Interpopulation Variation in Darter Oocyte Production

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ABSTRACT

Interpopulation variation in oocyte production of darter species from three tributaries of the Allegheny River system was examined. Significant differences across localities for numerous darter species were identified. Several potential biotic and abiotic ecosystem attributes such as competition and water quality constituents differed across the study sites and may influence oocyte production. This study demonstrates the importance of including several populations in life history studies in order to describe the intraspecific range of oocyte production.

INTRODUCTION

The majority of darter studies that have included oocyte information were intended to provide an overview of the life history of a single species. Such studies typically consisted of collections from one locality or examined pooled data from several populations (Johnson and Hatch 1990, James et al. 1991). Other studies have examined temporal variation in ooctye production but again used a single collection locality or pooled information from several sites (Parrish et al. 1991, Schenck and Whiteside 1977). Another approach centered on multiple spawning clutches in single darter populations (Heins and Baker 1993, Heins and Baker 1989).

Interpopulation oocyte variation has not been explored in most cases. A few studies have addressed the issue, but they were based on a single species and did not evaluate oocyte production in an ecosystem context (Guill and Heins 1996, cf. citations in Page 1983). The principal objective of our study was to examine intraspecific variation of ooctye production for several darter species. Secondarily, we sought to document oocyte production in several rare darter species for which little life history information is known.

METHODS AND MATERIALS

Three tributaries of the Allegheny River in northwestern Pennsylvania were selected for sampling. Three collection sites were located on French Creek in Crawford County; one site was on Brokenstraw Creek in Warren County; and one site was on Oil Creek in Crawford County. The creeks at all of the sites were approximately 20-40 m wide, and the riparian zones and aquatic habitats were similar among the localities.

Darters were collected with a 1.5 m x 2.5 m x 5 mm mesh seine over a five year period of time during peak breeding seasons. Females were fixed in 10% formalin and later transferred to 50% isopropyl alcohol. Standard length, age, and oocyte production were determined for each individual. Standard length was taken as the length from the tip of the snout to the caudal peduncle in millimeters using digital calipers. Age was estimated using scales removed from above the lateral line (Jearld 1983). Both ovaries were removed and all oocytes were counted in each. Oocyte production of each individual was taken as the total number of oocytes present. Although more refined classification scales for oocyte and ovary development have been proposed (Heins and Baker 1993, Heins and Baker 1992), a total oocyte count was deemed an appropriate level of resolution given the objectives of this study.

All statistical tests were performed using MINITAB 10 for Windows, and the accepted statistical significance level was $P < 0.05$. Given the close proximity of our three French Creek sites (less than 16 km apart) and the similarity in community composition (Stauffer et al. 1996), the possibility of pooling data from these sites was evaluated. Mann-Whitney pairwise tests were used to compare the total oocyte levels across the three sites for each of the species collected. Mann-Whitney tests were also employed to assess the possibility of combining oocyte data that were collected on different days within French, Brokenstraw, and Oil Creeks, again on a species-specific basis. The same test was used to make comparisons of a particular species' oocyte totals across the three streams sampled in this study. Finally, to assess stream-to-stream differences in median length for a given fish species, pairwise tests were made among standard lengths.

Linear regression was used to determine whether the standard length or the age of a species accounted for more variation in oocyte totals within a given stream. The independent variable (standard length or age) that accounted for the most variation in total oocyte counts was used to subdivide each species collection into smaller subsets. If age accounted for the most variation, the age classes from the scale analysis were used. Conversely, if standard length was the most critical variable, the range of length represented in the species collection was divided into three even class intervals. This approach would reveal any across stream differences in species oocyte production that were being masked by considering the collection as a whole. Again, we used Mann-Whitney pairwise tests to make comparisons among study sites within a given length/age class and to compare the oocyte totals among the different length/age classes at a given site.

RESULTS

Fecund specimens of numerous darter species were represented in the collections, with species richness being the highest in French Creek (Table 1). Although sample sizes for some species were relatively small, it was deemed appropriate to include these fishes in the analysis given the scarcity of information on their life histories. An intermediate level of species richness was present in Brokenstraw Creek, while relatively few darter species were found in Oil Creek (Table 1). Only Etheostoma blennioides Rafinesque (greenside darter), Etheostoma flabellare Rafinesque (fantail darter), and Etheostoma zonale (Cope) (banded darter) were found in all three tributaries. Etheostoma caeruleum Storer (rainbow darter), Etheostoma variatum Kirtland (variegate darter) and Percina caprodes (Rafinesque) (logperch) were found in both French Creek and

Table 1. The median and range of oocyte production and standard length for each species by site.

Species	Site	Sample Size	Median Fecundity	Minimum Fecundity	Maximum Fecundity	Median Std. Length	Minimum Std. Length	Maximum Std. Length
Etheostoma blennioides	French Creek	41	617.0	0.0	1246.0	57.60	37.90	70.50
	Brokenstraw Creek	21	383.0	244.0	668.0	53.12	46.51	56.95
	Oil Creek	5	871.0	630.0	1187.0	62.71	57.82	165.78
Etheostoma caeruleum	French Creek	35	311.0	0.0	806.0	41.20	28.30	48.00
	Brokenstraw Creek	35	249.0	107.0	496.0	40.44	32.29	48.93
Etheostoma camurum	French Creek	14	343.5	106.0	507.0	39.80	36.10	48.20
Etheostoma flabellare	French Creek	20	241.5	111.0	429.0	39.65	31.50	48.13
	Brokenstraw Creek	5	130.0	97.0	207.0	40.03	38.13	47.67
	Oil Creek	3	290.0	168.0	563.0	36.47	24.97	43.53
Etheostoma maculatum	French Creek	32	350.0	139.0	829.0	54.00	41.85	60.70
Etheostoma nigrum	French Creek	11	272.0	99.0	727.0	35.87	33.55	45.26
Etheostoma tippecanoe	French Creek	4	240.5	143.0	397.0	27.95	26.87	28.96
Etheostoma variatum	French Creek	29	348.0	0.0	572.0	57.60	35.00	68.30
	Brokenstraw Creek	18	271.5	172.0	423.0	53.91	40.72	63.57
Etheostoma zonale	French Creek	43	557.0	174.0	996.0	40.80	28.60	48.90
	Brokenstraw Creek	74	312.5	106.0	1026.0	38.82	30.03	47.26
	Oil Creek	5	376.0	237.0	1072.0	36.24	33.93	50.36
Percina caprodes	French Creek	19	1472.0	670.0	7829.0	88.13	73.31	110.43
	Brokenstraw Creek	3	402.0	297.0	1266.0	105.68	100.77	112.50
Percina evides	French Creek	9	976.0	741.0	1326.0	51.20	46.80	57.80

Brokenstraw Creek, whereas Etheostoma camurum (Cope) (bluebreast darter), Etheostoma maculatum Kirtland (spotted darter), Etheostoma nigrum Rafinesque (johnny darter), Etheostoma tippecanoe Jordan and Evermann (tippecanoe darter), and Percina evides (Jordan and Copeland) (gilt darter) were only found in French Creek.

The Mann-Whitney pairwise comparisons yielded results that allowed much of the data to be pooled. Out of the eleven species present at the three sites on French Creek, only Etheostoma caeruleum showed significant across-site differences in oocyte totals. We therefore pooled all sites at French Creek for a given day. Similarly, the date of collection within a tributary accounted for variation in oocyte totals in only Etheostoma maculatum and P. caprodes at French Creek. These dates were likewise pooled.

There was a general trend of greater oocyte production from Brokenstraw, to French, to Oil Creeks (Table 1). Oocyte totals for E. blennioides, E. flabellare, E. variatum, and E. zonale at French Creek were significantly higher than at Brokenstraw Creek. Furthermore, the oocyte production of E. blennioides at Oil Creek was significantly higher than at Brokenstraw Creek. Percina caprodes from French Creek had higher oocyte counts than the same species at Brokenstraw Creek, and although it was not statistically significant ($p=0.0557$), it is worth noting given the small representative sample size. The comparison of the median standard length of a fecund fish for a given species across sites yielded few differences. Fecund E. blennioides were significantly longer at French Creek than at Brokenstraw Creek; conversely, P. caprodes were significantly longer at Brokenstraw Creek. Differences in length at maturation therefore contributed little to the median oocyte divergence across streams.

Linear regression analysis revealed that standard length, not age, accounted for more of the variation in total oocyte levels in the majority of the species (Table 2), and the exact relationship was species specific (Figures 1a and 1b). Age, however, did account for more total oocyte variation in E. camurum (Table 2). By separating species into either length or age classes for across stream comparisons, several noteworthy although not statistically significant differences across streams were found. Etheostoma zonale at Oil Creek had marginally greater fecundities ($p=0.0771$) than Brokenstraw for the third length class. Additionally, E. caeruleum at French Creek were marginally more fecund than at Brokenstraw Creek for length class two ($p=0.0541$) and significantly more fecund for age class 3.

Comparisons across species length or age classes within a specific stream yielded significant differences in oocyte production, with a few noteworthy exceptions. Etheostoma flabellare, E. caeruleum, and E. variatum from Brokenstraw Creek did not show differences between length classes 2 and 3. Finally, at French Creek neither P. caprodes nor E. maculatum showed oocyte production differences between length classes 2 and 3.

DISCUSSION

Median oocyte production in darter species collected in Brokenstraw Creek tended to be low. The total oocyte levels of darters from Oil and French Creek were consistently high for all species, and although the two streams yielded

Table 2. Regression equations describing the relationship between oocyte production (OP) - standard length (SL) and oocyte production (OP) - age (A). The R-squared value (%) for each regression is shown in parentheses following each equation.

Species	French Creek Regression Equations	R-sq.	Brokenstraw Creek Regression Equations	R-sq.	French Creek Regression Equations	R-sq.
Etheostoma blennioides	OP = -1053.0 + 29.5 SL	(78.7)	OP = 12.0 + 7.44 SL	(3.3)	OP = 519.0 + 4.06 SL	(77.4)
	OP = 79.1 + 213.0 A	(53.6)	OP = 509.0 - 40.0 A	(3.7)	OP = 946.0 - 35.0 A	(0.8)
Etheostoma caeruleum	OP = -711.0 + 26.1 SL	(79.7)	OP = -292.0 + 13.8 SL	(36.4)	NA	
	OP = -98.3 + 156.0 A	(56.0)	OP = 367.0 - 45.5 A	(12.4)	NA	
Etheostoma camurum	OP = -211.0 + 13.0 SL	(15.2)	NA		NA	
	OP = 66 + 105.0 A	(17.2)	NA		NA	
Etheostoma flabellare	OP = -252.0 + 12.2 SL	(73.7)	OP = -349.0 + 11.7 SL	(93.5)	OP = 922.0 - 16.6 SL	(59.2)
	OP = 108.0 + 64.9 A	(26.8)	OP = 194.0 - 24.7 A	(9.1)	NA (all same age fish)	
Etheostoma maculatum	OP = -785.0 + 22.4 SL	(36.2)	NA		NA	
	OP = 287.0 + 46.0 A	(2.6)	NA		NA	
Etheostoma nigrum	OP = 363 - .536 SL	(14.8)	NA		NA	
	OP = 179.0 + 76.0 A	(1.8)	NA		NA	
Etheostoma tippecanoe	OP = 2320.0 - 73.9 SL	(35.1)	NA		NA	
	OP = 311.0 - 32.0 A	(2.1)	NA		NA	
Etheostoma variatum	OP = -430.0 + 13.6 SL	(55.1)	OP = 142.0 + 2.82 SL	(4.2)	NA	
	OP = 2.7 + 140.0 A	(41.9)	OP = 313.0 - 11.0 A	(0.6)	NA	
Etheostoma zonale	OP = -816.0 + 35.1 SL	(70.3)	OP = 142.0 + 2.82 SL	(4.2)	OP = -1184.0 + 42.7 S	(4.7)
	OP = -22.4 + 216.0 A	(58.4)	OP = 223.0 + 47.2 A	(4.7)	OP = -373.0 + 356.0	(29.6)
Percina caprodes	OP = -5889.0 + 88.3 SL	(39.9)	OP = -8421.0 + 85.4 S	(89.4)	NA	
	OP = 1110.0 + 373.0 A	(6.1)	OP = -1282.0 + 484.0	(83.0)	NA	
Percina evides	OP = -1231 + 42.9 SL	(60.0)	NA		NA	
	OP = 370.0 + 230.0 A	(33.7)	NA		NA	

comparable results, individuals from Oil Creek tended to have slightly higher oocyte totals. Oil Creek had the fewest number of darter species and also the lowest densities of fishes.

The population density of the darter community in each stream was estimated using historical collection records from The Pennsylvania State University Fish Museum. Ten collections over the time that this study was conducted were randomly selected, and an index of the number of darters captured per minute of time was calculated. The darter density estimates were 3.25, 2.35, and 0.36 darters collected per minute for French, Brokenstraw, and Oil Creeks respectively. The relative order of the density estimates agrees with extensive snorkeling and other observations by one of us (JRS) on the three streams. The negative impacts of high population density on oocyte totals has been demonstrated in numerous aquatic systems (Billard et al. 1981).

In addition to density comparisons, we conducted a microhabitat partitioning study at the same sites in French Creek (Stauffer et al. 1996). The three species present in Oil Creek (E. blennioides, E. flabellare, and E. zonale) occupied the same microhabitats during parts of the year in French Creek. It therefore seems plausible that competitive release may be contributing to the high oocyte totals attained by the darters in Oil Creek.

The consistently lower oocyte production of the Brokenstraw Creek darters compared to those in French Creek is somewhat surprising in light of the similar species richness and density estimates. The U.S. Department of Environmental Protection analyzed the concentrations of heavy metals in the tissue of Micropterus dolomieu Lacepede (smallmouth bass) from each stream during the course of our study. Although M. dolomieu and darters exist at different trophic levels, the accumulation of heavy metals in M. dolomieu generally indicates the presence of these metals in the water over an extended time. Interestingly, the M. dolomieu tissue samples from Brokenstraw Creek did show higher levels of the majority of heavy metals than the samples from French or Oil Creeks (Table 3). These metals (lead, cadmium, copper, and chromium) do impact fish health and reproduction (Kime 1995).

Table 3. Concentrations of pollutants in adult *Micropterus dolomieu* tissue.

	French Creek	Brokenstraw Creek	Oil Creek
# analyzed	5	4	5
lead (ug/gm)	0.18	0.11	0.09
cadmium (ug/g	0.02	0.05	0.04
copper (ug/gm)	1.00	1.63	1.00
chromium (ug/g	0.06	0.20	0.06

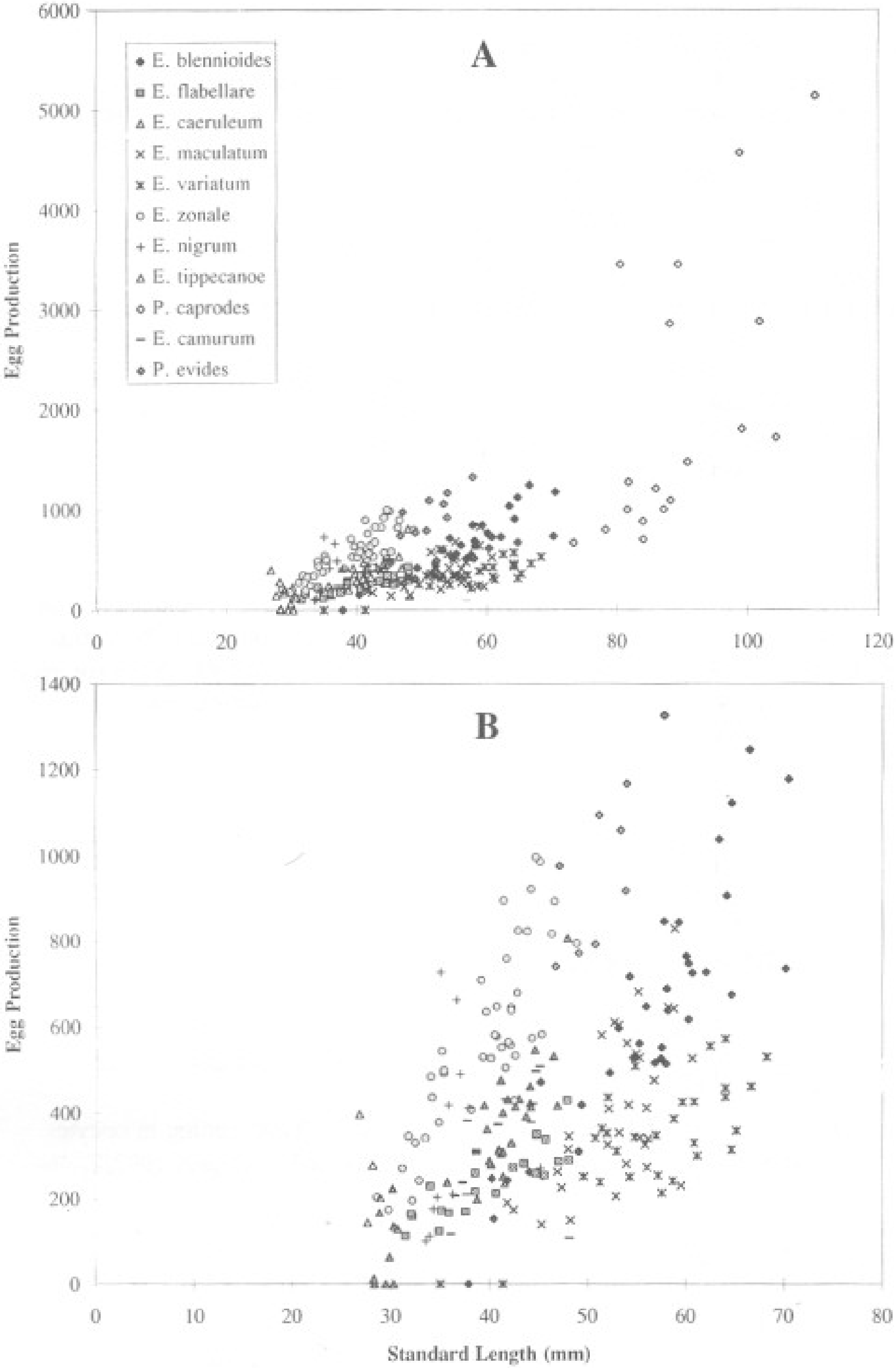

Figure 1. A) Oocyte totals versus length plots for darter species in French Creek. Only French Creek data are shown because the full complement of darter species were represented in this stream. B) Oocyte totals versus length plots for darter species in French Creek with Percina caprodes excluded so that the relationships between the remaining darter species could be viewed more clearly.

The argument for the detrimental impact of water quality constituents on Brokenstraw Creek darters is reinforced by the total oocyte comparisons made across the length classes within a species. Etheostoma flabellare, E. caeruleum, and E. variatum, showed no significant differences in oocyte totals among length classes in Brokenstraw Creek, whereas in French and Oil Creeks totals increased with fish size. It is possible that contaminants were suppressing oocyte totals throughout the lifetime of the organisms in Brokenstraw Creek, overriding the positive association of length on oocyte production.

In summary, oocyte production was highly variable across the three populations evaluated in this study. The level of differentiation was rather surprising given that the populations reside in the same drainage in relatively close proximity. Although similar in size, habitat, and riparian zone, the three creeks differed in several biotic and abiotic attributes that may indeed influence oocyte production in darters (i.e., darter density and species richness, and water quality constituents). These observations of interpopulation variation in oocyte production may have implications for life history, conservation, and evolutionary investigations.

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LITERATURE CITED

Billard, R., Bry, C., and Gillet, C. 1981. Stress, environment and reproduction in teleost fishes. In Stress and Fish (Pickering, A. D., ed.), pp. 185-208. London: Academic Press.

Guill, J. M. and Heins, C. 1996. Clutch and egg size variation in the banded darter, Etheostoma zonale, from three sites in Arkansas. Envir. Biol. Fish. 46:409-413.

Heins, D. C. and Baker, J. A. 1993. Clutch production in the darter Etheostoma lynceum and its implications for life-history study. Jour. Fish. Biol. 42:819-829.

Heins, D. C., Baker, J. A., and Dunlap, W. P. 1992. Yolk loading in oocytes of darters and its consequences for life-history study. Copeia 1992(2):404-412.

Heins, D. C. and Baker, J. A. 1989. Growth, population structure, and reproduction of the percid fish Percina vigil. Copeia 1989(3):727-736.

Jearld, Jr., A. 1983. Age determination. In Fisheries techniques (Nielsen, L. A. and Johnson, S. L., eds), pp. 301-324. Bethesda, MD: Amer. Fish. Soc.

James, P. W., Maughan, O. E., and Zale, A. V. 1991. Life history of the leopard darter Percina pantherina in Glover River, Oklahoma. Am. Midl. Nat. 125:173-179.

Johnson, J. D. and Hatch, J. T. 1991. Life history of the least darter Etheostoma microperca at the northwestern limits of its range. Amer. Mid. Nat. 125:87-103.

Kime, D. E. 1995. The effects of pollution on reproduction in fish. Rev. Fish Biol. Fish. 5:52-96.

Page, L. M. 1983. Handbook of darters. TFH Publications, Neptune City, 271 pp.

Parrish, J. D., Heins, D. C., and Baker, J. A. 1991. Reproductive season, clutch parameters and oocyte size of the johnny darter Etheostoma nigrum from southwestern Mississippi. Am. Midl. Nat. 125:180-186.

Schenck, J. R. and Whiteside, B. G. 1977. Reproduction, fecundity, sexual dimorphism and sex ratio of Etheostoma fonticola (Osteichthyes: Percidae). Am. Midl. Nat. 98(2):365-375.

Stauffer, J. R., Boltz, J. M., Kellogg, K. A., and van Snik, E. S. 1996. Microhabitat partitioning in a diverse assemblage of darters in the Allegheny River system. Envir. Biol. Fish. 46:37-44.

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