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Selection of sites for egg deposition and spawning dynamics in the waccamaw darter

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Synopsis

We provided 93 experimental spawning covers for the waccamaw darter. We grouped the covers (3 sizes of slate and one of concave tile) in three arrangements at six Lake Waccamaw locations to separate the variables of water depth, distance from shore, cover density and cover type. Tag returns of marked males suggest low fidelity for nest sites. Egg production under the 3 different sizes of slate was not significantly different. Egg production under the tile was significantly less than that under the slates. Egg production was significantly higher off the undeveloped southeastern shore in 2 m of water and lowest at the shallowest location with the highest experimental cover density. The number of eggs in nest is positively correlated with male size. We conclude that medium size slate covers placed in a linear arrangement in 2 m of water on a mixed sand bottom result in the highest egg production for the waccamaw darter.

Introduction

The sites of egg deposition in darters have been summarized for approximately one-third of the species (Page 1983, Page et al. 1982). Darters bury their eggs in the substrate, attach them to the tops or sides of objects (plants or rocks) or cluster or clump them underneath an object (rock or log). In the former two modes, eggs are abandoned after deposition; in the latter two, they are guarded by the male. The factors that govern nest site selection are unknown for most species. Winn (1956) experimented in the laboratory with egg site choice for *Etheostoma blennioides*, *E. caeruleum* and *E. spectabile*, species that abandon their eggs after spawning. No nest site selection experiments have been performed on egg guarding species (but see Speare 1965 and Constanz 1979 for related observations on *E. nigrum* and *E. olmstedi*).

The waccamaw darter, *E. perlongum*, is an egg-clustering annual species (see Lindquist et al. 1981 and Shute et al. 1982 for breeding behavior and early life history) endemic to Lake Waccamaw, North Carolina (Hubbs & Raney 1946, Bailey 1977). In connection with a survey to assess the status and conservation of the waccamaw darter, we placed artificial nesting covers in Lake Waccamaw. Objectives were to: (1) determine the size, shape and lake placement of artificial spawning covers for maximizing nest egg numbers; (2) investigate spawning dynamics and egg site selection; and (3) assess the effect of madtom catfishes, which share the artificial nesting covers, on darter egg numbers in nest.

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Methods and materials

During the first week in March 1981 a total of 93 spawning covers were placed in six different areas of Lake Waccamaw lacking logs, sticks, rocks or other potential spawning sites (Table 1). Two stations (2 and 4) were located off the northeast shore, three (1, 3 and 6) off the southeast shore and one (5) off the south shore. Three of the covers (types 1, 2 and 3; Table 1) were flat slate, 1.5 to 2 cm thick and 21.6, 29.2 and 44.5 cm square, respectively. Cover type 4 (Table 1) was a 36 x 23 cm concave terracotta roofing tile. The slates were elevated 2 to 3 cm on one side by a peg driven into the sand. The tiles were placed concave side down with one end buried leaving a single entrance at the opposite end. Covers in linear arrangements (Table 1) were 1 m apart with elevated ends facing a common direction. One each of the type 3 covers was used at stations 1, 2 and 3 and were followed by alternating types 1, 2 and 4 (5 each). Station 4 was identical, except for the absence of the type 3 cover. Station 5 was a rectangular cluster (4 slates wide and 5 slates long) of 20 alternating type 1 and 2 covers. The covers were separated by 2 to 20 cm and also were elevated 2 to 3 cm on one side. The side elevated was chosen by random number designation.

We sampled each spawning cover five to six times at regular intervals for darters and darter eggs until spawning had terminated on June 11, 1981. Other fishes (mainly the tadpole madtom, *Noturus gyrinus*, and the undescribed broadtail madtom, *Noturus* sp.) under the slates were also enumerated.

Darters were captured under cover types 1, 2 and 4 with a capture box (Downhower & Brown 1977) made of pine (2 x 2 x 30 cm) forming an open frame cube (34 cm sides). Otherwise, handnets were used to capture darters. Three sides of the capture box were covered with net (2 x 5 mm mesh) and the other side had a 85 cm long bag of 1 mm mesh net attached. The top and bottom were left open. The open bottom was weighted on two sides and three 18 cm aluminium nails could be pushed through three sides of the bottom frame into the bottom, thus anchoring the capture box to the sediment. Once the capture box was placed over the spawning cover, (without disturbing neighboring covers) the cover was lifted through the open top of the capture box exposing darters (and other fishes) that could then be forced into the net bag. Covers with egg clusters adhering to their undersides were photographed next to a ruler and replaced to their original positions. Darters were sexed and measured; marked (during initial half of spawning season only) by injecting acrylic dye (Thresher & Gronnel 1978) under a few scales (cheek, nape, under dorsal or anal fins and caudal peduncle), and released under their original spawning covers where they resumed normal behavior.

The photo transparencies of the egg clusters were used to determine egg numbers by direct count (small clusters) or by estimation (large clusters). Large egg numbers were estimated by projecting the transparency onto a small screen and tracing the outline of the cluster while taking 2 to 4 egg density samples. The area of the egg cluster was measured with a planimeter and then multiplied by the mean density estimate to arrive at the total number of eggs. A direct count check of our estimation technique gave a mean accuracy of 86% (N = 30). Data analysis was assisted with the

Table 1. Protocol for experimental spawning cover arrangements. See text for description of cover types.

Station	Water depth (m)	Offshore (m)	Cover type(s)	Cover arrangement	Total covers
1	0.5	300	1, 2, 3, 4	Linear	16
2	1	200	1, 2, 3, 4	Linear	16
3	2	1000	1, 2, 3, 4	Linear	16
4	2	600	1, 2, 4	Linear	15
5	0.2	10	1, 2	Cluster	20
6	0.5	350	4	Linear	10

Statistical Analysis System (SAS) computer programs.

Results

No marked females (N = 35) and only 24 (15%) of the marked males were recaptured under the spawning covers. No darter was recaptured more than once. Marked and recaptured males were 'at large' (between captures) an average of 26 days (range 9–66 days) or 1.5 sampling intervals (range 1–4 intervals) and had moved an average of 2.6 m. Only three of the recaptured males were recaptured under their original spawning cover.

Egg production for the four spawning covers located at stations 1, 2, 3 and 4 was greater on the three flat slates (cover types 1, 2 and 3) than on concave tile (Fig. 1). Single peaks of egg production for the four covers occur during each of the months of March, April and May with April having the greatest egg production except for cover type 3 which has a peak of nearly 5000 in May (Fig. 1). Duncan's multiple range test (DMRT)

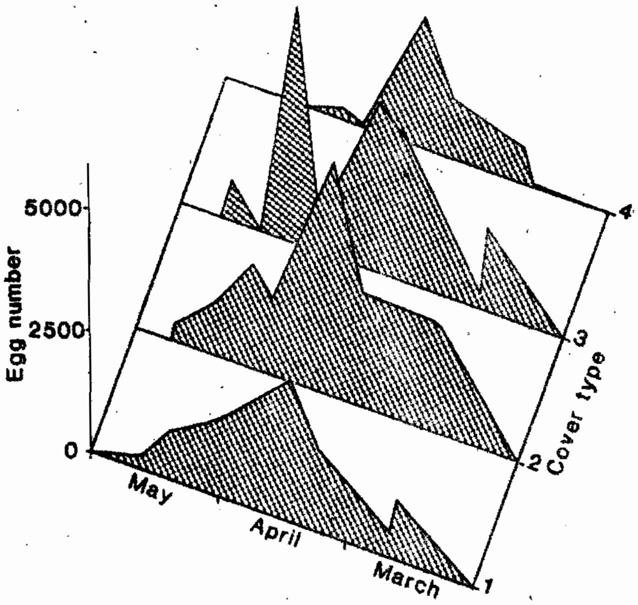

Fig. 1. Egg production (mean egg numbers) by observation date on the four spawning cover types (including covers with no eggs) combined for stations 1, 2, 3 and 4. Cover types 1, 2 and 3 are 23, 29 and 44 cm slates, respectively, and type 4 is the concave tile.

for mean egg production by cover type across the spawning season gives means with non-significant differences of 1059, 1560 and 1754 eggs for types 1, 2, and 3, respectively. The concave tile, type 4, has a mean of 474 eggs which is significantly less ($p<0.05$) than the three flat slates.

Egg production for station 6, which has concave tiles only, compares favorably with egg production for concave tiles at station 3 where darters could choose between the four cover types (DMRT, Table 2). However, egg production for concave tiles at stations 1, 2 and 4 was significantly less than that at station 6 (DMRT, Table 2). These results suggest that egg production under concave tiles can be increased by providing them as the only spawning cover (e.g., station 6, Table 2).

A comparison of mean egg production at all six stations for all cover types shows that station 3, 2 m in depth and 1000 m off the undeveloped southeastern shore, is significantly ($p<0.05$) most productive (DMRT, Table 3). Station 6, consisting of linear tiles, is also significantly more productive than station 5, having the cluster of slates. There are no significant ($p>0.05$) differences for mean egg production for stations 1, 2, 4 and 5 (DMRT, Table 3). Station 5, the shallow (0.2 m) cluster, has the lowest mean egg production.

A linear regression of nest egg numbers on the standard length (SL) of the attendant male for all samples shows a positive correlation ($r = 0.22$, $N = 222$), that is significantly different from zero ($p = 0.001$). The regression line predicts 1000 ± 400 (= 95% Confidence Limits) eggs for a 55 mm male, 1500 ± 200 eggs for 68 mm and 2000 ± 300 eggs for a 76 mm male. Mean male standard length for each sample date (all samples) regressed over the spawning period (March-June) indicates a significant negative correlation ($r = -0.82$, $p = 0.002$ and $N = 11$). The regression line predicts a mean SL of 71 ± 2 mm for March, 68 ± 1 for April, 65 ± 2 mm for May and 62 ± 3 mm for June. A comparison of mean male SL for the four cover types at stations 1, 2, 3 and 4 (DMRT, Table 4), shows significantly larger males tending nests under the medium size slates when compared to the smaller and larger slates. Male size for tiles is not significantly different large egg numbers under the tiles, e.g., maximum 7354 eggs for cover type 4 at station 3.

Based on our limited number of observations for the large (44.5 cm^2) slates, we suggest that these do not offer any significant increase in nest quality and egg numbers, despite a more than twofold increase in surface area. Large nesting males and large egg clusters were more often associated with the medium size slate. This may be due to the decrease in the angle with the horizontal associated with large slates (5° for the larger slates and 10° and 15° for the medium and small slates, respectively). Speare (1965) reported that his spawning plates set at 10° were most frequently used by *E. nigrum* males. In order to be more effective, our large slates may need an additional elevation of 2 to 5 cm. Even with the darter's capability to dig out sand and adjust the cover height, this large slate area (1976 cm^2) may be too much for a small fish to adjust.

Station 3, located farthest from the shore, was the most productive. Previous study by Lindquist et al. (1981) indicated that no natural cover occurs offshore and that males undergo an offshore to onshore migration in March, thus enabling rapid colonization of the onshore stations. In addition, station 3 is off the relatively undisturbed and undeveloped southeastern shore which may contribute to better water and sediment quality.

Our results show that large males hold the artificial nest sites early in the spawning season and then are gradually replaced by smaller males. Larger males also are associated with nests having larger egg numbers. This is expected if suitable spawning cover is limited. Large males win the early aggressive encounters for nest sites and females choose these early nest sites because they offer more uncovered spawning surface (Constantz 1979). Large males may depart after available nest area is used and then search for more nest area (Constantz 1979), or they may be dying due to poor condition (Shute et al. 1982).

The maximum number of eggs in a single nest for *E. perlongum* reported by us here is considerably larger than that for other reported darter nests. We believe this is a direct result of our concentration of nest sites that effects a lek-like system that maximizes nest egg production. Conservation practices for *E. perlongum* should include medium size slate covers placed in a linear arrangement in 2 m of water on a mixed sand bottom. The choice of medium size slates is most effective in egg production.

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References cited

Bailey, J.R. 1977. Freshwater fishes. pp. 265–98. *In:* J.E. Cooper, S.S. Robinson & J.B. Funderburg (ed.) Endangered and Threatened Plants and Animals of North Carolina, N.C. State Museum of Natural History, Raleigh.

Constantz, G.D. 1979. Social dynamics and parental care in the tessellated darter (Pisces: Percidae). Proc. Acad. Nat. Sci. Phila. 131:131–138.

Downhower, J.F. & L. Brown. 1977. A sampling technique for benthic fish populations. Copeia 1977:403–406.

Hubbs, C.L. & E.C. Raney. 1946. Endemic fish fauna of Lake Waccamaw, North Carolina. Misc. Publ. Mus. Zool. Univ. Mich. 65: 1–30.

Lindquist, D.G., J.R. Shute & P.W. Shute. 1981. Spawning and nesting behavior of the waccamaw darter, *Etheostoma perlongum*. Env. Biol. Fish. 6:177–191.

Page, L.M. 1983. Handbook of darters. T.F.H. Publications, Neptune City. 271 pp.

Page, L.M. & B.M. Burr. 1976. The life history of the slabrock darter, *Etheostoma smithi*, in Ferguson Creek, Kentucky. Illinois Nat. Hist. Surv. Biol. Notes 99:1–11.

Page, L.M., W.L. Keller & L.E. Cordes. 1981. *Etheostoma (Boleosoma) longimanum* and *E. (Catonotus) obeyense*, two more darters confirmed as egg-clusterers. Trans. Ky. Acad. Sci. 42: 35–36.

Page, L.M., M.E. Retzer & R.A. Stiles. 1982. Spawning behavior in seven species of darters (Pisces: Percidae). Brimleyana 8:135–143.

Shute, P.W., J.R. Shute & D.G. Lindquist. 1982. Age, growth and early life history of the Waccamaw darter. *Etheostoma perlongum*. Copeia 1982:561–567.

Speare, E.P. 1965. Fecundity and egg survival of the central johnny darter *(Etheostoma nigrum nigrum)* in southern

Michigan. Copeia 1965:308–314.
Thresher, R.E. & A.M. Gronnel. 1978. Subcutaneous tagging of small reef fishes. Copeia 1978:352–353.
Winn, H.E. 1956. Egg site selection by three species of darters. Anim. Behav. 5:25–28.

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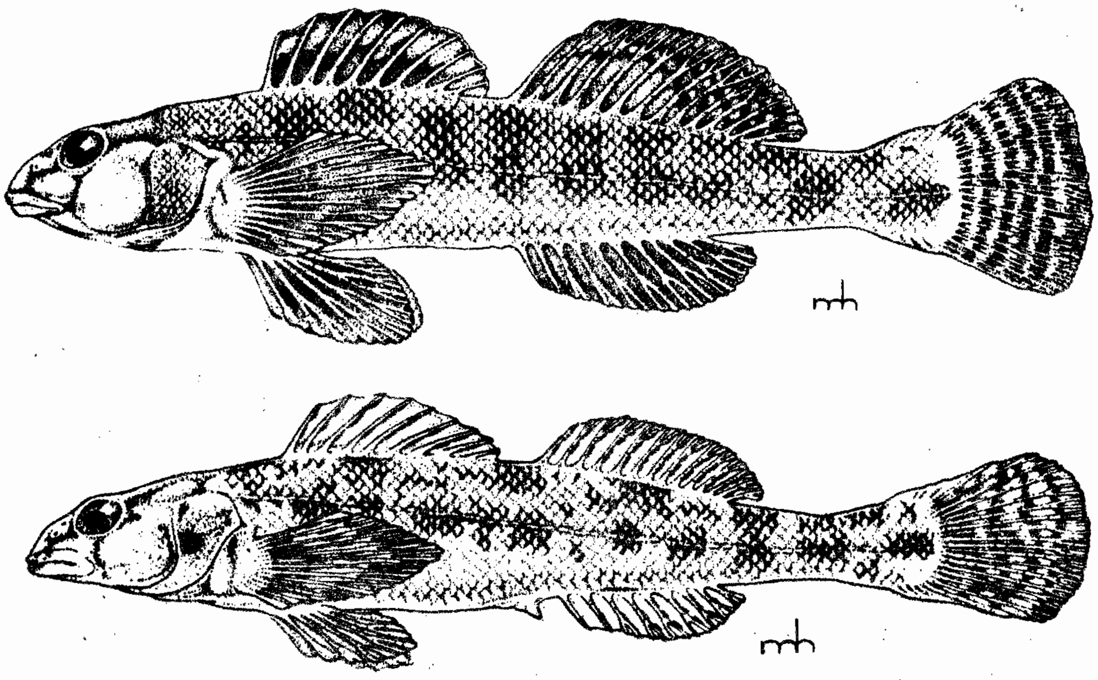

Male (above) and female of the waccamaw darter,, *Etheostoma perlongum*.