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AGE AND GROWTH OF LEAST CHUB, *IOTICHTHYS PHLEGETHONTIS*, IN WILD POPULATIONS

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Key words: *Iotichthys phlegethontis*, least chub, age, growth, otolith analysis, life history.

Least chub (*Iotichthys phlegethontis*) are small cyprinids endemic to the Bonneville Basin of Utah. Historically, they were scattered throughout the Bonneville Basin in a variety of habitats including Utah Lake, Provo River, Sevier River, Beaver River, streams and freshwater ponds near the Great Salt Lake, and springs and marshes scattered throughout central and southern Utah (Fig. 1; Sigler and Sigler 1996). Several populations of least chub have become extinct over the last century because of habitat loss and the introduction of nonnative species. Currently, least chub are found in only 9 isolated spring pools in the central and west desert regions of Utah (Perkins et al. 1998).

In response to this large-scale population decline, least chub are potential candidates for federal listing as an endangered species, but a conservation agreement by the State of Utah has forestalled this action. The goal of the conservation agreement is to stop further declines and to begin a process for management and recovery of least chub, thus obviating listing.

Management and recovery of the least chub is dependent on an understanding of its biology. However, because of their rarity, least chub are difficult to study and much of their biology is unknown. In particular, growth rates and longevity in wild populations can only be inferred from laboratory studies. Studies on captive individuals suggest that least chub are short-lived (not more than 3 years) and that they grow slowly (Sigler and Workman 1975, Workman et al. 1976, Crawford 1979). However, captivity can affect growth and longevity, and to effectively manage least chub it is important to understand their growth and longevity in their natural habitat. In this paper

we analyzed otoliths to determine growth and longevity of least chub in wild populations.

The Utah Division of Wildlife Resources (UDWR) collected least chub with minnow traps at the following 5 sites: Gandy Marsh, Lucin Pond, Mills Valley, Mona Springs, and Walter Spring (Fig. 1). A total of 38 fish were >1 year of age and could be used to analyze otoliths for growth and longevity (Table 1). Fish were preserved in alcohol and transported to Brigham Young University where individuals were rinsed in water, blotted dry, and weighed to the nearest 0.001 g, after which standard length (SL) was determined using electronic calipers (0.01-mm resolution). Otoliths (lapillae) were removed from each fish, ground to a thin-section, and analyzed under a compound microscope.

We determined age of each fish by counting opaque bands on otolith thin-sections. Identification of annuli was aided by creating a digitized image of each otolith for computer analysis. We used marginal increment analysis (MIA) to validate that opaque bands represented true annuli (Johnson 1983, Hyndes et al. 1992, Fowler and Short 1998, Campana 2001). Otoliths having 1 or 2 opaque bands were included in the MIA. Using computer image analysis software (SigmaScan Pro 5.0, SPSS, Inc. 1999), we then measured (0.001-mm resolution) annual growth increments along the longest axis of the otolith. To verify annuli formation, we conducted a 1-way ANOVA using increment width as the dependent variable and date collected as the independent variable.

To compare the growth of fish in each habitat, we back-calculated the length of each fish at each age from otolith measurements using a modified Fraser-Lee formula (Campana 1990):

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$$L_x = L_0 + (L_c - L_0)(R_x - R_0)/(R_c - R_0),$$

where L_x is estimated SL at age x , and R_c is otolith radius at capture. L_0 is the estimated length at swim-up, equal to 4 mm (Crawford 1979), whereas R_0 is otolith radius at swim-up. Growth rates of age-1 fish were compared across 4 sites (Lucin Pond, Mills Valley, Mona Springs, and Walter Spring) using a 1-way ANOVA and a Tukey multiple means comparison (S-Plus[®] version 6, Insightful Corporation 2001). Because only 2 fish were collected from Gandy Marsh, this site was excluded from the growth analysis. We also used separate t tests

to compare differences in standard length of age-2 and age-3 least chub in Lucin Pond versus Mills Valley. We did not include Mona Springs or Walter Spring in the growth analysis of age-2 and age-3 fish because only age-1 fish were collected at these sites. Diagnostic plots were used to verify parametric assumptions in each analysis.

Mean annual temperature in Mills Valley was monitored with continuously recording thermographs (StowAway[®], ONSET Corporation 2000). Seasonal "spot" measurements were used to characterize the annual temperature regime in Lucin Pond.

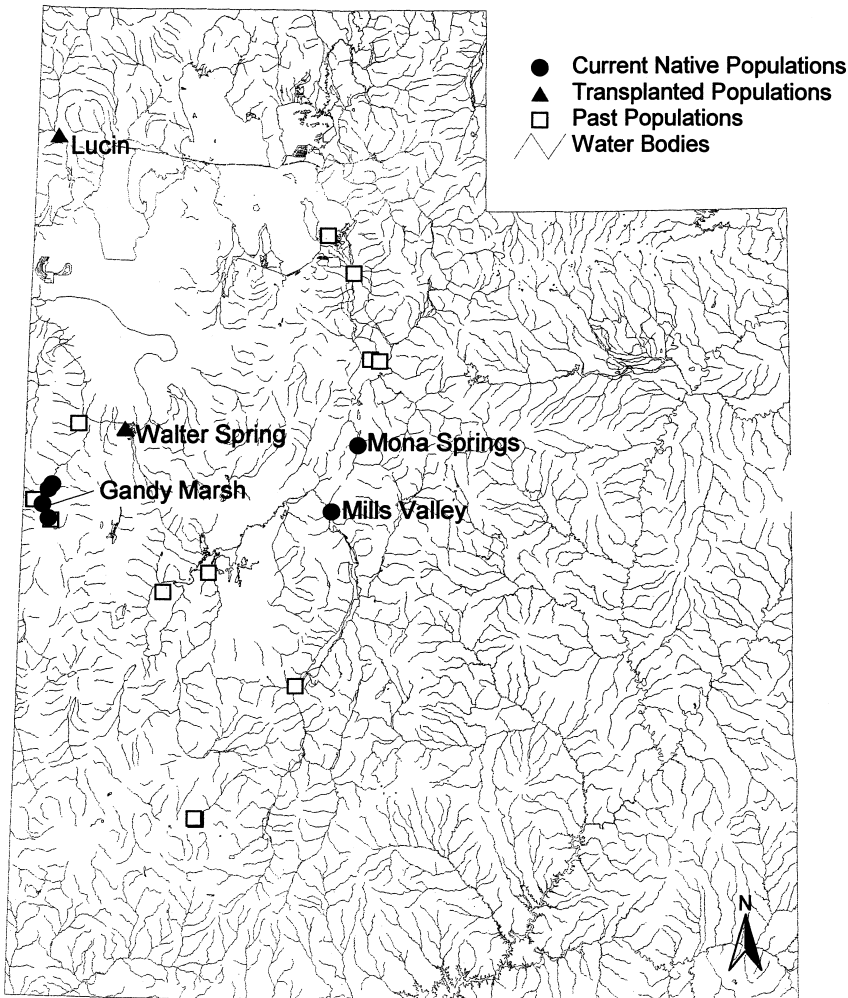


Fig. 1. Map showing current and past least chub populations in the State of Utah (Sigler and Sigler 1996, Perkins et al. 1998). The 2 transplanted populations came from Gandy Marsh.

TABLE 1. Month in which fish were collected from each site and number of fish collected for age and growth analysis.

| Site | Month collected | Number of fish analyzed | Number of fish in each age class |
|---------------|-----------------|-------------------------|--|
| Gandy Marsh | May | 2 | Age-4: 1, age-6: 1 |
| Lucin Pond | February | 15 | Age-1: 4, age-2: 3, age-3: 5, age-4: 2, age-6: 1 |
| Mills Valley | July | 11 | Age-2: 5, age-3: 3, age-4: 2, age-5: 1 |
| Mona Springs | November | 4 | Age-1: 4 |
| Walter Spring | July | 7 | Age-1: 7 |

Marginal increment analysis was consistent with formation of 1 opaque band per year; thus, we refer to opaque bands as annuli. Increment size varied significantly with date of collection ($F = 7.734$, d.f. = 22, $P = 0.03$), as the smallest marginal increments were found for fish collected in July with increment size increasing thereafter (Fig. 2). Thus, it appears growth rates are maximum during the summer months, approximately June through September.

Longevity in this study was double that reported for captive populations. Six-year-old individuals were found in both Lucin Pond and Gandy Marsh populations, and the oldest fish collected in Mills Valley was 5 years old. Mean standard length of age-1 fish differed among populations ($F = 10.012$, d.f. = 38, $P < 0.05$; Tukey < 0.05). Age-1 fish from Mona Springs were significantly larger than those from the other 4 populations. Growth rates of age-2 ($t = 1.73$ d.f. = 18, $P = 0.0004$) and age-3 ($t = 1.81$ d.f. = 10, $P = 0.0003$) least chub in Lucin Pond were higher than in the Mills Valley population (Fig. 3).

Least chub in wild populations live significantly longer than previously believed. Our analysis clearly indicates that these fish can live up to 6 years. Finding 8 fish of age-4 and greater in our small samples from these sites leads us to believe that fish of this age are common in these populations (Table 1). Environmental differences and different aging techniques could explain the discrepancy between our data and previous studies on captive least chub. Previous studies (Sigler and Workman 1975, Workman and Workman 1976) were conducted in aquaria, where conditions can differ from those found in the wild (e.g., food availability). Also, scales, rather than otoliths, were used to measure longevity in these captive populations. Estimates from scales tend to

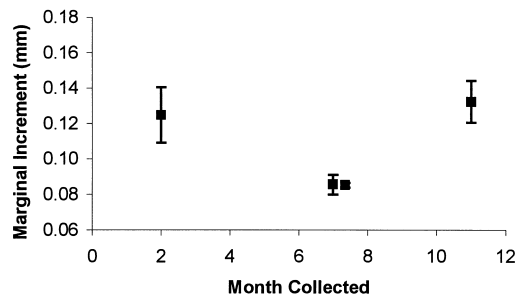


Fig. 2. Plot of marginal increment width for 1- to 2-year-old fish versus month of the year when fish were collected. Error bars represent 1 standard deviation.

underestimate longevity (Beamish and McFarlane 1983).

Growth comparisons of age-2 and age-3 fish between Lucin Pond and the Mills Valley populations showed a higher growth rate in the colder Lucin Pond, which had an approximate mean annual temperature of 8° or 9°C. Mills Valley had a mean annual temperature of 11°C. Mills Valley is groundwater fed with relatively constant seasonal water temperatures, whereas Lucin Pond is fed by a pipe from nearby springs and freezes in the winter. Although differences in growth rates between Lucin Pond and Mills Valley may reflect differences in a variety of interacting processes (e.g., food availability, genetically based traits, fish density), it is clear that warmer temperatures do not have an overriding influence on growth. Future studies on the effects of temperature on least chub growth could isolate causes of the observed variation.

These estimates of growth and longevity can help guide efforts to restore and manage least chub. Accurate estimates of longevity are important for developing population growth

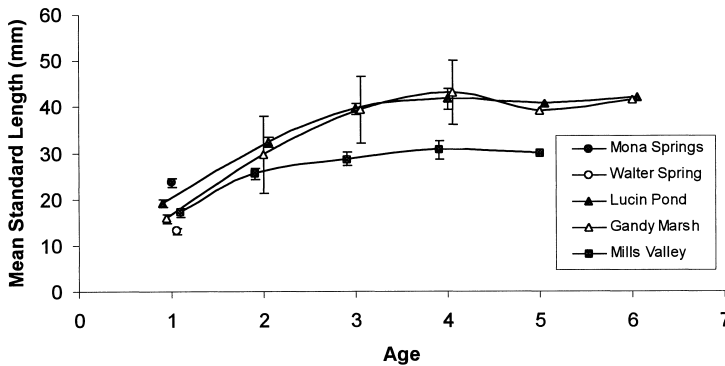


Fig. 3. Plot of mean back-calculated standard length versus age of least chub. Error bars represent 1 standard error. Only age-1 fish were collected from the Mona Springs and Walter Springs.

models, while accurate estimates of growth can aid in determining the sensitivity of different life stages to potential threats. For example, the western mosquitofish (*Gambusia affinis*), an introduced exotic predator, can prey on small young-of-the-year least chub (Mills et al. 2004). Our life history data can be used to estimate how long sensitive size classes may be exposed to predation before reaching a size refuge. Also, estimates of growth in wild populations provide an important baseline for comparison with growth in restored or reintroduced populations. Population viability models are dependent on accurate estimates of growth and longevity in the wild. Such growth comparisons could provide valuable information on the health of recently established populations.

In summary, we found that least chub in natural systems live longer than suggested by previous studies conducted on captive fish. Growth rates vary among populations, the causes of which should be explored through future research.

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