 year olds are more striking. Mean TL among red snappers at age 4 years has shown a consistent decline from about 525 mm to about 445 mm. Red snappers at age 5 showed mean TL decreasing abruptly from 590 mm in 1999–475 mm in 2002 and subsequently increasing to 495 mm the following two years.

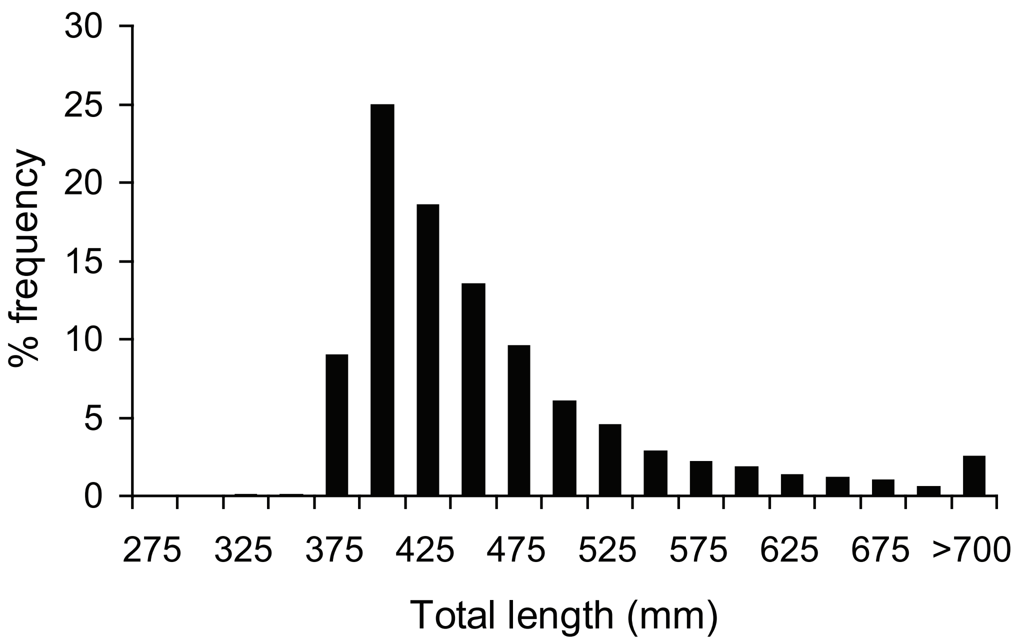

Figure 1. Total length frequency histogram for red snapper *Lutjanus campechanus* sampled from the commercial harvest of the northern Gulf of Mexico off Louisiana, 1998–2004. Total sample size = 6,077 specimens.

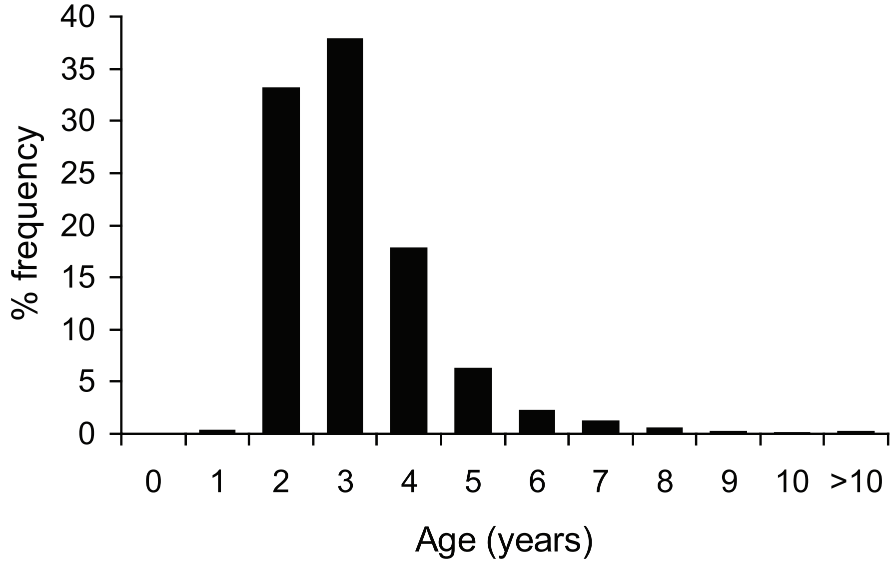

Figure 2. Age frequency histogram for red snapper *Lutjanus campechanus* sampled from the commercial harvest of the northern Gulf of Mexico off Louisiana, 1998–2004. Total sample size = 6,152 specimens.

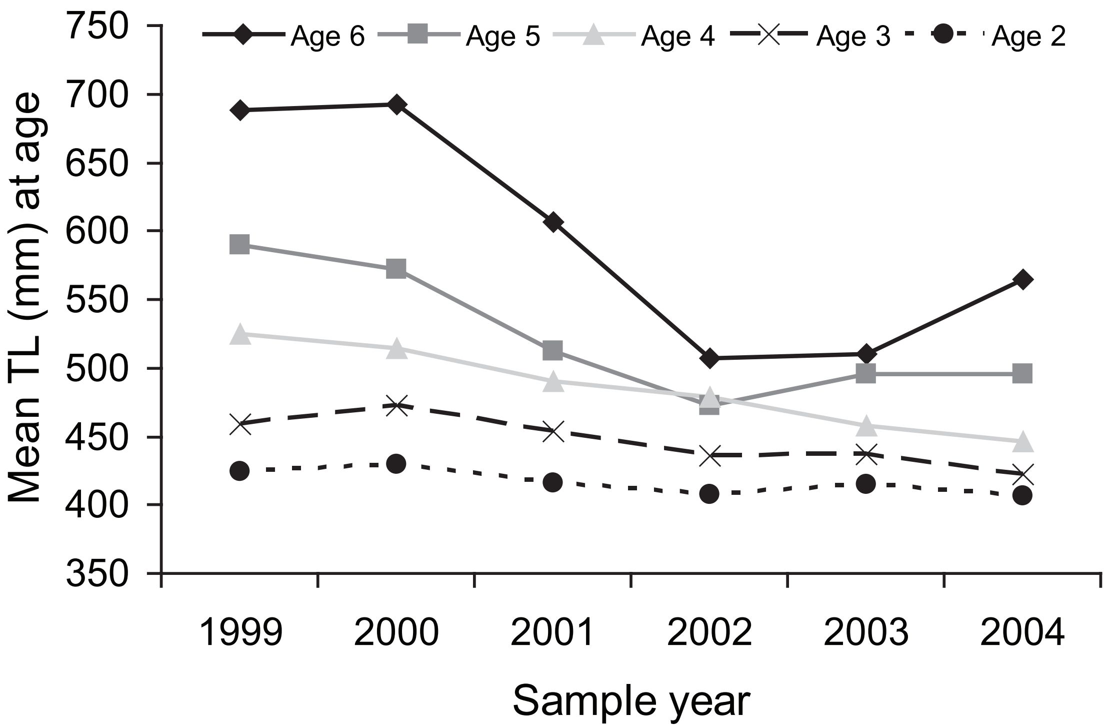

Figure 3. Mean total length at age for red snapper *Lutjanus campechanus* from the commercial harvest of the northern Gulf of Mexico off Louisiana by sample year (1999–2004). Sample year sample size ranges: 165–554 (mean = 338) at age 2 years, 309–445 (mean = 383) at age 3 years, 74–248 (mean = 177) at age 4 years, 35–109 (mean = 61) at age 5 years, and 8–32 (mean = 23) at age 6 years.

Table 1. Analyses of variance and Tukey's Studentized Rage (HSD) Tests on red snapper *Lutjanus campechanus* mean total length at age by sample year. Within each age, similar letters indicate no difference in mean total length (α = 0.05).

	ANOVA		Tukey's (HSD) comparisons of mean TL at age by sample year					
Age (years)	*F*	*P*	1999	2000	2001	2002	2003	2004
2	28.83	<0.0001	B	A	C	D	C	D
3	51.5	<0.0001	B	A	B	C	C	D
4	38.23	<0.0001	A	A	B	B	C	C
5	18.63	<0.0001	A	A	B	C	BC	BC
6	16.2	<0.0001	A	A	B	C	C	BC

The most striking changes in mean TL, from 692 mm in 2000 down to 507 mm in 2002 and back up to 565 mm in 2004, are seen among red snappers of age 6 years. Although the decreasing trends in red snapper mean TL at age are obvious, they are also statistically significant decreases. Both the ANOVA and the Tukey's (Table 1) demonstrated the differences among mean TL at age among sample years.

Discussion

As stated above, we could reasonably expect that compensatory processes espoused in density dependence theory would produce individuals of smaller size-at-age in an expanding population of red snapper. Thus the declines in red snapper TL seen in red snapper sampled in Cameron, LA may be an expression of recovery of overfished populations. Conversely, the heavy commercial (Figure 2) and recreational harvest of young red snapper, the vast majority of them at the very minimum TL required for harvest, may have resulted in both a selective removal of individuals predisposed to rapid growth and an inadvertent selection for the survival of slow-growing individuals. Such selective harvest may also result in declines in fecundity, egg volume, larval size at hatch, larval viability, larval growth rates, food consumption rate and conversion efficiency, vertebral number, and willingness to forage (Walsh et al. 2006) and reduce the capacity for population recovery. Severe overexploitation previously has been invoked as a major contributory factor in the decreases in size at age experienced by red porgy *Pagrus pagrus* in both the western north Atlantic Ocean and the eastern Gulf of Mexico (Harris and McGovern 1997; Hood and Johnson 2000; Vaughan and Prager 2002) and by the vermilion snapper *Rhomboplites aurorubens* in the South Atlantic Bight (Zhao et al. 1997).

However, the age and size structure of the commercial catch in Louisiana may not be representative of the red snapper population Gulf-wide. The regulations applied to the fishery and the very nature of the fishery itself may be more important determinants of the composition of the commercial harvest. The 15 in minimum size, the 2,000 lb trip limit, and a restricted number of fishing days have resulted in a "derby" fishery that dictates maximum catch in a minimum of time. Thus, red snapper are harvested as soon as they achieve legal size as fast-growing 2 year olds, as 3 year olds, or shortly thereafter (Figure 1); they disappear from the fishery, due either to mortality or to emigration to alternative habitats, within a few years (Figure 2). The heavy harvest sustained by the younger age-classes of red snapper in the northern GOM appears to have produced populations showing symptoms (decreasing size at age (Fischer et al. 2004; this study), decreasing size at maturity (Woods 2003)) of overfishing and concomitant juvenescence.

Total length (Figure 1) and age (Figure 2) histograms indicate that the commercial harvest of red snapper in the northern GOM is dominated by relatively small (375–625 mm TL) and relatively young (2–6 years) individuals; larger specimens over age 10 years are becoming less frequently observed in the commercial harvest (Nieland et al. this volume). The concentrated commercial and recreational harvest of young red snapper may have brought about the selective elimination of individuals predisposed to fast growth and an unintentional selection for the survival of slow-growing individuals. This and the similarly dramatic decreases in numbers of older, larger individuals (Nieland et al. 2007, this volume) may be the portent of detrimental changes in the red snapper populations of the northern GOM.

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