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Host Fish Suitability for Glochidia of Ligumia recta

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ABSTRACT.—In the early 1900s several hosts were identified for the black sandshell *Ligumia recta.* Recent attempts to propagate juvenile *L. recta* with two of the reported hosts (bluegill *Lepomis macrochirus* and largemouth bass *Micropterus salmoides*) have produced inconsistent results and few juveniles. We conducted this study to determine which of the reported hosts or other fish hosts were the most suitable for glochidial metamorphosis. The duration of glochidial metamorphosis varied among seasons. Despite similar water temperatures, juveniles metamorphosed sooner and over a shorter period of time in the spring than early fall; the modal day of metamorphosis differed by 78 d. Relatively few juveniles were recovered from bluegill and largemouth bass in three trials. White crappie *Pomoxis annularis* and black crappie *P. nigromaculatus* were marginally suitable hosts. Although glochidia encysted on all hosts, >10× more juveniles metamorphosed on sauger *Stizostedion canadense* compared to other hosts tested.

INTRODUCTION

The black sandshell (*Ligumia recta*) is widely distributed but uncommon throughout much of its range (Cummings and Mayer, 1992). Historically, *L. recta* occurred throughout much of the Great Lakes area and the Mississippi River drainage (Boepple and Coker, 1912; Wilson and Clark, 1914; Coker *et al.*, 1921; Ortmann, 1925). During the past 50 y populations of *L. recta* have declined; it is now considered a species of special concern and is listed as threatened in Virginia and Ohio (Williams *et al.*, 1993). Few *L. recta* were found in recent surveys of the Licking, Green and Barren rivers, Kentucky (Cochran, 1993; Laudermilk, 1993; Weiss and Layzer, 1995). Similarly, Ahlstedt and Tuberville (1997) rarely collected *L. recta* in quadrat samples in the Clinch and Powell rivers. Due to its low abundance and seemingly declining status, the black sandshell is a species in need of management.

The larvae (glochidia) of *Ligumia recta*, like those of most unionid species, are obligate parasites on fish. The degree of host specificity varies widely among unionids. For instance, only one fish species has been identified as a host for *Potamilus alatus* (Howard, 1912) but 14 species have been reported as hosts for *Amblema plicata* (Lefevre and Curtis, 1912; Surber, 1913; Howard, 1914; Wilson, 1916; Coker *et al.*, 1921; Stein, 1968). Undoubtedly, the number of recognized hosts for a species is conservative because of the difficulty in attempting to collect and examine all fish species occurring sympatrically throughout the range of the unionid.

Hosts of mussels are typically identified either by collecting fish and attempting to identify encysted glochidia or by artificially infesting many fish species and then isolating each species until metamorphosis occurs. The information obtained by either method is incomplete. Alone, each of these methods can provide the identity only of what should be considered as potential host species. In the wild, fish bearing encysted glochidia may in fact slough the glochidia before metamorphosis. In the laboratory, metamorphosis may occur on some fish species that, under natural conditions, may never come in contact with glochidia.

Many of the reported host species for *Ligumia recta* were discovered by identifying glochidia on naturally infested fish; however, many reported hosts were not verified with lab-

oratory infestations. Encysted glochidia of *L. recta* have been found on: banded killifi (*Fundulus diaphanus*), black basses (*Micropterus spp.*), bluegill (*Lepomis macrochirus*), gree sunfish (*L. cyanellus*), orangespotted sunfish (*L. humilis*), crappie (*Pomoxis spp.*) and saug (*Stizostedion canadense*) (Young, 1911; Lefevre and Curtis, 1912; Surber, 1913; Wilson, 191 Coker *et al.*, 1921; Pearse, 1924).

Recent attempts to propagate *Ligumia recta* with some of the reported hosts have pr duced inconsistent results and few juveniles. For instance, only 56 juveniles were recovere from 31 infested fingerling largemouth bass *Micropterus salmoides* (O. Westbrook, Tennesse Technological University, pers. comm.). Successful transformation of *L. recta* glochidia c green sunfish, largemouth bass and bluegill in other studies has been variable (Hove *et a* 1994a, 1994b; Steg and Neves 1997). The results of these studies suggest that host suitabili for glochidia of *L. recta* varies among fish species and individuals. The objective of our stu was to determine which of the reported hosts were the most suitable for juvenile met morphosis.

METHODS

Largemouth bass, bluegill, white crappie (*Pomoxis annularis*), green sunfish and northe studfish (*Fundulus catenatus*) were collected by electrofishing lakes and streams containi few or no mussels to minimize current or prior glochidial infestations. Fingerling bla crappie (*Pomoxis nigromaculatus*) were obtained from the Normandy Hatchery, Norman Tennessee. Sauger were collected from the middle Cumberland River drainage where m sels (including *Ligumia recta*) occur.

Gravid female *Ligumia recta* were collected from the Tennessee River about 15 km bel Pickwick Dam. All mussels were collected by hand with the aid of self-contained underwat breathing apparatus (SCUBA). Mussels were examined in the field and gravid individu were transported to the laboratory in insulated coolers. In the laboratory females were he in a living stream at 10 C to prevent abortion.

Glochidia were obtained by anaesthetizing mussels with 250 ppm of MS-222 and th flushing water through each water tube of the marsupial gills with a hypodermic syring Three to four female *Ligumia recta* were used in each trial. Glochidial viability was check by introducing a NaCl solution to a subsample. Glochidia were considered viable if ≥95 of the subsample snapped shut. The remaining glochidia were poured into a cooler co taining test fish and the water was stirred frequently to keep glochidia in suspension. Gl chidia were allowed approximately 10 min to attach to the fish. Black crappie and northe studfish were each placed into a 38 L aquaria; individuals of all other species were isolat in either 38 or 95 L aquaria. In Trial 1 only one of six sauger infested survived the ency ment period in static 38 L aquaria. Therefore, in Trial 2 sauger were placed into recirc lating aquaculture systems for the first 13 d postinfestation. On day 14 fish were placed in separate 95 L aquaria. In Trial 3 sauger were placed directly into separate 95 L aqua following glochidial infestation.

Aquaria were siphoned with a flexible 18-mm hose every day for the first 5 d followi infestation and every other day for the remainder of the trial. The siphonate, collected a 100 μm mesh screen, was washed out into a gridded petri dish and then examined wi cross-polarized microscopy; all juveniles and glochidia were counted. Juveniles were ch acterized by the presence of two adductor muscles, closed valves and movement within h. Trials were terminated 1 wk after the last juvenile was recovered or examination of t gills revealed no encysted glochidia. The total number of glochidia and juveniles recover throughout the trial from an individual tank was considered to be the initial infestati intensity.

TABLE 1.—Number of fish that juveniles metamorphosed on, mean infestation intensity (glochidi + juveniles) and mean number of juveniles/fish for each species tested

Species	N	Number of fish that juveniles metamorphosed on	Mean infestation intensity ± SD	Mean # of juveniles/ fish ± SD
Largemouth bass	16	3	3118 ± 2382	4 ± 15
Bluegill	17	1	1301 ± 523	<1 ± 0.9
Sauger	4	4	5467 ± 2415	3157 ± 2080
Sauger	3	3	*	881 ± 183
White crappie	1	1	3540	85
Black crappie	6	N/A**	605	20
N. studfish	7	0	232	0
Green sunfish	3	0	608	0

* Glochidia were not counted for sauger in Trial 2

** All black crappie fingerlings were kept in a single aquarium

RESULTS

Although individuals of each species were simultaneously exposed to glochidia in the same cooler, infestation intensities varied among species (Table 1). All hosts experience high glochidial sloughing rates during the first 3 d postinfestation. Bluegill and largemout bass sloughed the majority of their glochidial load 2 to 3 d postinfestation and glochidia sloughing was nearly complete 9 to 12 d post infestation.

The mean number of juveniles metamorphosed on sauger was over an order of magnitude greater than any other species tested (Table 1). Both *Pomoxis* species were marginall suitable hosts and transformed ≤85 juveniles per fish. Largemouth bass and bluegill wer poor hosts and, on average, produced ≤4 juveniles per fish. Metamorphosis did not occu on northern studfish or green sunfish (Table 1). Glochidial metamorphosis occurred o 19% of the largemouth bass and 6% of the bluegill infested (Table 1). In contrast, juvenil transformation occurred on all infested sauger. Less than 5% of the glochidia on largemouth bass, bluegill and crappie species metamorphosed into juveniles. In contrast, 53% of the glochidia on sauger transformed into juveniles.

Temporal patterns in juvenile metamorphosis on sauger differed among trials (Fig. 1) The modal day of juvenile metamorphosis varied among trials conducted from spring t fall (Table 2). Mean water temperature ranged from 18.2 C to 21.9 C among trials. Althoug mean water temperatures were not significantly different between Trial 1 and Trial 3 (ANOVA and Tukey's multiple range test, P > 0.05), metamorphosis occurred sooner and ove a shorter time period in Trial 1 (Fig. 1). Juvenile metamorphosis was complete by day 4 in Trial 1, whereas in Trial 3 <0.002% of the juveniles had dropped off by day 48. A highe percentage of juveniles transformed in Trial 3 than Trial 1 (Table 2).

DISCUSSION

Mean infestation intensity differed among fish species despite infesting fish simultaneously. Some differences in infestation intensity were due to fish size and consequently, differences in gill surface area; however, infestation intensity also varied between similar size fish. For instance, largemouth bass were 25 to 35 cm long and sauger were 30 to 35 c long but substantially higher infestations occurred on the sauger. Due to these variation in glochidial attachment, the number of glochidia sloughed from each fish should be count

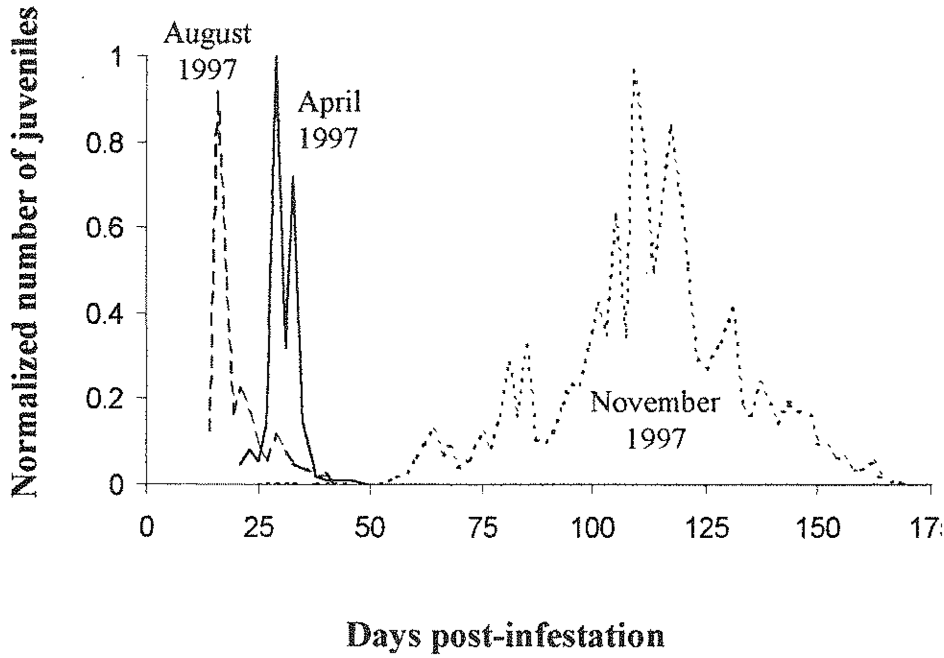

FIG. 1.—Mean normalized numbers of juveniles metamorphosed on sauger in three trials conduct during different months

ed in future host suitability studies. Juvenile production from hosts is most useful for cor parative purposes when the infestation intensity is known. For example, twice as many gl chidia attached to sauger in Trial 3 compared to Trial 1 despite similar glochidial exposu times. Examining the percentage of glochidia that transform into juveniles is useful f determining the suitability of potential host fishes. If sloughed glochidia are counted, tl percentage of glochidia that metamorphosed into juveniles can be assessed and compa sons among trials, season and other tests of suitability can be made.

The duration of glochidial metamorphosis has often been attributed to water temperatu (Zale and Neves, 1982; Yeager and Saylor, 1995). In our study, however, the amount of tin glochidia were in the marsupial gills was more important than temperature in regulati the length of time to metamorphosis on sauger. In Trials 1 and 3 water temperatures we similar but the modal day of metamorphosis differed by 78 d. The primary differen between these trials was the amount of time glochidia were in the marsupial gills. Bla sandshells spawn in the late summer and become gravid in early fall *i.e.,* Sept., and son females retain glochidia through the following summer (Ortmann, 1909; Leferve and Cu tis, 1912; J. Khym and J. Layzer, pers. obs.). Therefore, glochidia used in April (Trial were in the marsupial gills about 7 mo, whereas glochidia used in November (Trial 3) we in the marsupial gills about 2 mo. Corwin (1920) and Tedla and Fernando (1969) al reported that the season glochidia were obtained from two other lampsiline mussels *Lam silis luteola* and *L. radiata* affected the duration of the attachment period. Glochidia m be undergoing further maturation in the marsupial gills and the longer they remain in tl marsupial gills the shorter the time required to metamorphose.

TABLE 2.—Dates of mussel collections and fish infestations, mean water temperatures and juvenile metamorphosis data for sauger in each trial

Trial	Date collected	Date infested	Mean water temperature ± SD	N (sauger)	Mean # of juveniles/fish ± SD	% Juvenile transformation	Metamorphosis period (postinfestation)	
							Modal day	Range (days)
1	4-15-97	4-23-97	19.0 ± 1.0	1	689	26	31	21–48
2	8-11-97	8-12-97	21.9 ± 0.5	3	882 ± 183	N/A*	16	15–44
3	10-16-97	11-13-97	18.2 ± 1.4	3	3978 ± 1560	61	109	25–180

* Sloughed glochidia were not counted

All reported hosts for *Ligumia recta* tested were not equally suitable; clearly, sauger w the most suitable host. The decline and low abundance of *L. recta* in many rivers is co cordant with a decline in sauger runs. Many reservoirs were constructed across the Unite States from the 1940s through the 1960s. The closure of dams inhibits upstream migratio and reduces spawning habitat for sauger. These two factors can lead to a decline in saug populations (Nelson, 1968; Nelson and Walburg, 1977; Alexander, 1987). Although th decline in sauger populations is poorly documented, its occurrence is chiefly responsib for the initiation of sauger stocking programs by many state agencies, *e.g.*, Tennessee Wil life Resources Agency stocks on average 926,000 fingerlings annually (Tim Churchill, Te nessee Wildlife Resources Agency, pers. comm.). Ahlstedt and Tuberville (1997) rarely co lected *L. recta* in the Clinch River above Norris Reservoir. Sauger are also rare in the upp Clinch River (Charles Saylor, Tennessee Valley Authority, pers. comm.). In the Licking an Barren rivers sauger and *L. recta* are present in low numbers (Kornman, 1989; Laudermil 1993; Weiss and Layzer, 1995). In contrast, sauger are relatively abundant below Pickwi Dam on the Tennessee River (Pegg *et al.*, 1997) where we found black sandshells to b common.

The loss of many mussel populations can be attributed to pollution and habitat destru tion rather than a decline in host fish abundance. In many cases, however, the facto responsible for population declines are unknown. In such instances, the status of host fis populations should be examined. Moreover, it would be best to determine which of th reported hosts or newly identified hosts are the most suitable. We believe that the use percent transformation is the best means of comparing host suitability at this time.

Management of fish populations and conservation of unionids should not be viewed separate resource issues; opportunities exist to achieve both goals simultaneously. Clearl habitat restoration undertaken to enhance fish populations could significantly benef unionids. Additionally, many host species, such as sauger, are also sportfish that are com monly stocked by management agencies. Potentially, these stockings could provide a gre opportunity to enhance populations of some mussel species such as *Ligumia recta* if th hatchery fish were infested with glochidia prior to release.

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