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Batch spawning in five species of minnows (Cyprinidae) from Ontario, Canada

Norman W.S. Quinn

47 Old Troy Road, R.R. #3, Tweed, Ontario K0K 3J0 Canada; email: normq4@gmail.com

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Abstract

Batch spawning, the act of spawning more than once within a spawning season, is assessed in six species of minnows (Cyprinidae) from Ontario, Canada. The bimodal frequency distribution of egg size in mature specimens suggests that the following species are batch spawners: Blacknose Dace (*Rhinichthys atratulus*), Brassy Minnow (*Hybognathus hankinsoni*), Common Shiner (*Luxilus cornutus*), Creek Chub (*Semotilus atromaculatus*), and Hornyhead Chub (*Nocomis biguttatus*). However, there is no evidence that Northern Pearl Dace (*Margariscus nachtriebi*) is a batch spawner. Thus, we now have evidence that 11 of 39 cyprinid species in Ontario are batch spawners. Knowledge about the reproductive habits of these species should be integrated into the comprehensive standards for the protection of fish habitat in Ontario to ensure the survival of populations.

Key words: Cyprinidae; minnows; spawning; batch; Ontario

Introduction

Batch (or fractional) spawning is widespread among fishes (e.g., Conover 1985). The phenomenon is defined as spawning more than once during a spawning season as opposed to spawning only once in a relatively short period, hereafter, referred to as "conventional" spawning (Conover 1985). Batch spawning presents a problem to fisheries managers because it confounds or renders impossible any attempt to estimate total fecundity (e.g., Conover 1985). Batch spawning has been frequently reported in the minnows (Cyprinidae; e.g., Heins and Rabito 1986).

The objective of this study was to report on the occurrence of batch spawning in some Ontario cyprinids through the examination of ovaries of mature individuals of six species: Blacknose Dace (*Rhinichthys atratulus*), Brassy Minnow (*Hybognathus hankinsoni*), Common Shiner (*Luxilus cornutus*), Creek Chub (*Semotilus atromaculatus*), Hornyhead Chub (*Nocomis biguttatus*), and Northern Pearl Dace (*Margariscus nachtriebi*).

Methods

In 2013–2015, minnows were captured with standard (40 × 20 cm) cylindrical wire traps set overnight from late April (ice out) to 30 June, a period when spawning of these fish is underway. Five of the six species were caught in Clarke Creek (45°06′N, 77°48′W) near Bancroft, Ontario. Hornyhead Chub was caught in an unnamed creek near Madoc, Ontario (44°30′N, 77°39′W).

Standard length and weight of fish were recorded on capture. Ovaries were removed and preserved in 10% buffered formalin. The gonadosomatic index (GSI) was calculated as ovary weight divided by total weight (including ovaries). Cyprinids typically spawn with a GSI of about 10% (e.g., Abiden 1986).

The approach used to determine mode of spawning was based on frequency distribution of the size of eggs in ovaries. Batch spawners in or near spawning condition should show a multimodal distribution of egg sizes. Large, fully mature eggs should be observed in the presence of mid-sized eggs, the latter representing the batch to be spawned at a later date. Conventional, one-batch spawners should show only mature eggs amid a mass of very small "recruitment" eggs (Conover 1985; Powles *et al.* 1992) to be spawned the following year. This approach has been used previously, including with cyprinids (Heins and Rabito 1986; Powles *et al.* 1992; Heins and Baker 1993; Wang *et al.* 2014); as Heins and Baker (1993: 15) state, two separate groups of developing eggs is "a profile typical of fish that produce multiple clutches".

Ovaries from specimens in or near spawning condition, that is, having mature eggs (as described below) were examined to determine the frequency distribution of egg sizes. The fixed ovaries were

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weighed to the nearest 0.01 g. A sample of the ovarian matrix was obtained by cutting out two small pieces, one from each ovary. Herrera and Fernandez-Delgardo (1994) and Al Saleh *et al*. (2012) found that the size of eggs is more or less independent of position in the ovaries of minnows. The samples were weighed (typically 0.05–0.15 g) and placed on a glass slide, covered with a drop of water, and the eggs were spread out with the flat of a scalpel. The sample was then examined under a microscope at 40× magnification and all eggs were counted and sorted into one of three size classes: 0.20–0.60 mm, 0.61–1.00 mm, and >1.00 mm. The slides had an underlying grid to help prevent double counting of eggs, and an ocular micrometer was used to measure eggs when size class was not obvious. The overall colour of eggs in each size class was noted.

The size classes correspond to the three categories in Powles *et al*. (1992) for the minnow Northern Redbelly Dace (*Chrosomus eos*): 1) "immature" ("recruitment" in Conover 1985), white-grey with no yolk; 2) "maturing" (or mid-sized), vitellogenic (accruing yolk) and yellow or orange; and 3) "mature", >1.00 mm and translucent, but with yellow hues. Eggs in the mature category were fully developed (Conover 1985; Powles *et al*. 1992). No mature eggs of any observed species were greater than 1.20 mm; thus, it is assumed that size at development stage of eggs of these species and that of *C. eos* eggs is comparable (Brassy Minnow, an exception, is discussed below). The subsamples typically contained 150–400 eggs. An estimate of total number of eggs and number in the three size categories was made by multiplying the weight of the ovary divided by weight of subsample times eggs counted in the subsample. Mid-sized eggs in the presence of mature eggs were deemed evidence of batch spawning.

To produce more precise frequency distributions for graphic illustration, eggs were counted and measured a second time. The subsample was again placed under the microscope and the diameter of 100 eggs measured with an ocular micrometer. To avoid bias, eggs were measured in the order of appearance in the field of view while the slide traversed the field of view. Distorted and ovoid eggs were quite common, but only round eggs were measured.

Results

Most mature female Creek Chub, Common Shiner, Blacknose Dace, and Hornyhead Chub had hundreds of mid-sized eggs in the presence of mature eggs, supporting the hypothesis that they are batch spawners (Table 1). All Brassy Minnow specimens had relatively small eggs. The 12 Brassy Minnow females (caught between 4 May and 24 June in all three years) had GSI >10% and hundreds of vitellogenic eggs, but none >1.00 mm. However, five females had bimodal frequency distributions of egg size (Figure 1l). Thus, Brassy Minnow appears also to be a batch spawner. Northern Pearl Dace is the anomaly in this group; the four mature females had essentially all eggs in the mature category (Figure 1o,p) with negligible immature or mid-sized eggs. With this limited evidence, Northern Pearl Dace appears to be a conventional spawner.

Figure 1 shows selected frequency distributions of egg size (from the 100 measured eggs per specimen). The histograms were selected as typical of patterns observed for each species. Note that most (except for Northern Pearl Dace) show mid-sized eggs in the presence of mature (>1.00 mm) eggs.

TABLE 1. Gonadosomatic index (GSI) and egg-size distribution in mature females of six Ontario cyprinids.

	No. mature females	Mean standard length, cm	Mean GSI, % body weight	No. (%) of fish with mid-sized eggs	Egg-size distribution, means* (%)
Creek Chub (*Semotilus atromaculatus*)	29	11.05	9.78	29 (100)	2603/959/107 (100/36.8/4.1)
Common Shiner (*Luxilus cornutus*)	22	8.40	10.56	22 (100)	1587/427/480 (100/26.9/30.3)
Blacknose Dace (*Rhinichthys atratulus*)	28	7.46	12.95	25 (89)	1440/245/535 (100/17.0/37.2)
Brassy Minnow (*Hybognathus hankinsoni*)	12	7.74	10.76	—†	3294/0/1028 (100/0/31.2)
Hornyhead Chub (*Nocomis biguttatus*)	8	9.52	14.31	8 (100)	2560/723/850 (100/28.2/33.2)
Northern Pearl Dace (*Margariscus nachtriebi*)	4	7.90	15.87	0	775/757/28 (100/97.7/3.6)

*Means of total no. eggs/mature eggs/mid-sized eggs. Mature eggs >1 mm, mid-sized 0.6–1.0 mm.
†Size categories of eggs of Brassy Minnow are an exception (see text for explanation).

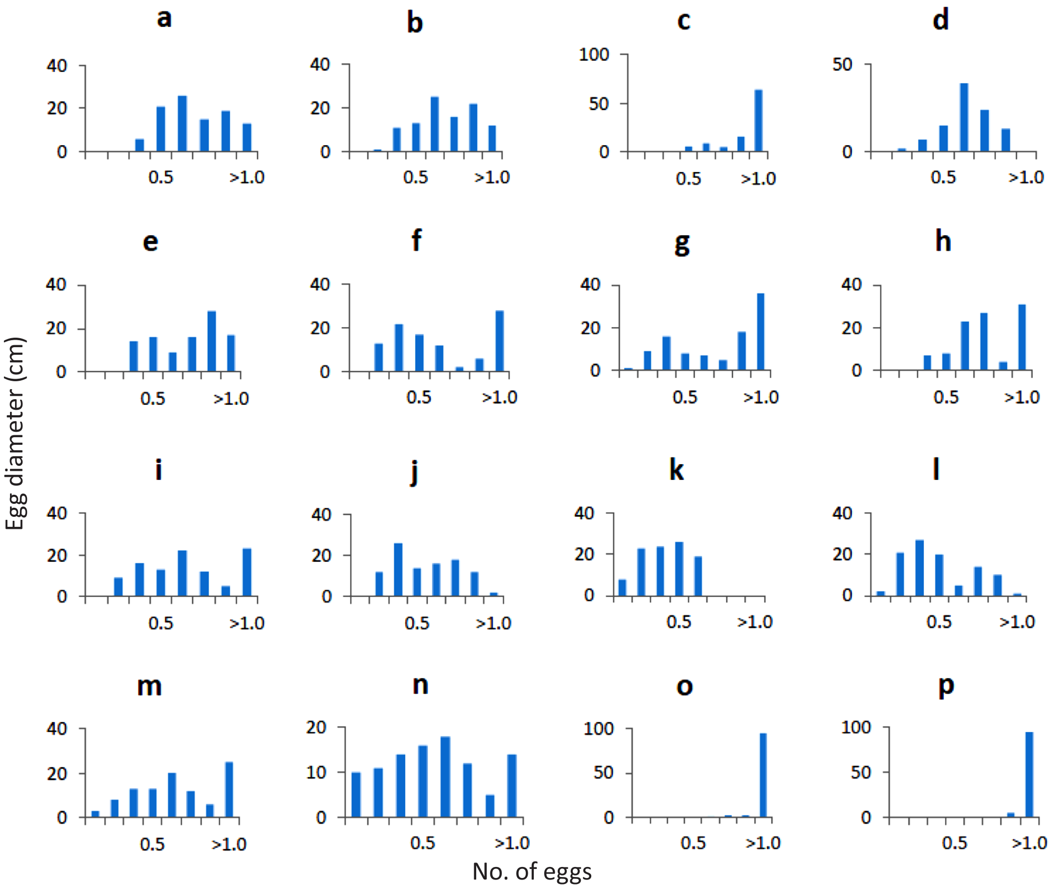

FIGURE 1. Selected egg-size distributions for six Ontario cyprinids. a–d: Creek Chub (*Semotilus atromaculatus*), e–g: Common Shiner (*Luxilus cornutus*), h–j: Blacknose Dace (*Rhinichthys atratulus*), k and l: Brassy Minnow (*Hybognathus hankinsonii*), m and n: Hornyhead Chub (*Nocomis biguttatus*), o and p: Northern Pearl Dace (*Margariscus nachtriebi*).

Discussion

Batch spawning is reported frequently in the Cyprinidae and from locations as disparate as Spain (Herrera and Fernandez-Delgrado 1994), Iraq (Al Saleh *et al*. 2012), and Malaysia (Abiden 1986). Conventional spawning is also occasionally reported (e.g., Wang *et al*. 2014). This study adds five species to the six cyprinid species already documented as batch spawners in Ontario. These other species are: Blacknose Shiner (*Notropis heterolepis*; Roberts *et al*. 2006), Bluntnose Minnow (*Pimephales notatus*; Gale 1983), introduced Common Carp (*Cyprinus carpio*; Ivanov 1976), Fathead Minnow (*Pimephales promelas*; Gale and Buynak 1982), introduced Goldfish (*Carasius auratus*; Ivanov 1971), and Northern Redbelly Dace (Powles *et al*. 1992). Thus, 11 of the 39 Ontario cyprinids have been confirmed to be batch spawners.

This study suggests that Northern Pearl Dace is a conventional spawner. The evidence for batch spawning reported here is indirect because direct observation in the field is difficult (Conover 1985).

Ontario has developed comprehensive standards for the protection of fish habitat (e.g., Anonymous 2006). For example, timing restrictions force work in water away from periods when spawning or egg development may occur (Anonymous 2006). In systems with complex fish communities, this can mean that work is restricted to a few weeks in late summer. However, because of batch spawning, the reproduction of cyprinids may be prolonged; some species, for example, Fathead Minnow, spawn more than 15 times in a season (Gale and Buynak 1982). Such a prolonged spawning period suggests that even late summer restrictions may be inadequate to fully protect cyprinid populations.

The evolution of batch spawning has been interpreted according to three adaptive scenarios or hypotheses. It may be a "bet hedging" life history pattern

(Morrongielo *et al.* 2012), whereby a variable post-hatch environment and consequent unpredictable mortality of young favour a reproductive effort that is spread out temporally, thus increasing the probability of survival of the progeny. Second, Schlosser (1998) and Matthews *et al.* (2001) suggest that fish in confined environments, such as streams, extend reproduction to minimize intraspecific competition for the developing young. Third, Coburn (1986) argues that developmental and ecological factors limit egg size to a certain minimum. Thus, fish with small adult body size, having smaller ovaries, compensate for less output by laying multiple clutches.

More basic research and data on cyprinid reproductive patterns are needed to verify these adaptive hypotheses.

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