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Oregon Department of Fish and Wildlife

2011 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 borosilicate 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 from proposed 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 have fluctuated between ~4,100 and 37,000 fish (Salzer 1997; Scheerer and Jacobs 2010). The basis for the Borax Lake chub's listed status was not population size, but the vulnerability 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 and have a dramatic effect on 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, primarily by protecting the 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 large portion of the basin. In addition, detailed studies of the chub and their habitat 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 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 delist the species. Under the RMA, the cooperators (BLM, TNC, U.S. Fish and Wildlife Service, and Oregon Department of Fish and Wildlife) 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).

This report describes results from monitoring conducted by Oregon Department of Fish and Wildlife's Native Fish Investigations Project (NFIP) in 2011. 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 seventh 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 captured chub using baited minnow traps (N=115, 1/16" mesh). We distributed the traps approximately every 25 m along transects that crossed the lake and along the shoreline (see Scheerer and Jacobs 2010) and left them in place overnight (~16 h). We also placed traps in the associated wetland and in the outflow channel. In addition, we fished a small fyke net (1/8" mesh) at the mouth of the wetland channel, which also acted as a block net to prevent movement of chub in and out of the wetland. Following capture, we marked fish with partial caudal fin clip and measured the total length (TL) of a sub-sample of fish (N=287). After all fish were marked, we returned them to the water by distributing them evenly throughout the lake. The same night, we set the traps at approximately the same location. The traps were cleared the following morning and 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 calculated abundance estimates separately for the lake, the outflow, and the wetland. Trapping was conducted on the nights of September 26 and 27, 2012

We assessed the recent trend in population abundance by calculating a linear regression of abundance over time for the past seven 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).

We monitored water temperatures (°C) at five locations using Hobo® recording thermographs from 22 September 2010 to 28 September 2011. Temperature was recorded at 1 h intervals.

We assessed the condition of the lake's shoreline, the wetland, and the outflow channels from pedestrian surveys established in 2005 (Scheerer and Jacobs 2005). In September 2011, we mapped the lake bathymetry, installed piezometers, and surveyed critical site elevations of the lake to describe the current habitat conditions and to document changes in wetted area and water volume that occur with changes in water elevation. We installed a Hobo® U20 water level data logger (piezometer) in the northwest end of the lake. We placed the piezometer into a length of 5 cm diameter polyvinyl chloride (PVC) pipe that extended from the lake substrate approximately 0.3 m. We suspended the piezometer ~0.05 m above the substrate of the lake by attaching it to a length of wire which was connected to an eye bolt inserted through a threaded PVC cap. We glued a PVC cap to the bottom of the pipe and drilled holes in the side of the PVC pipe, from top to bottom. We covered the pipe with a well sock to minimize sediment movement into the pipe. We installed a staff gage on the outside of the PVC pipe, outside of the well sock, and secured both the sock and staff gage to the pipe using heavy duty, UV-resistant cable ties. We anchored the PVC pipe casing to the lake bottom with a 20×20 cm cinder block and installed the pipe vertically (perpendicular to the water surface). To further anchor the casing and to maintain vertical orientation, we attached the casing to a metal "T" fence post driven ~0.5 m into the substrate. After the piezometer was installed, we recorded the Universal Transverse Mercator (UTM) coordinates of the unit. We measured the corresponding depth of the piezometer on the staff gage at the time of installation. To adjust water level readings for changes in barometric pressure, we installed a second piezometer in the greasewood thicket on the southeast side of the lake. Note that these data loggers also record water and air temperatures in the lake and greasewood thicket, respectively.

To identify critical water elevations below which the lake and the wetland are disconnected and calculate reductions in water volume/area that would result from changes in lake elevations, we used a rotating laser level, laser sensor, and telescoping survey rod to record lake widths and depths (±0.05 m) every 3-5 m along regularly spaced transects (~25 m apart). We recorded UTM coordinates at each location where depth measurements were taken. We collected the UTM coordinates in North American Datum 1927 (NAD27) coordinate system and projected them in Transverse Mercator. At each location where depth was measured, we noted the presence or absence of aquatic vegetation and recorded the dominant substrate type (silt and organics, sand, gravel, cobble, boulder, and bedrock or stromatolites), following the protocol of Moore et al. (2008). We recorded all depth measurements from the bank full lake elevation to the lake substrate. When deep silt was encountered, measurements were taken to the top of the substrate, to describe only the open water habitat that was available for fish to use. We used the laser level to reference the initial water level monitor reading with the initial lake water level (on the staff gage) at the time when we installed the water level monitor and will do so again each time when we download the data from the monitoring device. We used ArcGIS® (version 9.3.1) to generate a Triangulated Irregular Network file from the surveyed geographic coordinates and measured depths. We used this file to generate bathymetric contour maps using ArcGIS®.

RESULTS

Population Estimate

In 2011, the estimated population size of Borax lake chub was 26,571 fish (95% CI: 24,946-28,301). The fish ranged in size from 18–107 mm TL. This estimate was significantly higher ($p<0.05$) than the estimates from 2005 through 2009 and similar to the estimate from 2010 (Table 1; Figure 1). The population has exhibited an increasing trend in abundance over the past seven years ($p=0.036$). However, the 2010 and 2011 abundance estimates were still less than the peak estimates obtained in the early 1990's. We captured a broad range of sizes (TL) with no discernible age-classes, similar to results from prior years (Figure 2).

Table 1. Details of mark-recapture population estimates for Borax chub, 2005-2011.

					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
2011	5,127	4,994	963	**26,571**	24,949	28,301

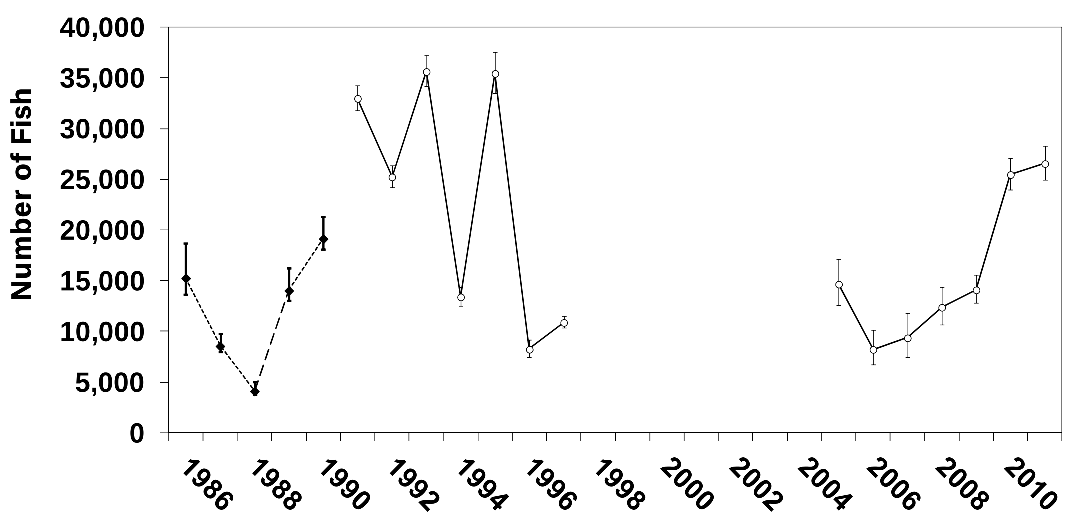

Figure 1. Borax Lake chub population abundance estimates (1986-1997 and 2005-2011). Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols), the entire lake was trapped. Estimates are not directly comparable across these time periods (Salzer 1992).

Water Temperatures

The pattern of change in water temperature was similar at all sites throughout the lake between September 2010-September 2011. Peak temperatures (26.5°C to 38.3°C) were observed in July and August (Figure 3). Average water temperatures in the main portion of the lake ranged from 24.1 to 26.7°C. The average water temperature was substantially cooler in the wetland (18.4°C) (Table 2). Daily temperature fluctuations were typically less than 5°C. We observed intra annual differences in the 7-day running average maximum daily temperatures recorded on the northwestern shoreline of Borax Lake. Water temperatures were cooler in the summers of 2008, 2010, and 2011than in 2005-2007 and 2009 (Figure 4). The temperatures in 2010 and 2011 were significantly cooler than in 2009 along the northeast and northwest shorelines and in the wetland, significantly warmer than in 2009 along the southeast shoreline, and similar to previous years in the outflow channel ($p<0.05$) (Table 2). The 7-day average maximum temperatures in the lake in 2011 represent some of the most extreme conditions that exist in the lake, and rarely exceeded the species critical thermal maximum of 34.5°C (Williams and Bond 1983). In past years, this hasn't always been the case (Scheerer and Jacobs 2009; 2010). However, fish can seek refuge from the warmest temperatures by moving to cooler areas of the lake, including the wetland (Figure 3). 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.

Table 2. Comparison of mean temperatures recorded at five locations in Borax Lake, 2009-2011. 95% confidence intervals are shown in parentheses. Comparisons of means between years at locations which have matching superscripts are significant ($p<0.05$).

	Location				
Year	Wetland	NE	Outflow	SE	NW
2009	23.0[a]	27.9[a]	24.6	22.9[a]	27.3[a]
	(22.4-23.6)	(27.2-28.5)	(24.0-25.3)	(22.2-23.5)	(26.7-28.0)
2010	20.0[a]	25.6[b]	24.3	25.9[b]	26.0[b]
	(19.5-20.5)	(25.1-26.1)	(23.8-24.9)	(25.3-26.4)	(25.4-26.6)
2011	18.4[b]	26.3[b]	24.1	25.3[b]	25.6[b]
	(17.9-18.9)	(25.6-26.9)	(23.4-24.7)	(24.6-25.9)	(25.0-26.2)

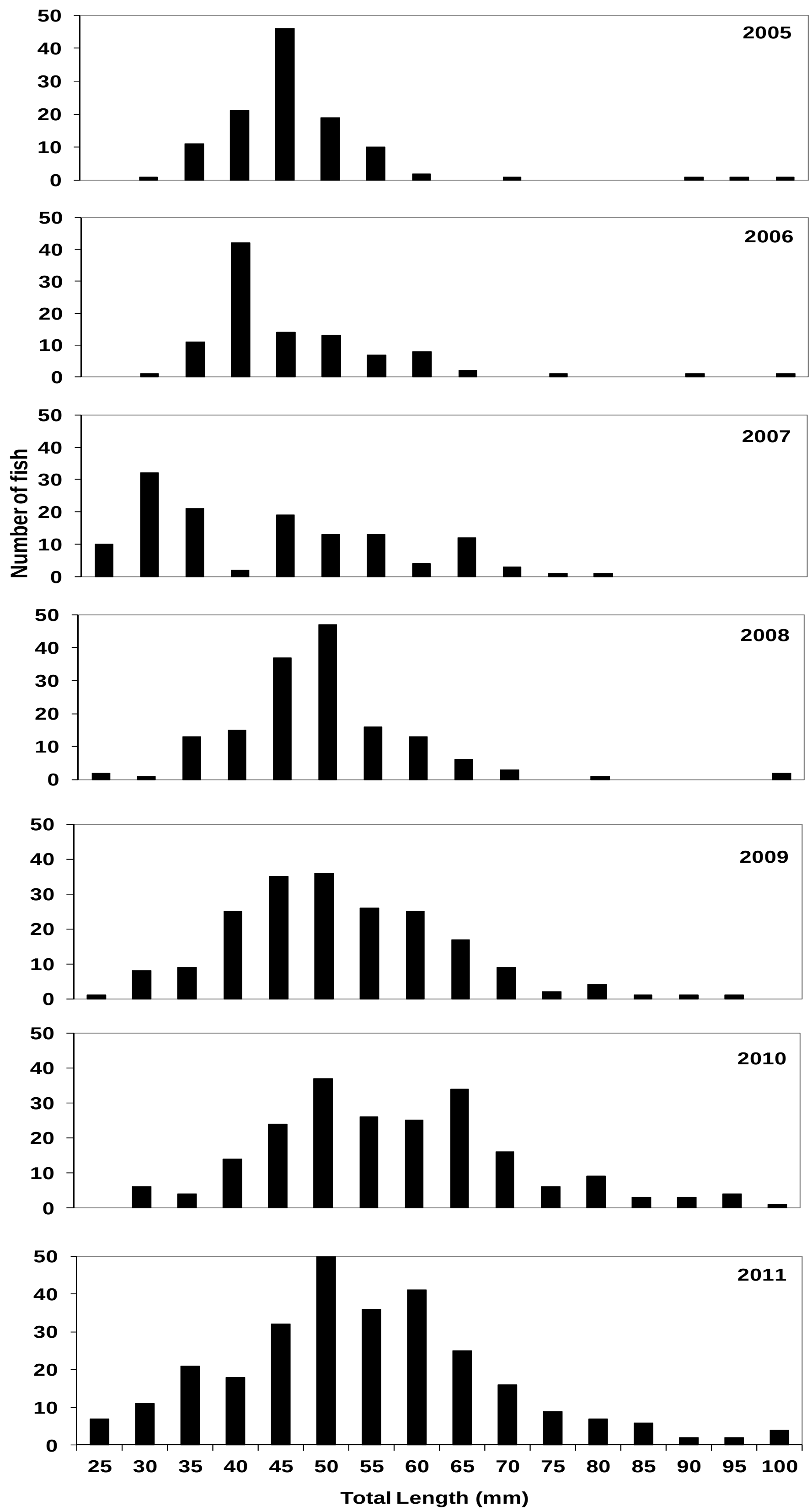

Figure 2. Length-frequency histograms for Borax Lake chub, 2005-2011.

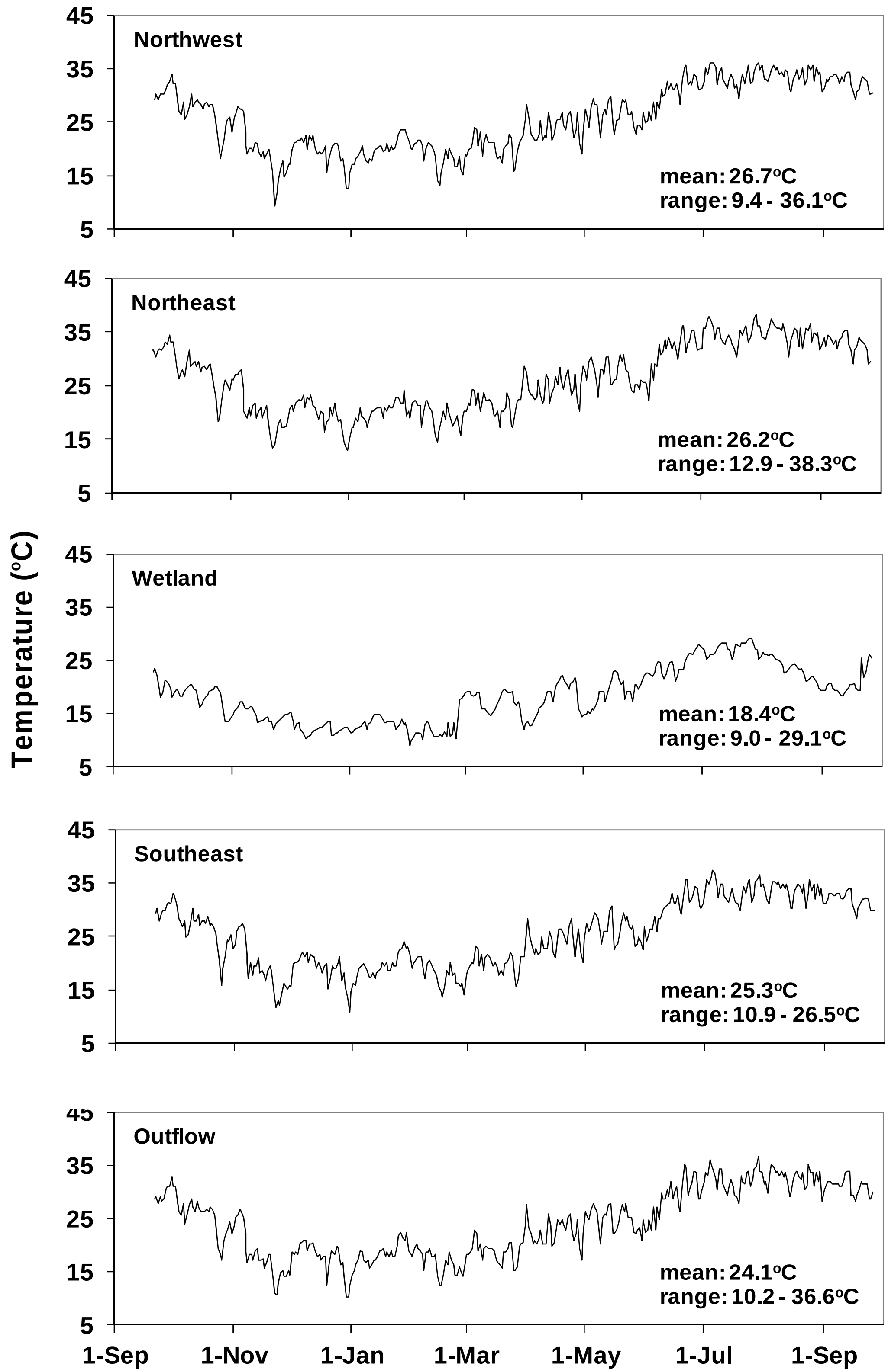

Figure 3. Water temperatures recorded at five locations in Borax Lake from September 2010 through September 2011.

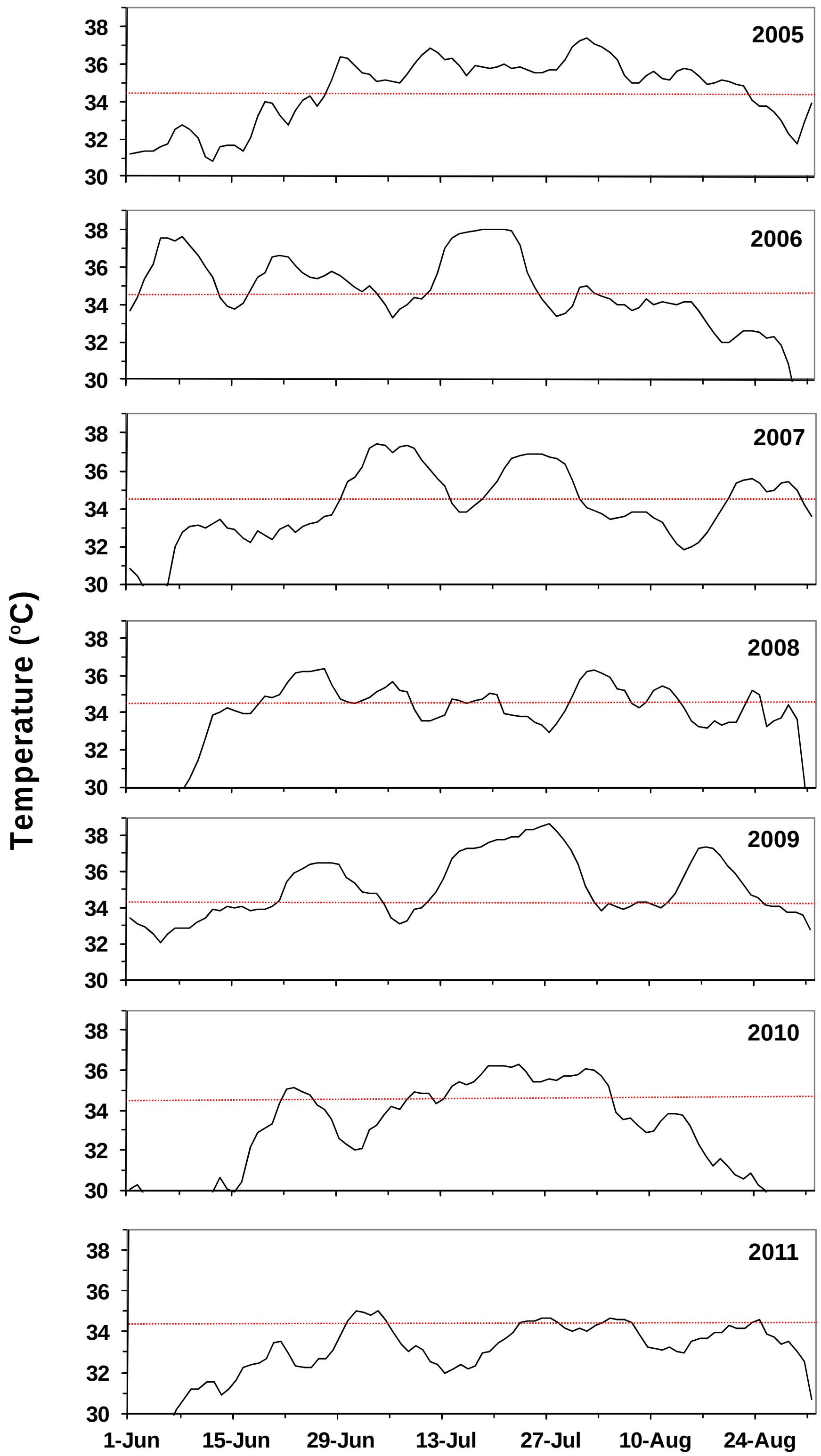

Figure 4. Seven-day running averages of maximum daily temperatures recorded on the northwestern shoreline of Borax Lake, 2005-2011. Red lines denote the critical thermal maximum temperature of 34.5°C for Borax chub. Note: temperatures in early-June 2007, 2008, 2010, and 2011 were less than 30°C.

Shoreline Surveys and Habitat Mapping

The majority 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 documented any recent changes in the shoreline habitat conditions at Borax Lake (Scoppettone et al. 1995; Scheerer and Jacobs 2005; 2006; 2007; 2008; 2009; 2010).

We mapped the bathymetry of Borax Lake, including the wetland, and created maps showing the spatial distribution of lake depths and temperatures (Figures 5-6). The wetted surface area and volume of the lake were 39,117 m^2 and 15,460 m^3, respectively. The lake substrate was dominated by flocculent silt substrate (76%), with smaller proportions of bedrock/stromatolites (22%) and gravel (2%). Bedrock/stromatolites and gravel were limited to a narrow band on the eastern shore of the lake. Aquatic vegetation in the lake was sparse, however approximately 61% of the lake had some stonewort (*Chara hornemannii*) growing from the flocculent substrate. Dense aquatic vegetation surrounded the wetland, which was dominated by Olney's rush (*Scirpus olneyi*) and beaked spikerush (*Eleocharis rostellata*). Although we did not map the lake's riparian vegetation, it was composed of a mix of alkali saltgrass (*Distichlis stricta*), greasewood (*Sarcobatus vermiculatus*), Baltic rush (*Juncus balticus)* and shadscale (*Atriplex confertifolia*) (Furnish et al. 2004). We identified the water elevation when the wetland would become disconnected from the lake (0.25 m drop). We also calculated the effects of reduced water elevations on habitat area/volume. For example, if lake elevations were reduced by 0.5 m, then wetted area and volume would decrease 36% and 14% respectively. If lake elevations were reduced by 1.0 m, then wetted area and volume would decrease by 71 and 61% respectively (Figure 7). Only the vent and wetland would be wetted if water elevations were reduced by 1.5 m.

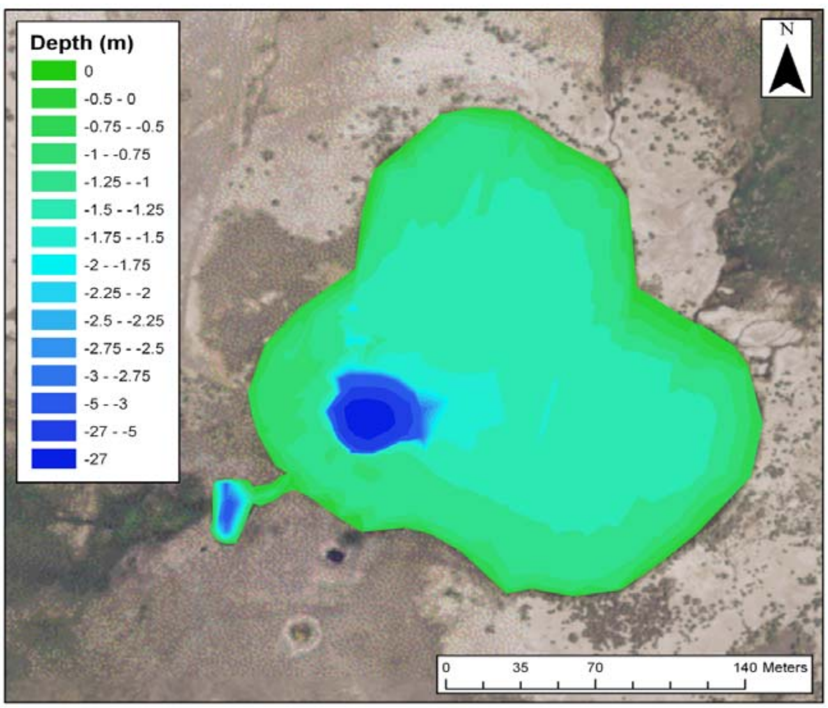

Figure 5. Map of the bathymetry of Borax Lake on 28 September 2011.

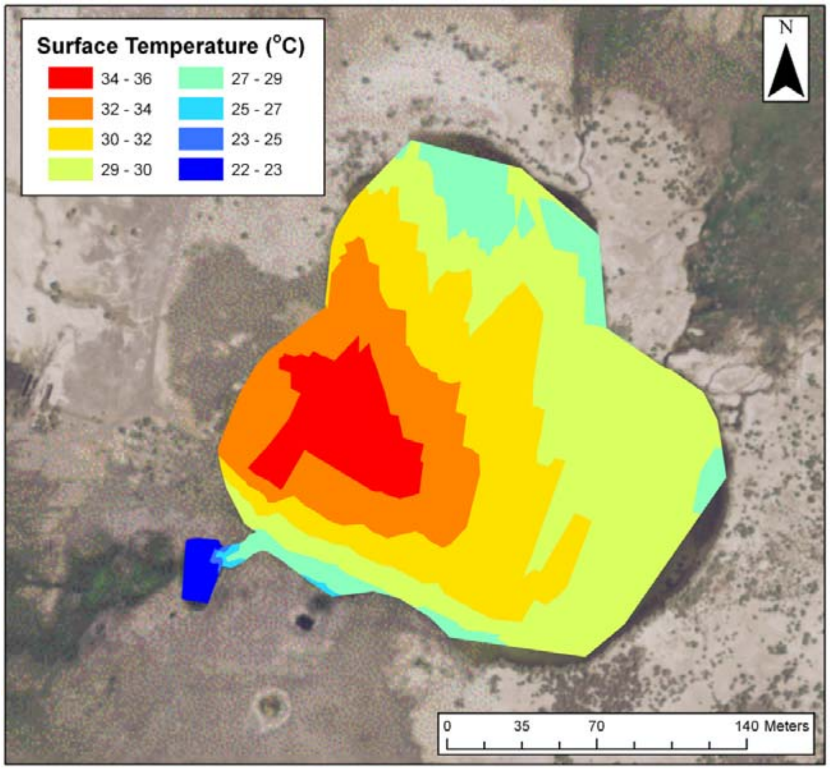

Figure 6. Map showing the spatial distribution of pond temperatures in Borax Lake on 28 September 2011.

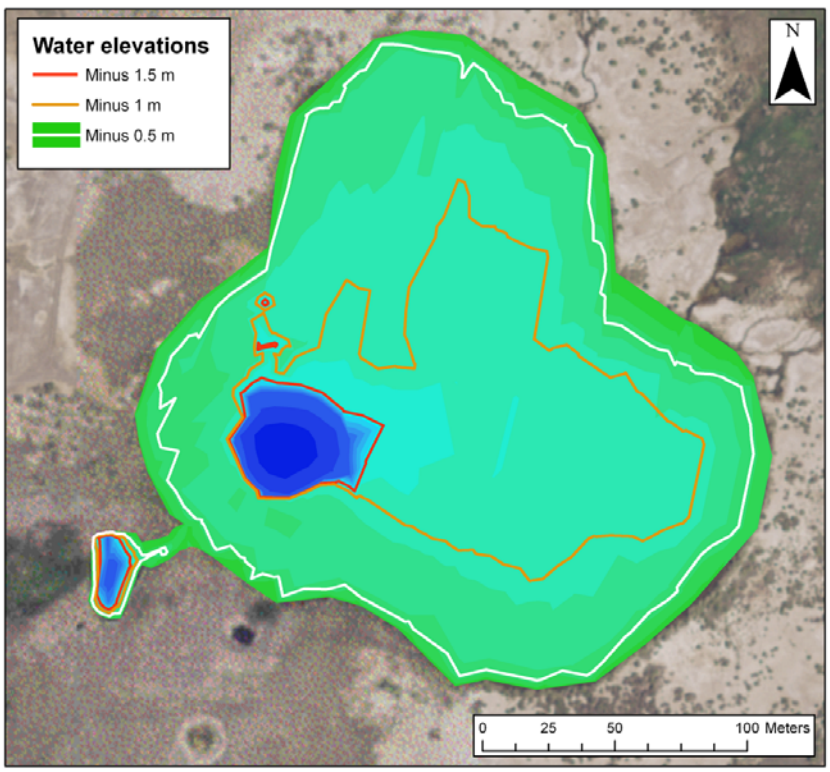

Figure 7. Map showing the limits of wetted surface area if water elevations were reduced by 0.5 m, 1.0 m, and 1.5 m from the level recorded on 28 September 2011.

DISCUSSION

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 included implementation actions to restrict vehicle access, recreational boat use, and vehicle parking to protect Borax Lake and its fragile shoreline. In 2011, BLM and TNC completed a perimeter fence to exclude vehicles from the lake. To date, no locks have been installed on the gates, thus limiting the effectiveness of the fence. There are plans to install educational interpretive signs near the lake (biological, geological, and historical/archaeological). We encourage the BLM and TNC to complete the design and install these signs in the near future.

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 a decrease in the lake's water elevation, if drilling disrupts the hot water aquifer that supplies the lake, through changes in lake inflow and/or changes in water temperatures. 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.

To monitor the effects of future geothermal development, if it occurs, within the aquifer that supplies water to Borax Lake, ODFW mapped the lake bathymetry and installed water level monitors in 2011. The data that we will acquire in the next few years will be used to describe the natural, seasonal variability in lake elevations, the quantity, quality, and availability of different lake habitats, and the connectivity of the lake and wetland. This baseline information can be used, if needed, to assess the effects of future groundwater mining on Borax chub and their habitat. For example, if groundwater extraction reduces lake inflows and lake elevations are reduced, this could restrict the connectivity of the lake and the wetland (the channel connecting the two is very shallow). If connectivity is eliminated, then the chub would not have access to the cooler waters in the wetland during periods of thermal stress (high lake temperatures), which could negatively affect their survival. Also, reduction in water levels could affect recruitment. The sand, gravel, and stromatolite (bedrock) substrates which were areas where the majority of chub protolarvae ($\leq$6 mm) were captured, are presumably the same areas that are used for spawning, exist only in the shallow, near-shore areas of the lake and reduced water levels could significantly decrease reproductive success (Perkins et al. 1996).

Borax Lake chub continue to be abundant. For the past two years, the estimated abundance of Borax chub has increased significantly, totaling over 25,000 fish. The

2010 and 2011 estimates were more than double the average abundance from 2005 through 2009 and nearly as large as the peak estimates obtained in the early 1990's. In 2010 and 2011, we recorded substantially cooler lake temperatures than those recorded in 2006 through 2009. Although interpretation of the length frequency histograms is complicated by the short life spawn and protracted spawning period of the species, these data suggest that the recent increase in chub abundance is primarily a result of increased survival, rather than increased recruitment.

We recommend continuing research and monitoring at Borax Lake, particularly to obtain population estimates and monitor habitat conditions. Because Borax Lake chub are short lived and presumed to be an annual species, i.e. most fish are <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. Research should be directed to identify which are environmental factors and habitat conditions responsible for the large fluctuations in annual abundance. To assess the condition of the fragile lake crust, we recommend continuing annual shoreline pedestrian surveys. To provide baseline data for monitoring the effects of proposed geothermal development on private lands near Borax Lake, we recommend continued monitoring of lake water temperature and water elevation. To assess changes in Borax Lake chub age structure over time and to identify size/age-at-maturity, we recommend the initiation of a proposed ageing study. We also recommend the initiation of a proposed genetic study to describe the relationship between Borax Lake and Alvord chub (*Gila alvordensis*); results of which could have implications on the conservation and listing status of both species.

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