

SEASONAL VARIATION IN USAGE OF A COMMON SHELTER RESOURCE BY JUVENILE INQUILINE SNAILFISH (*LIPARIS INQUILINUS*) AND RED HAKE (*UROPHYCIS CHUSS*).—The inquiline snailfish, *Liparis inquilinus*, and the red hake, *Urophycis chuss*, are marine fishes that have overlapping shelter requirements. During the first months after settlement from the plankton, juveniles of each species seek refuge in the mantle cavity of the sea scallop, *Placopecten magellanicus* (Welsh, 1915; Musick, 1969; Able and Musick, 1976). Because both of these fishes are commensals, in the same host species, but not obligate ones, biotic interactions are possible. These interactions would be most apparent during periods of overlap in sea scallop occupancy. Although both fishes have been collected inside as well as outside of sea scallops (Musick, 1969; Able and Musick, 1976), there have been no studies of the seasonal nature of use of the sea scallops by these two fishes, especially during periods of overlap. Here we describe the seasonal pattern of shelter use for these two species associated with a sea scallop population at one location and discuss the implications for the survival of these newly settled fishes.

Liparis inquilinus (Liparidae) ranges from Cape Hatteras, North Carolina, to Nova Scotia, Canada (Able, 1973). Adult *L. inquilinus* spawn in March and April, larvae hatch from demersal eggs in May at 5 mm, and juveniles appear in scallops during July, when the fish are 14–45 mm in total length (Able and Musick, 1976; Able et al., 1986). Snailfish are not found in large numbers in scallops after Nov., and one-year-old fish are thought to migrate inshore to spawn (Able and Musick, 1976).

Urophycis chuss (Gadidae) ranges over the western North Atlantic continental shelf from North Carolina to Nova Scotia (Musick, 1969; Musick, 1974). Adult fish spawn between the months of April and Oct.; and the eggs, larvae, and prejuveniles remain in the plankton for 1–2 mo (Musick, 1969; Markle et al., 1982). From Sept. to Dec., prejuveniles migrate from the plankton to the benthos and become inquiline within the mantle cavity of sea scallops (Musick, 1969; Steiner et al., 1982; Garman, 1983). Recruitment of prejuveniles to the benthos increases markedly through the months of Oct. and Nov., and the timing of this descent is de-

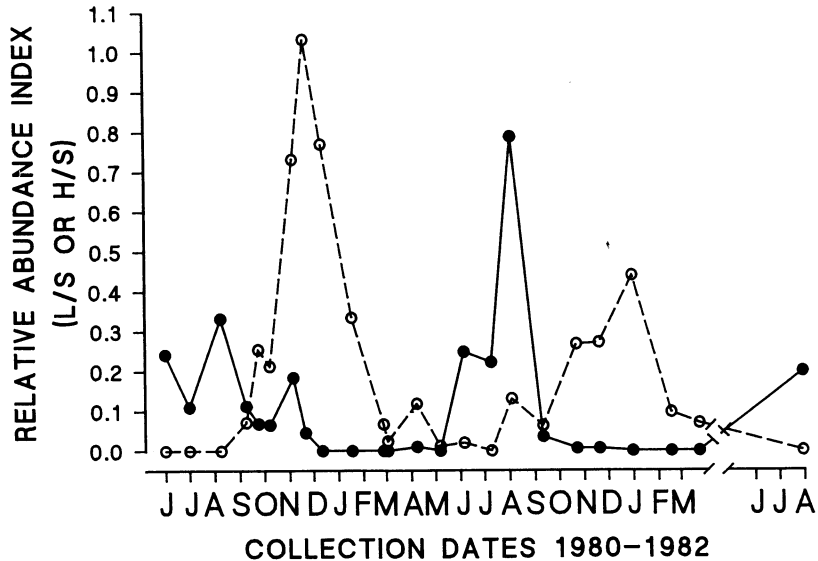


Fig. 1. Monthly variation in relative abundance of *Urophycis chuss* (H/S; open circles with dotted lines) and *Liparis inquilinus* (L/S; closed circles with solid lines) from June 1980 to July 1982. All fish were taken while inquiline in sea scallops. The relative abundance indices H/S and L/S represent the number of *U. chuss* and *L. inquilinus* collected each month divided by the number of scallops collected (see Steiner et al., 1982).

pendent on water temperature and the breakdown of a thermocline in continental shelf areas (Musick, 1969; Steiner et al., 1982; Steiner and Olla, 1985). The sea scallop-red hake association continues for 2–3 mo until the fish outgrow the sea scallops (Musick, 1974; Steiner et al., 1982). However, the juveniles do not necessarily leave the sea scallop bed and have been observed in nature resting against the outer surface of a sea scallop valve for shelter (Wigley and Theroux, 1971).

Methods.—*Liparis inquilinus* and *U. chuss* were collected along with sea scallops at regular monthly intervals between June 1980 and July 1982. We took sea scallops from a scallop bed in the Mid-Atlantic Bight off the coast of New Jersey (40°15'N, 73°50'W) aboard the R/V Kyma using a 1.21 m scallop dredge with 75 mm diameter steel rings in the collection bag in water depth of 30 m. One sample (Jan. 1981) was collected aboard a commercial scallop vessel, the F/V *Moby Dick*, using two 3.65 m wide scallop dredges which were also fitted with steel rings measuring 75 mm in diameter. We collected sea scallops by making 3–4 tows with the dredge (one tow with the two 3.65 m dredges) over fixed distances between known LORAN C bearings. Tows lasting from 20–45 min were conducted between 1100 and 1400 h Eastern

Standard Time, and were pulled at 1–2 knots. Bottom temperatures were recorded with every sample except for the months of June–Aug. 1980 and Feb. 1981. We examined a total of 3828 sea scallops during the study, and sample size ranged from 15–696 scallops per month.

Coolers filled with ambient seawater were used to hold sea scallops until their valves opened and any fish trapped inside the mantle cavity escaped. We collected some red hake and inquiline snailfish from the water in the coolers during dissections of all sea scallops. Sea scallop valve heights (distance across the shell) were measured from Feb. through Dec. 1981 (except in July 1981); valve heights varied from 38–159 mm. We measured total lengths (TL) from all *U. chuss* specimens over the entire two-year study period; however we only measured total lengths for *L. inquilinus* taken during June, Sept., and April 1980 and after June 1981. During 1981, *L. inquilinus* specimens were preserved in 5% formalin prior to measurement whereas most *U. chuss* individuals were measured alive and used for behavioral observation (results in Steiner et al., 1982). To examine the size-specific usage of sea scallops by newly settled red hake and inquiline snailfish, we recorded the valve height of each sea scallop in

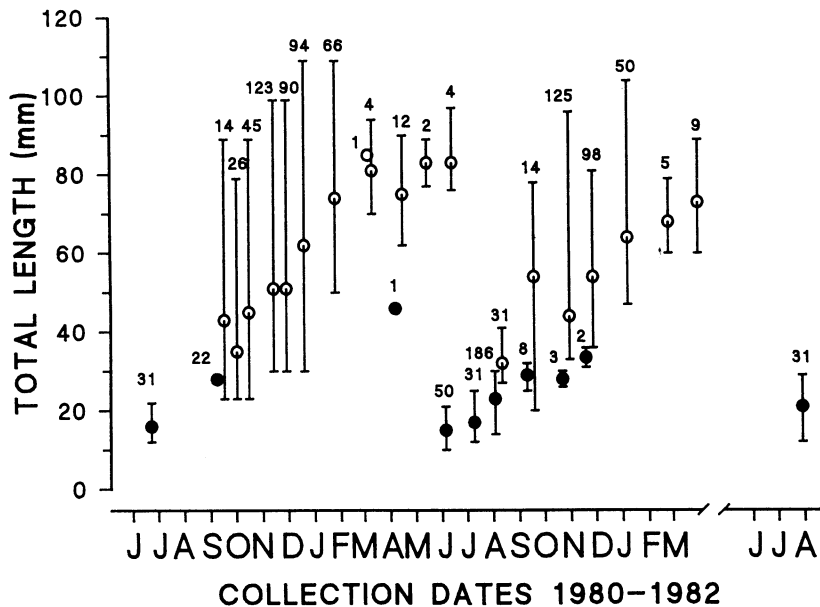


Fig. 2. Monthly mean and range of total lengths of *Urophycis chuss* (open circles) and *Liparis inquilinus* (closed circles) from June 1980 to July 1982 taken while inquiline in sea scallops. *Liparis* individuals were not measured during the months of July, Aug., Oct., and Nov. 1980.

which a fish was discovered upon dissection during the months of Aug. through Dec. 1981. We calculated the ratio of the total number of *U. chuss* collected to the total number of sea scallops collected (hake/scallop ratio = H/S; Steiner et al., 1982). We calculated the ratio of *L. inquilinus* to the total number of sea scallops collected (*Liparis*/scallop ratio = L/S) each month. These ratios normalize the observed variation in fish abundance to a standard number of sea scallops but do not indicate the proportion of sea scallops containing fish, because some of the sea scallops may have contained more than one fish of each species or both species (Able and Musick, 1976).

Results and discussion.—*Liparis inquilinus* was most abundant on the sea scallop bed from June through Sept., whereas *U. chuss* was most abundant from Sept. through Jan. with peaks on 20 Nov. 1980 and 30 Dec. 1981 (Fig. 1). From Feb. through May, both fishes were uncommon or absent from the sea scallop bed. The average total lengths of both *U. chuss* and *L. inquilinus* increased during the periods when the fish were found in inquiline relationship with the sea scallops (Fig. 2). The red hake–sea scallop commensal association ended during June when *U.*

chuss individuals averaged 83 mm (\pm SE = 4.82) TL (Figs. 1, 2). *Liparis inquilinus* ended its commensal association with sea scallops in Nov. when individuals had reached an average length of 33.5 mm (\pm SE = 2.50) TL (Figs. 1, 2). *Urophycis chuss* abundance (H/S) was negatively correlated with *L. inquilinus* abundance (L/S), but this correlation was not significant ($r = -0.195$; $df = 18$; $P > 0.50$). *Liparis inquilinus* was very abundant during months in which significant numbers of *U. chuss* had not yet settled from the plankton (June through Sept.) but declined in abundance after Nov. 1980 and Oct. 1981 when the red hake abundance (H/S) was increasing. More frequent sampling during this period may have allowed us to detect a significant negative correlation in the abundances of these two species. During the fall of 1981, when 1155 sea scallops were dissected, we found 173 *U. chuss* and a single specimen of *L. inquilinus*, with no joint occupation. However, Able and Musick (1976) reported that these two species co-occur “frequently and in considerable numbers” during Sept., Nov., and Dec. *Liparis* and *Urophycis* juveniles clearly use the scallops as shelter during different periods of each year, with a short period of overlap.

Bottom temperatures ranged from highs of

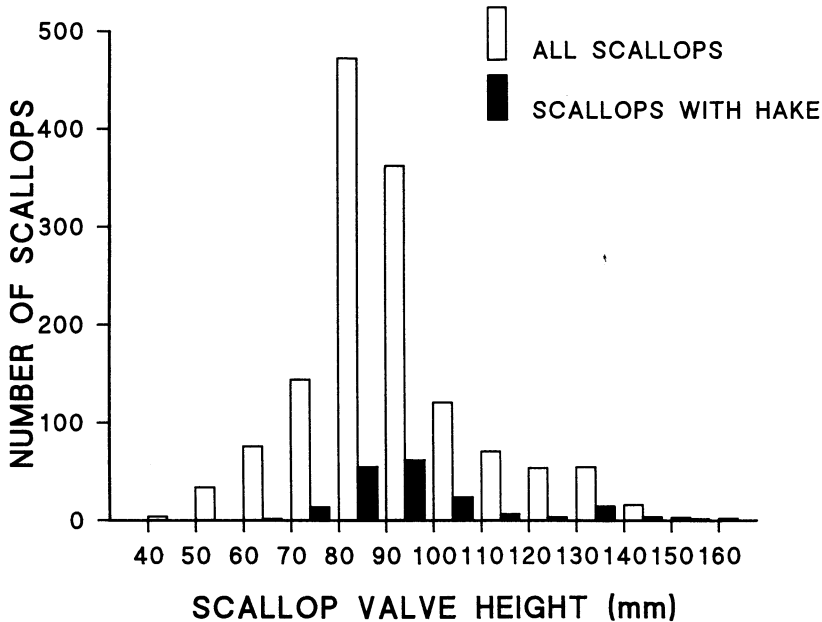


Fig. 3. The size distribution of sea scallops used by juvenile red hake, *Urophycis chuss*, in fall (Aug.–Dec. 1981) compared against the size distribution of all scallops collected. Open bars are the number of scallops collected during the fall in each size class; solid bars are the number containing hake.

approximately 15.0 C in Oct. to lows averaging 2.7 C during March. The relative abundance of both species of fish on the sea scallop bed did not significantly correlate with bottom temperature (*U. chuss*: $r = 0.150$; $df = 18$; $P > 0.50$; *L. inquilinus*: $r = 0.247$; $df = 18$; $0.20 < P < 0.50$). Recruitment of *U. chuss* was at its peak immediately following the breakdown of the thermocline in Oct. 1981.

Although the average size of sea scallops during Feb. through Dec. 1981 varied significantly (ANOVA $F_{9,2015} = 23.68$, $P > 0.0001$), the median size of sea scallops was the same during the period of maximum red hake recruitment (81 mm valve height during Aug., Sept., and Oct.). Red hake abundance appeared to peak during the months when median sea scallop size was at the minimum for this site (78 mm in Nov. 1981). Although the relative abundance of *U. chuss* was negatively correlated with the mean sea scallop size ($r = -0.74$; $df = 8$; $P < 0.05$), it is clear that, if any sea scallop size preference by settling juvenile red hake exists, it is for large, not small, sea scallops. *Urophycis chuss* inhabited sea scallops that were in the middle and upper tail of the sea scallop size distribution available during fall (chi square test, $\chi^2 = 34.09$; $P = 0.0015$; Fig. 3). *Liparis inquilinus* abundance did not cor-

relate with sea scallop size ($r = 0.11$; $df = 8$; $P > 0.50$), and we did not measure size-specific usage and availability of sea scallops for *L. inquilinus*. Able and Musick (1976) and Steiner et al. (1982) noted that large (>100 mm valve height) sea scallops held more individuals of these two species than did small (<100 mm) sea scallops. In our samples, *U. chuss* and *L. inquilinus* were found in sea scallops as small as 58 mm valve height. The recruitment patterns of the fishes seem to be unrelated to variations in sea scallop density and size.

Despite the lack of a significant correlation between the relative abundance of *U. chuss* (H/S) and *L. inquilinus* (L/S), it was obvious that an inverse relationship existed in the temporal abundance patterns of the two species of fish: *Liparis* was present first and was followed by *Urophycis* with a brief period of overlap. The causes underlying the patterns of shelter usage demonstrated above are unknown, but several explanations for the decline in snailfish abundance each autumn are possible: (1) during Sept. and Oct., newly recruited hake may prey on snailfish already inhabiting the mantle cavity of the host scallop; (2) newly recruited hake may displace the scallop's previous tenant(s); (3) settlement times differ; and (4) physical factors,

i.e., temperature variation, and thermal stratification, may restrict the settlement of red hake prejuveniles (but not snailfish larvae) and trigger the migration of inquiline snailfish juveniles and adults inshore.

We do not think that predation by or competition with *U. chuss* was responsible for the decline of *L. inquilinus* during Sept. and Oct. Predator-prey interactions are size dependent with predators typically consuming prey that are less than 50% of their total length (Miller et al., 1988). During the study period, the mean total length of *U. chuss* was always greater than the mean total length of *L. inquilinus* for any given month during which both species were on the sea scallop bed. For example, during Sept. and Oct., snailfish averaged 28.5 (range: 14–32) mm TL and red hake averaged 49.0 (range: 23–96) mm TL (Fig. 2). Because (1) this size difference is relatively small (*L. inquilinus* averaged 58% of *U. chuss* TL), (2) both species have been found in the same sea scallop (Able and Musick, 1976), although not in this study, and (3) no snailfish were found in red hake stomachs collected from sea scallops (Luczkovich and Olla, 1983; Garman, 1983), we suspect that predation by commensal *U. chuss* did not play a role in determining the abundance of *L. inquilinus*. We are not able to conclude that *U. chuss* and *L. inquilinus* competed for the sea scallop resource because we cannot say whether the scallop shelter was in short supply. We found many unoccupied sea scallops (85%) during Aug.–Dec. 1981. Furthermore, the relationship is not an obligate one.

A difference in settlement times for *U. chuss* and *L. inquilinus* is the most likely explanation for the observed shelter usage pattern. *Liparis inquilinus* was the first fish to settle from the plankton to the sea scallop bed in both years, recruiting in June and July. Also, *L. inquilinus* was able to persist through Nov., concurrent with increases in the abundance of *U. chuss*. Settlement times of *U. chuss* and *L. inquilinus* could be influenced by physical factors such as thermal boundaries that routinely occur each summer over the continental shelf of the Mid-Atlantic Bight. The majority of *U. chuss* prejuveniles, which are neustonic after hatching from pelagic eggs, recruit to the benthos after the summer thermocline has overturned in Sept. or Oct., and the bottom temperatures rise above 12 C (Steiner et al., 1982; Steiner and Olla, 1985). We observed a sharp increase in the abundance of *U. chuss* during the months of Oct.

in both years, although *U. chuss* abundance was apparently not well correlated with bottom temperature. Perhaps this is because of ontogenetic changes in temperature tolerances. The larvae of *L. inquilinus* are frequently collected in mid-water and hatch from demersal eggs (Able et al., 1986). We observed snailfish using sea scallops during summer when the thermocline was already present. Because snailfish larvae hatch below this thermal feature, the thermocline may not be as significant a barrier to migration of inquiline snailfish as it appears to be for red hake prejuveniles (Steiner and Olla, 1985). Increasing bottom temperatures may trigger inquiline snailfish emigration from the sea scallops. Further study is needed to determine exactly what factors are involved in controlling the timing of benthic recruitment and emigration from sea scallops for both juvenile red hake and inquiline snailfish.

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