

Size structure of mutton snapper, *Lutjanus analis*, associated with unexploited artificial patch reefs in the central Bahamas

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The mutton snapper, *Lutjanus analis* (Cuvier, 1828) (Pisces: Lutjanidae), is an important component of shallow water reef fisheries in the tropical western Atlantic (Bortone and Williams, 1986). However, overfishing of shelf-edge spawning aggregations has contributed to a major decline in landings and, in some locations off Florida and Cuba, to a total collapse of the fishery (Brownell and Rainey, 1971; Gulf of Mexico Fishery Management Council, 1992). Much of what we know about *L. analis* (i.e. age and growth, reproductive, and trophic biology) is based on samples from commercial and recreational catches (Rojas, 1960; Erhardt and Meinel, 1977; Erhardt, 1978; Pozo, 1979; Claro, 1981, 1983; Mason and Manooch, 1985; Palazón and González, 1986). Quantitative behavioral studies are few (Mueller, 1994; Mueller et al., 1994), and field investigations concerning the population structure of *L. analis* under natural conditions are lacking.

Visual censuses are useful for comparison of temporal changes in the size structure of fish populations on exploited reefs with those of fish populations on unexploited reefs (Craik, 1981; Russ, 1985). However, such methods have several inherent biases. At best, visual censuses provide reasonably precise records of the fish fauna that

are not greatly influenced by conditions of water clarity (Sale and Douglas, 1981). Because counting all the fish in a given area is nearly impossible, size frequencies derived from visual censuses should be used for relative comparisons between populations (Craik, 1981). Using visual census techniques, I describe a preliminary study of seasonal variation in the size structure of *L. analis* on unfished reefs for the purpose of making comparisons with fish of this species that are subjected to fishing pressure.

Materials and methods

Size frequencies of *L. analis* associated with two artificial patch reefs off Lee Stocking Island, Exuma Cays, Bahamas (23°46.21'N, 76°06.59'W), were monitored during snorkeling excursions between 22 May 1991 to 14 December 1992. The primary reef (reef 1, area=491 m²) was located in a shallow (2.7 m), moderately dense *Thalassia testudinum* Koenig meadow (biomass=40–80 g dry wt·m⁻², Stoner and Sandt, 1991), whereas a smaller reef (reef 2, area=78 m²) was located in deeper water (4 m), 107 m west of reef 1. A distinct, gently sloping contour in the seagrass bed was evident between the two reefs. Both reefs were composed of man-

made materials and had a sparse cover of the living corals *Millepora alcicornis* Linnaeus and *Porites porites* (Pallas). The position of and distance between the reefs were determined by using a Magellan™ global positioning system unit. Reef areas were determined by using a waterproof measuring tape during SCUBA dives. Although natural patch reefs occurred in the area, this site was selected because it was unexploited and had a large number of *L. analis* associated with the reefs.

Data were collected every 4–11 weeks, only during the flood tide (greatest water clarity) between 0600–1900 h (daylight hours) to maximize visibility. By comparing my position with the known distance between reef structures at reef 1, I inferred that the maximum limit of my visibility during flood tide was approximately 20 m. Current directions of the flood and ebb tides at the study site were west (180°) and east (0°), respectively. During flood tide, I was able to drift (>30 cm per second) from reef 2 to reef 1 in five minutes or less. Using the natural water flow and bottom topography as references, I followed the same path between the two reefs during each census. All fish observed within 20 m (the approximate limit of my visibility) to either side or end of this quasi-transect (total search area including reefs ≈5,600 m²) were counted and measured. Fork lengths (FL) were estimated visually within 5 m of fish by comparing subjects to a known scale, the 30-cm length of a hand-held underwater slate. Fish were placed into one of three size classes relative to my slate: 20, 30, and ≥40 cm FL (shorter than, equal to, and longer than the slate, respectively). *Lutjanus analis* swam into the current (positive rheotaxis); therefore once I had passed

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a fish, I did not encounter that fish again during the drift. To confirm the accuracy of my underwater FL estimates, I compared markings on my slate (1-cm increments) with structural relief that *L. analis* rested on or passed by at reef 1. I repeated this practice until I could discern between the three size classes ± 5 cm from distances up to 5 m away.

On each sampling date, I performed three replicate drifts from reef 2 to reef 1. Size frequencies were derived from the largest number of fish counted in each of three size classes, irrespective of replicate, because the number of fish in each size class was at least equal to the greatest number of that size class seen during a single drift (Sale and Douglas, 1981).

Results and discussion

Four individual *L. analis* were recognized from census to census for periods up to one year. Fish were identified by body size, scars, fin anomalies, or shape of the black upper-body spot. However, owing to the wary nature of *L. analis*, it was difficult to remain within close proximity of subjects to identify adequately all fish by this method. Although individuals were considered resident, it is possible that others were transient or wandering fish. Still, my observations are consistent with a previous study (Beaumariage, 1969) that indicated little movement in adult *L. analis*.

On each sampling date, up to 56 *L. analis* were counted and measured at the study site. Fish ranged in size from 15 cm FL (half the length of my underwater slate) to 65 cm FL (>twice the length of my slate). Small (20-cm-FL), medium (30-cm-FL), and large (≥ 40 -cm-FL) *L. analis* were aged 1+ yr, 2+ yr, and 3+ yr, respectively (sensu Claro, 1981; Mason and Manooch, 1985). The number of small and medium-size fish observed varied from 6 to 24 and 12 to 25, respectively. The number of large fish never exceeded 13 (Table 1). From April to July, fish sizes were normally distributed; however, during August, fish sizes became negatively skewed. On 23 February 1992, water clarity was extremely poor (<5 m), which may account for the low number of small fish recorded on this date (Table 1).

The causes for seasonal variation in the size structure of *L. analis* are difficult to isolate from my observations; however, some inferences can be drawn from previous studies. For example, the increase of small fish in late August (Table 1) corresponds well with the peak recruitment to seagrass beds reported for juvenile *L. analis* (<7 cm FL) during August (Springer and McErlean, 1962) and September (Garcia-Arteaga et al., 1990). Jones (1990) described

a similar pattern in ambon damselfish, *Pomacentrus amboinensis*, Bleeker, 1868, and showed that adult densities increased in proportion to juvenile recruitment success after a two-year period (=maturation time).

The simultaneous decrease in medium-size fish during August (Table 1) is not easily explained. The population structure of unexploited reef fish is determined by a complex sequence of events that includes recruitment, demographic changes (i.e. mortality, migration, and growth), and ecological processes such as habitat structure, resource availability, and intraspecific competition (Jones, 1991). For instance, variable patterns in growth can have a major and direct influence on the size structure of a population (Jones, 1991). Individuals that grow faster may subordinate conspecifics and establish a dominance hierarchy (Forrester, 1990). Once established, hierarchies are often extremely stable (Morse, 1980). For example, where individually recognized recruits were followed over time, juvenile humbug, *Dascyllus aruanus* (Linnaeus, 1758), never outgrew other group members in size during an eight-month period (Forrester, 1990).

Lutjanus analis exhibits much variation in length for a specific age (Mason and Manooch, 1985) but matures sexually at fork lengths above 38 cm (Claro, 1981). In the central Bahamas, *L. analis* form groups of variable-size fish that occupy seagrass meadows

Table 1

Size frequencies of mutton snapper, *Lutjanus analis*, sampled from a population associated with two artificial patch reefs located off Lee Stocking Island, Exuma Cays, Bahamas. Fork lengths were estimated visually by comparing fish to a known scale (30-cm length of a hand-held underwater slate) and are ± 5 cm.

Sample date	Fork length (cm)			Total no. sampled
	20	30	≥ 40	
22 May 91	6	21	8	35
1 July 91	16	25	5	46
29 July 91	11	24	11	46
24 August 91	23	12	6	41
5 October 91	16	12	10	38
7 December 91	22	13	6	41
23 February 92	6	20	10	36
20 March 92	23	18	7	48
19 April 92	8	23	13	44
18 May 92	10	22	6	38
17 June 92	12	22	5	39
16 August 92	24	18	9	51
26 October 92	19	17	9	45
14 December 92	18	25	13	56

near inlets and patch reefs (Dennis¹). Size-specific asymmetries in both social and foraging behaviors suggest that these groups form dominance hierarchies (Mueller, 1994; Mueller et al., 1994). Assuming that large *L. analis* did not migrate from the study site (Beaumariage, 1969; author's personal observ.) and given that higher proportions of aggressive encounters occur among medium-size and large fish compared with small fish (Mueller et al., 1994), it is possible that the few large, dominant *L. analis* limited the number of medium-size fish on site through social interactions (sensu Doherty, 1983; Jones, 1987; Forrester, 1990). However, because empirical evidence is not available to support this conclusion, experiments should be designed to test whether large *L. analis* are a limiting factor.

Changes in the size structure of *L. analis* between 1991 and 1992 (i.e. the shift from small towards medium-size fish; Table 1) may also be related to growth. For example, small *L. analis* (1+ yr) feed proportionally more often than medium-size or large fish during daylight hours (0600–1730) and are involved in very few intraspecific encounters (Mueller et al., 1994). By limiting their interactions with conspecifics, small fish ostensibly have more time and energy available for growth (≥ 0.8 cm/mo during years 1 and 2; Claro, 1981; Mason and Manooch, 1985). Further studies may be designed to test this hypothesis.

In conclusion, managers of reef fisheries are challenged with determining whether shifts in the size structure of populations are due to normal recruitment and postrecruitment events or to fishing pressure. For example, low abundance of a certain size class may be due to intraspecific competition (Doherty, 1983; Jones, 1987; Forrester, 1990) or growth rather than to the effects of fishing. However, previous studies also indicate lower average size and abundance of fish captured on exploited reefs as opposed to unexploited reefs (see review by Russ, 1991). I have provided evidence of seasonal variation in the size structure of *L. analis* associated with unfished reefs. Although potential biases exist, this information should be useful for making relative comparisons with analogous populations subjected to fishing pressure.

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