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Ovarian weight as an index of fecundity, maturity, and spawning periodicity

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Ovarian weight and related indices such as gonadosomatic index were used to index fecundity, egg maturity, and spawning season in gizzard shad *Dorosoma cepedianum*. Individually, in simple regression, fecundity and mean egg volume each accounted for only about 50% of the variability in ovarian weight. Together, in multiple regression, fecundity and mean egg volume accounted for 86% of the variation in ovarian weight. The percentage of the variability in ovarian weight explained by each independent variable, while holding constant the value of the other independent variable (partial coefficient of determination), was 72% for fecundity and 78% for mean egg volume. Thus, ovarian weight of gizzard shad confounded information about fecundity and egg maturity and separately could not index them adequately. Attempts to remove the effect of fecundity, so that ovarian weight could serve as an index of maturity, and to remove the effect of egg size so that ovarian weight could serve as an index of fecundity, were unsuccessful. Nevertheless, seasonal oscillations of ovarian weight served as a crude indicator of population spawning season.

Key words: ovarian weight; fecundity; maturity; gonadosomatic index.

INTRODUCTION

Before egg release, ovarian weight usually increases and then decreases. Thus, ovarian weight has often been used to index fish reproductive cycles (Nikolsky, 1963; deVlaming *et al*., 1982). Egg number and egg size are correlated positively with ovarian weight, and should account for most of the variability in ovarian weight. However, rarely has the degree of association among egg count, egg size, and ovarian weight been examined simultaneously, and results have been inconclusive (West, 1990).

Associations among egg count, egg size, ovarian weight, and spawning of gizzard shad *Dorosoma cepedianum* Lesueur were investigated, as this species exhibits large seasonal fluctuations in ovarian weight (Miller, 1960; Miranda & Muncy, 1987), and fish were readily available. The gizzard shad is native to the eastern half of North America east of the Rocky Mountains. It attains sexual maturity at 180 mm total length (age 2), and spawns several batches of eggs in spring when the water temperature reaches 15–17° C (Bodola, 1966; Miranda & Muncy, 1987).

A high degree of association among egg count, egg size, and ovarian weight would justify using ovarian weight (or variables derived from ovarian weight, such as the gonadosomatic index; Delahunty & deVlaming, 1980) as an index of

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fecundity, thus eliminating the need for counting eggs, or as an index of maturity which would eliminate the need to measure egg size.

MATERIALS AND METHODS

Gizzard shad were collected weekly by electrofishing from randomly selected nearshore areas in Bay Springs Reservoir (2711 ha) and Sardis Reservoir (12 990 ha), Mississippi, March–May 1991. Fish were measured to the nearest 1 mm for total length (L) and to the nearest 0·1 g for total body weight. Ovaries were dissected and weighed to the nearest 0·1 g within 24 h of collection, and then preserved in Gilson's fluid (Snyder, 1983). About 6–12 weeks later, ovaries were processed to estimate ova number and size.

Eggs were counted using a variation of the volumetric method described by Snyder (1983). A pair of ovaries was mixed into 1 l of water, and the mixture stirred with a planar motion to avoid formation of vortices which would produce a heterogenous mixture. Two 1-ml samples were taken from each 1-l mixture of free eggs and water to estimate the total number of eggs. Each sample was then counted in a tray under 30 × magnification. Most count pairs differed by <5% and were averaged to estimate total number of eggs. However, if they differed by more, a third sample was counted and included in the estimation. Several sampling techniques were tested, but the method outlined produced the least variability among samples. Eggs <0·1 mm diameter were not counted, because they were difficult to distinguish from ovarian tissue. Counts were extrapolated to the entire ovaries to estimate batch fecundity, defined as the number of eggs ≥0·1 mm in the ovaries, and functional fecundity, defined as the number of mature eggs in the ovaries. Ovarian tissue was considered to be a minor and consistent fraction of the ovarian weight.

Egg diameters (d, nearest 0·03 mm) were measured with an ocular micrometer in nearly half of the ovaries included in the fecundity estimates. This subsample included all ovaries containing mature eggs, initially set arbitrarily at >0·3 mm (Cox & Willis, 1987), and some ovaries containing only immature eggs. The samples excluded contained only immature eggs. Because eggs were often not spherical, diameters were estimated by measuring random diameters (Clark, 1934).

Preservation of ovaries in Gilson's fluid reportedly reduces egg size (Schaefer & Orange, 1956; Cayre & Laloe, 1986). Most of the shrinkage occurs within the first 2 weeks of preservation (Witthames & Greer-Walker, 1987). To estimate shrinkage and adjust the estimates of egg diameter, the two lobes of each ovary were separated in a subsample of 20 gizzard shad ranging in total length from 162 to 332 mm. One set of lobes was refrigerated (5° C) and the other was preserved in Gilson's fluid. After 10 weeks of preservation in Gilson's fluid, the mean egg diameter in ovaries was estimated to have been reduced by 14% (range 12–17). No correlation between egg diameter and percent shrinkage was detected (P=0·67). Therefore, the shrinkage was corrected by dividing our estimated mean egg diameters uniformly by 0·86.

The corrected egg diameters (d) were used to estimate egg volume. The volume of each egg was approximated with the equation for the volume of a sphere ($\pi d^3/6$).

Relations among variables were assessed with regression analyses (SAS Institute, 1989). Regressions of fecundity and egg volume on ovarian weight (dependent variable) indicated minor differences in fecundity and egg volume between reservoirs, but no differences in the relation between ovarian weight and fecundity and egg volume. Thus, the two data sets were combined for further analyses. All tests of significance were made at the α=0·05 level.

RESULTS

Egg diameters and volumes were measured on 151 813 eggs from 413 gizzard shad (mean L: 247 mm, range: 145–365) with ovaries weighing 0·2–26·9 g.

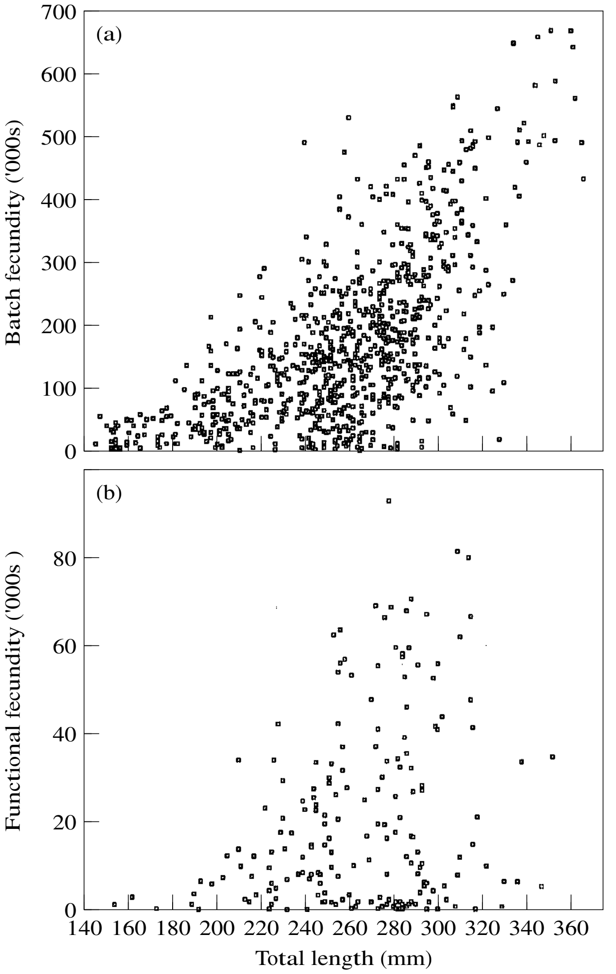

FIG. 1. Relation between ovarian weight and (a) batch (eggs >0·1 mm diameter) and (b) functional (egg >0·65 mm) fecundities.

Maturing females generally had up to three modes of eggs in their ovaries (<0·35, 0·35–0·65, and >0·65 mm), whereas immature fish had only the smallest mode. Thus, eggs >0·65 mm diameter were considered mature because they represented the largest mode of multimodal egg–frequency distributions. Egg diameters ranged up to 1·13 mm (volume=0·756 mm^3), but averaged 0·273 mm (volume=0·027 mm^3). Diameters of mature eggs averaged 0·84 mm (volume= 0·414 mm^3).

Batch fecundity was estimated on 862 fish, averaged 176 000 eggs, and ranged from 2000 to 696 000 eggs. Functional fecundity (number of eggs >0·65 mm diameter) was estimated on 413 of the 862 gizzard shad, but mature eggs were identified only in 214 fish. Functional fecundity averaged 10 900 eggs and ranged from 0 to 92 500 eggs. Batch and functional fecundities increased with fish length, but varied greatly among fish of similar length (Fig. 1).

TABLE I. Relations between $\log_{10}$ ovarian weight (dependent variable) and various independent variables identified above each set of statistics

Model	b_0	b_1	b_2	n	$100\ r^2$	P
			$\log_{10}$ total length			
1	−8·57	3·73		862	41	<0·01
			$\log_{10}$ fecundity including all fish and all egg sizes (batch fecundity)			
2	−3·06	0·681		862	50	<0·01
			$\log_{10}$ fecundity including fish with only immature eggs			
3	−2·47	0·535		648	61	<0·01
			$\log_{10}$ fecundity including only fish with mature eggs (functional fecundity)			
4	−1·01	0·250		214	67	<0·01
			$\log_{10}$ mean egg volume of all eggs			
5	1·61	0·513		413	47	<0·01
			$\log_{10}$ mean egg volume of eggs >0·65 mm			
6	0·83	0·037		214	01	0·87
			$\log_{10}$ batch fecundity, $\log_{10}$ mean egg volume of all eggs			
7	−1·62	0·609	0·481	413	86	<0·01

The b_0 represents the intercept of regression, b_1 and b_2 the slopes of regression, n the sample size, $100\ r^2$ the percentage of the variance in the dependent variable explained by the independent variables, and P the probability value.

Ovarian weight for 862 gizzard shad, averaged 4·0 g (range 0·2–26·9), but it increased with fish length (Table I, model 1), fecundity (Table I, models 2–4), and mean egg volume of all eggs (Table I, model 5). However, it was not affected significantly (P>0·05) by mean egg volume of mature eggs only (Table I, model 6). Functional fecundity explained more variability in ovarian weight than any other single-variable model examined (Table I).

Individually, in simple regression, batch fecundity and mean egg volume of all eggs each accounted for only about 50% of the variability in ovarian weight (Table I, models 2 and 5). In multiple regression, these two independent variables (not correlated, r=0·03) accounted for 86% of the variation in ovarian weight (Table I, model 7). Moreover, in model 7, the percentage of the variability in ovarian weight explained by each independent variable, while holding constant the value of the other independent variable (partial coefficient of determination), was 72% for batch fecundity and 78% for mean egg volume.

Through the spring, mean egg volume, functional fecundity, and ovarian weight increased, peaked, and then decreased (Fig. 2). Thus, the spawning period was suggested by the trend in ovarian weight.

DISCUSSION

Although number and average size of eggs together accounted for 86% of the variation in ovarian weight, separately they accounted for substantially less variation (number, 50–67%; size, <50%; Table I). This reduction in

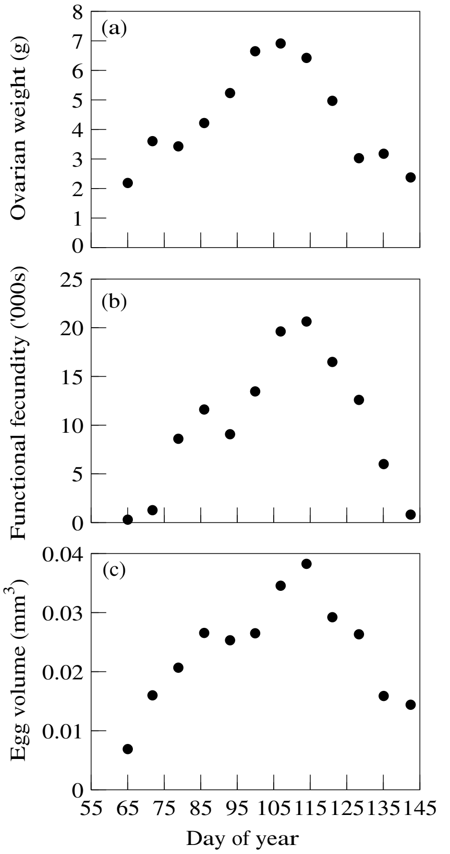

FIG. 2. Relation between day of year and (a) mean ovarian weight; (b) mean functional fecundity; (c) mean egg volume.

accountability suggests that ovarian weight is affected by egg number and size concurrently; this association was demonstrated by the partial coefficients of determination that showed increased explanatory ability of egg number (72%) or size (78%). Therefore, ovarian weight confounded information about fecundity and egg maturity. This interdependence of ovarian weight, fecundity, and mean egg volume suggested that if either egg size or fecundity could be held constant, ovarian weight could be used to index the other.

Accordingly, possible approaches for holding egg size and batch fecundity constant were examined. In practice, egg size may be made more uniform by limiting evaluations to fish collected before the spawning season, when egg maturation may not have begun yet or is less pronounced. However, ovarian weight was not an adequate index of batch fecundity, even after egg sizes were made more uniform, by excluding fish with mature eggs (r^2=0·61, model 3, Table I). Likewise, in practice, batch fecundity may be made more uniform by limiting evaluation to fish of similar size or age, which are more likely to have similar fecundities. However, ovarian weight was not an adequate index of maturity either, because fecundity varied greatly among fish of the same length (Fig. 1).

Consequently, fixing fish length did not lead to sufficiently invariable fecundities. Ovarian weight was a better indicator of functional fecundity (r^2=0·67, model 4, Table I).

Although it was not a precise index of egg maturity or fecundity, ovarian weight increased, peaked, and decreased, and was a rough index of the population spawning cycle. Egg maturation seemed to exert the greatest influence on ovarian weight fluctuation during the spawning season. Fecundity changed only during loss of eggs due to spawning. Because heavy, mature eggs were being released during the spawning period, egg maturity played a more important role in determining ovarian weight than the relatively small numerical percentage of eggs being lost.

The degree of association between ovarian weight, egg size and fecundity varies greatly among fish species (Duarte & Alcaraz, 1989; Schultz & Warner, 1991), even in fish of the same taxonomic family (Miller, 1984). Although ovarian weight may not be an adequate index of fecundity or egg maturity in gizzard shad, it may be so in other fish species and warrants further investigation.

We conclude that variability in ovarian weight is influenced largely by size of eggs and number of mature eggs. Ovarian weight, standardized for fish weight (i.e. gonadosomatic index) or not, may be suitable as a rough indicator of population spawning cycles when monitored over time. However, ovarian weight may not be suitable for comparing, predicting, or even indexing maturity stages or fecundities of individuals as has been suggested (Anderson & Gutreuter, 1983). Validity of such usage may be species- and possibly even locality-specific and should be validated with each usage.

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