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NOTE

Use of sandy beach habitat by *Fundulus majalis*, a surf-zone fish

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ABSTRACT: Habitat use by the striped killifish *Fundulus majalis* was examined at Nannygoat Beach, a sandy beach on Sapelo Island, Georgia, USA. *F. majalis* catch per unit effort (CPUE) was greater in runnel habitat than in any other intertidal region, and no *F. majalis* were captured in the low-tide surf zone. Some *F. majalis* occupied the same runnel on consecutive tidal cycles. *F. majalis* distribution may have been influenced by distributions of potential prey (surf clams *Donax* spp. and *Mulinia* spp.) and predators (blue crab *Callinectes sapidus*).

KEY WORDS: Habitat use · *Fundulus majalis* · Sandy beach Spatial heterogeneity

Like all intertidal species, sandy beach surf-zone fishes are adapted to conditions of continuous physical flux created by tides and waves. Such adaptations may be morphological, such as the flattened bodies of pleuronectid and batoid fishes, or behavioral, such as migrations into and out of the intertidal zone or preferential use of discrete habitat types (Abou-Seedo et al. 1990, Burrows et al. 1994, Gibson et al. 1996). Fishes may use such habitats for key functions such as foraging, predator avoidance, and spawning, as demonstrated in many sandy beach ecosystems (Robertson & Lenanton 1984, Romer 1990, Ayvazian & Hyndes 1995).

An important feature on Nannygoat Beach, a sandy beach on the southeastern shore of Sapelo Island, Georgia, USA, is the ridge-runnel systems (sensu Komar 1998). Ridges are elevated, elongated areas of sand that extend along the beach roughly parallel to the shore. Receding tides expose the ridges, and water is trapped behind them in ephemeral troughs called runnels. Runnels remain connected to the ocean at low tide by narrow drainage channels.

This study evaluated the null hypothesis that catch per unit effort (CPUE) of fishes would be equal at all tide heights and in the exposed runnel habitat, implying that fishes move in and out with the tides; alternatively, differences in CPUE would imply that particular habitats (e.g. the exposed runnel or a particular tide height) were preferred. The relationship of such habitat preference to fish size, feeding, and predator avoidance was considered. The study focused on striped killifish *Fundulus majalis*, a common fish in the Nannygoat Beach intertidal zone, whose habitat use patterns were more distinctive than other fishes present.

Methods. ***Field collections:*** The study took place from 19 to 24 October 1997 in the intertidal zone proximate to a large ridge-runnel system on Nannygoat Beach. The runnel, located halfway between the low tide and high tide lines (tidal amplitude ~3 m), was ~300 m from end to end. Fishes were captured by beach seine (1.5 × 10 m, 8 mm stretch mesh) at 3 tide heights each day (Fig 1): high tide (ridge and runnel submerged), mid tide (runnel submerged, waves breaking over the still-submerged ridge), and low tide (runnel and ridge completely exposed). Two seiners waded 25 m from shore, spread the seine, and moved slowly ashore perpendicular to the shoreline. Five seine hauls were made per tide level per day. The exposed runnel was seined at low tide (Fig. 1). Two seiners spread the seine and swept several cross-sections of the runnel. Volume swept was estimated from the distance across the runnel, the width of the seine, and the maximum depth seined. Fishes were identified at least to genus, and subsamples placed on ice for measurement (total length ± 1 mm, weight ± 0.01 g) and gut content analysis.

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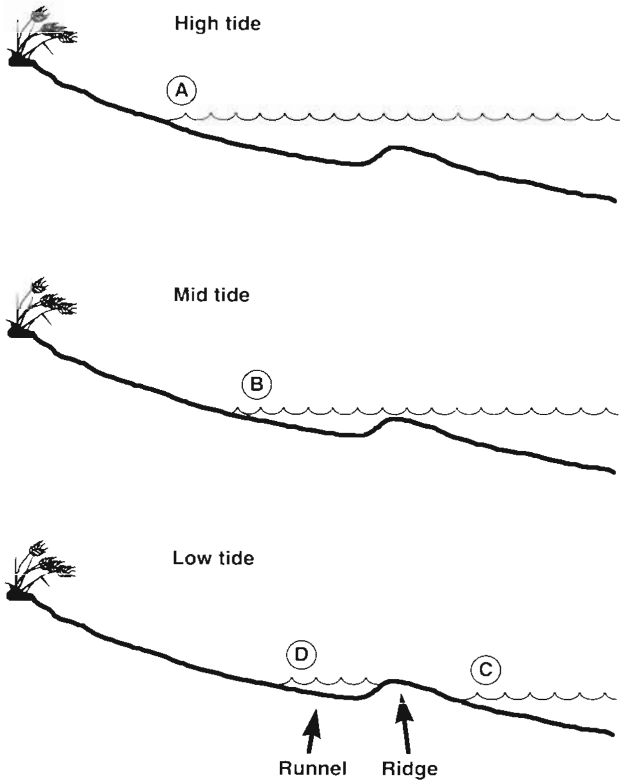

Fig. 1. Profile of sampling site (not drawn to scale). The leading 25 m of the surf zone was sampled at high tide (A), mid tide (B), and low tide (C). The exposed runnel was seined (D) while the tide was low

Of the 16 species captured, *Fundulus majalis* had the most distinctive pattern of habitat use, with especially high densities in the exposed runnel (see 'Results'). A mark-recapture experiment was done on the final 2 d of the study to determine if individual *F. majalis* occupied the runnel on successive tidal cycles; 149 *F. majalis* were marked by clipping the upper lobe of the caudal fin and released into the exposed runnel at ~12:00 h on 23 October. During routine seining on 24 October, all *F. majalis* captured were carefully examined for fin clips.

Gut content analysis: Guts from 50 *F. majalis* (25 high tide, 5 mid tide, 20 exposed runnel) were examined. The entire alimentary canal was removed and weighed (± 0.0001 g), the contents were removed, and the empty gut was reweighed to estimate total gut content weight. Gut contents were examined under a dissecting microscope (6 to 50×); prey items were identified and their percent of total gut contents was visually estimated.

Data analysis: One-factor ANOVAs (factor = habitat; $\alpha = 0.05$; Bonferroni post-hoc test) were used to compare CPUE (no. per 10 m^3 swept), lengths, weights, and gut content weight of *Fundulus majalis* in the 4 habitats (high, mid, and low tide, and exposed runnel). For CPUE comparisons, catch data from the 5 hauls at a given tide height on a given day were pooled to represent a single sample. Fish from all dates were pooled by habitat for comparison of mean lengths, somatic weights, and gut content weights to determine if habitat use was related to fish size or diet. Diet composition data were evaluated in a strictly qualitative manner.

Results. A total of 2069 fish were captured, 316 of which were *Fundulus majalis*, in the 4 habitats sampled. Other abundant species were Atlantic silverside *Menidia menidia*, gulf kingfish *Menticirrhus littoralis*, Florida pompano *Trachinotus carolinus*, and anchovies *Anchoa hepsetus* and *A. mitchilli*. Mean CPUE of *F. majalis* and other abundant fishes in each habitat is shown in Fig. 2; means are based on pooled samples from 6 high tides, 7 mid tides, 6 low tides, and 3 exposed runnel collections. CPUE of *F. majalis* was greater in the exposed runnel than in all other habitats ($F_{3,18} = 18.25$, $p < 0.001$), and *F. majalis* was never observed at low tide. Other abundant species had different distributional patterns (Fig. 2). Habitat type influenced the CPUE of *M. menidia* ($F_{3,18} = 3.50$, $p = 0.037$) and *T carolinus* ($F_{3,18} = 3.35$, $p = 0.041$), though post-hoc analysis yielded no pairwise differences among habitat types. *M. littoralis* CPUE was greatest at low tide ($F_{3,18} = 5.36$, $p = 0.008$). *Anchoa* spp. CPUE

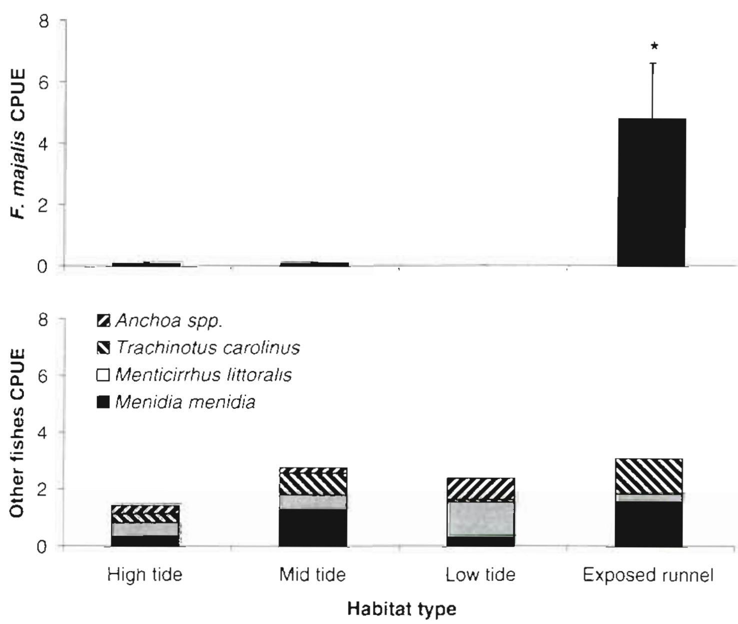

Fig. 2. Catch per unit effort (CPUE, + SE) of *Fundulus majalis* (top) and other abundant fishes (bottom) in 4 habitat types at Nannygoat Beach. Asterisk denotes significant difference at $\alpha = 0.05$

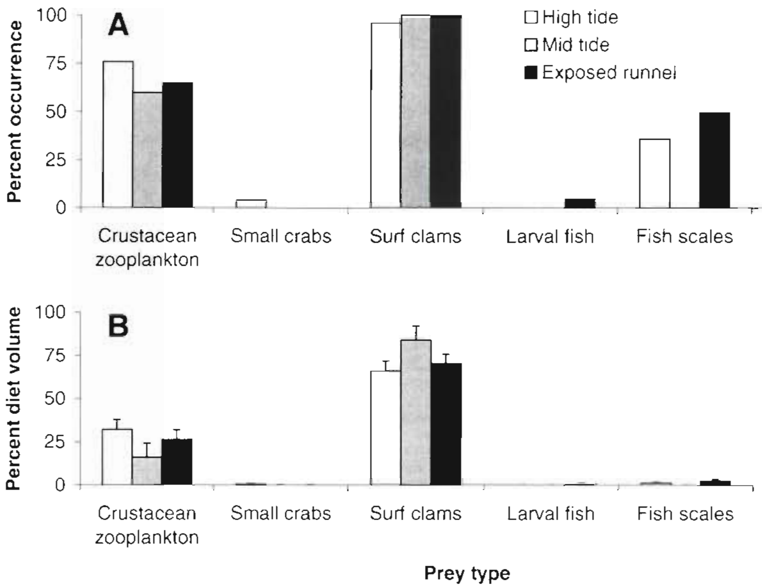

Fig. 3. Gut content analysis of *Fundulus majalis* from 3 habitat types at Nannygoat Beach. (A) Frequency of occurrence of prey items. (B) Estimated % gut content volume (+ SE) of prey items

was similar at all tide heights ($F_{3,18}$ = 1.24, p = 0.326), though they were not observed in the exposed runnel.

Of the 149 *Fundulus majalis* marked and released in the exposed runnel on 23 October, 11 (7.4%) were recaptured in the exposed runnel on 24 October during routine sampling between 09:00 and 10:00 h. Ninety unmarked *F. majalis* were caught in the same sampling period. Following the routine sampling, the entire upper half of the runnel was seined, and 125 *F. majalis* were captured, 17 of which were marked (13.6%).

Fundulus majalis lengths and weights were not significantly different in the 3 habitats where they occurred (length: $F_{2,133}$ = 3.04, p = 0.051; weight: $F_{2,133}$ = 2.47, p = 0.088). The near-significance is probably related to small sample size at mid tide, where only 5 fish were measured (n = 25 at high tide and 106 in the runnel). Mean lengths (± SE) at high tide, mid tide, and exposed runnel were 72 (± 1), 66 (± 2), and 74 (± 1) mm, respectively. Mean weights (± SE) were 4.81 (± 0.28), 3.64 (± 0.38), and 5.15 (± 0.16) g, respectively.

Gut content:body weight ratio and habitat were not related ($F_{2,47}$ = 1.82, p = 0.173), nor were size (length) and gut content:body weight ratio (n = 50; r^2 = 0.00, p = 0.89). Small (<3 mm) surf clams (*Donax* spp. and *Mulinia* spp.), crustacean zooplankton, fish scales, and sand occurred in most *F. majalis* guts regardless of habitat, although fish scales were not important at mid tide (Fig. 3A). Surf clams made up the greatest estimated volume of any prey item (Fig. 3B; the % volume of sand was not included in this analysis, though it was typically <5%).

Discussion. *Fundulus majalis* appeared to make preferential use of the runnel habitat at Nannygoat Beach. *F. majalis* was never caught at low tide, and densities in the runnel were about 45× greater than at mid or high tide. Over a tidal cycle, as the tide rises over the runnel, *F. majalis* inhabit the swash zone in low densities; as the tide recedes, they remain in the runnel rather than moving to the low-tide swash zone. Roughly 10% of marked *F. majalis* were recaptured in the runnel a full tidal cycle after release, which may indicate site fidelity; Lotrich (1975) found that *Fundulus heteroclitus* in a tidal creek exhibited a discrete home range, although Butner & Brattstrom (1960) described similar behavior by *F. heteroclitus* as a chance event.

The distributions of other abundant species differed from *Fundulus majalis*. *Anchoa* spp. appeared to move in and out with the tide, as predicted by the null hypothesis. *Menticirrhus littoralis*, *Trachinotus carolinus*, and *Menidia menidia* all had non-random distributions, although none exhibited preferential use of the runnel, and only *F. majalis* displayed such a dramatic (i.e. 45-fold) difference in CPUE in a specific habitat.

Individual size was not a factor in *Fundulus majalis* distribution, nor were diet composition and gut content weight; however, prey availability may explain why *F. majalis* was not found at low tide. Densities of small surf clams, the most important prey for *F. majalis*, may not have been suitably high in low tide sediments. During this study, densities of *Donax* spp. and benthic amphipods at Nannygoat Beach were greatest in the upper half of the intertidal zone (T. O'Keefe, Department of Zoology, University of Wisconsin, unpubl. data). At low tide, many species of *Donax* remain in the saturated sand above the low tide line (Mikkelsen

Table 1. *Callinectes sapidus*. Catch per unit effort (CPUE) of blue crab in the 4 habitats sampled at Nannygoat Beach

Habitat	Total volume swept (m^3)	Crab CPUE	SE
High tide	2600	0.07	0.05
Mid tide	1500	1.37	0.61
Low tide	2450	1.69	0.79
Exposed runnel	525	0.10	0.10

1981, Leber 1982, Donn et al. 1986, but see Bonsdorff & Nelson 1992). Thus, as the tide receded, *F. majalis* may have remained in the runnel, where food was still available judging from gut contents, rather than moving out into the low-tide swash zone where prey availability may have been lower.

Predators may also have influenced *Fundulus majalis* distributions. During this study, 477 adult female blue crabs *Callinectes sapidus* were captured at low and mid tide, but only 23 in the runnel and at high tide (Table 1). Many *C. sapidus* were observed exiting the runnel as the tide ebbed. It is possible that *F. majalis* used the exposed runnel as refuge from *C. sapidus*, which preys on many intertidal fishes, including *F. heteroclitus* (Kneib 1982, Smith & Weis 1997).

The fish community composition of sandy beaches varies on both a seasonal and a diel scale (Modde & Ross 1980, Gibson et al. 1993, 1996). The scope of this study is not sufficient to describe partitioning of heterogeneous habitat by Nannygoat Beach fishes on either temporal scale. However, this study strongly implies that partitioning of habitat, in this case the runnel, occurs among the fishes of a sandy beach. Because sandy beaches serve as nursery habitat for juveniles of many pelagic fish species (Modde & Ross 1980, Brown & McLachlan 1990, Gibson et al. 1993), habitat heterogeneity of sandy beaches may be linked to coastal fish production.

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