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MOVEMENT AND GROWTH OF RED SNAPPER, *LUTJANUS CAMPECHANUS*, FROM AN ARTIFICIAL REEF AREA IN THE NORTHEASTERN GULF OF MEXICO

Stephen T. Szedlmayer and Robert L. Shipp

ABSTRACT

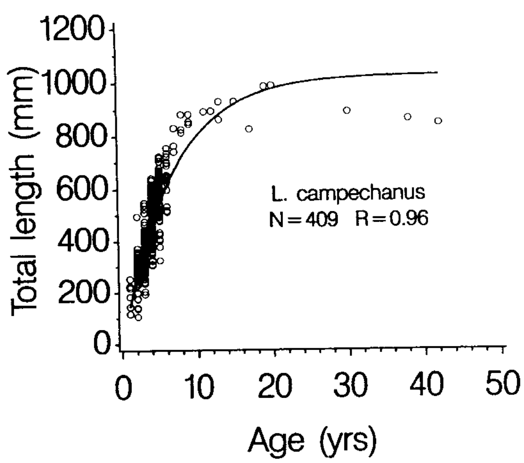
Artificial reefs increase fish catches, but whether reefs function by production or simply attraction is still unresolved. Coastal Alabama has few natural reefs but extensive artificial reef habitat. Thus, this area was suitable for the study of artificial reef effects on fish populations. We studied the movement, abundance, age, and growth of red snapper, *Lutjanus campechanus*, and the age and growth of lane snapper, *L. synagris*, from artificial reefs in the northeastern Gulf of Mexico. We estimated by trawling the highest *L. campechanus* CPUE (mean = 790 fish·h^{-1}) from coastal Alabama compared to any other location or time period from previously reported values. Growth rates of *L. synagris* appeared faster off Alabama, compared to growth rates reported in previous studies. Also, *L. campechanus* showed larger sizes and older ages (42 years) from this area off Alabama, a substantial increase over the oldest previously reported age (13 years). Most (74%) of the marked and recaptured *L. campechanus* were recaptured within 2 km of their release site. Also, distance moved was not related to amount of time at large, even after extended periods (up to 430 d). These factors, including high CPUE, faster growth, larger sizes, older age, high residence, and very few natural reef habitats, suggest increased production rather than attraction as the operating mechanism for increased catches of *L. campechanus* from this artificial reef area.

Artificial reefs may affect fish populations by increasing production or simply attracting fish from other areas. Which mechanism is dependent on several factors, including the presence of natural reefs, fish behavior, and if recruitment is habitat limited (Bohnsack, 1989). Thus, the northeastern Gulf of Mexico continental shelf off Alabama was an ideal location for artificial reefs, because the area is primarily dominated by sand/mud substrates and there are relatively few natural reef habitats (Parker et al., 1983; Shultz et al., 1987).

The red snapper, *Lutjanus campechanus*, is an important commercial and recreational species, but catch rates on a Gulf wide basis have been declining recently (Goodyear and Phares, 1990). However, catches of this species from coastal Alabama have remained high relative to other regions in the Gulf. For example, a recreational harvest landed in Alabama of more than 600,000 pounds in 1990 represented a third of the total catch from the entire U.S. coast of the Gulf of Mexico (National Marine Fisheries Service, 1991, pers. comm.).

Moseley (1966) suggested that *L. campechanus* reef association changed over its life history with the early stages found over sandy or mud substrate, while larger fish were more abundant near hard limestone with irregular formations. Others have suggested that this species was more abundant on isolated outcroppings rather than rich concentrated coral reef areas (Sonnier et al., 1976; Smith, 1976; Clarke, 1986). However, despite the vast amount of literature on artificial reefs (Bohnsack, 1989), we know little about their effects on *L. campechanus* in the northeastern Gulf of Mexico.

We studied the movement, abundance, age, and growth of red snapper, *L. campechanus*, and the age and growth of lane snapper, *L. synagris*, from artificial reef sites in coastal Alabama. We compared these data with information on artificial reef construction in this area, and address whether the high catches of *L. cam-*



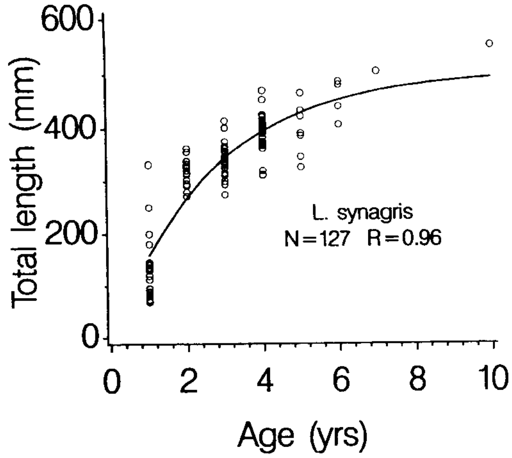


Figure 1 (left). Total length at age von Bertalanffy growth model of red snapper, *Lutjanus campechanus,* from the northeastern Gulf of Mexico.

Figure 2 (right). Total length at age von Bertalanffy growth model of lane snapper, *Lutjanus synagris,* from the northeastern Gulf of Mexico.

pechanus from this area can be attributed to production or attraction of artificial reefs.

Materials and Methods

Age and Growth.—We collected *L. campechanus* and *L. synagris,* for otolith analysis from January 1989 through October 1991. All fish were caught by private, charter, or commercial fishermen by

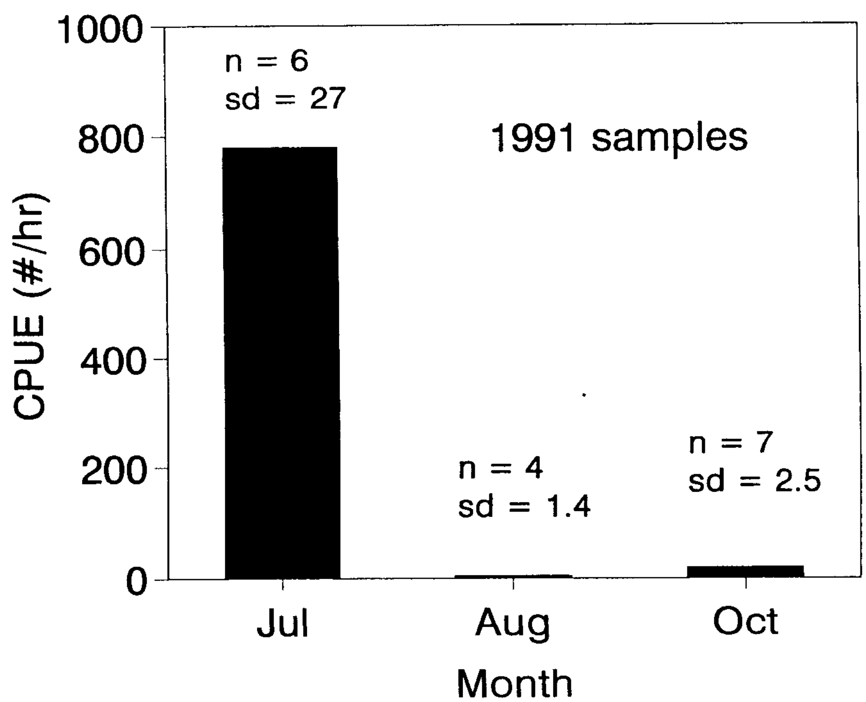


Figure 3. Mean catch-per-unit-effort (number/h) of juvenile red snapper, *Lutjanus campechanus,* in July, August, and October 1991. N = number of 20 min tows. SD = standard deviation.

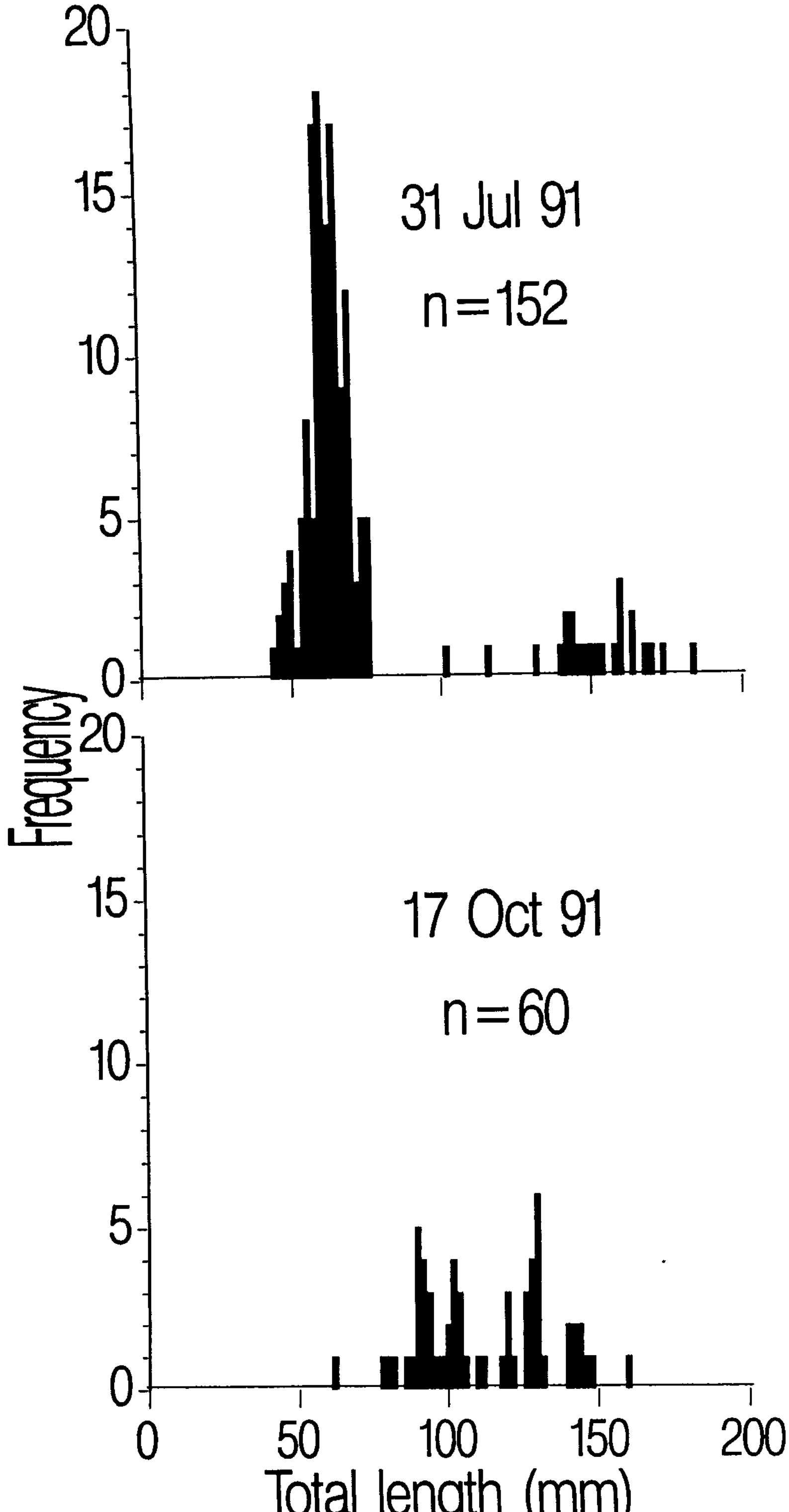
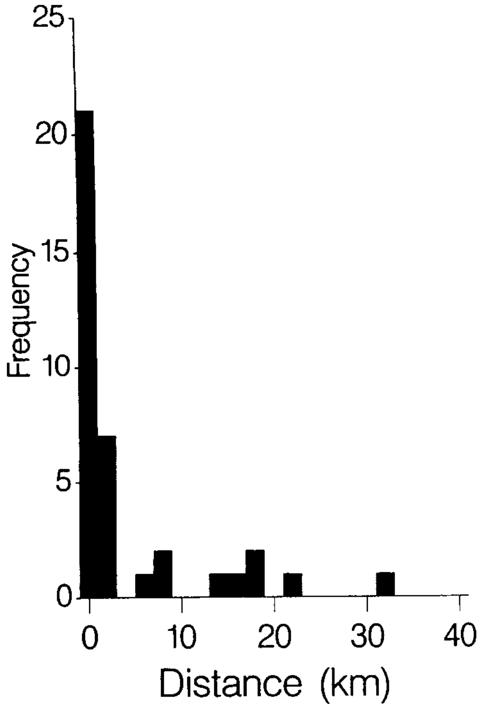


Figure 4. Size frequency distribution of juvenile red snapper, *Lutjanus campechanus*, in July and October 1991.



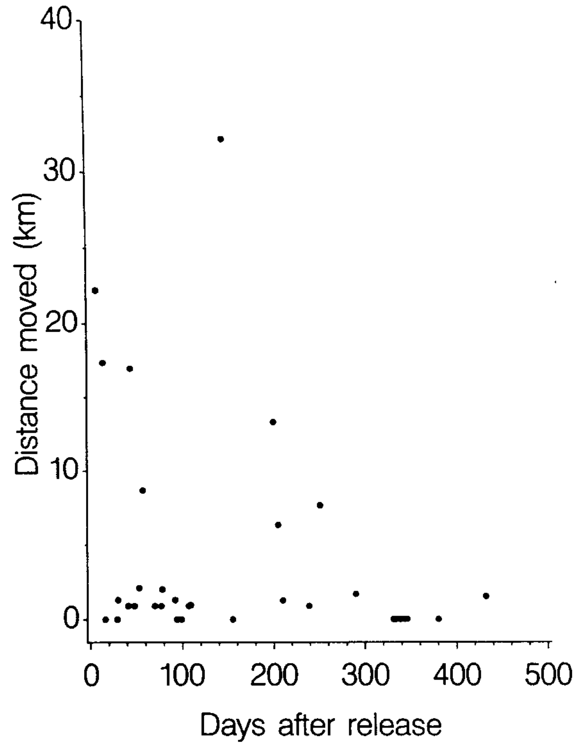


Figure 5 (left). Frequency distribution of distance moved from release site of tagged red snapper, *Lutjanus campechanus,* in the northeastern Gulf of Mexico.

Figure 6 (right). Distance moved as a function of days after release of tagged red snapper, *Lutjanus campechanus,* in the northeastern Gulf of Mexico.

hook and line off the coast of Alabama at artificial reef sites. Total lengths were measured and fish were frozen for later removal of otoliths. After removal, both sagittae were stored in dry vials. One otolith from each fish (right and left otoliths were assumed the same) was sectioned with a diamond blade and Buehler Isomet low speed saw. Three transverse sections (0.5 mm thick) were taken through the center of each otolith and mounted with Crystal bond (Aremco Co.) on individual glass slides. Sections were polished with 600 grit wet-dry sandpaper and 0.3-μm type-A-alumina on micropolishing cloth (Buehler, Inc.). Three independent readers made blind counts of annuli on otolith sections. If counts differed among readers (32% of total), otoliths were reexamined. If total agreement was not reached among readers after reexaminations, samples were not used (7% of the total). A von Bertalanffy growth model was fit to length at age data. In addition, a linear regression was applied to *L. campechanus,* for fish under 10 years old.

Juveniles.—We collected juvenile *L. campechanus* (age-0 and 1) with a semi-balloon otter trawl (12 m, 50-mm body and 41-mm cod end stretch mesh) in July, August, and October 1991. On each sampling date, at least four daytime 20-min trawl tows were made, at the same location in the northeastern Gulf of Mexico, approximately 6 km south of Dauphin Island, Alabama. All *L. campechanus* were counted and total length measured for the first 150 collected.

Tagging.—Internal anchor tags (Floy Tag, Inc.) were attached to small *L. campechanus* (mean ± SE = 287 ± 0.9 mm TL; size range = 177 to 410 mm TL). All fish were collected by hook and line (N = 1,155), measured live, and anchor disks were inserted into the peritoneal cavity through a small incision. Fish were released immediately after tagging at the capture site. A subsample of 30 fish was held in the laboratory for 6 months to estimate any tag related mortality or infection. Recaptures were dependent on commercial, charter boat, and private fisherman. A phone number and reward offer labeled each tag and fishermen were requested to return tag and fish.

RESULTS

We aged and measured 409 *L. campechanus* from hook and line samples. Size ranged from 107 to 988 mm TL. Age ranged from 1 to 42 years. The von Ber-

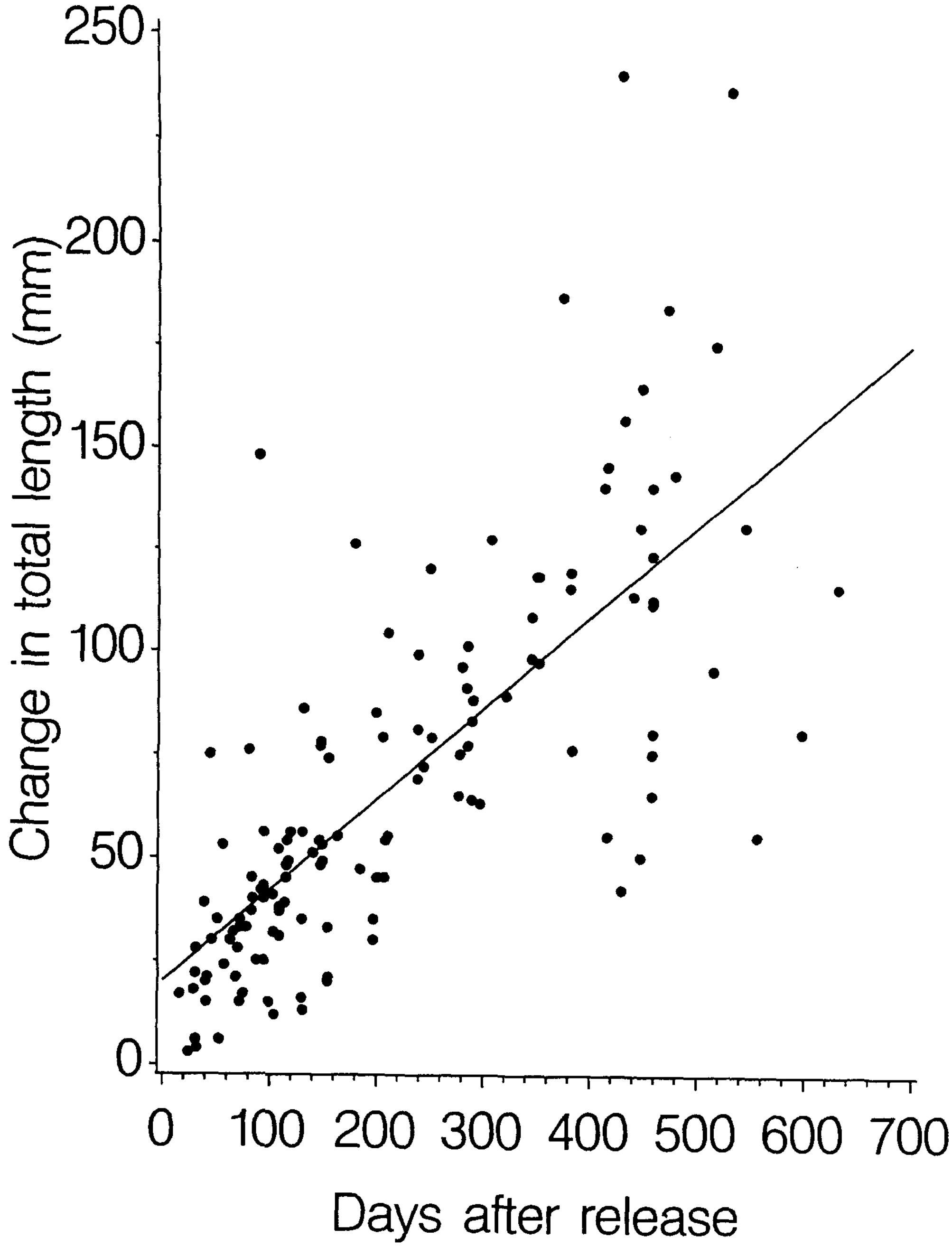


Figure 7. Change in total length since release of tagged red snapper, *Lutjanus campechanus*, in the northeastern Gulf of Mexico.

talanffy growth equation was: TL = 1,025 (1 − exp(−0.15 age)), R = 0.96 (Fig. 1). However, for this species growth rate also appeared linear for the first 10 years: TL = 97.7 age + 67.6, N = 397, R = 0.87. We aged and measured 127 *L. synagris*. Size ranged from 68 to 549 mm TL. Age ranged from 1 to 10 years. Growth fit the von Bertalanffy growth model: TL = 504 (1 − exp(−0.38 age)), R = 0.96 (Fig. 2).

Trawl samples showed the greatest catch-per-unit-effort (CPUE = num-

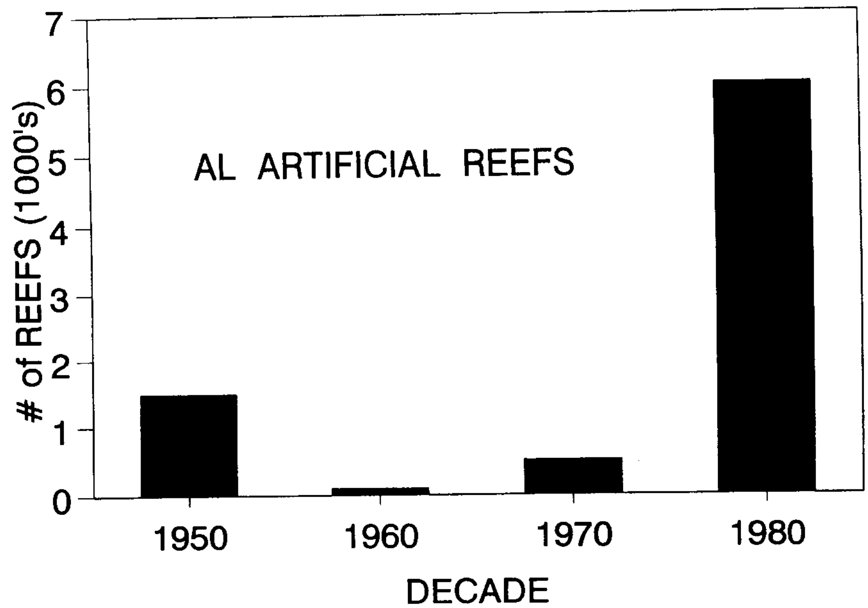


Figure 8. The number of known artificial reefs placed off Alabama's coast by decade.

ber·h^{-1}·tow^{-1}) for age-0 to 1 juvenile *L. campechanus* in July, with CPUE significantly (ANOVA, $P < 0.05$) lower in August and October (Fig. 3). There was little difference in salinity (35.0 to 36.8‰) and temperature (23.4 to 24.9°C) among sample dates. However, in August, 0 ppm dissolved oxygen was measured from 2 m below the surface to the bottom (15 m) at the trawl site. The smallest age-0 fish were collected in July (40 to 75 mm TL), and age-0 size range increased in October (65 to 160 mm TL; Fig. 4).

We tagged and released 1,155 *L. campechanus* from May 1990 to October 1991. We recovered 146 tagged fish; however only 37 tag returns were used for movement information because recapture locations of the other returns were unknown. This species showed little movement with 57% of the recaptures taken at their respective release site, and 76% recaptured within 2 km of their release site (Fig. 5). The greatest movement by a single *L. campechanus* was 32 km. Distance moved was not related to time since release, i.e., the longest time at large for an individual fish was 430 d but this fish was recaptured within 2 km of its release site (Fig. 6). Growth rate estimated from recaptured tagged fish (0.22 mm TL·d^{-1}, $N = 132$, $R = 0.55$; Fig. 7) was similar to the growth rate estimated from TL at age regression from otolith analysis for all fish <10 years old (0.27 mm TL·d^{-1}, $N = 397$, $R = 0.87$). In addition, laboratory held fish showed no tag related mortality or infections.

Discussion

Several aspects of the life history of *L. campechanus* and *L. synagris* and the particular habitat in the northeastern Gulf of Mexico off Alabama indicate that artificial reef construction has resulted in increased production and not simply attraction of these species. First, the continental shelf off Alabama contains very little natural reef structure and is mostly vast areas of sand and mud substrate (Shultz et al., 1987). However, the area does contain large numbers of artificial reefs, i.e., approximately 6,000, as estimated from the number of permits issued

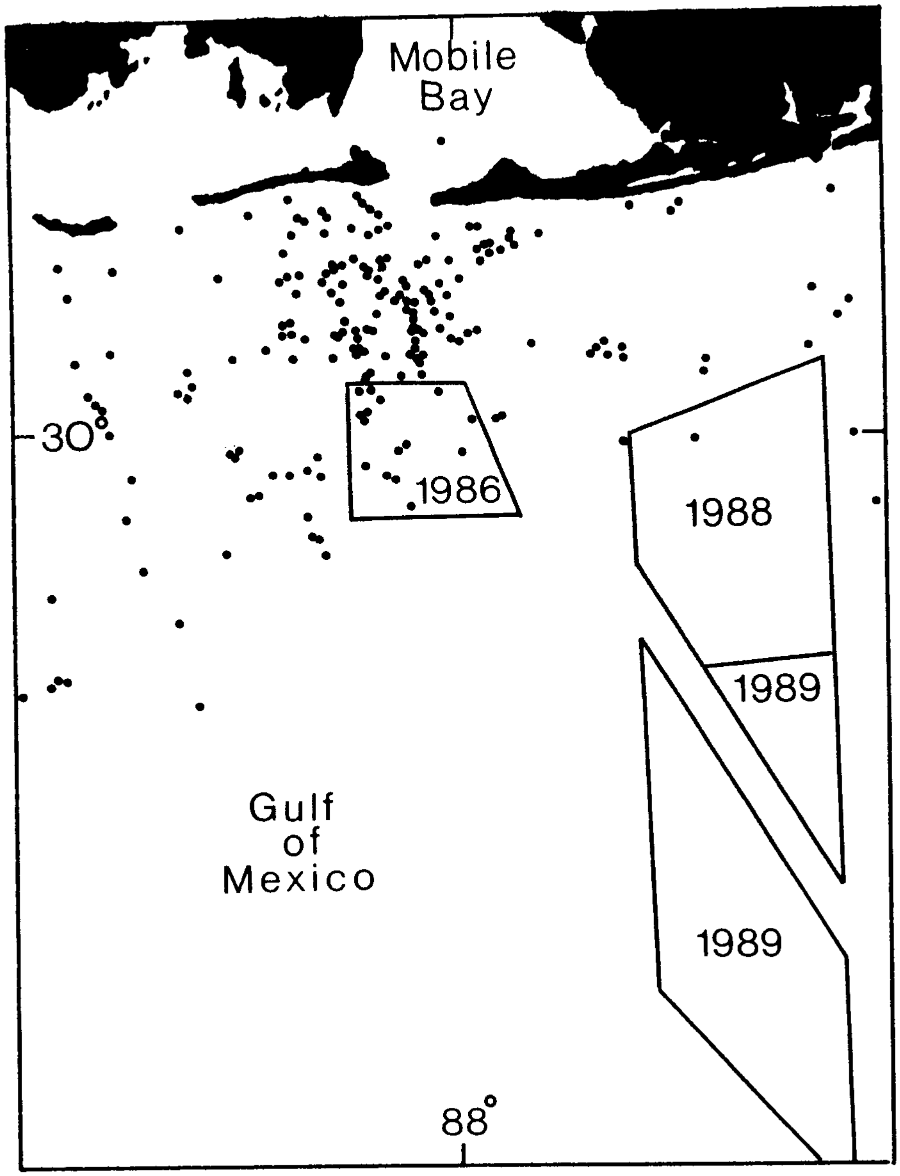


Figure 9. Locations of known artificial reefs (dots) and permitted reef areas off Alabama (number in each box is year designated).

from the Marine Resources Division (MRD) of the Alabamà Department of Conservation. Major artificial reef deployments in this area were started as early as the 1950's by the MRD. In that early effort over 1,500 car bodies were placed in 20 to 30 m depths. The reef building slowed in the 1960's then increased dramatically in the 1980's with the creation of permitted reef areas (Hosking and Swingle, 1989; Fig. 8). The exact locations of individual reefs within the permitted areas are usually known only to the builder, however there are over 280 public reefs in coastal Alabama, ranging from oil rigs to sunken liberty ships (Fig. 9).

Second, the abundance of *L. campechanus* off the Alabama coast appears to surpass all other areas in the Gulf of Mexico and South Atlantic. For example, Darnell et al. (1987) showed the greatest abundance of *L. campechanus* off the

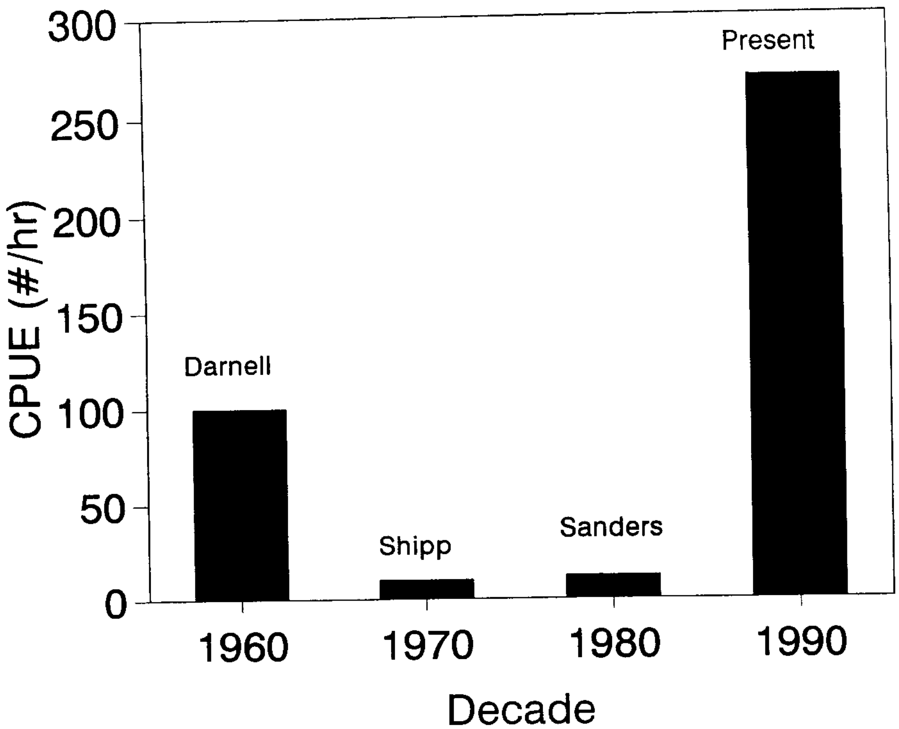
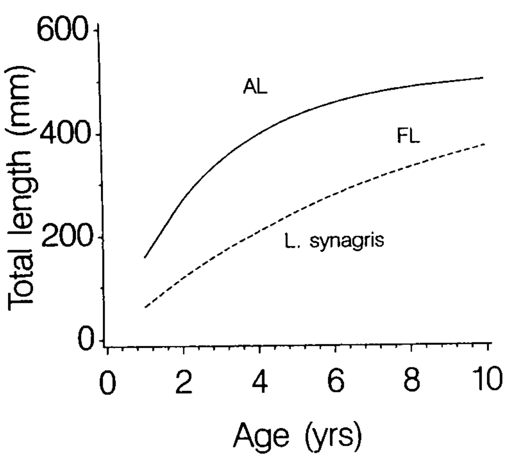


Figure 10. Catch-per-unit-effort (number/h) of red snapper, *Lutjanus campechanus*, by different studies each decade. 1960's = Darnell et al., 1987; 1970's = R. L. Shipp, unpublished data; 1980's = Sanders et al., 1991; 1990's = present study.

coast of Alabama in the 1960's, compared to all other Gulf of Mexico areas. If we allow for a time lag between reef construction and subsequent stock increase, comparison of trawl CPUE with reef deployment by decade both show the same general trend (Figs. 8, 10). For example, the high fish abundance in the 1960's



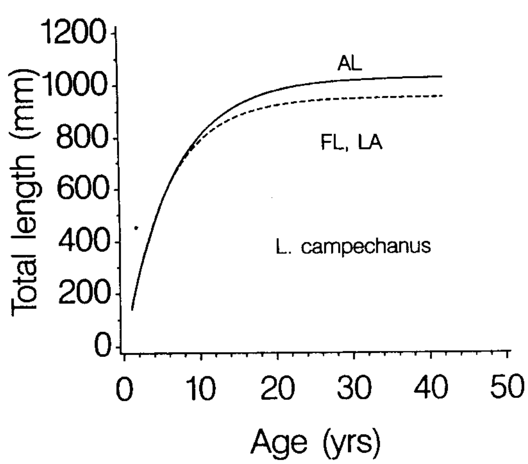


Figure 11 (left). Lane snapper, *Lutjanus synagris*, von Bertalanffy growth model comparisons of the present study in Alabama (solid line) with Florida (Manooch and Mason, 1984).

Figure 12 (right). Red snapper, *Lutjanus campechanus*, von Bertalanffy growth model comparisons of the present study in Alabama (solid line) with Louisiana and Florida (Nelson and Manooch, 1982).

may correspond to the car bodies deployed in the 1950's; and the high CPUE in the present study may be related to the dramatic increase in artificial reef construction that has occurred in the past few years. A limiting factor of car body reefs is that their average life span is about 5 years, and this lack of persistence may help explain the reduced numbers of *L. campechanus* in the 1960's and 1970's.

Third, growth rate of *L. synagris* appears faster off Alabama from the present study, compared to growth rates reported from other areas of the Gulf of Mexico (Manooch and Mason, 1984; Fig. 11). In addition, *L. campechanus* appear to reach larger sizes in this artificial reef area off Alabama compared to other locations (Nelson and Manooch, 1982; Fig. 12). We also estimated the oldest *L. campechanus* from Alabama at 42 years, and this age represents a substantial increase over the oldest reported age of this species from previous work at 13 years (Nelson and Manooch, 1982). If growth rate, size, and age can be used as an index of habitat value, because they integrate other environmental factors, artificial reef construction off Alabama may have resulted in optimal habitats for these particular species.

Fourth, *L. campechanus* showed a high degree of residence, with most fish recaptured within 2 km of their release site, even after extended periods (up to 430 d, Fig. 6). Thus, it seems doubtful that Alabama's reefs are attracting this species from other areas of the Gulf (i.e., Texas, Louisiana, Florida). However, this high degree of residence may not hold for other species or different life stages of *L. campechanus,* e.g., pelagic larvae may drift greater distances, or older fish may be more migratory.

In conclusion, no single factor is evidence for production as the primary mechanism of increased catches off Alabama. However, the combined factors of faster growth, larger size, older age, high residence, greater numbers than anywhere else in the Gulf or Atlantic, very few natural reef habitats, and extremely high numbers of artificial reefs provide evidence for production rather than simply attraction.

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ADDRESSES: *(S.T.S.) Auburn University Marine Extension and Research Center, Department of Fisheries and Allied Aquacultures, 4170 Commanders Drive, Mobile, Alabama 36615; (R.L.S.) Department of Marine Science, University of South Alabama, Mobile, Alabama 36688.*