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2010 Borax Lake Chub Investigations

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INTRODUCTION

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

Population abundance estimates obtained since 1991 indicate a fluctuating population ranging between approximately 4,100 and 37,000 fish (Salzer 1997; Scheerer and Jacobs 2009). 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 (U.S. Fish and Wildlife Service 1982). Because Borax Lake is shallow (average depth ~1 m) and situated above salt deposits on the desert floor, alteration of the salt crust shoreline could reduce lake levels, which would affect the quantity and quality of habitat available to Borax Lake chub.

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 (BLM) designated the public land as an Area of Critical Environmental Concern. The Nature Conservancy (TNC) began leasing the private lands in 1983 and purchased them in 1993, bringing the entire critical habitat into public or conservation ownership. TNC 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. In addition, detailed studies of the chub and their habitat have added substantially to our knowledge of basic Borax chub biology and the Borax Lake ecosystem (Scoppettone et al. 1995, Salzer 1992, Perkins et al. 1996).

In a recent conservation review, Williams and Macdonald (2003) listed three primary threats which remain for Borax Lake chub: 1) 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), 2) the threat of introduction of nonnative species, and 3) potential negative impacts to the aquifer from geothermal groundwater withdrawal if groundwater pumping were to occur on private lands outside the protected areas. This threat resurfaced in 2009, when Pueblo Valley Geothermal proposed a geothermal energy project on 2,000 acres of private property within 5 km of Borax Lake.

In September 2009, the BLM completed a draft, multi-agency "Borax Lake Chub (*Gila boraxobius*) Recovery Management Agreement" to manage and protect the Borax Lake area for the conservation and recovery of the Borax Lake chub. The Recovery

Management Agreement (RMA) was developed to establish a strategy and framework to identify responsibilities for collaboration to complete conservation related tasks to fully recover Borax Lake chub and delist the species. Under the RMA, the cooperators (BLM, USFWS, TNC, and ODFW) will work together to achieve the delisting criteria stated in the recovery plan (U.S. Fish and Wildlife Service 1987) as follows, "The Borax Lake chub will be recovered when complete control exists over management of surface and subsurface waters by The Nature Conservancy or a public resource agency within the 640 acres of critical habitat; and when a self-sustaining population of Borax Lake chubs has been maintained free of threats for five consecutive years". To reach recovery, Borax Lake 1) must be protected from disturbance, 2) historic wetlands must be restored, 3) disturbance to the fragile salt-crust shoreline must be prevented, 4) the geothermal aquifer must be maintained in its natural condition, and 5) Borax Lake chub must exist throughout its native ecosystem without threats (U.S. Fish and Wildlife Service 1987). In 2010, work was initiated to construct a perimeter fence and gates to exclude vehicles from the lake and to install interpretive signs.

This report describes results from monitoring conducted by Oregon Department of Fish and Wildlife's Native Fish Investigations Project (NFIP) in 2010. The NFIP initiated a study in 2005 to develop methods for monitoring the biological status of Borax Lake chub and their habitat. This year marks the sixth consecutive year of this effort.

The objectives of this study are 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.

METHODS

We used baited minnow traps to capture chub to obtain a mark-recapture population estimate. We fished 114 traps overnight ($\simeq$16 hours). The traps were distributed approximately every 25 m along transects that crossed the lake and along the shoreline (Figure 1). Traps were also placed in the associated wetland and in the outflow channel. We measured total length (TL) on a sample of 212 fish collected in the traps. 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 checked the traps and 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 recorded data separately for each transect, for the wetland, and for the outflow channel to assess potential spatial differences in the proportion of marked fish to the total at locations throughout the lake, differences that could potentially indicate bias in our estimate.

We assessed the recent trend in population abundance by calculating a linear regression of abundance over time for the past six years. We determined whether the slope of this regression was significantly different from zero ($P \leq 0.10$) to assess whether there was no trend (not significantly different from zero), an increasing trend (positive and significantly different from zero), or a declining trend (negative and significantly different from zero).

From 23 September 2009 through 22 September 2010, we monitored water temperatures (^oC) at five locations using Hobo® recording thermographs. Temperature was recorded at 1-hour intervals. We also examined the condition of the shoreline of the lake, the wetland, and the outflow channels.

RESULTS

Population Estimate

On 22 September 2010, we obtained a Borax Lake chub population estimate of 25,849 fish (95% CI: 23,999-27,071), which ranged in length from 27 mm to 103 mm TL. This estimate was significantly higher than the estimates from 2005 through 2009 (Table 1; Figure 2). The population has not exhibited any trend in abundance over the past six years (p=0.16). Chub abundance was highest in the eastern shoreline habitats (transects 2-4). The proportion of marked fish to the total catch of fish on the recapture date did not indicate any bias in our estimate, i.e. the ratios observed at individual transects were not significantly different from the average ratio for all transects (X^2=13.2, 13 df, p>.30) (Table 2). Ratios of marked fish to total catch ranged from 13% to 27% and didn't show any spatial pattern. The 2010 abundance estimate was nearly as high as the peak estimates obtained in the early 1990's.

Length-frequency analysis showed a broad range of sizes with no discernable age-classes (Figure 3). Interpretation of these histograms is complicated by the short life spawn and protracted spawning period of the species. However, it appears that the increase in chub abundance may have been due to increased survival, rather than increased recruitment.

Water Temperatures

The water temperatures recorded in Borax Lake from September 2009 through September 2010 showed similar patterns throughout the lake with peak temperatures (36.3 ^oC to 37.4^oC) occurring in September 2009 and July-August 2010 (Figure 4). Average water temperatures in the lake ranged from 25.6-26.0^oC. The average water temperature was substantially cooler in the wetland (20.0 ^oC). Daily temperature fluctuations were typically $\leq$4-5^o C. The maximum 7-day running average daily temperatures recorded on the northwestern shoreline of Borax Lake showed different patterns during the summers of 2005 through 2010, with 2008 and 2010 being cooler (Figure 5). The 2010 temperatures were significantly cooler than the 2009 on the NE and NW shorelines and in the wetland, significantly warmer on the SE shoreline, and unchanged in the outflow (p<0.05). The 7-day average maximum temperatures in the lake represent some of the most extreme conditions that exist in the lake and exceed the species critical thermal maximum of 34.5^oC (Williams and Bond 1983). However, fish can seek refuge from the warmest temperatures by moving to cooler areas of the lake, including the wetland (Figure 4). This behavioral thermoregulation was noted by Williams et al. (1989) in July 1987, when presumed high temperature induced mortality was observed and chubs congregated in cooler portions of the lake.

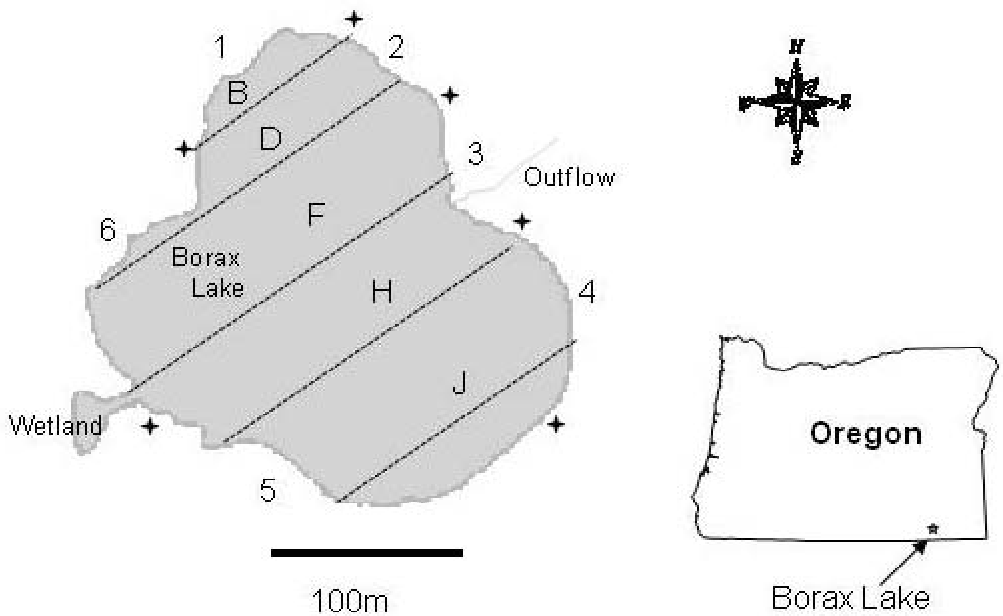

Figure 1. Map of Borax Lake showing the locations of shoreline transects (numbered 1 through 6; bounded by stars), open water transects (dotted lines lettered B, D, F, H, and J), the outflow channel, and the wetland. Data regarding numbers of fish captured and the ratio of recaptures to catch were summarized according to these strata when the 2010 population estimate was obtained. Transects, and their associated letter designations, were based on those developed by Scoppettone et al. (1995).

Table 1. Details of mark-recapture population estimates for Borax chub, 2005-2010.

					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
2008	1,127	1,879	170	**12,401**	10,681	14,398
2009	2,087	2,676	395	**14,115**	12,793	15,573
2010	5,263	5,122	1,057	**25,489**	23,999	27,071

Shoreline Pedestrian Surveys

When we conducted shoreline pedestrian surveys, we found most of the shoreline was in good condition. However, we did observe localized areas on the northern shore with recent off-road vehicle damage. We have not observed any notable change in shoreline conditions over the past six years.

Table 2. Ratios of marked fish to total catch of Borax chub during the recapture portion of the population estimate, listed by transect location. Locations are shown in Figure 1.

Location	Number of traps	Marked	Catch	Recaptures	Recaptures/ catch
Shoreline- 1	11	886	1,001	236	24%
Shoreline- 2	11	1,054	689	164	24%
Shoreline- 3	10	796	805	164	20%
Shoreline- 4	10	581	380	87	13%
Shoreline- 5	15	64	223	30	27%
Shoreline- 6	8	213	199	54	23%
Transect J	6	169	188	37	13%
Transect H	7	308	221	47	21%
Transect F	7	225	295	50	17%
Transect D	7	212	160	28	18%
Transect B	6	264	245	45	18%
Outflow	6	185	365	68	19%
Wetland	10	306	351	47	13%
	114	5,263	5,122	1,057	21%

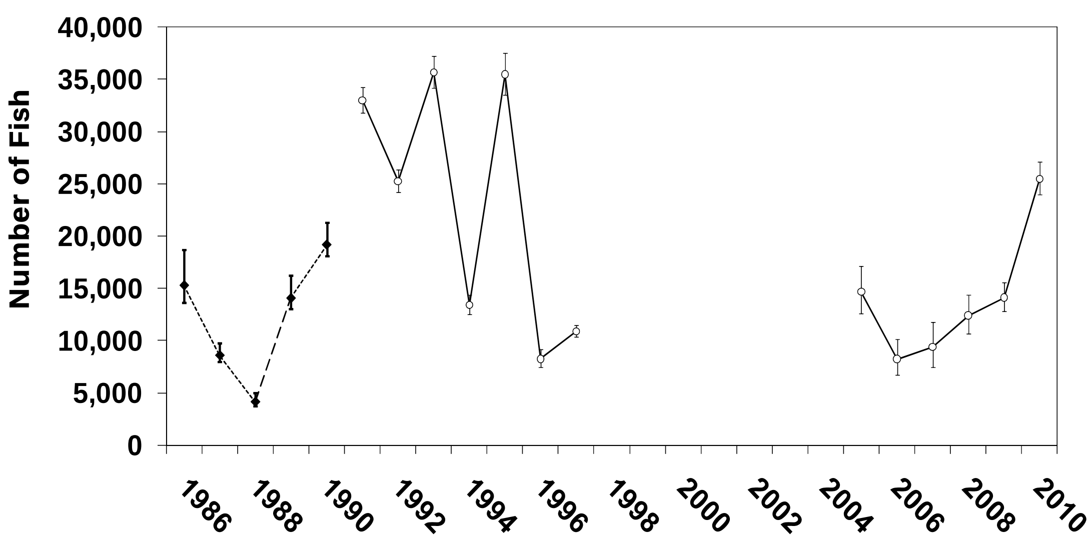

Figure 2. Borax Lake chub population abundance estimates from 1986 through 1997 and from 2005 through 2010. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols), the entire lake was trapped. Estimates are not directly comparable across these time periods (Salzer 1992).

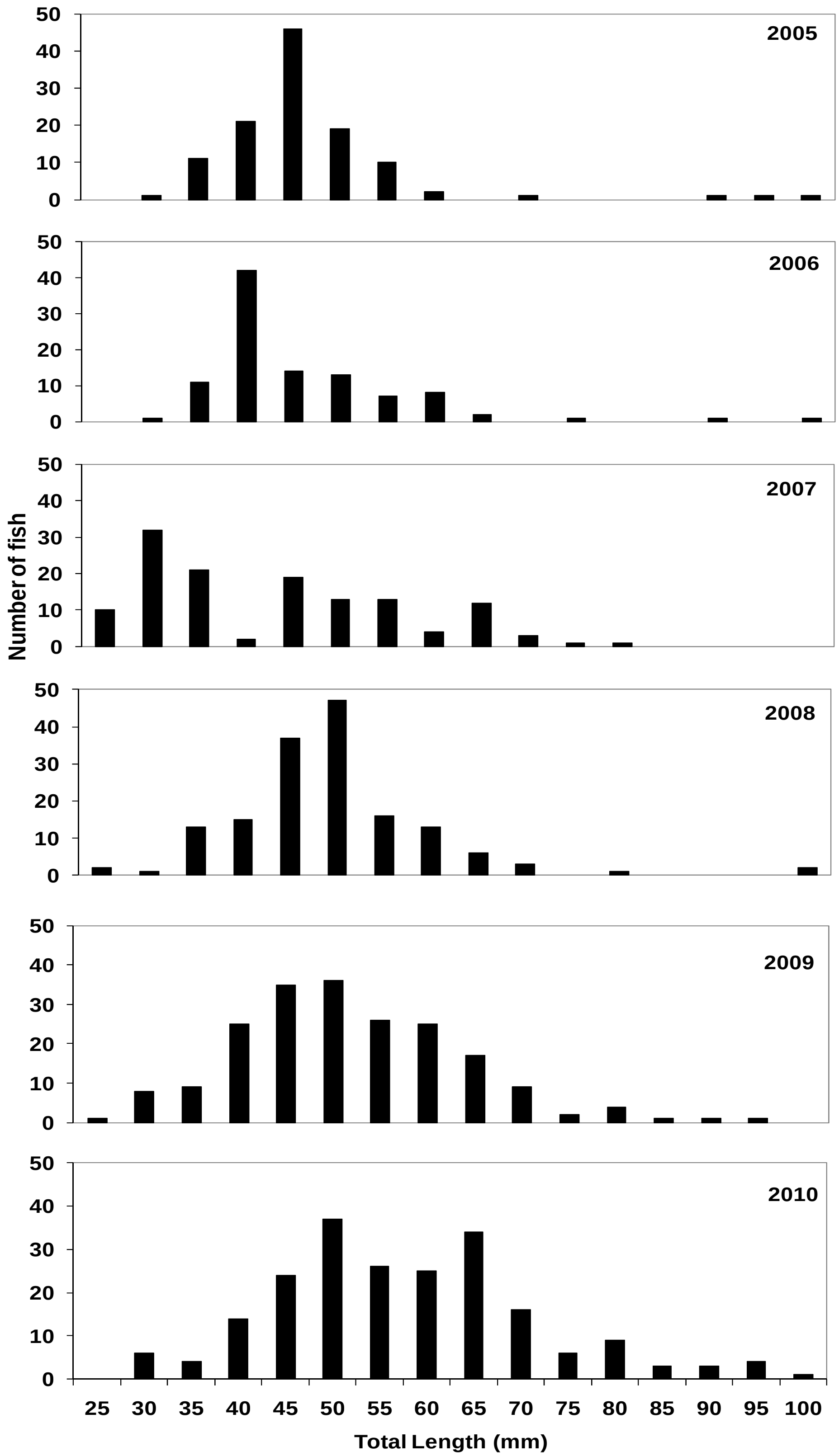

Figure 3. Length-frequency histograms for Borax Lake chub collected in mid-September, 2005-2010.

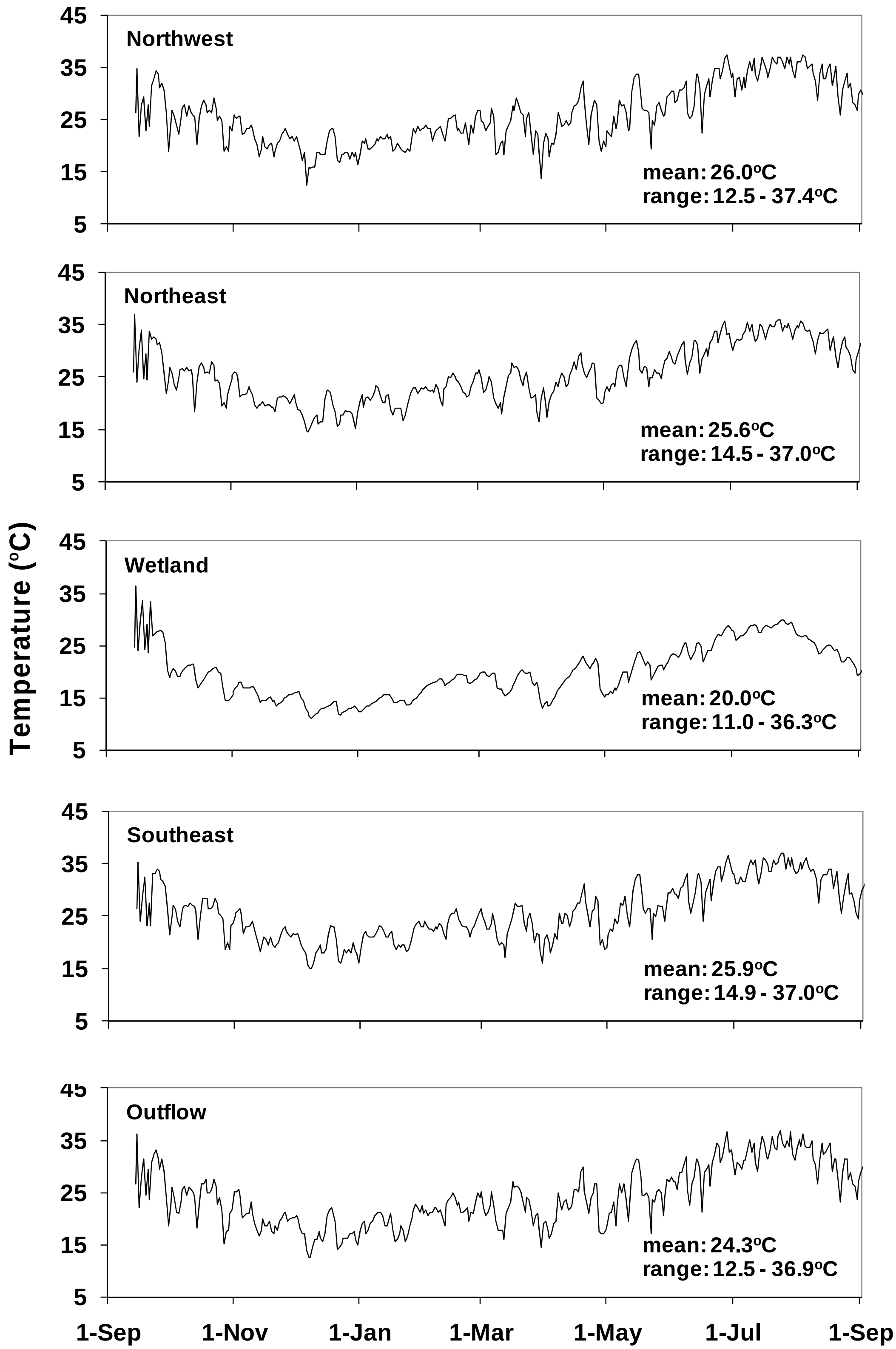

Figure 4. Water temperatures recorded at five locations in Borax Lake from September 2009 through September 2010.

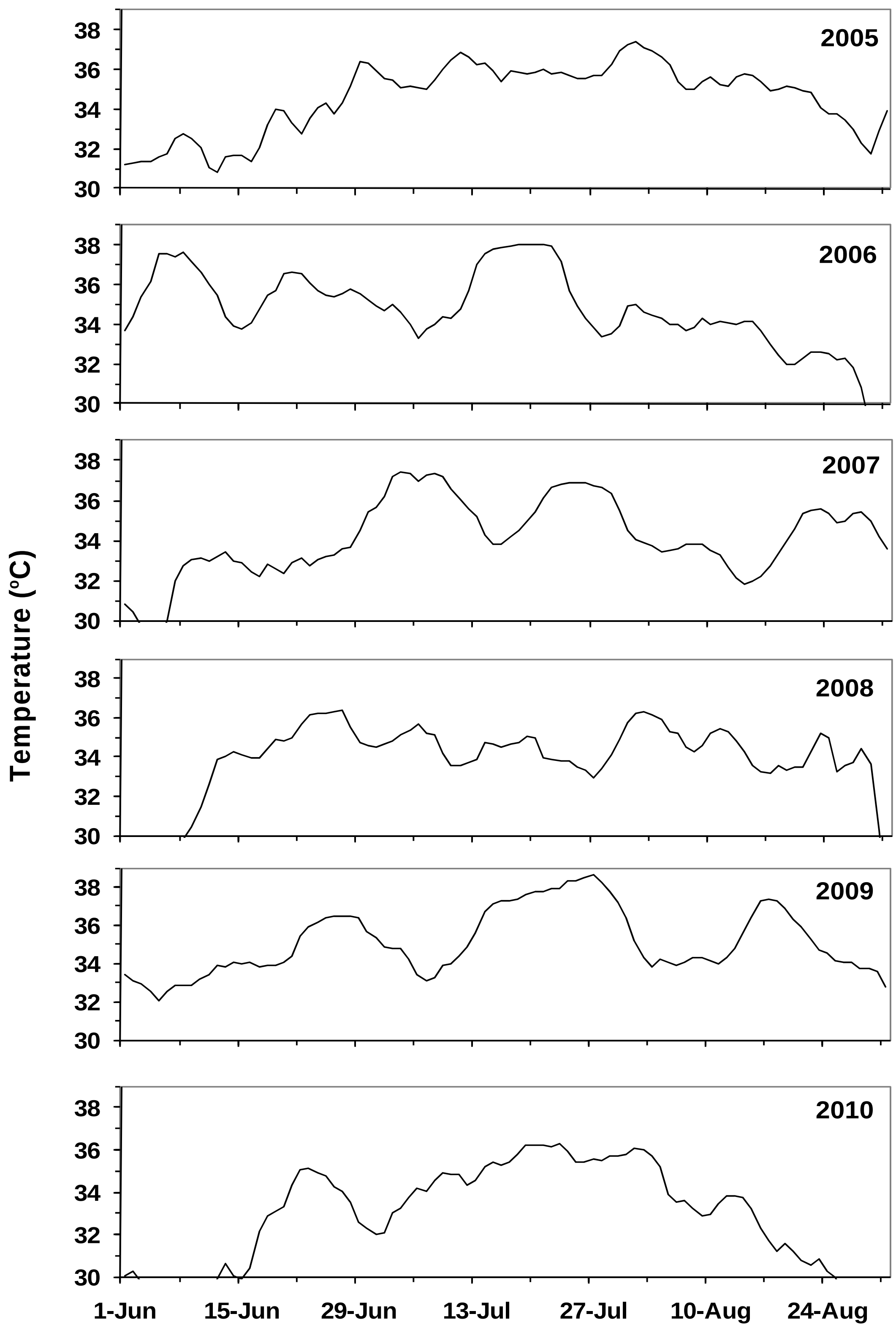

Figure 5. Seven-day running averages of maximum daily temperatures recorded on the northwestern shoreline of Borax Lake, 2005-2010. Note: temperatures in early-June 2010 were less than 30°C.

DISCUSSION

The Recovery Plan for the Borax Lake Chub states that "The Borax Lake chub will be recovered when complete control exists over management of surface and subsurface waters by The Nature Conservancy or a public resource agency within the 640 acres of critical habitat; and when a self-sustaining population of Borax Lake chubs has been maintained free of threats for five consecutive years". To reach recovery, 1) Borax Lake must be protected from disturbance, 2) outflows must be channeled in such a fashion that Borax Lake is protected and historic wetland habitats for the species are restored, 3) disturbance to fragile salt-crust shoreline must be prevented, 4) the underground water system (geothermal aquifer) must be maintained in its natural condition, and 5) Borax Lake chub must exist throughout its native ecosystem without threats (U.S. Fish and Wildlife Service 1987).

There has been substantial progress made towards recovery of Borax Lake chub, but two main threats to the species and its habitat remain. The primary remaining threats include habitat degradation of the lake shoreline, resulting from increased recreation use in the area, 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).

To address protection of the fragile lakeshore, BLM's Resource Management Plan includes implementation actions which address restricting vehicle access, recreational boat use, and vehicle parking to protect Borax Lake and its fragile shoreline. In 2010, work was initiated by BLM and TNC to construct a perimeter fence to exclude vehicles from the lake and to install interpretive signs.

Regarding potential geothermal development on private lands, in 2009 Pueblo Valley Geothermal proposed to develop a geothermal energy project on 2,000 acres of private land within 5 km of Borax Lake. The development of geothermal energy has the potential to have adverse effects on Borax Lake and the Borax Lake chub. These potential effects include impacts to the lake's water elevation, if drilling disrupts the hot water aquifer that supplies the lake, thus changing lake inflows or temperature. In response to this proposed geothermal development and to address concerns outlined in the recovery plan (U.S. Fish and Wildlife Service 1987), a multi-agency recovery team, consisting of representatives from BLM, USFWS, TNC, and ODFW, was assembled in 2010 to identify the information/research needed to assess the potential short and long-term effects of geothermal development on private lands on Borax Lake and the Borax Lake chub.

In 2010, we estimated the abundance of Borax chub at approximately 25,000 fish, similar to some of the highest estimates from the early 1990's. This is a significant increase over the 2009 estimate and was double the average of approximately 12,000 fish estimated in 2005 through 2009. From previous analyses, we did not find evidence that the estimates from the early 1990's were biased (Scheerer and Jacobs 2009). In 2010, we recorded substantially cooler lake temperatures than those recorded in 2006 through 2009, which may have been responsible for improved chub survival.

The physical habitat conditions at Borax Lake in 2010 did not differ from those reported in the past (Williams and Bond 1983; Scoppettone et al. 1995; Scheerer and Jacobs 2005; 2006; 2007; 2008; 2009), except that water diversions were discontinued in

1993, resulting in higher lake elevations. During shoreline surveys, we found evidence of continued off-road vehicle usage.

In 2009 BLM biologists discovered chub in a small pond located ~400 m northeast of Borax Lake. Preliminary examination of these chub by Dr. Markle, Oregon State University, indicates that they are Alvord chub, *Gila alvordensis*. This finding was unexpected, considering the close proximity of the pond to Borax Lake and the apparent overland seepage that connects Borax Lake to the pond.

We recommend continued future investigations at Borax Lake that include obtaining mark-recapture population estimates using protocols that limit handling to approximately 20% of the total population size (Scheerer and Jacobs 2009). Because Borax Lake chub are short lived and presumed to be an annual species, i.e. most fish are $\leq$1 year old (Scoppettone et al. 1995), we feel that this sampling should be conducted at least every 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 validate and assess changes in age structure over time, to determine the timing of annulus formation, and to identify size/age-at-maturity. To assess the condition of the fragile lake crust, we recommend continuing annual shoreline pedestrian surveys. We also recommend continued lake water temperature and habitat monitoring to provide baseline data and to monitor the effects of recently proposed geothermal development, if it is permitted to occur on private lands near Borax Lake. We propose mapping the lake bathymetry and installing a water level monitor to monitor changes in lake levels, per methods developed by Bangs et al. (2010). 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 reduce the impacts of off-road vehicular traffic and to educate the public.

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