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OBSERVATIONS ON THE REPRODUCTION, SOURCES OF MORTALITY, AND DIET OF THE KENDALL WARM SPRINGS DACE

Andrew D. Gryska1 and Wayne A. Hubert1

ABSTRACT.—The life history of the endangered Kendall Warm Springs dace (Rhinichthys osculus thermalis) is largely unknown. Our study of its reproduction, sources of mortality, and diet indicated that Kendall Warm Springs dace seem to be reproductively active throughout the year, but the rate of reproduction appears to decrease during the winter. Males become sexually mature at 34 mm total length and females at 40 mm total length. We observed 2 sources of mortality: (1) emigration from the warm spring stream over a waterfall into the Green River and (2) predation on larvae by dragonfly (Lepidophlebia satara) nymphs. Stomachs of Kendall Warm Springs dace contained small (≤1.5 mm total length) benthic invertebrates, primarily dipterans and mollusks.

Key words: Kendall Warm Springs dace, Rhinichthys osculus thermalis, reproduction, mortality, diet.

The Kendall Warm Springs dace (Rhinichthys osculus thermalis) is endemic to a single spring creek. Because of its restricted habitat, it has been listed as an endangered species, and a recovery plan has been developed that requires a more thorough description of its life history (U.S. Fish and Wildlife Service 1982). Hubbs and Khune (1937) and Binns (1978) made limited life history observations of the fish, but most aspects of its life history are poorly understood, including reproduction, sources of mortality, and diet.

STUDY AREA

Kendall Warm Springs Creek originates from several thermal springs (29.5°C) in a small limestone bluff 50 km north-northwest of Pine­dale, Wyoming (Hubbs and Khune 1937, Binns 1978, Breckenridge and Hinckley 1978). The creek has a discharge of 2.0–2.5 m³/s and courses for 340 m before cascading over a 4-m-high waterfall into the Green River. This waterfall prevents Green River fish from entering the spring creek. The creek has a mean depth of 10.6 cm, mean wetted width of 8.6 m, mean water velocity of 25 cm/s at the bottom, and a substrate composed mostly of a mix of fine (0.1–3.2 cm) and coarse (3.3–7.6 cm) limestone pebbles (Gryska 1996). Water flows through a braided network of channels among large vegetation mats (largely Chara spp.).

METHODS

During June, July, and August 1995, and January, May, June, and July 1996, we captured fish in traps in Kendall Warm Springs Creek. Traps were constructed of 3-mm-square-mesh hardware cloth. Measuring 5.5 x 11 x 31 cm, with a fusiform shape when viewed from the side, the traps had a V-shaped mouth with a vertical slot entrance. Traps were set in the main channel, secondary channels, and vegetated mats over the length of the spring creek during day and night (see Gryska 1996 for a detailed description of traps and sampling protocols). Gender and spawning condition were determined from external morphology and by manually extruding semen or ova. Sexually mature males were also identified by the presence of minute nuptial tubercles on the fore­head, dorsal surface, and fins, and a longer (than immature males), whitish anal papilla. We did not observe the purple coloration reported in spawning males described by Hubbs and Khune (1937). Females were identified by the absence of nuptial tubercles, a larger (than immature females), clear anal papilla. Females were considered to be in spawning condition.

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if they had a distended abdomen and eggs could be extruded by gentle pressure to the abdomen. Gender and total length (TL, mm) of captured fish judged to be in spawning condition were recorded.

Observations of the presence of larval fish (6–15 mm TL) were made June through August 1994, and January and May through July 1995. During each sampling month we made visual observations with the aid of a powerful light between 2200 and 2400 h during at least a 5-d period by walking along each bank of the stream. We searched shoreline habitat that was 1–5 cm deep, without measurable current, and vegetated by Chara spp.

We observed a dragonfly (Libellula saturata) nymph in association with larval fish in shallow (<5 cm deep), slow-moving, near-shore habitat. To assess the density of dragonfly nymphs and larval fish, we randomly selected 10 sampling sites 2.0 m long and 0.6 m away from the bank where larval fish were observed. Thirty quadrats (0.02 × 0.02 m) were identified within each site. Each site was sampled 5 nights, 7–14 June 1995, between 2200 and 2400 h. Using a powerful light, we counted dragonfly nymphs and larval fish and observed the predatory behavior of dragonfly nymphs. The light did not appear to affect the behavior of either dragonfly nymphs or larval fish. Dragonfly nymphs and larval fish were counted in 3 randomly selected quadrats within each site.

The number of fish emigrating downstream out of Kendall Warm Springs Creek was estimated using two 0.4-m-diameter (500-micron-mesh openings) drift nets set at 2 points at the upstream edge of the cascade. Due to greater channel slope and current velocity (>1 m/s) at this location, fish collected there were being carried over the waterfall when captured. Nets were set horizontal to each other on a transect across the creek so that each net sampled a unique portion of the flow. Nets were set daily for 24-h periods between 22 July and 22 August 1994, 5 and 10 January 1995, and 25 May and 23 July 1995. Each drift net occupied 3.9% of the total stream width (10.4 m) at the falls. Traps were set and retrieved between 1000 and 1100 h. Fish were measured to the nearest millimeter (TL) and identified as larvae (<16 mm TL) or post-larvae (>16 mm TL). Total number of fish emigrating daily over the falls was calculated by dividing the mean number of fish captured per 24-h net set by the proportion of total stream width (0.078) sampled with the 2 nets.

Trapping mortalities and fish caught in drift nets immediately upstream from the cascade were preserved in 70% ethanol and their stomach contents analyzed. The abdominal cavity of fish >20 cm TL was injected with a 70% ethanol solution to preserve stomach contents. In the lab we removed the stomach of each specimen and pooled the contents into 4 classes: (1) fish <40 mm TL captured during January 1995, (2) fish ≥40 mm TL captured during January 1995, (3) fish <40 mm TL captured May, June, or July 1995, and (4) fish ≥40 mm TL captured May, June, or July 1995. This enabled a comparison of food items between winter and summer and between 2 length classes, but it did not allow for assessment of variation among individual fish. Invertebrates in each identifiable taxon were enumerated by the Bureau of Land Management Aquatic Ecosystem Laboratory, Logan, Utah.

RESULTS

A total of 22,942 juvenile and adult fish were sampled with traps during the study. During each sampling month (January, May, June, July, and August) several fish were examined for the presence of semen or ova. Measurements of the lengths of individual fish with and without semen or ova could not be made because of the potential mortality associated with handling. The minimum length at which semen or ova could be extruded differed by gender. For males the minimum length at which semen could be extruded was 34 mm TL, whereas the shortest length at which ripe eggs could be extruded from females was 40 mm TL. Semen and ova could be extruded from males and females during all sampling months.

Larval fish were also observed during all sampling months. Mean densities in June were 2.8 larvae/0.04-m² quadrat, and larval fish were observed in 67% of the sampled (n = 150) quadrats. Estimates of densities of larval fish were not made using the sampling protocol outside of July 1995; however, visual observations along the shoreline indicated that densities were similar from May through August but substantially lower in January.

A total of 453 fish (329 larvae) were captured in drift nets at the upstream edge of the
waterfall. From May through August average capture per 24-h sampling period was 3.96 ($\bar{x} = 0.35$) fish, including 2.90 ($\bar{x} = 0.34$) larvae in each of the 2 nets. We estimated that 100 (95% C.I. 85–120) fish emigrated from the stream each day (May–August), 75 of which were larval fish. Catch rates were substantially lower in January, averaging 0.81 fish, including 0.09 larvae, in each net per 24-h sampling period.

Dragonfly nymphs were 10–25 mm long and larval fish were <16 mm TL. Estimated density of dragonfly nymphs in larval fish habitat was 22.5 nymphs/m$^2$ ($\bar{x} = 2.25; n = 138$). Dragonfly nymphs were frequently observed either grasping or attempting to grasp larval fish, but no records of capture rates were obtained.

Many fish collected in traps had died and were in a state of decomposition, thus rendering them unsuitable for stomach content analysis; some fish had empty stomachs. Two fish ≥40 mm TL sampled in January had food items in their stomachs, and only 3 Physella, 4 Hydracarina, and 1 Chironomidae were found (Table 1). Two fish <40 mm TL sampled in January contained Chironomidae, Optioservus, Physella, and Hyallela (Table 1). During summer 32 fish ≥40 mm TL had Orthocladiinae and Planorbidae as the most common taxa (Table 1), and 38 fish <40 mm TL had predominantly riffle beetles (Elmidae), Chironomidae, Physella, Planorbidae, Hyallela, and Simulium in their stomachs (Table 1). Prey of Kendall Warm Springs dace were all ≤1.5 mm in length.

**Discussion**

Our observations of Kendall Warm Springs dace and the work by Binns (1978) indicate that breeding occurs year-round. Males and females were observed in spawning condition and larval fish were observed during each sampling month (January, May, June, July, and August), indicating that the Kendall Warm Springs dace is reproductively active throughout the year.

We found evidence that reproduction decreases during winter. Very few larval fish were seen along the shoreline, and the number of drifting larvae was substantially less in January (0.09 larvae/24-h net set) than in May through August (2.90 larvae/24-h net set). Additionally, Gryska (1996) captured significantly fewer juvenile and adult fish in traps during winter than during summer, and mean length of fish captured in January was significantly greater than in summer. We submit 2 potential reasons for the decline: (1) an overall reduction in primary productivity due to shorter days and reduced intensity of sunlight, and (2) cooler water temperatures in shallow, near-shore larval fish habitat during the winter. Gryska (1996) measured water temperatures as low as 10°C in near-shore habitats in January 1995. Kaya (1991) was unable to stimulate spawning by R. o. *thermales* in laboratory aquaria by varying photoperiod, water temperature, or current. Our observations suggest that photoperiod and/or water temperature influence reproductice rates.

Minimum length at sexual maturity was 34 mm TL for males and 40 mm TL for females. John (1963) found female speckled dace in Arizona to mature at age 2 and 45 mm standard length (SL). Kendall Warm Springs dace of 45 mm SL were 54 mm TL; they may mature at a smaller size compared to other speckled dace subspecies. Our longest captured Kendall Warm Springs dace was 63 mm TL (see Gryska 1996 for length frequency data).

Kendall Warm Springs dace regularly drifted out of the creek into the Green River during all sampling months (January, May, July, and August), and 75% of the drifting fish were larvae. Because larval fish are relatively poor swimmers, they are easily displaced downstream by the current. Larger fish found in the nets were often partly decomposed, and we suspect they may have been dead upon entrance. We probably underestimated the mean number of fish captured per 24-h period because larval fish were difficult to see and were often torn apart either by water flowing through the nets or by dragonfly nymphs captured in the nets.

We estimate that 75 larval fish per day drifted from the creek into the Green River from May through August (a total of about 9200 fish). Average larval fish densities were 2.8 larvae/0.04-m$^2$ quadrat, and larval fish habitat occupied 17% (329 m$^2$) of the creek (Gryska 1996). Given the density of larval fish and the area of larval fish habitat, we estimate the population to be about 24,000 larval fish in June, but the actual population was probably higher because it is unlikely that all larval fish were observed in each sampled quadrat. Given these
TABLE 1. Numbers of organisms found in the stomachs of 2 length classes (mm) of Kendall Warm Springs dace collected during winter (January) and summer (May–July) 1995. Number of fish stomachs pooled to form the sample is in parentheses.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Life stage</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;40</td>
<td>≥ 40</td>
</tr>
<tr>
<td>Amphipoda, Hyallela</td>
<td>adult</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Hydracarina</td>
<td>adult</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Elmidae, Optiopercula</td>
<td>larval</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Chironomidae</td>
<td>puddle</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Orthocladiinae</td>
<td>larval</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Simuliidae, Simulium</td>
<td>larval</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Stratiomyidae</td>
<td>larval</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>adult</td>
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<td>1</td>
</tr>
<tr>
<td>Odonata, Libellulidae</td>
<td>larval</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Trichoptera</td>
<td>puddle</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hydropsychiidae, Cheumatopsyche</td>
<td>larval</td>
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<td></td>
</tr>
<tr>
<td>Hydropsychiidae</td>
<td>larval</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Physidae, Physella</td>
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<td>19</td>
<td>4</td>
</tr>
<tr>
<td>Planorbidae</td>
<td>adult</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

estimates, it appears that the drift of larval fish from the stream may represent a substantial segment of the larval fish population. However, because reproduction appears to occur throughout the year, our estimates of larval fish abundance should be considered minimal estimates.

We estimate that 25 juvenile and adult fish per day drifted from the creek into the Green River from May through August (a total of about 3000 fish). We have no estimates of density of juvenile and adult fish, but a total of 22,942 fish were captured with 867 trap sets during summer 1994. Traps were set at least 4 m apart over the length of Kendall Warm Springs Creek, so only a portion of the population in the creek was sampled at one time. It seems unlikely that drift of juveniles and adults from the creek into the Green River causes a substantial loss from the population.

Dragonfly nymphs preying on larvae and small juveniles (<20 mm TL) contribute to mortality among Kendall Warm Springs dace, but the extent of the mortality is unknown. In addition to dragonfly nymphs, a number of other potential predators were observed along Kendall Warm Springs Creek during our study: dippers (Cinclus mexicana), Brewer’s Blackbirds (Euphagus cyanocephalus), Great Blue Herons (Ardea herodias), and wandering garter snakes (Thamnophis elegans vagrans).

Kendall Warm Springs dace diet had not been reported previously. Our stomach analysis indicates they feed on epibenthic and epiphytic organisms, consuming small (<1.5 mm total length) benthic invertebrates, particularly dipterans, riffle beetles (Elmidae), mollusks, amphipods (Hyallela), and water mites (Hydracarina). This is similar to other speckled dace that suck and scrape invertebrates from the substrate by using a subterminal mouth specifically adapted for benthic foraging (Baltz et al., 1982, Van Eimeren 1988). Although feeding behavior has not been recorded for speckled dace, other species of Rhinichthys have been observed feeding between and under rocks and on the upper and downstream surfaces of rocks (Gibbons and Gee 1972). Diets of other speckled dace subspecies have included Diptera, Ephemeroptera, Gastropoda, Coleoptera, water mites, and algae (Baker 1967, Li and Moyle 1976, Van Eimeren 1988). It appears that Kendall Warm Springs dace feed on items also utilized by other Rhinichthys species (Gibbons and Gee 1972, Reed and Moulton 1973, Brazo et al. 1978). Sample sizes were small because no fish could be sacrificed; only incidental mortalities in traps and fish captured in drift nets at the waterfall into the Green River were available for stomach analysis. Diet data we obtained are limited because stomach contents were pooled within seasons and length classes (<40 and ≥40 mm TL), and substantial digestion and deterioration of stomach contents were common because samples largely comprised fish that had died in traps or were captured in drift 12–24 h prior to being collected and preserved. Additionally, it
is not known where the fish captured in drift nets resided previously in the creek. Consequently, fish stomach contents that we analyzed may not fully represent the diet of Kendall Warm Springs dace.

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LITERATURE CITED


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