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THE VERTICAL DISTRIBUTION AND FEEDING CHRONOLOGY OF LARVAL BEAR LAKE SCULPIN (Cottus extensus) IN BEAR LAKE, UTAH-IDAHO.

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ABSTRACT

Preliminary sampling in Bear Lake, Utah/Idaho, with bottom trawls and larval fish nets indicated that larval Bear Lake sculpin (Cottus extensus) occupy the benthic region during the day and migrate into the water column at night. Densities in the water column after dusk averaged only 0.01 larvae/m<sup>3</sup>. The larval diet (n=29) reflected the diel migration pattern, as 90% of the food items were copepods (Epischura sp.) and 10% benthic ostracods. In contrast, the diet of adult sculpin (n=18) was dominated by benthic prey (ostracods 68%; chironomids 5%; fish eggs 4%). Adaptive advantages for the observed migration and feeding patterns are discussed.

INTRODUCTION

The existence of circadian rhythms is a well known and widely accepted phenomenon in aquatic organisms. Diel vertical migrations of algae, zooplankton and fish have been documented in a variety of systems (Hutchinson 1967; Northcote 1967) and several hypotheses have been put forth to explain these movements. McLaren (1963) proposed that zooplankton migrate to gain an energetic advantage by reducing respiration costs by spending a portion of the day in the cool hypolimnetic waters of lakes. Brett (1971) forwarded this hypothesis as an explanation for the vertical migration of sockeye salmon (Oncorhynchus nerka). Another hypothesis suggests this behavior developed in predators as a way of tracking vertically migrating prey. For example, alewives (Alosa pseudoharanegus) in Lake Michigan migrate from deep to shallow water synchronously with Mysis relicta, their major prey species (Janssen

and Brandt, 1979). A third hypothesis proposes that organisms reduce their risk to predation by migrating into shallower strata at night to feed and then moving to deeper, dark waters during the day where they can avoid predation. A simulation model developed by Wright (1976) demonstrated that a migrating population of zooplankton have a higher rate of survivorship than a non-migrating population.

In this paper we report preliminary data on the diel vertical migration of larval Bear Lake sculpin (Cottus extensus) in Bear Lake, Utah/Idaho. Although vertical migrations of many adult fish species in lakes are well documented, little is known about either the daily migration patterns or the adaptive advantage(s) of this behavior in larval fish (see however, Seliverstov 1974, and Fortier and Leggett 1983, for some descriptive work on larval fish in the oceans). The Bear Lake sculpin was chosen to study this behavior because: (1) It is an abundant species in the lake and consequently is relatively easy to census; (2) They are endemic to Bear Lake, poorly studied (Smart 1958, Dalton et al. 1965, and Williamson 1970), and potentially endangered by cultural eutrophication of the lake (Lamarra et al. 1983), and; (3) They are an important component of the diet of the Bear Lake cutthroat trout (Salmo clarki), an important game species (Nielson 1981).

The objectives of this study were : (1) To determine when and where larval sculpin could be caught; (2) To determine if the larvae were undergoing a vertical migration; (3) To investigate the feeding chronology of the larvae, and; (4) To collect information which would allow us to refine our sampling techniques. Continuing studies on the fish will focus on testing which of the three previously mentioned hypotheses regarding the adaptive benefit of diel vertical migration of aquatic organisms will best explain the movement patterns of the larvae.

#### STUDY AREA

Bear lake is located on the border of Utah and Idaho (42°00' 0N; 111°20' 0W) at an elevation of 1806 m. It is an oligotrophic lake with a surface area of 285 km<sup>2</sup> and a maximum depth of 63 m. It is usually dimictic with surface temperatures reaching 21°C in the summer, and dropping to about 4°C below the thermocline. The Secchi depth in July, 1984 was 6.5 m.

The pelagic zooplankton community is dominated by Epischura, a calanoid copepod, and the rotifer Conochilus (Nyquist 1968; D. Lentz pers. comm.). The benthic invertebrate community is sparse and dominated by ostracods and chironomids (Smart 1958; Erman 1969). The fish fauna in the lake consists of nine native species, four of which are endemic and are the most abundant fish captured in trawling operations. These include the Bonneville cisco (Prosopium gemmiferum), the Bear Lake and Bonneville whitefish (P. abyssicola, P. spilonotus), and the Bear Lake sculpin (Ohlhorst and White 1984). Further limnological characteristics of the lake can be found in McConnell (1957), Workman (1964), and Lamarra (1983).

## METHODS

Data were collected on three dates, August 10, 1983 and July 2 and 3, 1984, under thermally stratified conditions just off-shore from the Bear Lake Biological Laboratory (Figure 1). In 1984 the moon was in one-quarter phase, setting ca. 0115, hrs while in 1983 it was nearly full throughout the collections.

In 1983 samples were collected along the 18 m contour during daylight (1530 - 1945 hrs) and at night (2130 - 2300 hrs). Fish were collected with an 8 m beam, semi-balloon otter trawl with a fine meshed liner in the cod end, and a 1 m diameter larval fish net with 1 mm mesh. Both nets were towed at approximately 1 m/sec for 20 minutes in two strata: thermocline (7.0 m), and bottom. The larval fish net was also towed at the surface. To fish deeper strata a wooden diving plane was attached to the larval fish net. Larvae collected in 1983 were not preserved for gut analysis.

In 1984 fish were collected over a 24-hour period, and net tows were made perpendicular to the depth contours. At approximately 3 hr intervals a set of three 20 minute long tows with the larval fish net were made at depths of 2.5 m (surface), 7.3 m (thermocline), and 14.6 m (hypolimnion) (Figure 2).

Stomach contents of both juvenile and adult fish from 1984 were examined. In larval fish, contents of both the foregut (esophagus to the constriction midway through the digestive tract) and hindgut (constriction to anus) were enumerated separately. Identifications of food items were made with a 30X dissecting scope. Zooplankton from the foregut of the larval sculpins were further classified as fresh (appendages

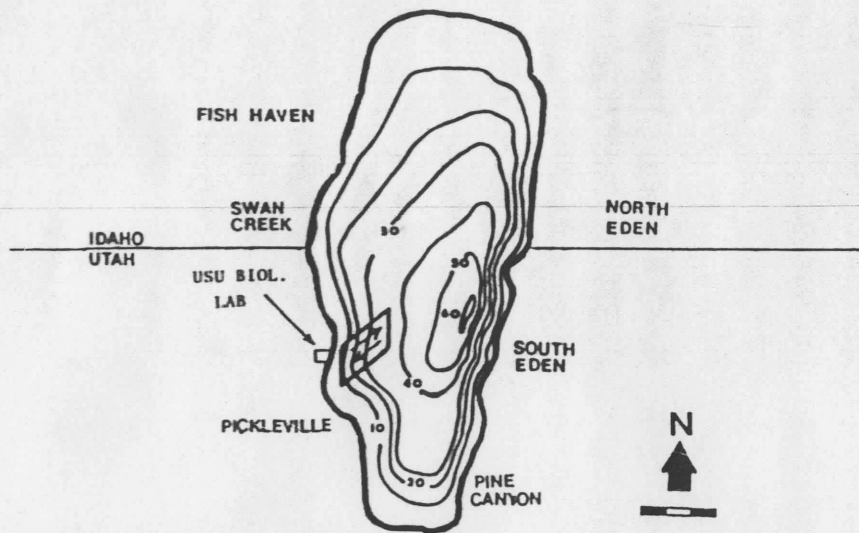


Figure 1. Bear Lake, Utah-Idaho, showing area sampled (trapezoid). Depth isopleths in meters.

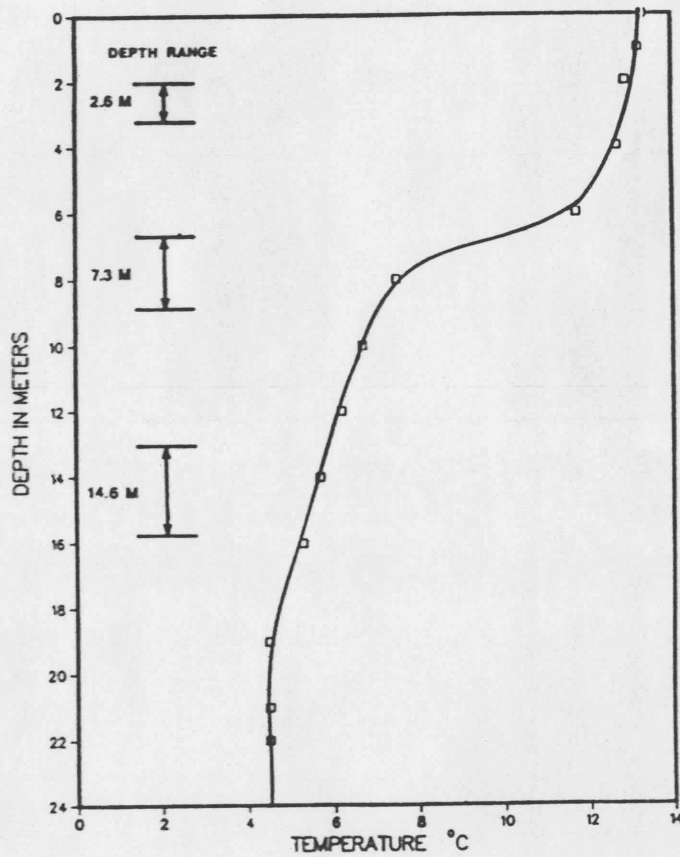


Figure 2. Temperature structure and depths at which tows of larval fish nets were made (2-3 July 1984). In the text, trawl depths are referred to as "surface" (2.6 m), "thermocline" (7.3 m) and "hypolimnion" (14.6 m).

intact; positively identified as a copepod) or digested (many appendages missing; shape resembling a copepod).— Zooplankton in the epilimnion were collected with a 20 cm diameter Wisconsin net.

## RESULTS

Both coregonid and Bear Lake sculpin larvae were collected in the larval fish net. Bottom trawls captured adult and juvenile coregonids, salmonids, Utah suckers (Catostomus ardens), and adult and larval Bear Lake sculpin.

Sampling in both 1983 and 1984 suggested that larvae undergo a diel vertical migration into the water column at night. In 1983 when we sampled with both a larval fish net and bottom trawl, larval sculpin were captured only on the bottom during the day, while at night they were found only in the surface and thermocline strata (Figure 3). In 1984 when we sampled in the water column with a larval fish net, larval sculpin were captured only during the dark hours (Figure 4). Densities were low near the surface, while relatively high numbers were captured in the thermocline region. Just prior to dawn, densities in the thermocline region declined. Larvae were not captured in the hypolimnion until dawn.

Sampling in both 1983 and 1984 produced relatively low numbers of larval sculpin per trawl which is indicative of the low productivity associated with oligotrophic Bear Lake. Assuming 100% sampling efficiency of the larval net, there were an average of 0.01 larvae/m<sup>3</sup> in the water column at night (mean of 6 tows). Due to the low numbers of fish captured and the small number of replicate trawls, the results presented here must be considered preliminary.

Although sculpin larvae were present in the water column throughout the night, feeding was not continuous during that period. Before 0200 hrs the larvae contained considerable amounts of fresh food, but later most or all of the food was digested, indicating that feeding had ceased during or before darkness (Figure 5). Because our sample sizes were low (mean = 3.7 fish/tow) and because no larvae were collected during the day in 1984, the exact feeding cycle of the fish is unclear.

The diet of the larval sculpin consisted of approximately 90% copepods and 10% ostracods (benthic) by number (n=29 fish; Figure 6). The copepods were primarily Epischura sp., the dominant crustacean in the water column (98%).

Figure 3. Numbers of larval sculpin caught during the day (1530-1945 hrs) and night (2130-2300 hrs) using a larval fish net and an 8 m otter trawl at the surface, near the thermocline, or on the bottom of Bear Lake, 10 August 1983.

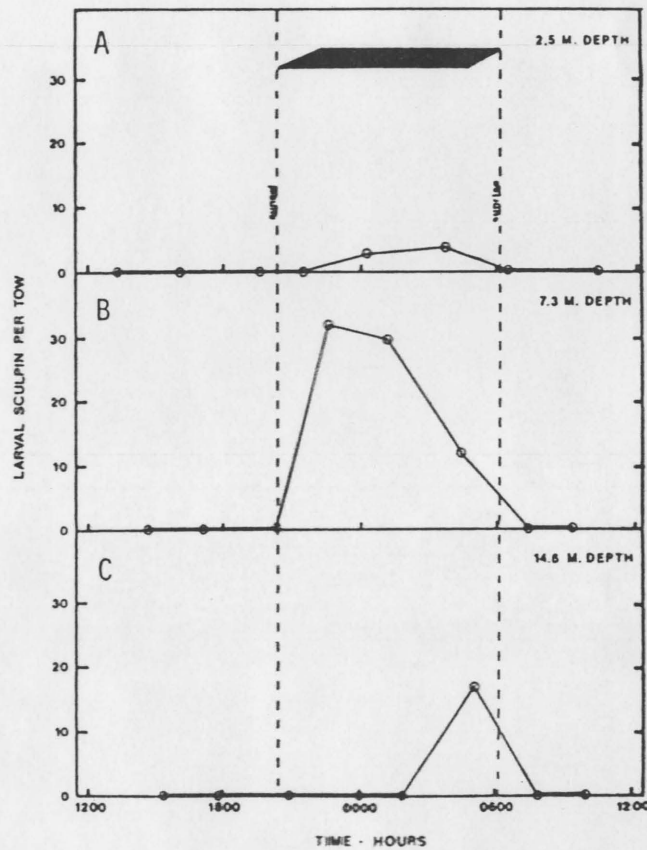
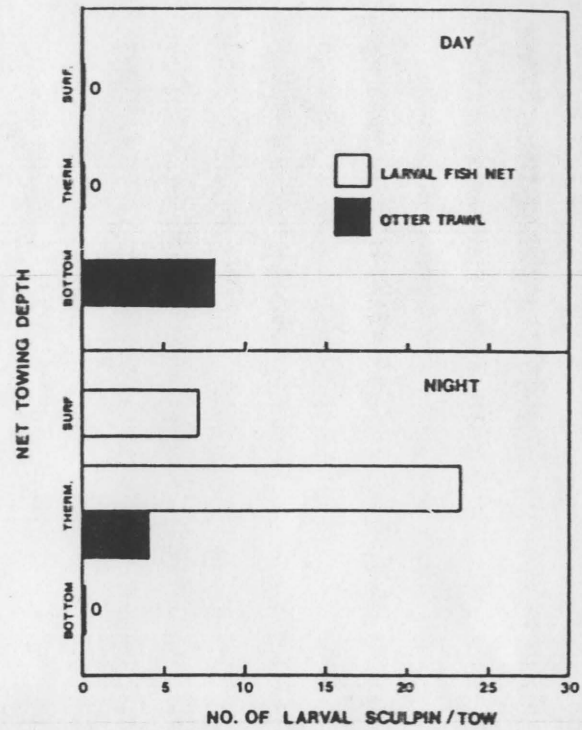


Figure 4. Numbers of larval Bear Lake Sculpin caught using a larval fish net in the surface (A), thermocline (B), and hypolimnion (C) strata. Each point represents one tow lasting 20 minutes at 1m/sec, 2-3 July 1984. Dashed vertical lines indicate local sunrise and sunset.

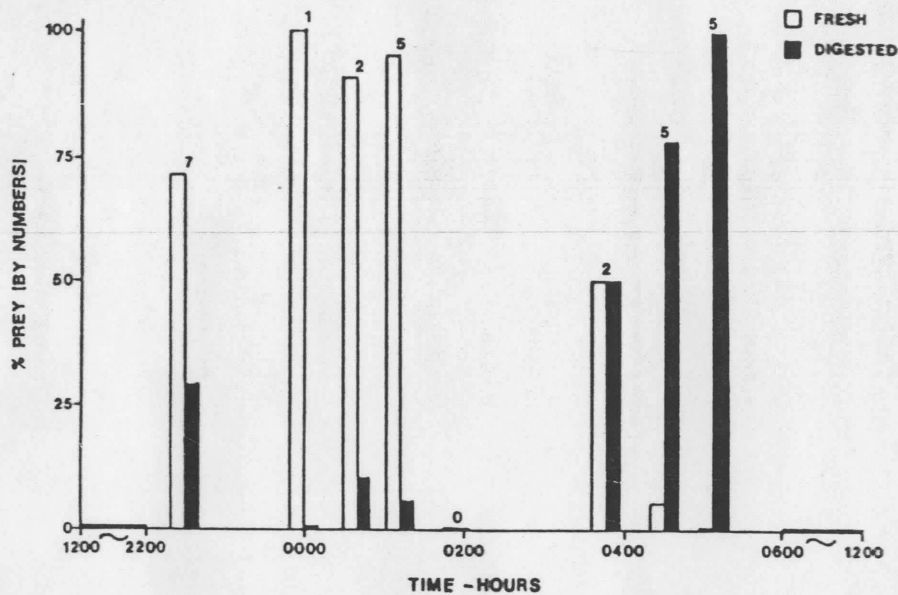


Figure 5. Temporal changes in the state of digestion of food in the foreguts of larval Bear Lake Sculpin captured 2-3 July, 1984. Numbers over each pair of bars indicates the sample size. "0" indicates one fish with an empty gut.

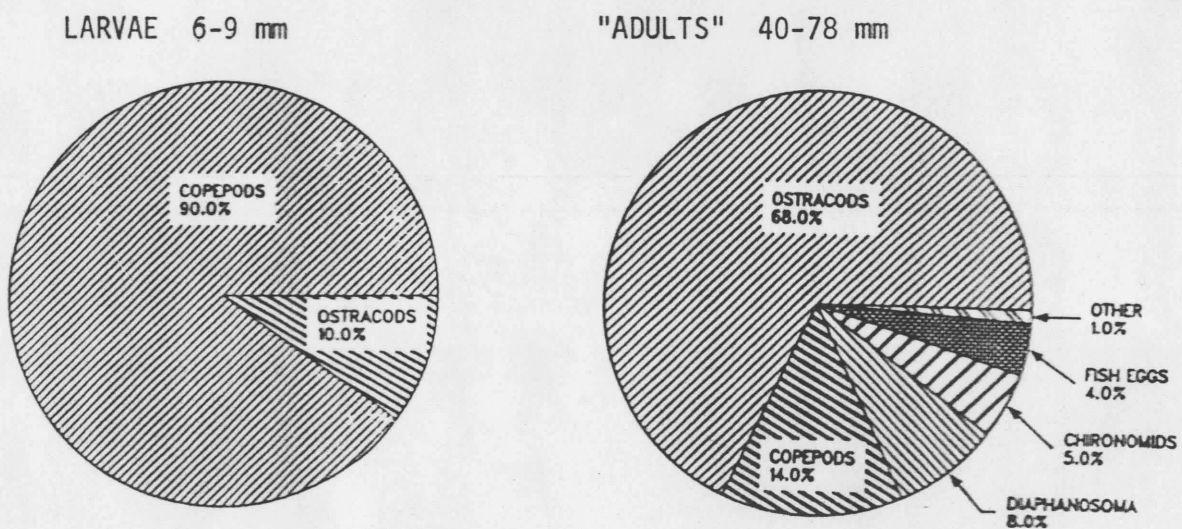


Figure 6. Diet composition (% by number) of larval and "adult" sculpin (n=29 and n=18, respectively). Larval fish were collected 2-3 July 1984. "Adults" were collected on 8 August 1983 and 13 September 1984.

The diet of larger sculpin (40-78 mm) included more benthic prey than the diet of the larvae (Figure 6). Ostracods and chironomids represented 73% of the diet (by number) and fish eggs were found in one fish. "Zooplankton" were consumed by adults, but much of this consisted of harpacticoid and cyclopoid copepods, many of which occupy benthic habitats.

#### DISCUSSION

Our limited sampling indicates that larval Bear Lake sculpin undergo diel vertical migrations since they are captured in the water column at night and are present on the bottom during the day (Figures 3,4). Other researchers have noted significant increases in numbers of larvae caught after dark and attribute this to a vertical migration (Seliverstov 1974). However, some investigators have ascribed a significant decrease in the number of larvae caught in the water column during the day to strong visual net avoidance (Van Den Avyle 1980). Consequently, the absence of larval sculpin in our daytime pelagic tows could be an artifact rather than an indication of diel migration. Diet analysis, however, also suggests a vertical migration of the larvae, as they consumed both pelagic and benthic prey (Figure 6). The limited data suggest that larvae migrate into the water column at dusk to feed on zooplankton. In the single diel study in which we analyzed gut contents, fresh zooplankton was found in the guts of larvae until moonset at 0115 hours, after which digested food dominated, indicating that feeding has ceased. Moonlight can be quite important in the feeding cycles of pelagic planktivores (Bohl 1980; Gliwicz 1983) and could influence larval feeding. However, our criteria for freshly eaten food is not precise enough to preclude the possibility that zooplankton were eaten before sunset and remained relatively intact for several hours into the night. In a related study, Williamson (1979) suggested that juvenile and adult Bear Lake sculpin do not feed during darkness, as indicated by trends in gut fullness during three 24-hour collections.

The diets of both "adult" and larval sculpin are indicative of the habitat where they were captured. Epischura dominates the pelagic zone and is the major prey item consumed by the larvae. Adults were found to feed primarily on ostracods and chironomids, which are found only on the bottom.

Low larval fish densities and consequent low sample sizes were a problem in our study. Average catches of sculpins were



less than 1 fish/minute (Figures 3,4). In comparison, catches of larval threadfin shad (Dorosoma petenense) in oligo-mesotrophic Lake Powell often reach 100 larvae/minute using similar nets (Gustaveson et al. 1979). The low density of larvae may be due to the oligotrophic nature of Bear Lake (Lamarra et al. 1983). In addition to low productivity, the small sample sizes we obtained could also be due to sampling at a period of low seasonal larvae abundance. Sampling throughout the field season and improving sampling techniques will hopefully minimize the problem of small sample size in future studies and allow us to better define the patterns of feeding chronology and vertical migration in Bear Lake sculpin. Improvements will include; (1) Sampling using a 4 m<sup>2</sup> midwater Tucker trawl, and; (2) Incorporating bottom trawling into all 24-hour sampling periods.

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