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PEBBLE-NESTS OF FOUR *SEMOTILUS* SPECIES

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Abstract – The pebble-nest microhabitats of four species of *Semotilus* were compared. Pit/mound nests of *Semotilus corporalis* were significantly larger than the pit/ridge nest of *Semotilus atromaculatus*, *Semotilus lumbee*, and *Semotilus* sp. Nests of *S. corporalis* were in wider and deeper streams. Pits of *S. lumbee* nests were longest of the four species; those of *S. corporalis* were widest and deepest. There was no significant difference by weight in the electivity index (percentage of nest pebble sizes versus those of the substrate) among the species for the three largest stone sizes (6.0, 11.3, and 23.0 mm). Although the greatest percentage of stones in the nests of *S. corporalis* were 23 mm, they did not represent the greatest electivity index as that stone size had a high percentage in the substrate. Mounds and ridges of pebble nests served as breakwaters, reducing the flow to near zero in the downstream spawning pit below the ridge or mound of the nest.

INTRODUCTION

Males of four species of *Semotilus* (Cyprinidae) build spawning nests by placing pebbles in mounds or ridges at the head of riffles in clear montane, Piedmont or upper Coastal Plain streams. *Semotilus corporalis* (fallfish) has been considered a pit/mound nest builder. The other three species, *Semotilus atromaculatus* (creek chub), *Semotilus lumbee* (Sandhills chub), and *Semotilus* sp. (= *Semotilus thoreauianus* of Woolcott and Maurakis, 1988), are closely related pit/ridge nest builders. The latter, a diminutive form (adult males approximately one-half the length of adult male *S. atromaculatus*) collected and studied primarily in northeastern Georgia, is tentatively identified as *Semotilus* sp. until its systematics can be reconciled.

Prior to spawning, mounds of *S. corporalis* nests are built by a breeding adult male that excavates an area and later fills it with stones (Raney, 1969). Although this species has not been observed constructing nests following the spawning act as is characteristic of the creek chubs, we have found fallfish eggs covered by pebbles immediately upstream of the pit of a mature nest under construction by the male. Male creek chubs begin a nest by digging a pit and placing the pebbles from it at the pit's upstream margin. Following spawning, the male moves pebbles from the downstream end of the pit and puts them over the eggs deposited in the upstream end of the pit. Thus, as spawning continues, the ridge increases in length and the pit is displaced downstream (Woolcott and Maurakis, 1988).

As most studies of nest construction have been limited to generalized descriptions of nests (e.g. overall dimensions), an objective of this study was to compare the materials and construction of the nests among four species of *Semotilus*. A second objective was to examine the effects of the physical characteristics of pebble-nests on water currents in spawning pits.

MATERIALS EXAMINED

The collection number, number of nests (in parentheses), drainage, locality, and date for *Semotilus atromaculatus*, *Semotilus corporalis*, *Semotilus lumbee*, and *Semotilus* sp. are:

Semotilus atromaculatus. Virginia: EGM-VA-106 (1), Rappahannock, Fauquier Co., unnamed tributary of Thumb Run at Co. Rt. 688, 300 yds. upstream from bridge, 7 May 1983. EGM-VA-107 (2), Rappahannock, Fauquier Co., Carter Run at Co. Rt. 688 bridge, 7 May 1983. EGM-VA-115 (1), Potomac, Fairfax Co., Indian Run at bridge on Edsal Rd., 0.75 mi. E of I-395, 21 April 1984. EGM-VA-116 (3), Potomac, Fairfax Co., Indian Run at bridge on Edsal Rd. 0.75 mi. E of I-395, 21 April 1984. EGM-VA-117.1 (1), Potomac, Fairfax Co., Indian Run at bridge on Edsal Rd. 0.75 mi. E of I-395, 21 April 1984. EGM-VA-117.3 (1), Potomac, Fairfax Co., Indian Run at bridge on Edsal Rd. 0.75 mi. E of I-395, 21 April 1984. EGM-VA-209 (2), Potomac, Fairfax Co., unnamed tributary of Indian Run, 0.5 mi. E of I-395 jct. with Edsal Rd., 23 April 1988. WSW-VA-365 (1), James, Appomattox Co., small drainage near jct. St. Rt. 24 and Co. Rt. 627 opposite Appomattox National Park, 15 May 1987. WSW-VA-369 (1), York, Hanover Co., tributary of Falling Cr. at Co. Rt. 667 approximately 2 mi. N of Ashland, 23 May 1987. Maryland: EGM-MD-121 (1), Potomac, Montgomery Co., unnamed creek of Monocacy R. on Rt. 28, 0.5 mi. from turnoff to PEPCO Dickerson Plant, 13 May 1984.

Semotilus corporalis. Virginia: EGM-VA-54 (2), Rappahannock, Madison/Green Co. line, Conway R. at Co. Rt. 667 and Rt. 613 bridge, 16 May 1982. EGM-VA-108 (2), Rappahannock, Fauguier Co., Great Run at St. Rt. 211 bridge, 4 mi. W of Warrenton, 7 May 1982. WSW-VA-381 (2), James, Campbell Co., Opossum Cr. at bridge on Co. Rt. 669, 1 mi. S of Co. Rt. 664, 9 May 1988.

Semotilus lumbee. North Carolina: EGM-NC-104.1 (1), EGM-NC-105 (1), EGM-NC-208 (3), Peedee, Moore Co., tributary of Drowning Cr. on Co. Rt. 1122, 2.3 mi. W of jct. with Co. Rt. 1004 at Foxfire, 25 April 1982, 16 April 1983, 16 April 1988, respectively.

Semotilus sp. Georgia: EGM-GA-199 (1), Savannah, Stephens Co., Gibson Branch on Ray Rice's farm St. Rt. 124, 13 April 1986. EGM-GA-204 (1), Altamaha, Barrow Co., tributary of Mulberry Cr. on W. C. Wade's farm on St. Rt. 211, 3 mi. W of Winder, 11 April 1987. EGM-GA-207 (3), Altamaha, Barrow Co., tributary of Mulberry Cr. on W. C. Wade's farm on St. Rt. 211, 3 mi W of Winder, 10 April 1988. EGM-GA-208 (1), Savannah, Stephens Co., Zebulon Branch, tributary of N. Fork Broad R. on Ray Rice's property, approximately 1.5 mi. from jct. Rt. 124, N of Toccoa, 11 April 1988.

METHODS

Morphological and meristic characteristics of *Semotilus* sp. are compared with those described for *Semotilus thoreauianus* by Jordan (1877) (Table 1).

Pebble nests were collected from streams in Georgia, North Carolina, and Virginia in April, May, and June from 1982 through

1988. The total number of nests were: *S. atromaculatus*, 14; *S. corporalis*, 6; *S. lumbee*, 5; and *Semotilus* sp., 6.

Table 1. Characteristics of 10 specimens of *Semotilus* sp. compared with *Semotilus thoreauianus* of Jordan (1877).

Character	sp.	*thoreauianus*
Body	robust, short	robust, short
Head	short, round	short, round
Tubercles	8 (anterior bilobed)	8 (anterior bilobed)
Fin rays		
Dorsal	8	8
Anal	8	7
Dorsal position	behind pelvic origin	behind pelvic origin
Pelvic length	reaches vent	short of vent
Pectoral	short	short
Scales		
LL	49.3 (48-51)	48
Above LL	9.2 (9-10)	9
Below LL	6	5

Pebble samples from nests were collected from the upstream, middle, and downstream portions of ridges and mounds. Substrate samples were restricted to the area adjacent to ridges except for those for *S. corporalis* where additional random samples of the substrate were collected as far as 20 m from the nest. Nest and substrate samples were stored in tagged plastic bags and returned to the laboratory for analysis. Pebbles were air-dried and sifted through five custom-built wire sieves. Mesh sizes, restricted to commercially available prefabricated screen sizes were 23.0 mm, 11.3 mm, 6.0 mm, 2.5 mm, and 0.8 mm. Material that sifted through the smallest size mesh was collected in a pan. The weight of material in each sieve was used to calculate the percentage of material per mesh size. Hereafter, all references to percentage of mesh size classes are based on weights.

Fishes over nests were collected with a pulsed DC electroshocker, preserved in 10 percent formalin, measured to SL, and stored at the University of Richmond.

Stream depth (cm), width (m), and temperature (C) were recorded. The velocity of water currents (1 cm above nests and 1 cm above substrates) measured with a Marsh-McBirney current meter were recorded 0.5 m upstream of the ridge, 0.5 m downstream of the ridge, above the ridge, and in the spawning pit. Ridge length, height, and width; and pit depth, length, and width of each nest were measured and used to calculate mean values for each parameter. The Froude number (Davis and Barmuta, 1989) was used for the classification of mean stream flows. The equation, Froude no. $= S\frac{U}{gD}$ [where U = water velocity, g= acceleration due to gravity (9.8 m/ sec^2), and D = depth] was calculated for flows before the nest, above the ridge or mound, and in the pit. Near stream bed flow, expressed as ratios k/L, D/k, and D/j (where k = ridge height, D = water depth, L = ridge length + pit length, and j = pit length) were calculated following Davis and Barmuta (1989).

An electivity index (Ivlev, 1961) was calculated for each pebble size class per nest of each species. The equation $E = \frac{(r_1 - p_1)}{(r_1 + p_1)}$ (where E = pebble size selection, r = percentage of a particular pebble size in the nest, and p = the percentage of a particular pebble size in the substrate of the stream) was used to determine if selection of pebble size from the substrate was nonrandom. Electivity index values range from 1 to – 1. Values closer to 1 indicate a greater selection of a particular pebble size. Percentages and electivity index values were transformed to arcsin equivalents. Average values of electivities, percent pebble composition of nests, and stream dimensions, derived from analysis of variance (ANOVA), were compared between and within species with Duncan's Multiple Range Test (alpha = 0.05; Steel and Torrie, 1980). Backward stepwise regression (SAS, 1985) was used to examine relationships of water current in pits to physical dimensions of the nests and streams.

RESULTS

Nests of *S. corporalis* were in significantly deeper ($\bar{x}$, 52.7 cm) and wider ($\bar{x}$, 5.7 m) streams than were those of other *Semotilus* species (Table 2). Water temperature at active nests for all species ranged from a mean of 13.2 C (*S. atromaculatus*) to 15.0 C (*Semotilus* sp.). Differences were not significant (Table 2). The nonadhesive, demersal eggs were found in nests of all species.

Table 2. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for stream characteristics among *Semotilus atromaculatus*, *Semotilus corporalis*, *Semotilus lumbee*, and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

					ANOVA	
Stream depth					df	F
Species	sp.	*atromaculatus*	*lumbee*	*corporalis*		
Mean (cm)	12.5	15.5	20.7	52.7	26	7.87
Stream Width						
Species	sp.	*lumbee*	*atromaculatus*	*corporalis*		
Mean (m)	1.7	1.9	2.7	5.7	30	24.2
Water Temp.						
Species	*atromaculatus*	*lumbee*	*corporalis*	sp.		
Mean (C)	13.2	13.3	14.7	15.0	30	1.11
Range (C)	11.1-16.7	12.5-16.1	13-15.6	10-17		

Approximately 83% of the pebbles in nests of *S. corporalis* were in size class 23.0 mm. (49.3%) or 11.3 mm (33.6%) (Table 3). Average percentage of pebbles in the 11.3 mm size class followed by those of the 6.0 mm size class were high in nests of *S. atromaculatus* (38.5% and 23.0%, respectively), *S. lumbee* (48.7% and 33.5%, respectively), and *Semotilus* sp. (31.2% and 25.1%, respectively) (Table 3).

Nests of the largest of the four species, *S. corporalis* (♂ 128.9-265.7 mm), had a significantly greater number of 23.0 mm pebbles than those of the other species. Mean percentage of 11.3 mm pebbles in nests of intermediate sized *S. lumbee* (♂ 129.1-185 mm) were significantly greater than those of *S. corporalis* and the smallest species, *Semotilus* sp. (♂ 67.1-67.5 mm). *Semotilus lumbee* nests also had the greatest percentage of 6.0 mm pebbles but differed significantly only form those of *S. corporalis*. *Semo-*

Table 3. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average percentage of nest material according to size class (mm) within *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

							ANOVA	
S. corporalis							df	F
Stone size	<0.8	0.8	2.5	6.0	11.3	23.0		
Mean	0.20	0.60	4.6	11.8	33.6	49.3	6	15.57
S. atromaculatus								
Stone size	<0.8	0.8	2.5	23.0	6.0	11.3		
Mean	2.6	5.1	15.3	15.7	23.0	38.5	6	28.99
S. lumbee								
Stone size	<0.8	0.8	23.0	2.5	6.0	11.3		
Mean	0.70	1.7	6.8	8.6	33.5	48.7	12	52.42
Semotilus sp.								
Stone size	<0.8	0.8	23.0	2.5	6.0	11.3		
Mean	6.3	7.2	10.1	14.0	25.1	31.2	18	12.44

tilus atromaculatus (♂ 130-145.2 mm) and *Semotilus* sp. nests had similar high percentages of 2.5 mm pebbles and were significantly different from those of *S. corporalis*. Percentages of 0.8 mm pebbles in the nests of *Semotilus* sp. and *S. atromaculatus* were significantly greater than those for the other two species. The average percentage of particles less than 0.8 mm in nests of *Semotilus* sp. was greater than those for other species (Table 4).

Table 4. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average percentage of nest material according to size class (mm) among *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differe significantly (alpha = 0.05).

					ANOVA	
23.0					df	F
Species	*lumbee*	sp.	*atromaculatus*	*corporalis*		
Mean	6.8	10.0	15.7	49.3	7	11.8
11.3						
Species	sp.	*corporalis*	*atromaculatus*	*lumbee*		
Mean	31.2	33.6	38.5	48.7	7	4.1
6.0						
Species	*corporalis*	*atromaculatus*	sp.	*lumbee*		
Mean	11.8	23.0	25.0	33.5	7	4.1
2.5						
Species	*corporalis*	*lumbee*	sp.	*atromaculatus*		
Mean	4.6	8.6	14.0	15.3	7	5.1
0.8						
Species	*corporalis*	*lumbee*	*atromaculatus*	sp.		
Mean	0.6	1.7	5.1	7.2	7	14.7
<0.8						
Species	*corporalis*	*lumbee*	*atromaculatus*	sp.		
Mean	0.2	0.7	2.6	6.3	7	19.1

Substrate material at nests of *S. corporalis* was comprised of 61.1% of the 23.0 mm size class pebbles. In all other size classes, the percentage of substrate material at *S. corporalis* nests was lowest of the four species (Table 5).

Table 5. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average percentage of substrate material according to size class (mm) among *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

					ANOVA	
23.0					df	F
Species	*lumbee*	*atromaculatus*	sp.	*corporalis*		
Mean	2.5	6.8	8.9	61.1	7	13.3
11.3						
Species	*corporalis*	*atromaculatus*	sp.	*lumbee*		
Mean	19.8	24.9	25.7	33.6	7	1.6
6.0						
Species	*corporalis*	sp.	*atromaculatus*	*lumbee*		
Mean	10.9	15.7	17.7	25.1	7	4.1
2.5						
Species	*corporalis*	sp.	*lumbee*	*atromaculatus*		
Mean	4.8	10.4	13.2	14.8	7	5.6
0.8						
Species	*corporalis*	sp.	*lumbee*	*atromaculatus*		
Mean	1.5	7.3	8.9	9.8	7	9.6
<0.8						
Species	*corporalis*	*lumbee*	*atromaculatus*	sp.		
Mean	1.8	16.7	26.0	32.0	7	13.4

Electivity indices were highest for pebbles in size classes 11.3 and 6.0 mm in all four species (Tables 6 and 7). *Semotilus atromaculatus* selected significantly more 23.0 mm pebbles than pebbles 2.5 mm and smaller. Although 23.0 mm size pebbles were most abundant in *S. corporalis* nests (Table 3), they did not have a high electivity index as they also were most abundant in the substrate. Numbers of pebble sizes (6.0, 11.3, and 23.0 mm) selected by *S. lumbee* were similar. There were no significant differences among the size classes 0.8 to 23.0 mm selected by *Semotilus* sp. (Table 6).

Mean electivity indices among species did not differ significantly for nest pebbles in the 23.0, 11.3, and 6.0 mm size classes. Except for *Semotilus* sp., no species selected stones less than 2.5 mm (Table 7).

Mean ridge length of *S. lumbee* nests was greatest but differed significantly only from that of *Semotilus* sp. nests. Average mound width and height of *S. corporalis* nests were significantly greater than the ridges of nests of the other three species (Table 8).

Average pit depths and widths of *S. corporalis* nests were significantly greater than those of nests of *S. atromaculatus* and *Semotilus* sp. Mean pit length of *S. lumbee* nests was significantly greater than that of the nest of S. *atromaculatus* (Table 8).

Table 6. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average electivity according to size class (mm) within *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

							ANOVA	
S. atromaculatus							df	F
Size Class	<0.8	0.8	2.5	6.0	11.3	23.0		
Mean	–0.90	–0.30	0.0	0.10	0.20	0.50	6	14.7
S. corporalis								
Size Class	<0.8	0.8	23.0	2.5	6.0	11.3		
Mean	–0.80	–0.50	–0.10	–0.02	0.03	0.30	6	9.9
S. lumbee								
Size Class	<0.8	0.8	2.5	6.0	11.3	23.0		
Mean	–0.90	–0.70	–0.20	0.20	0.20	0.30	12	25.5
Semotilus sp.								
Size Class	<0.8	0.8	11.3	2.5	6.0	23.0		
Mean	–0.70	0.07	0.10	0.10	0.20	0.50	18	4.0

Table 7. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average electivity according to size class (mm) among *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

					ANOVA	
23.0					df	F
Species	*corporalis*	*lumbee*	*atromaculatus*	sp.		
Mean	–0.10	0.30	0.50	0.50	7	0.44
11.3						
Species	sp.	*lumbee*	*atromaculatus*	*corporalis*		
Mean	0.10	0.20	0.20	0.30	7	0.67
6.0						
Species	*corporalis*	*atromaculatus*	*lumbee*	sp.		
Mean	0.03	0.10	0.20	0.20	7	1.63
2.5						
Species	*lumbee*	*corporalis*	*atromaculatus*	sp.		
Mean	–0.20	–0.02	0.00	0.10	7	3.66
0.8						
Species	*lumbee*	*corporalis*	*atromaculatus*	sp.		
Mean	–0.70	–0.50	–0.30	0.07	7	12.71
<0.8						
Species	*lumbee*	*atromaculatus*	*corporalis*	sp.		
Mean	–0.90	–0.90	–0.80	–0.70	7	4.71

Table 8. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for nest characteristics (cm) among *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

					ANOVA	
Ridge length					df	F
Species	sp.	*atromaculatus*	*corporalis*	*lumbee*		
Mean	35.2	68.6	81.6	96.2	28	2.6
Ridge width						
Species	sp.	*atromaculatus*	*lumbee*	*corporalis*		
Mean	18.2	21.6	28.0	60.9	28	26.8
Ridge height						
Species	sp.	*atromaculatus*	*lumbee*	*corporalis*		
Mean	4.0	4.2	6.9	38.1	27	8.3
Pit depth						
Species	*atromaculatus*	sp.	*lumbee*	*corporalis*		
Mean	6.7	7.6	9.4	14.5	25	1.8
Pit length						
Species	*atromaculatus*	*corporalis*	sp.	*lumbee*		
Mean	21.3	32.0	32.1	36.3	25	4.0
Pit width						
Species	*atromaculatus*	sp.	*lumbee*	*corporalis*		
Mean	16.2	25.5	29.6	39.0	24	6.1

Average velocity of water current over and near nests of all four species was similar with two exceptions: current velocity over the crest of the mounds of *S. corporalis* nests was significantly greater than that over the crest of ridges of *S. atromaculatus* nests; and average current downstream of *S. lumbee* nests was significantly greater than those of *S. atromaculatus* and *Semotilus* sp. (Table 9). In nests of all species, average current velocity in the pit was significantly less than average current velocity at other points on or near nests (Table 10). Ridge length and height, and water depth were the three physical factors associated with reduced water currents in the pit (Table 11). Froude number($\bar{x}$ range = 0.015 – 0.035) in the pit was lower than values in the stream ($\bar{x}$ range = 0.074 – 0.111) or over the ridge or mound ($\bar{x}$ range = 0.120 – 0.394) (Table 12). The ratios k/L and D/j never exceeded 1.0 for nests of all species. The mean D/k ration (0.610) for S. *corporalis* nests was lower than that (4.334 – 5.595) for nests of other *Semotilus* species.

DISCUSSION

Our study is the first to quantitatively analyze the construction and composition of spawning nests of nest-building species of *Semotilus*. Previously, investigators have given limited measurements and descriptions of the physical characteristics and composition of nests (Reighard, 1910; Moshenko and Gee, 1973; Ross, 1983; and Copes, 1978).

Table 9. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average current velocity (m/sec) before ridge, over ridge, in pit, and after pit among *Semotilus atromaculatus, Semotilus corporalis, Semotilus lumbee,* and *Semotilus* sp. Underscored means do not differ significantly (alpha = 0.05).

					ANOVA	
Before ridge					df	F
Species	*atromaculatus*	sp.	*corporalis*	*lumbee*		
Mean	0.05	0.13	0.16	0.16	12	1.1
Ridge						
Species	*atromaculatus*	*lumbee*	sp.	*corporalis*		
Mean	0.08	0.15	0.17	0.22	9	3.1
Pit						
Species	*atromaculatus*	*corporalis*	*lumbee*	sp.		
Mean	0.02	0.02	0.03	0.05	10	0.4
After Pit						
Species	*atromaculatus*	sp.	*corporalis*	*lumbee*		
Mean	0.13	0.17	0.28	0.37	9	4.7

Table 10. Analysis of variance (ANOVA) and Duncan's Multiple Range Test for average current velocity (m/sec) upstream of ridge, over ridge, in pit, and downstream of pit for all nest-building species of *Semotilus*. Underscored means do not differ significantly (alpha = 0.05)

					ANOVA	
Location	Pit	Upstream of ridge	Ridge	Downstream of Pit	df	F
Mean current	0.04	0.13	0.16	0.23	52	13.1

Table 11. Results of Backward Stepwise Regression (SAS, 1985) for effects of stream depth; ridge length, height, and width; pit depth, length, and width; stream flow; and flow over the ridge or mound on water currents in the pit of nest-building *Semotilus* species.

Parameter	B value	F value	Probability > F
Intercept	–0.05707285	999999.99	0.0001
Stream depth	0.84210059	999999.99	0.0001
Ridge length	–0.09544103	999999.99	0.0001
Ridge height	0.11541706	999999.99	0.0001
Ridge width	0.00000000	0	1.0
Pit depth	0.00000000	0	1.0
Pit length	0.00000000	0	1.0
Pit width	0.00000000	0	1.0
Stream flow	0.00000000	0	1.0
Ridge flow	0.00000000	0	1.0

Table 12. Classification parameters of average stream flow and pebble-nest microenvironments of *Semotilus* nests.

Parameter		Species			
		atromaculatus	*corporalis*	*lumbee*	sp.
Froude no.					
Stream					
	$\bar{x}$	0.106	0.111	0.074	0.108
	s.d.	0.078	0.025	0.015	0.061
Nest ridge/mound					
	$\bar{x}$	0.142	0.394	0.120	0.147
	s.d.	0.092	0.239	0.019	0.070
Nest pit					
	$\bar{x}$	0.018	0.015	0.021	0.035
	s.d.	0.009	0.012	0.006	0.005
k/l	$\bar{x}$	0.048	0.118	0.030	0.040
s.d.	0.020	0.001	0.017	0.018	
D/j	$\bar{x}$	0.783	0.715	0.803	0.473
	s.d.	0.169	0.421	0.332	0.104
D/k	$\bar{x}$	4.334	0.610	5.595	5.311
	s.d.	1.528	0.764	2.342	2.720

Hynes (1979) stated that larger fish occupy larger streams, and in accord, breeding males of *S. corporalis* are larger than those of *S. atromaculatus, S. lumbee,* and *Semotilus* sp. and are likely to live in larger streams. Stream dimensions are similar for the three smaller *Semotilus* species which are similar to each other and do not differ substantially from those reported by other investigators (Reighard, 1910; Hankinson, 1932; Sisk, 1966; Snelson and Suttkus, 1978; and Ross, 1983). According to the terminology developed by Davis and Barmuta (1989) for classifying mean stream flow, mean stream flows where we studied nests were subcritical and turbulent.

Semotilus species spawn in the spring and are the earliest spawners compared to other pebble nest-building cyprinid genera (i.e. *Exoglossum* and *Nocomis).* Nests were found at water temperatures comparable to those given for *S. corporalis* by Richardson (1935) and Reed (1971); for *S. atromaculatus* by Reighard (1910), Hankinson (1932), Sisk (1966), Miller (1967), Raney (1969), Moshenko and Gee (1973), and Copes (1978); for *S. lumbee* and *Semotilus* sp. by Woolcott and Maurakis (1988). Conversely, Miller (1964), in a field study of cyrpinids in New York, found S. *atromaculatus* spawning at temperatures as high as 23.3 C; about seven degrees higher than the highest temperature (16.7 C) in this study.

Larger pebble sizes (6.0-23.0 mm) were used more frequently in the construction of nests by all *Semotilus* species. Moshenko and Gee (1973), in the only available study that examined pebble sizes in a *S. corporalis* nest, reported fine gravel accounted for more than 50% of the ridge. As they did not provide actual pebble size, their data could not be compared to those given in this study.

We previously have observed that 90% of the pebbles in the pits and ridges of *S. lumbee* nests measured 11.3 mm or less; and 10% measured 23.0 mm.

Large pebble sizes (6.0-23.0 mm) were used in the construction of nests by all four species. Since all four species, regardless of the size of the male, showed a selective preference for these pebble size, interstices created by these sizes may provide optimal aeration of the water while providing protection for eggs and developing larvae against predation. Only *Semotilus* sp. selected pebble sizes less than 6.0 mm. It should be pointed out that even though the nests of *S. corporalis* did not reflect a high electivity index for the largest pebbles (23.0 mm), because of the large numbers of this size class in the substrate, nests were composed of almost 50% of this pebble size.

Pit-mound nests of *S. corporalis* are usually larger in all dimensions than the pit-ridge nests of the other three *Semotilus* species. Raney (1969) gave approximate values for the nests of *S. corporalis* of 180.0 cm in diameter and 60.0 cm high, which are similar to those of Wilson (1907), and Mansueti and Hardy (1967). Nest sizes in our study were within ranges reported by other investigators; however, as most *S. corporalis* nests were ridge-like (longer than wide), measurements for these dimensions could not be compared to those given by the above authors who did not specify the shape of the nests they observed. Reed (1971) suggested nest shape in *S. corporalis* nests is controlled by current. We could not confirm his statement that nests in a current have a downstream keel and those outside the current are dome shaped.

Comparison of ridge sizes within and among the other *Semotilus* species may be meaningless as ridge size is related to the length of time the male has been spawning. For example, in *S. atromaculatus* ridges there was a difference of about 200 cm (longest, 210.0 cm; shortest, 9.0 cm); in *S. lumbee*, the longest ridge was 120.0 cm and the shortest was 65.0 cm; and in *Semotilus* sp., the longest ridge was 66.0 cm and the shortest was 11.0 cm. Reighard (1910) reported ridge lengths as long as 5.5 m in *S. atromaculatus*. Woolcott and Maurakis (1988) observed ridge lengths of 4.6 m, and Moshenko and Gee (1973) noted ridges up to 2.0 m long in *S. atromaculatus* nests. Shorter ridge lengths (35.5-76.2 cm) for nests of *S. atromaculatus* were reported by Copes (1978).

All four *Semotilus* species excavate a pit at the downstream portion of the nest mound or ridge, a feature restricted to the members of this genus. Pit depths, lengths, and widths in S. *atromaculatus* nests examined in this study were comparable to those of Reighard (1910); Raney (1969); Moshenko and Gee (1973); Copes (1978); and Woolcott and Maurakis (1988). The similarity in ridge construction among the three creek chubs lends credibility to their monophyly. In S. *corporalis* nests, pebble excavation resulted in well-defined pit and a pebble ridge of deposited material from the pit during the early stages of nest construction. The concentration of large numbers of eggs in an area in the downstream base of the mound suggest that the *S. corporalis* we studied probably spawned in the early stages of nest construction. During the later stages of nest construction, time spent by *S. corporaalis* excavating the pit decreased as the frequency of pebbles collected away from the nest increased. Regardless from where the pebble was collected, the male always moved into the pit, and then moved forward to drop the stone on the ridge. This behavior resulted in the formation of a well-developed mound nest with a poorly-defined, shallow pit at the downstream edge of the mound.

Analysis of stream and nest measurements indicated that ridge/mound height and length, and water depth were the three factors associated with decreased water current velocities in the pit. According to flow microenvironment classification by Davis and Barmuta (1989), an isolated roughness flow is created when k/L is small. This related directly to the conditions created by the construction of *Semotilus* nests (i.e. ridge height and length, and pit length). Isolated roughness flows create horseshoe vortices behind the roughness element of nests. The significance of which is the slowest current was in the pit and facilitated the vertical descent of eggs and milt during the spawning act (Table 9). Because of the increased height of mounds which cause a condition comparable to a shallow riffle, microenvironment flow of mature S. *corporalis* nests may be considered as a chaotic flow (after the terminology of Davis and Barmuta, 1989). If measurements of flows had been made at the time that we postulate spawning occurred by the fallfish, flow over the smaller nest would have been like that over the nests of creek chubs. That *S. corporalis* in Virginia continues to build on the nest after spawning (evidenced by the presence of eggs covered by stones upstream of the pit) apparently is contrary to statements by Ross and Reed (1978) and Jenkins (pers. comm.) that more northern *S. corporalis* spawns communally over mounds. We have never found the eggs of *S. corporalis* randomly scattered on mounds of any of the 12 nests that were investigated. Rather, eggs were collected only in discrete areas in the downstream base of mature mounds.

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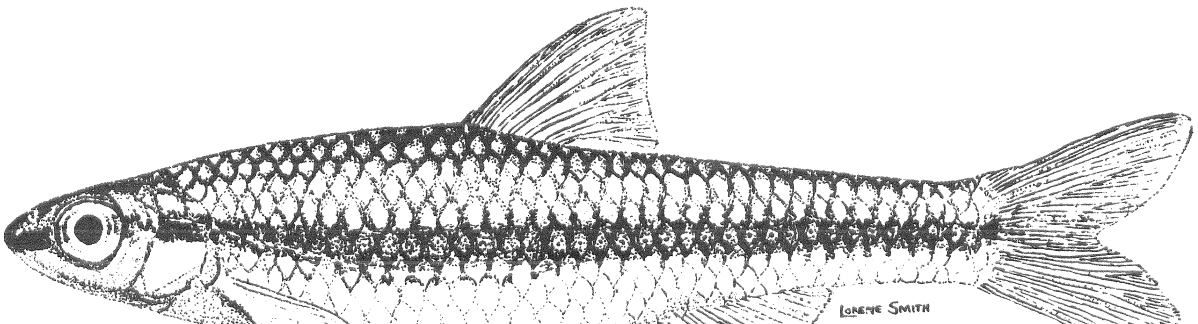

CAPE FEAR SHINER

The Southeastern Fishes Council wishes to thank Ms. Lorene Smith, of the Louisiana Marine Consortium, Chauvin, LA, who produced the above illustration that appeared on our most recent button. Ms. Smith, a member of the SFC, also provided the drawing of the rusty side sucker that appeared on our 1987 button.