PROGRESS REPORTS

2007

FISH DIVISION

Oregon Department of Fish and Wildlife

2007 Borax Lake Chub Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: 2007 Borax Lake Chub Investigations

PROJECT NUMBERS: Contracts E-2-41 and 134206M085 (USFWS) and HAP074439 (BLM)

PROJECT PERIOD: 1 January 2007 - 31 December 2007

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This project was financed with funds administered by the U.S. Fish and Wildlife Service and the Bureau of Land Management.

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INTRODUCTION

Borax Lake chub (*Gila boraxobius*) is represented by a single population that inhabits a 4.1 hectare geothermally-heated alkaline lake in Harney County, Oregon. The Borax Lake chub is a small minnow endemic to Borax Lake and adjacent wetlands in Oregon's Alvord Basin (Williams and Bond 1980). Borax Lake is a natural lake, perched 10 meters above the desert floor on sinter deposits, which is fed almost exclusively by thermal groundwater. The Borax Lake chub was listed as endangered under the federal Endangered Species Act in 1982 (U.S. Fish and Wildlife Service 1982).

Population abundance estimates obtained in 1991-1996 indicated a fluctuating population ranging from a low of 8,144 fish to a high of 34,634 fish (Salzer 1997). The basis for the Borax Lake chub's listed status was not population size, but the security of a very limited, unique, isolated, and vulnerable habitat. Because Borax Lake is situated above salt deposits on the desert floor, alteration of the salt crust shoreline could reduce lake levels and the habitat quantity and quality available to Borax Lake chub. At the time of the listing, Borax Lake was threatened by habitat alteration caused by geothermal energy development and alteration of the lake shore crust to provide irrigation to surrounding pasture lands. The Borax Lake chub federal recovery plan, completed in 1987, advocated protection of the lake ecosystem through the acquisition of key private lands, protection of groundwater and surface waters, controls on access, and the removal of livestock grazing (U.S. Fish and Wildlife Service 1987).

Recovery measures implemented since listing have improved the conservation status of Borax Lake chub and protection of its habitat (Williams and Macdonald 2003). When the species was listed, critical habitat was designated on 259 hectares of land surrounding the lake, including 129 hectares of public lands and two 65-hectare parcels of private land. In 1983, the U.S. Bureau of Land Management designated the public land as an Area of Critical Environmental Concern. The Nature Conservancy began leasing the private lands in 1983 and purchased them in 1993, bringing the entire critical habitat into public or conservation ownership. The Nature Conservancy ended water diversion from the lake for irrigation and livestock grazing within the critical habitat. Passage of the Steens Mountain Cooperative Management and Protection Act of 2000 removed the public BLM lands from mineral and geothermal development within a majority of the basin. These actions, combined with detailed studies of the chub and their habitat have added substantially to our knowledge of the Borax Lake ecosystem (Scoppettone et al. 1995, Salzer 1992, Perkins et al. 1996). However, three primary threats remain. These include the threat to the fragile lake shoreline, wetlands, and soils from a recent increase in recreational use around the lake (particularly off-road vehicle usage), the threat of introduction of nonnative species, and potential negative impacts to the aquifer from geothermal groundwater withdrawal if groundwater pumping were to occur on private lands outside the protected areas (Williams and Macdonald 2003).

A recent review of the conservation status of the Borax Lake chub by Williams and Macdonald (2003) cited the lack of recent and ongoing population and ecosystem monitoring as one argument against downlisting or delisting the species at that time. Although an increase in abundance is not a goal in the successful recovery of this species, monitoring trends in abundance over time is an important management tool to assess species status. From 1998-2004, data describing the abundance of the Borax Lake chub population are not available. Abundance estimates were obtained from 1986-1997 by The Nature Conservancy (Salzer 1997) (Figure 1). Abundance estimates for

1986-1990 are not comparable with those obtained in 1991-1997. Prior to 1991, estimates were obtained only from traps set around the perimeter of the lake. In 1991, estimates were obtained from traps set on a regularly spaced grid throughout the lake. A study comparing the methods suggests that prior to 1991 abundance was under estimated, perhaps by as much as 50 percent (Salzer 1992). Estimates obtained by Oregon Department of Fish and Wildlife in 2005-2007 are comparable with 1991-1997 estimates (Scheerer and Jacobs 2006).

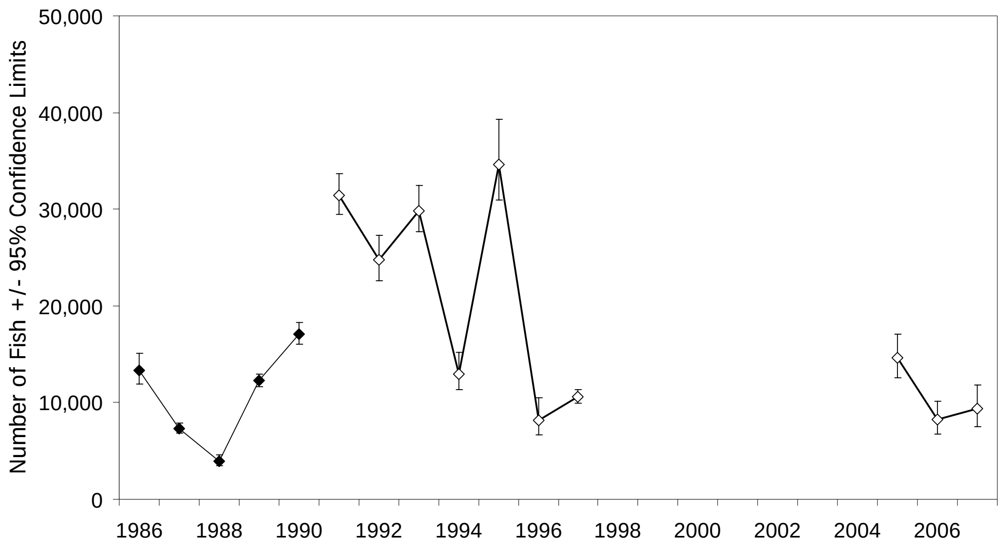

Figure 1. Borax Lake chub population abundance estimates from 1986 to 1997 and 2005 to 2007. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols) the entire lake was trapped. Estimates are not directly comparable across these time periods.

There are limited data on population age structure that offer valuable insight into the productivity of Borax Lake chub. Williams and Bond (1983) examined length-frequency data and concluded that the population consisted primarily of age 1 fish, with few age 2 and age 3 fish present. Limited opercle bone aging of chub collected in 1992-1993 also indicated that most Borax Lake were less than one year of age (67-79%), yet a few individuals were aged at 10+ years (Scoppettone 1995). Because Borax Lake chub are only found in one location and the population is apparently dominated by a single year-class of adults, the species has a high inherent risk of extinction.

The objectives of this study were to: 1) obtain a mark-recapture population estimate of Borax Lake chub and 2) to evaluate habitat conditions at Borax Lake, including the condition of the fragile lake shoreline and outflows. This report describes results from monitoring conducted for the 2007 season.

METHODS

The Oregon Department of Fish and Wildlife's Native Fish Investigations Project used baited minnow traps to obtain a mark-recapture population estimate. We fished 100 traps overnight (16 hours). Traps were fished at random locations throughout the lake. We marked all fish captured with a partial caudal fin clip and collected them in buckets. After all fish were marked, we returned them to the water by distributing the marked fish evenly throughout the lake. The following night, we again fished the traps and the next morning we recorded the total number of marked and unmarked fish captured. We estimated population abundance using single-sample mark-recapture procedures (Ricker 1975). We calculated 95 percent confidence intervals using a Poisson approximation (Ricker 1975). We measured total length (TL) on a sample of 131 fish collected in the traps.

We recorded physical habitat parameters in Borax Lake. The open water area (m^2) was measured using a laser range finder (+/- 0.5 m). Water depth was measured using a graduated depth staff (+/- 0.01 meter) or a digital depth sounder (+/- 0.5 m). From 12 September 2006 through 10 September 2007, water temperatures (^oC) were monitored at five locations using Hobo® recording thermometers. Temperature was recorded at 1-hour intervals. We used a Global Positioning System (GPS) to record site locations (UTM coordinates).

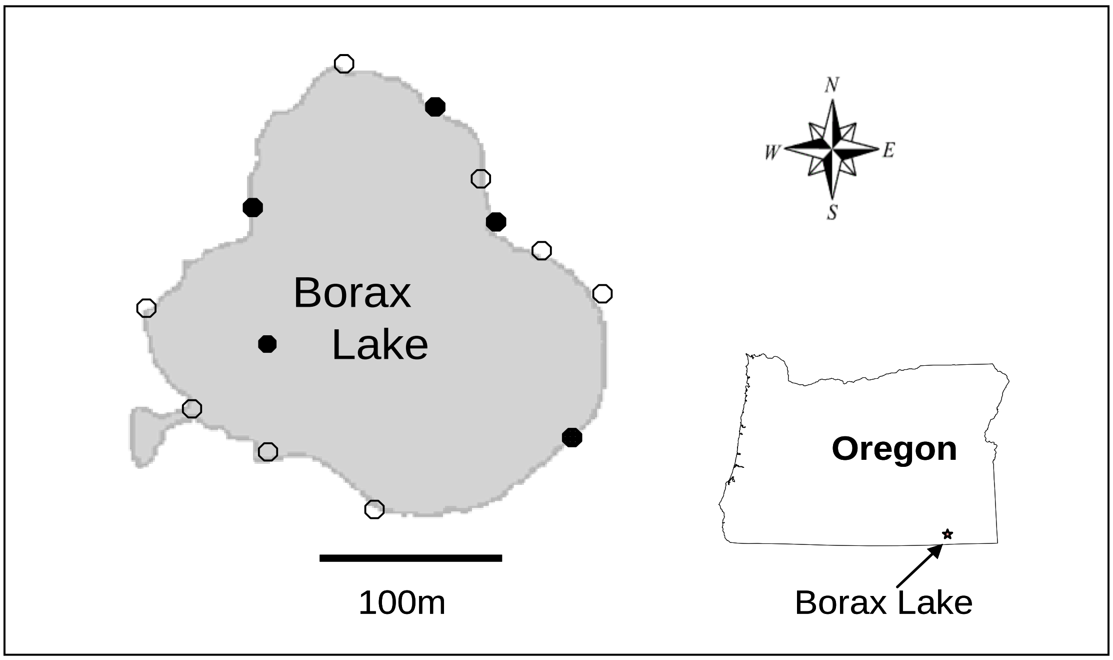

Figure 2. Map of Borax Lake showing the locations of photo points (circles). The dark circles indicate the location of both photo points and thermographs.

We conducted pedestrian surveys to monitor the condition of the lake shoreline, lake outflows, and adjacent wetlands. We established 12 photo points around the perimeter of lake in 2005 (Figure 2). Each photo point was marked with flagging and rebar and the location recorded using a GPS. The condition of the shoreline, including any human caused disturbance was recorded for each photo point and for the shoreline areas between successive photo points.

RESULTS

Population Estimate

On 12 September 2007, we obtained a Borax Lake chub population estimate of 9,384 fish (95% CI: 7,461-11,793) for chub ranging from 27-80 mm TL. This estimate was similar to the 2006 estimate of 8,246 fish (95% CI: 6,715-10,121) and lower than the 2005 estimate of 14,680 fish (95% CI: 12,585-17,120) (Table 1). Length-frequency analysis showed a broad range of sizes with three apparent size-classes (Figure 3). The larger proportion of small chub (≤30 mm) in the 2007 sample suggests recent successful recruitment to the population.

Table 1. Details of mark-recapture population estimates for Borax chub, 2005-2007.

					95% Confidence limits	
Year	Marked	Catch	Recaptures	Estimate	Lower	Upper
2005	1,216	1,941	160	14,680	12,585	17,120
2006	646	1,146	89	8,246	6,715	10,121
2007	687	981	71	9,384	7,467	11,793

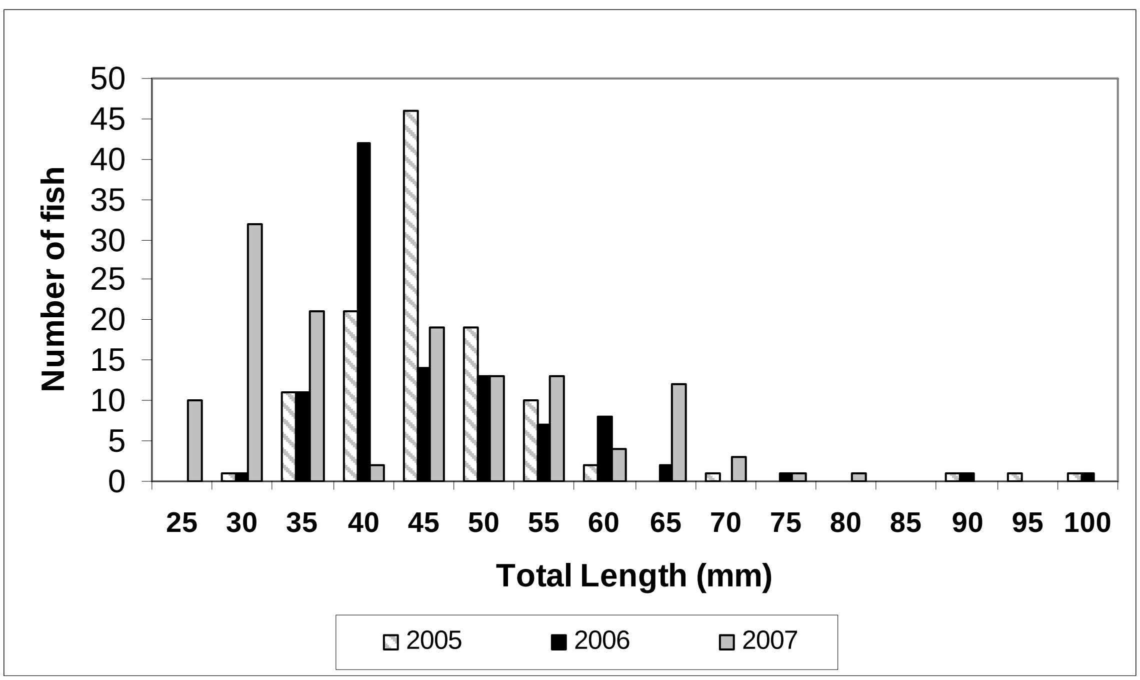

Figure 3. Length-frequency histogram for Borax Lake chub collected in 2005-2007.

Water Temperatures

The water temperatures recorded in Borax Lake from 12 September 2006 through 10 September 2007 showed similar patterns throughout the lake with peak temperatures (35.2-40.8°C) occurring in August. Average temperatures ranged from highs of 30.3 °C in the vent and 27.3 °C on the northwest shoreline to a low of 22.1°C on the northeast shoreline. Surprisingly, vent temperatures varied more than expected and more than temperatures observed at nearby hot springs (Jerry Fairley, University of Idaho, personal communication). Daily temperature fluctuations were typically 4-5° C (Figure 4).

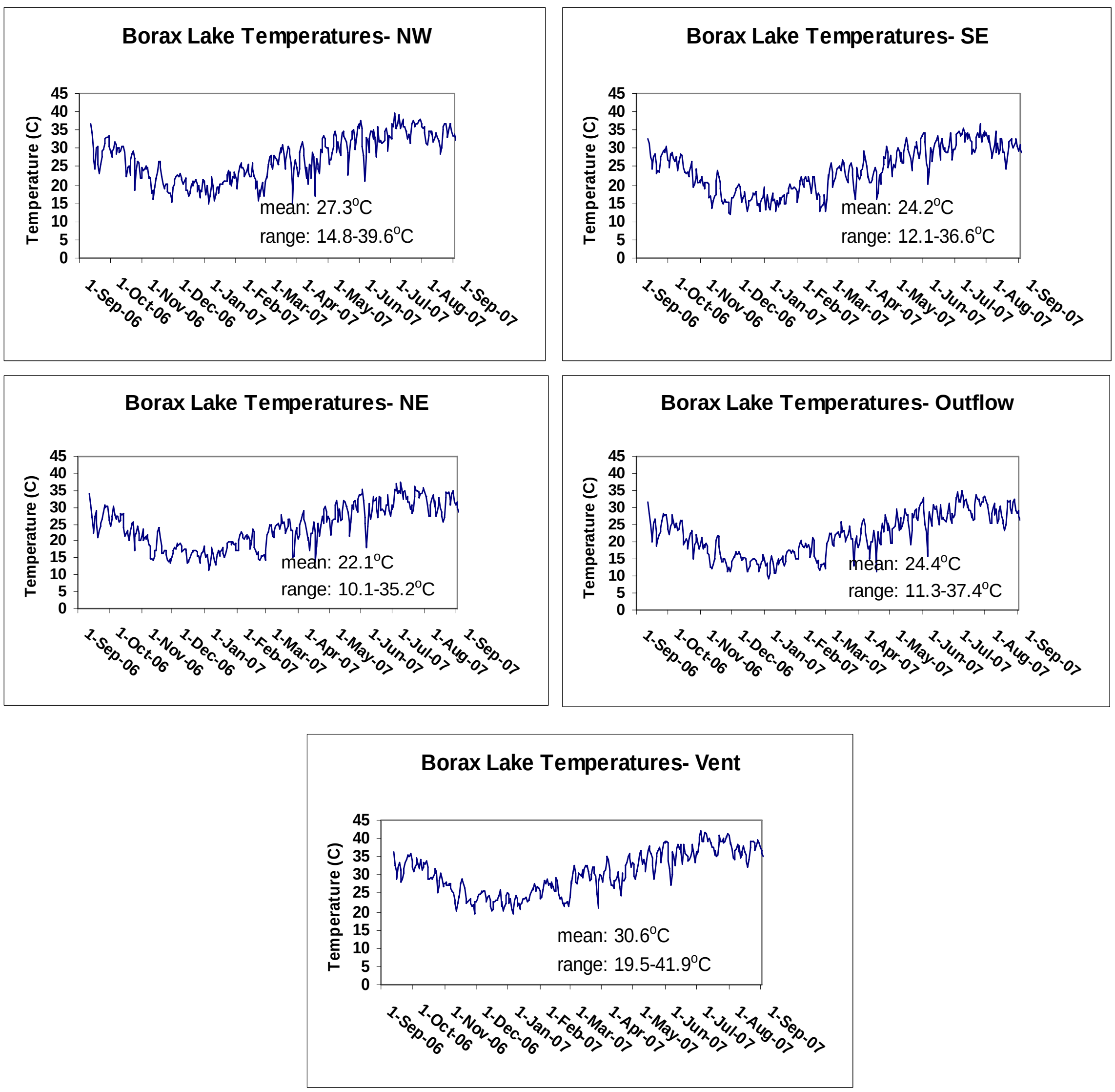

Figure 4. Water temperatures recorded at four locations in Borax Lake in 2006-2007.

Habitat Conditions

The total habitat available for chub in Borax Lake, including the surrounding wetlands was approximately 4.1 hectares. Water depth of the lake averaged approximately 1.0 m with a maximum depth of 27 m measured in the vent. Most of the lake substrate was covered by a thick layer (~0.5 m) of fine flocculent silt, with localized patches of bedrock and fine gravel. Approximately 25% of the substrate had a sparse growth of the aquatic macrophyte *Chara* sp. *Scirpus* sp. was abundant around the margins of the wetland alcove. For more detailed descriptions of the lake habitat see Scoppettone (1995).

During shoreline pedestrian surveys we found most of the shoreline to be in good condition. However, we did observe localized areas on the northern shore with substantial off-road vehicle damage. Photographs were taken at the 12 photo points established in 2005 (Scheerer and Jacobs 2005).

DISCUSSION

Substantial progress has been made towards recovery, but several threats to the species and its habitat remained. The primary threats include habitat degradation of the lake shoreline resulting from increased recreation use in the area, the potential threat of invasion by nonnative fishes, and impacts to the aquifer from geothermal groundwater withdrawal if increased groundwater pumping were to occur on private lands outside the protected areas (Williams and Macdonald 2003; Williams et al. 2005).

During the 2003 status review there was concern voiced that excessive handling of fish during mark-recapture estimation posed an additional threat to the species (D. Salzer, TNC and T. Walters, ODFW, personal communication). During previous abundance estimates, between 44 and 61 percent of the population was handled during marking and recapturing. In this study, we evaluated ways to reduce handling while obtaining population estimates. We examined existing data from mark-recapture abundance estimates obtained for other species and concluded that we could obtain mark-recapture estimates for populations totaling approximately 20,000 individuals with a precision of less than ± 20 percent by marking approximately 1,000 individuals and handling a total of 2,500-3,000 individuals. In 2005-2007, we obtained mark-recapture estimates with relatively high precision while reducing the proportion of the population that was handled. In 2005, we marked 1,216 fish (8 percent of the population), handled a total of 2,997 individual fish (20 percent of population), with a relative precision of ± 14% (Scheerer and Jacobs 2005). In 2006, we marked 646 fish (8 percent of the population), handled a total of 1,703 individual fish (21 percent of population), with a relative precision of ± 19% (Scheerer and Jacobs 2006). In 2007, we marked 687 fish (8 percent of the population), handled a total of 1,597 individual fish (19 percent of population), with a relative precision of ± 20%. It is the opinion of the authors that the handling of 20% of the population to obtain estimates with precision within 14-20 percent is acceptable and not a threat to the listed species. Over the three years of our study, only nine trap mortalities (0.1% of fish handled) resulted from our mark-recapture protocols. Furthermore, given expected precision of ± 14-20%, we have the ability to detect a 26-34% decline in abundance. In 2005-2006, we evaluated the use of snorkel surveys to track abundance trends. We found that snorkel surveys lacked sensitivity to detect all but major changes in population abundance (Scheerer and Jacobs 2006).

The habitat conditions at Borax Lake in 2005-2007 did not appear to differ from those reported in the past (Williams and Bond 1983, Scoppettone et al. 1995). The water was clear and visibility was good. The lake substrate included bedrock in the southeast areas of the lake, fine gravel and bedrock in the northern areas of the lake, and a flocculent silt dominating the remaining areas of the lake. The shoreline surveys found evidence of substantial off-road vehicle usage. Several members of the public visited with us during our population estimates, some driving their vehicles to the lakes edge.

We recommend continued future investigations at Borax Lake that include obtaining mark-recapture population estimates using protocols that limit handling to approximately 20 percent of the total population size. Because Borax Lake chub are an annual species, i.e. most fish are $\leq$1 year old, this sampling should be conducted every one to two years so that serious declines in population abundance and/or unauthorized introductions of nonnative fish can be detected before the results are irreversible. We recommend the initiation of an aging study to assess changes in age structure over time. Because small cyprinids typically show substantial overlap in length-at-age, this study is needed to accurately assess annual recruitment, which is difficult, at best, from length-frequency analysis. Other benefits of an aging study include determining the timing of annulus formation and identifying the size/age-at-maturity. We also recommend continuing annual shoreline pedestrian surveys to assess the condition of the fragile lake crust. Lastly, we recommend the prompt installation of interpretive signage and the development of a parking lot with the associated closure of access roads to both educate the public and reduce the impacts of off-road vehicular traffic.

ACKNOWLEDGEMENTS

We are grateful to Darren Brumback, Daryl Bingham, and Christine Young for assistance with the field work. We thank the Bureau of Land Management for use of the housing facilities in Fields. We gratefully acknowledge funding provided for this study by the US Fish and Wildlife Service and the Bureau of Land Management.

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