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Nest-site preference in male fathead minnows, *Pimephales promelas*

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Nest-site preference in fish is not often studied, and yet it should yield insight into their successful reproduction. I placed three sizes of artificial nest structures at three depths and on two sides of a Michigan pond to investigate nest usage patterns by male fathead minnows. Of 93 artificial nest structures available, 18 were used as nests. Northern nest sites were used more than southern sites, and structures of 100 and 200 cm² were used more than those of 50 cm². There was no differential use of structures between depths of 0.25 and 1 m. Other site preferences and alternative male mating strategies were also suggested.

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Chez les poissons, le choix d'un endroit pour nicher est rarement étudié et pourtant ce facteur peut certainement jeter de la lumière sur leurs chances de succès à la reproduction. J'ai placé des nids artificiels de trois tailles différentes, à trois profondeurs et de deux côtés d'un étang du Michigan, dans le but d'examiner l'utilisation de ces structures chez des Têtes-de-boule mâles. Des 93 « nids » disponibles, 18 ont été utilisés. Les nids situés du côté nord ont été utilisés plus que les nids situés au sud et les structures mesurant 100 et 200 cm² ont été utilisées plus que les structures de 50 cm². Les poissons n'ont pas manifesté de préférence marquée pour une profondeur donnée entre 0,25 et 1 m. D'autres préférences d'endroit et des stratégies de rechange ont également été examinées.

[Traduit par la rédaction]

Introduction

Parental investment and mate choice in fish have received considerable attention (reviewed by Blumer 1979; Perrone and Zaret 1979; Gross and Shine 1981; general reviews by Clutton-Brock 1991; Partridge and Halliday 1984). However, oviposition site selection has received little attention (Potts 1984), even in common or commercially important species. This is unusual because the choice of nest sites is likely to profoundly influence the fitness of the choosers and that of their mates.

Fathead minnows, *Pimephales promelas*, are common over a wide distribution in North America, particularly in ponds (Scott and Crossman 1973). Males establish and defend territories and care for eggs laid there (Unger 1983). They accept eggs from multiple females; each female may oviposit with several males (Andrews and Flickinger 1974). Nest sites are typically depressions under benthic debris or the cleared lower surfaces of submerged objects (Wynne-Edwards 1932).

Because of their high reproductive potential (Gale and Buynak 1982), fathead minnows are raised by wildlife managers, sport associations, researchers, and commercial bait breeders. Understanding nest-site selection could improve breeding of this commercially important and biologically interesting species. I

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TABLE 1. Contingency table showing the availability and use of artificial nest structures

Structure size (cm ²)	North (by depth), m						South (by depth), m						Subtotal (structure size)*, cm ²	
	0.25		0.50		1.0		0.25		0.50		1.0		A	U
	A	U	A	U	A	U	A	U	A	U				
50	7	1	5	1	4	0	3	0	7	0	6	0	32	2 (6.2)
100	4	1	3	2	1	1	6	2	10	1	4	1	28	8 (5.4)
200	6	4	3	1	4	0	6	0	7	2	7	1	33	8 (6.4)
Subtotal by depth:						Subtotal (pond side)*								
	A		U				North				South			
							A		U		A		U	
0.25 m	32		8 (6.2)				37		11 (7.2)		56		7 (10.8)	
0.50 m	35		7 (6.8)											
1.0 m	26		3 (5.0)											

NOTE: A, availability; U, use. Values in parentheses are expected values.

* $P < 0.05$.

conducted a field study to determine what microhabitat characteristics were preferred by male fathead minnows when establishing nests.

Methods

Study site and animals

The study was conducted from July to August 1989 in Cheboygan County, Michigan (45°26'N, 84°30'W). All experimentation was done in a small permanent pond with approximately 700 m² surface area. Vegetation consisted almost exclusively of *Chara*, with some emergent grasses. Natural nesting structure was sparse. Fathead minnows (*P. promelas*) accounted for the majority of fish in the pond, followed by northern redbelly dace (*Chrosomus eos*) and occasional brook stickleback (*Eucalia inconstans*).

Artificial nest structures

Unger (1983) found that rectangular clear-glass plates of 168 cm² covered by opaque tiles were adequate for oviposition. I chose slate tile because it is coarser and allows better egg adhesion (Benoit and Carlson 1977), and because it resembles natural material in the pond more than glass.

Black slate tiles (7 mm thick) were cut into squares of 50, 100, and 200 cm². Tiles used for the first trial were supported by 15-cm pine dowels (7 mm diameter) attached by epoxy glue to tile corners. However, several dowels broke during placement, so the attachment was modified for subsequent trials: dowels used in trials 2 and 3 were thicker (10 mm diameter), sharpened at one end, and attached by notching the unsharpened end halfway through and pressing the tile into the notch.

Experimental design

Before the experiment, I marked 22 nest sites along the north bank and 23 on the south bank. Nest sites were placed at 1.5-m intervals so that males could not control more than one nest site. Male fathead minnows in captivity defend only single nest sites and may maintain individual territories within 4 cm of each other (Unger 1983).

The experimental protocol was a 3 (structure sizes) × 3 (depths) × 2 (pond sides) factorial design. For each nest site on the north and south sides of the pond I randomly assigned one of the three structure sizes and one of three depths (0.25, 0.5, or 1 m). The range of depths used corresponds to that at which I observed spawning occurring in other ponds. Nests were positioned after removing vegetation from within 30 cm of the designated spot. Three trials were performed, but the second trial involved only southern nest sites; the total number of structures available for nesting in the study was 93 (45 + 23 + 45 – 20 broken during placement).

Sites were sampled 5–8 days after placement of the tiles, and fish were captured by lowering a green mesh net over the nest structures. Fish were immediately preserved in formalin (10%) to maintain color patterns, as patterns may change within minutes and were not discernible in situ. All structures were removed after each trial. I considered a structure to have been used if a male was captured, eggs were found, or a male was observed to be defending the nest. Data taken at each site included total length (to the nearest millimetre), color class and weight (nearest 0.01 g) of fathead minnows, number of eggs present, and the condition of each nest structure upon removal (i.e., presence or absence of crayfish, leaches, snails, nonconspecific fish, and debris). Color data were originally distributed among four classes following Unger (1983), but were later combined into two classes (dark and light) for statistical analysis.

Analysis

Data were analyzed using SPSS statistical software (Norusis 1990; SPSS Inc. 1990). A forward-entry logistic regression was run to determine how the probability of nest structure use depended upon the three experimental variables: depth, pond side, and size of structures. The criterion used for entry into the model was log-likelihood ratio χ^2 $P < 0.05$. The log-likelihood χ^2 statistics for each experimental variable are reported when the results for each variable are presented. Weight and total length as functions of the experimental variables were analyzed using Kruskal–Wallis and Wilcoxon signed-rank tests because the ANOVA design was unbalanced and contained too few data in some depth and structure size categories.

Results

Male fathead minnows were found at 18 of the 93 artificial structures (20%) that were available as nest sites. Thirteen males were captured, 3 were observed to be defending nest sites but were not captured, and two nests contained fathead minnow eggs but no males were observed or captured. The proportion of nests occupied did not differ significantly among trials ($G = 4.74$, $df = 2$, $P = 0.093$).

Nest structure use is summarized in Table 1. Structure use differed between sides of the pond at which structures were placed and among structure sizes (logistic regression; $P = 0.015$) but there was no significant pattern of structure use by depth ($G = 1.77$, $df = 2$, $P = 0.412$): all depths were used. Structures on the north side of the pond were more likely to be used than those on the south side ($G = 4.155$, $df = 1$, $P = 0.042$). The tiles measuring 50 cm² were used less than either

the 100- or 200-cm² tiles, which were used with approximately equal frequency ($G = 6.37$, $df = 2$, $P = 0.041$).

Male fathead minnows tended to use structures adjacent to each other (runs test, two-tailed; $z = 2.36$; $P = 0.018$), suggesting that the pattern of differential use of northern sites may be spurious. However, if clumps of adjacent nests that were used are considered as single sites, northern sites were still used more frequently (21% use, compared with 9% for southern sites. The difference, however, is no longer significant; $G = 2.82$, $df = 1$, $P = 0.089$).

No analyses were performed using egg number because only seven sites contained eggs. Based on examination of scale annuli and a length–frequency plot, 12 of 13 males captured on territories were in the 1-year class. Total length of 1-year-olds was 52 ± 2 mm (mean \pm standard deviation). Mean weight was 1.72 ± 0.21 g. The remaining male was in the 2-year class (71 mm, 3.36 g). Male weight did not differ among structure sizes (Kruskal–Wallis $\chi^2 = 0.464$, $N = 13$, $P = 0.793$) or depths (Kruskal–Wallis $\chi^2 = 3.98$, $N = 13$, $P = 0.137$). Also, no difference was found between the weight of males captured on the north and south sides of the pond (Wilcoxon test for independent samples, $P > 0.05$).

In contrast to Unger (1983), there were no significant differences between solitary- and clumped-nesting males in either color (Fisher's exact test; $P = 0.617$) or weight (Mann–Whitney $U_{[6,6]} = 25$, $P = 0.262$).

Discussion

Fathead minnows captured at artificial nest structures were using the structures as spawning sites rather than solely as refuge from predators. A single male in breeding condition (sensu Unger 1983) was captured at all but one site where fathead minnows were captured (the exception is discussed below). Furthermore, there were no macroinvertebrates, sticklebacks, or debris on or about structures with males, compared with considerable amounts elsewhere. This would be expected for structures tended by males as nests, but not for those used as refuge.

Nest structure use in this study (20%) was lower than expected based on, (i) the lack of typical *natural* spawning sites, (ii) the high density of fathead minnows (approximately 10–15/m² at the depths studied), and (iii) the high fecundity of the species (Gale and Buynak 1982). This low usage of structures (artificial nests) may be explained by observations that newly reproductive males in aquaria tend to take over the nests of males who are brooding, even when offered unoccupied nests lacking eggs (Unger and Sargent 1988). This male behavior is probably due to females choosing to oviposit in nests containing eggs (Sargent 1988; Unger and Sargent 1988). Therefore, newly available nest structures lacking eggs may have been less attractive to male fathead minnows than usurping nests with eggs.

Males that *did* establish new nest sites showed preference for northern sites and larger structures but showed no differential nesting by depth. Because I could not identify clear environmental differences between the north and south sides of the pond, the question remains as to the generalizability of the (northern) side preference. The preference could reflect a general affinity for properties of geographical north or a specific environmental condition peculiar to this pond only. Larger nest structures may have been preferred because of a greater predation risk for eggs under smaller structures. Brooding males (and their offspring) in natural nest sites are

probably sheltered to some degree from potential predators. The degree of protection afforded by nests is likely to depend on the size of nest structures. When approaching nest sites to capture the fish present, I could see territorial males under small structures from about 2 m away. Fish under larger nests were not detected beyond 1 m. Thus, search and attack by visual predators would have been hindered by larger nest structures.

The tendency toward clumped nesting could conceivably be a result of similar habitat selection, affinity of brooding males for each other, or both. The largest groups of males found nesting in a clumped manner involved the same nest sites across trials, even though all breeding males and structures were removed after each trial. Therefore, habitat choice is implicated, although affinity for other males cannot be excluded.

Unger (1983) found that males nesting near other males were heavier and more intensely colored than lone males, suggesting nest defense by deceit. I found no discernible difference between lone males and those nesting adjacent to others; however, males may need to be closer than 1.5 m for the effect to become evident. An interesting topic for future study would be to determine what the critical distance between males is wherein body color and weight are altered.

At one nest site I captured two males, one female, and 36 eggs. The female was probably ovipositing because, (i) other clutches in this study were (2–10 times) larger, and laboratory studies indicate a mean of about 400 eggs per spawning session (Gale and Buynak 1982), (ii) oviposition takes 2–4 h (Gale and Buynak 1982; Unger 1983), and (iii) females are driven away from nests by territorial males, unless they are ready to oviposit (Unger 1983). The largest male displayed nuptial tubercles and the typical breeding color pattern (Unger 1983), whereas the smaller male displayed tubercles but had the female color pattern. This suggests the possibility of alternative mating strategies (i.e., female mimicry, sneaky males) in male fathead minnows, similar to those of bluegill sunfish (Dominey 1980; Gross and Charnov 1980).

Because selection will have favored choice for nest sites that produced more offspring, applying information about nest choice should increase the mass production of fish. This is particularly important for commercially valuable or endangered species, yet nest site preference is not commonly studied and applied. This study indicated that fathead minnow reproduction could perhaps be improved by providing nest structures of 100 cm² or larger and by placing them primarily on the northern side of ponds (at any depth under 1 m) at the beginning of the spawning season.

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