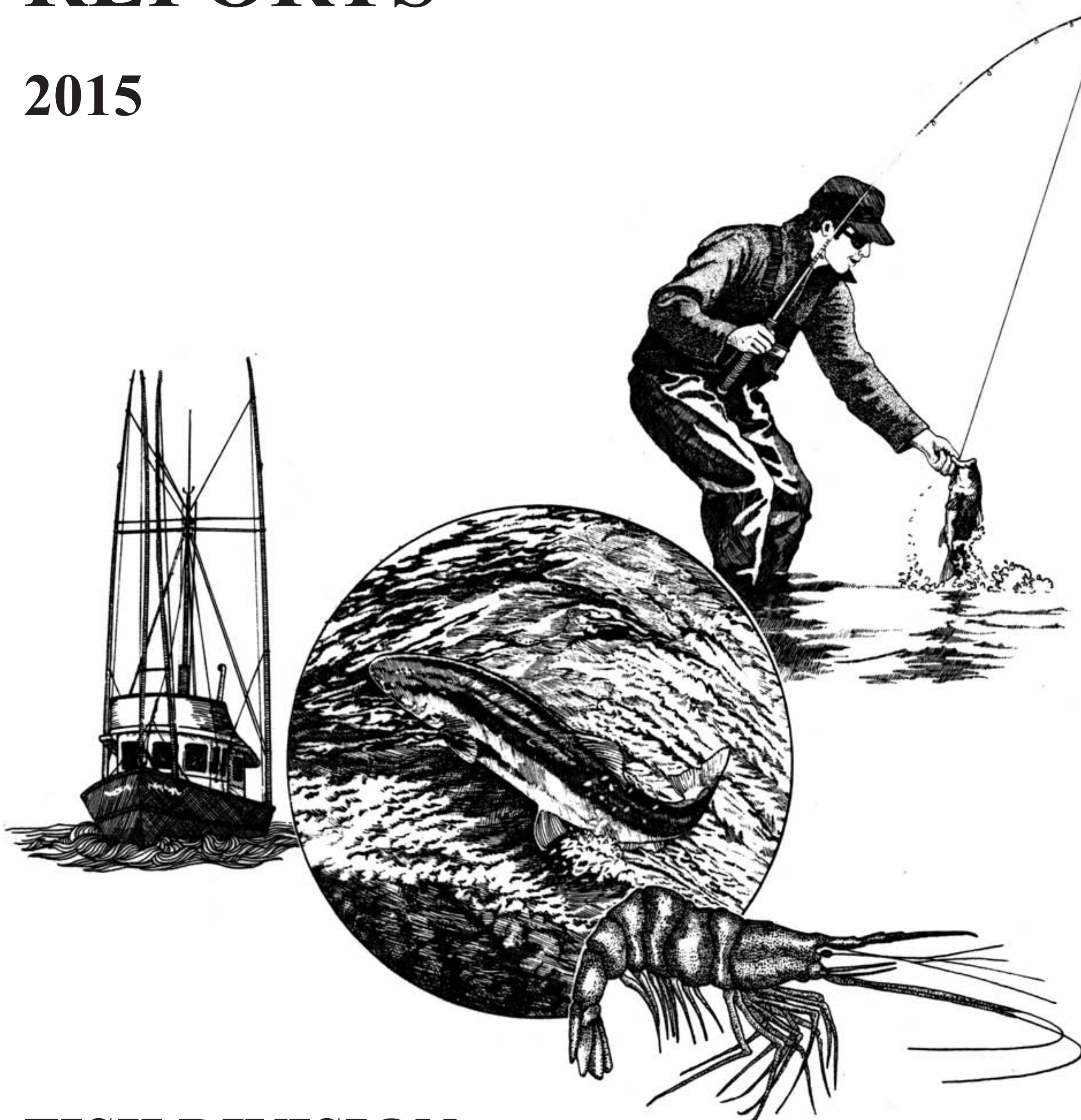
PROGRESS REPORTS

2015



FISH DIVISION

Oregon Department of Fish and Wildlife

2015 Borax Lake Chub Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: **2015 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 from 1991-2012 fluctuated from approximately 4,100 to 37,000 fish (Salzer 1997; Scheerer et al. 2012). The basis for the Borax Lake chub's listed status was not population size, but the vulnerability of a very limited, unique, and isolated, habitat (U.S. Fish and Wildlife Service 1982). Because Borax Lake is shallow (average depth $\lesssim$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 (Scheerer et al. 2015). 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. The BLM and TNC have since fenced the area surrounding the lake to exclude vehicular access. 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 and provided additional protections for development on private lands. 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).

This report describes results from monitoring conducted by Oregon Department of Fish and Wildlife's Native Fish Investigations Program (NFIP) in 2015. 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 ninth year of this effort. In 2015, our objectives were to: 1) estimate the abundance of Borax Lake chub, and 2) evaluate habitat conditions at Borax Lake, including a description of annual fluctuations in water temperatures and water levels, and the condition of the fragile lake shoreline and outflows.

METHODS

We captured chub using baited minnow traps (N=120, 1.6 mm mesh). We distributed the traps approximately every 25 m along transects that crossed the lake and along the shoreline (Figure 1) and left them in place overnight (~16 h). We also placed traps in the associated wetland and in the outflow channel. Following capture, we recorded the number fish in each of three size categories (small <35 mm TL, medium 35-59 mm TL, and large $\geq$60 mm TL), and measured the total length (TL) of a sub-sample of fish (N=335). After all fish were counted, we returned them to the water by distributing them evenly throughout the lake. The same afternoon, we set the traps at approximately the same locations. The following morning, we cleared the traps and recorded the number of fish in each size category. We conducted the trapping on the nights of 14-15 October 2015.

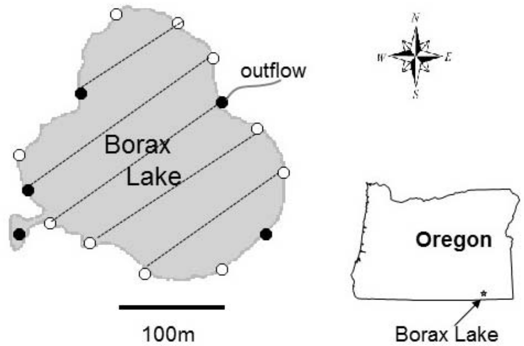

Figure 1. Map of Borax Lake showing the locations of open water transects (dotted lines), the outflow channel, the wetland, shoreline photo points (all circles) and thermographs (black circles only). Transects were based on those developed by Scoppettone et al. (1995).

We estimated the abundance of chub separately for the Borax Lake, the wetland, and the outflow channel using a state space model (Bolker 2008), which allows us to vary capture probabilities for different sized fish and habitats. Here the capture of fish was assumed to follow a binomial distribution:

$$c_{i,j,k} \sim bin(\hat{p}_{i,j,k}, \hat{N}_{i,j}),$$

where *c* is the number of fish captured, *p* is the estimated capture probability, and N is the estimated abundance for size class *i* in habitat *j* on sampling occasion *k*. Capture probabilities were estimated using the best approximating Huggins capture recapture models from Scheerer et al. (2012) which allowed us to reduce fish handling in 2015, compared to 2012 (two sampling occasions rather than three sampling occasions), and required no additional marking of the fish. Variability in the estimated capture probabilities was incorporated using a beta distribution with parameters that corresponded to the mean estimated capture probability and associated standard errors. The state space model was fit using Markov Chain Monte Carlo (MCMC) as implemented in WinBUGS software, version 1.4 (Lunn et al., 2000) with 10,000 iterations, 20,000 burn in and diffuse priors. These values were determined by fitting the model with 10,000 iterations and evaluating the output with the Raftery and Lewis (1995) diagnostic as implemented in the R package Coda (Plummer et al. 2006). We calculated 95 percent confidence intervals for the estimates according to Chao (1987).

We monitored water temperatures (ºC) at five locations with Hobo® recording thermographs. The thermographs recorded temperature at 1 h intervals. We downloaded data (water elevations and temperatures) from the piezometers we installed in 2011 (Scheerer and Bangs 2011), to describe the changes in wetted area and water volume that occur due to seasonal fluctuations in water elevation.

We assessed the condition of the lake's shoreline, the wetland, and the outflow channels from pedestrian surveys and photo points that we established in 2005 (Scheerer and Jacobs 2005).

RESULTS

Population Estimate

We estimated the 2015 abundance of Borax Lake chub to be 1,242 fish (95% CI: 1,077-1,456), which is significantly less than the last estimate of 9,702 fish (95% CI: 9,042-10,452), obtained in 2012. The 2015 estimate was also the lowest on record (Figure 2). The largest declines in abundance occurred in the lake and outflow channel, and were most apparent in the smaller size classes (Table 1).

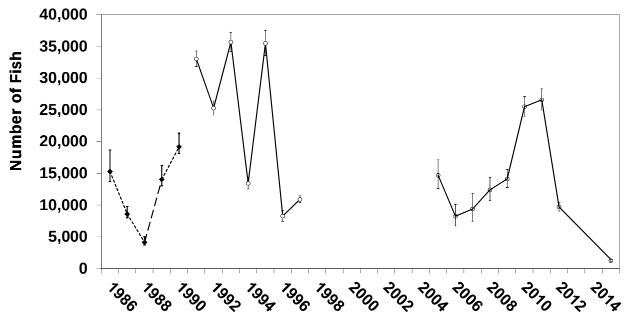

Figure 2. Borax Lake chub population abundance estimates obtained since 1986. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols), the entire lake was trapped. Estimates are not directly comparable across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

Table 1. 2012 and 2015 Borax Lake chub abundance estimates by habitat type. Note, 2012 was the last year when we obtained an abundance estimate at Borax Lake. Abundance estimates were significantly different between years (for any location-fish size combination) when the 95% confidence intervals did not overlap.

	2015			2012			
		95% Confidence intervals			95% Confidence intervals		Percent
Location	Estimate	Lower	Upper	Estimate	Lower	Upper	change
All areas							
Small	**197**	99	351	**2716**	2470	2997	-92.7%
Medium	**567**	496	643	**6432**	6018	6910	-91.2%
Large	**478**	378	619	**553**	507	609	-13.6%
All sizes	**1242**	1077	1456	**9702**	9042	10452	-87.2%
Lake							
Small	**7**	0	25	**1890**	1671	2145	-99.6%
Medium	**424**	357	496	**5313**	4712	6068	-92.0%
Large	**132**	58	259	**276**	227	341	-52.0%
All sizes	**563**	415	780	**7479**	6647	8492	-92.5%
Wetland							
Small	**189**	92	342	**584**	476	727	-67.6%
Medium	**142**	119	167	**813**	675	1575	-82.6%
Large	**344**	284	416	**272**	256	292	26.6%
All sizes	**675**	495	925	**1669**	1342	2300	-59.5%
Outflow							
Small	**1**	0	5	**243**	205	311	-99.5%
Medium	**2**	1	4	**306**	282	461	-99.5%
Large	**1**	0	4	**5**	4	104	-81.0%
All sizes	**4**	1	13	**554**	467	931	-99.3%

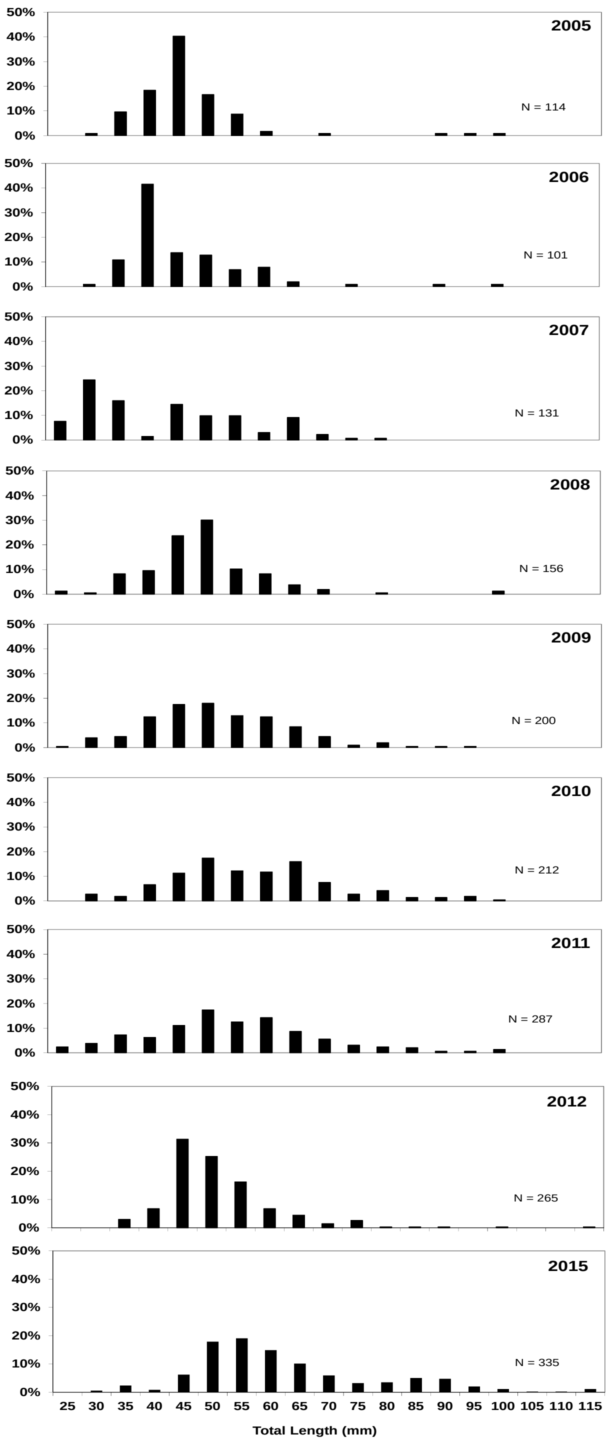

Figure 3. Length-frequency histograms for Borax Lake chub, 2005-2012.

We captured a broad range of sizes in 2015 with two apparent age-classes (Figure 3). The fish captured in 2015 ranged in size from 29-113 mm TL with few small fish <50 mm, suggesting there was minimal recruitment. We captured substantially larger fish in the wetland (the only habitat where we saw an increase in the abundance of large chub) than in the lake or outflow channel and also the presence of some smaller recruits (Figure 4). Additionally, we observed many young-of the-year chub in the wetland (smaller than ~20 mm) that we did not capture in our traps.

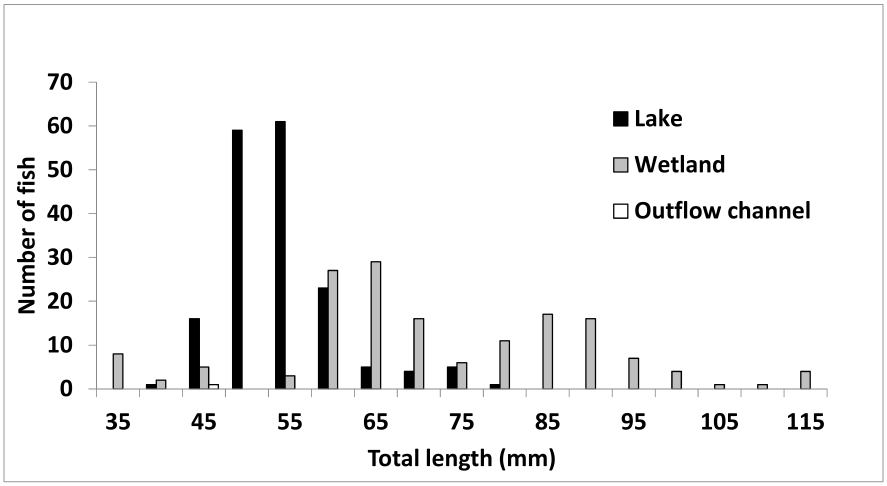

Figure 4. Length frequency histograms for Borax lake chub collected in the lake, wetland, and outflow channel of Borax Lake in 2015. Note, only one chub was collected in the outflow channel.

Water Temperatures

The pattern of seasonal fluctuations in Borax Lake water temperature was similar at all lake monitoring sites (except in the wetland), from September 2014 to September 2015. Daily temperature fluctuations were typically less than 5°C. Average water temperatures in the main portion of the lake ranged from 26.3–27.3°C, whereas the average water temperature (11.1°C) and range of temperatures (5.8-21.3 °C) in the wetland were substantially lower (Figure 5; Table 3). The average temperatures were significantly warmer in the southeastern portion of the lake and in the outflow channel in 2015, compared to 2014. Average water temperatures in the outflow channel and the southeastern portion of the lake have increased 2.7 °C and 4.7 °C, respectively, since 2009. 2015 peak water temperatures (39.3–43.9°C) were observed in June and July (Figure 5), coinciding with a period of high air temperatures.

Table 3. Mean water temperatures recorded in different areas of Borax Lake, 2009-2015. The numbers in parentheses represent the 95% confidence limits. Different superscripts within a column indicate a significant difference in mean temperature between years ($p < 0.05$).

	Location					
Year	Wetland	NE	Outflow	SE	NW	SW
2009	**23.0**[a]	**27.9**[a]	**24.6**[a]	**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**[a]	**25.9**[b]	**26.0**[b]	
	(19.5-20.5)	(25.1-26.1)	(23.8-24.9)	(25.3-26.4)	(25.4-26.5)	
2011	**18.4**[b]	**26.3**[b]	**24.1**[b]	**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)	
2012	**17.2**[b]	**25.7**[b]	**25.5**[c]	**26.1**[b]	**27.1**[a]	**27.2**[a]
	(16.7-17.9)	(25.0-26.3)	(24.8-26.1)	(25.4-26.8)	(26.8-27.7)	(26.5-27.9)
2013	**15.9**[c]	**26.0**[b]	**25.9**[c]	**26.3**[b]	**27.2**[a]	**28.1**[a]
	(15.2-16.5)	(25.3-26.6)	(25.2-26.5)	(25.7-26.9)	(26.5-27.8)	(27.5-28.7)
2014	**15.7**[c]	**25.8**[b]	**25.6**[c]	**26.1**[b]	**28.2**[a]	**26.5**[a]
	(15.1-16.3)	(25.2-26.4)	(25.0-26.2)	(25.5-26.7)	(27.6-29.0)	(25.9-27.1)
2015	**11.1**[d]	**26.3**[b]	**27.3**[d]	**27.6**[c]	**-**	**27.3**[a]
	(10.6-11.7)	(25.6-27.0)	(26.7-27.9)	(26.9-28.3)	*hobo stolen*	(26.7-27.9)

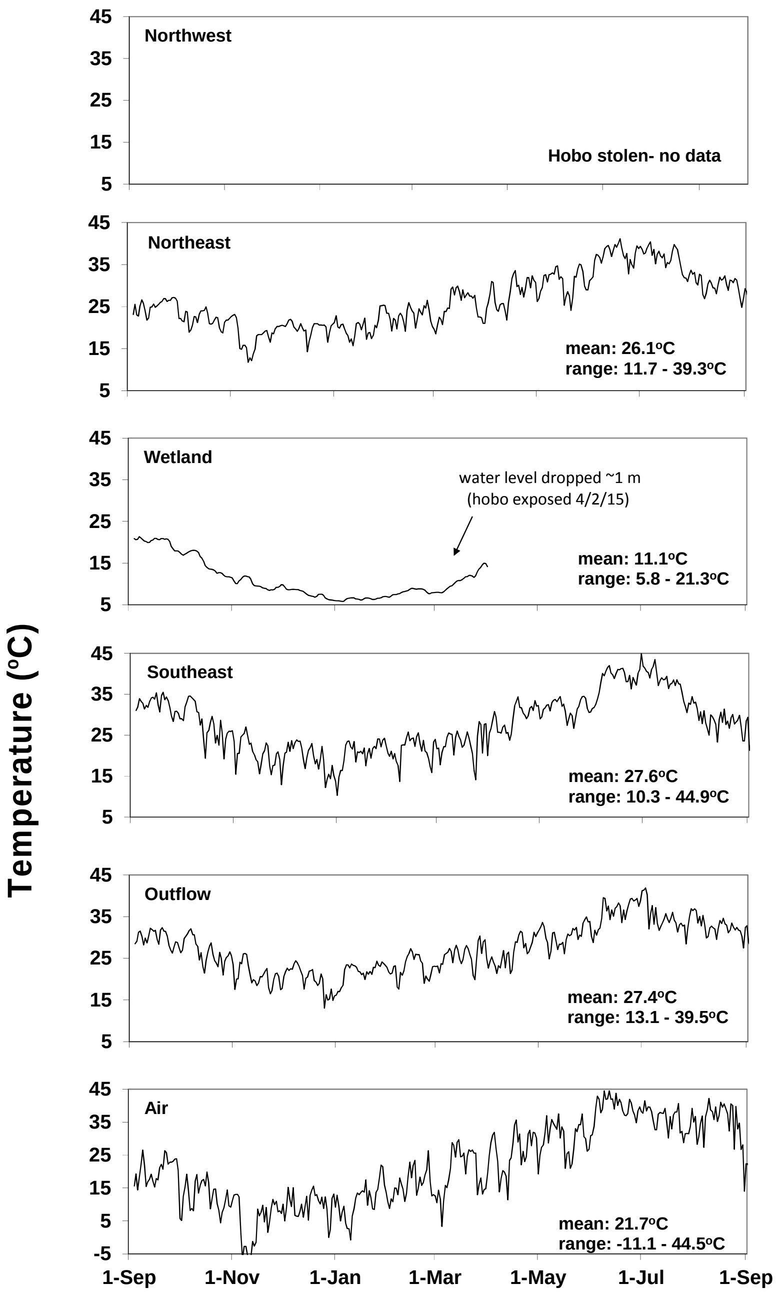

Figure 5. Water temperatures recorded at five locations in Borax Lake from September 2014 through September 2015. Also included are air temperatures.

The lake has experienced significant intra-annual differences in the deviation of maximum daily temperatures from the 2005-2015 mean on the northeastern shoreline of Borax Lake (near outflow channel). Since 2011, summer water temperatures have been consistently warmer than those recorded in 2010-2011, periods of peak chub abundance (Figure 6). In summer 2015, the 7-day average maximum temperatures in the lake greatly exceeded the species critical thermal maximum of 34.5ºC (Williams and Bond 1983) in all areas except for the wetland. Typically, fish can seek refuge from the warmest temperatures by moving to cooler areas of the lake. 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

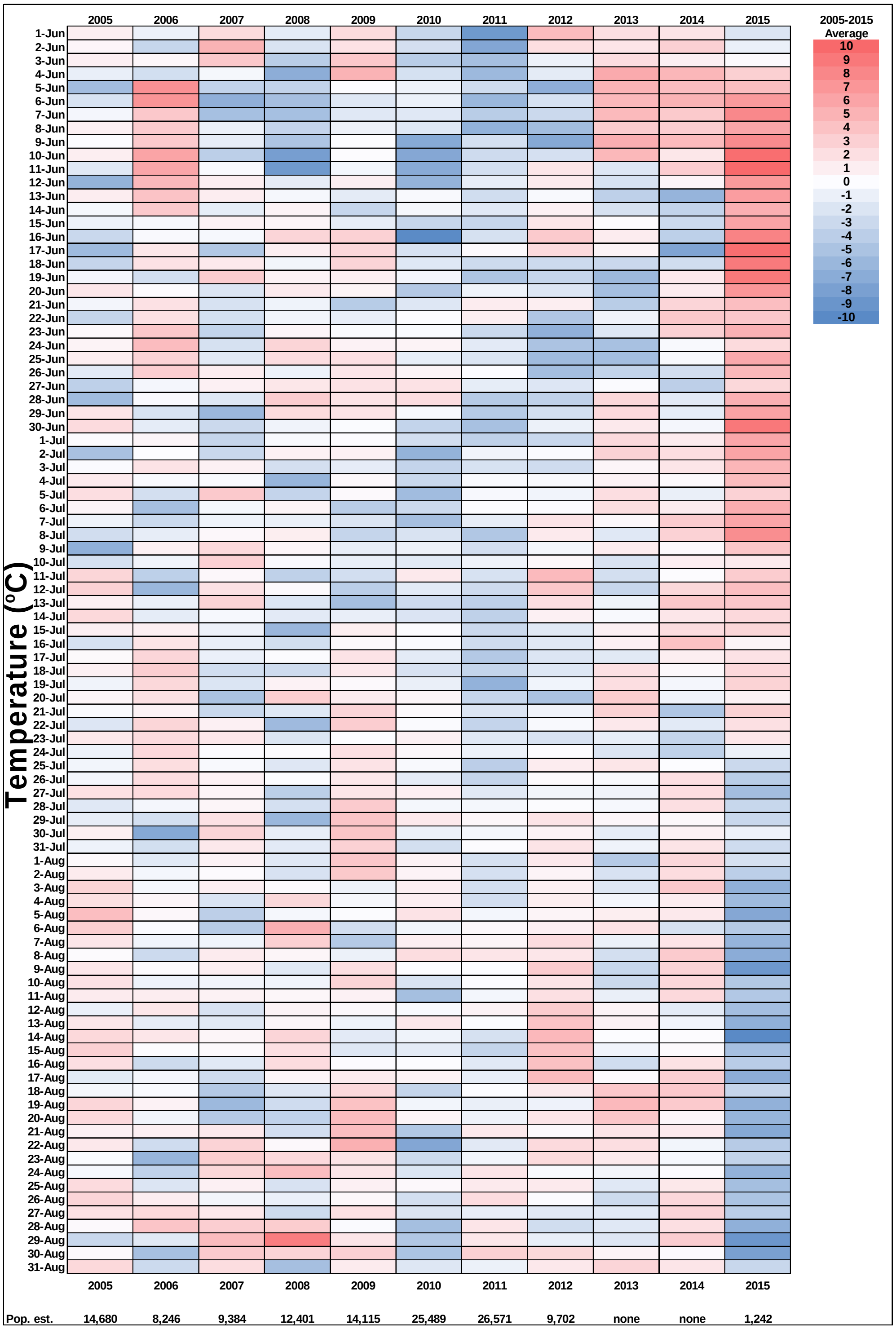

Figure 6. Deviation of the maximum daily temperature recorded on the northwestern shoreline of Borax Lake from the average maximum daily temperature from 2005-2015. Abundance estimates for each year are listed at the bottom of the figure.

However, in 2015, the water level declined in the wetland during the spring and summer such that it was isolated from the lake. The water level declined ~1 m by April 2, when the thermograph became exposed to the air, and did not refill until ~September 27 (Jarod Lemos, BLM, personal communication), approximately two weeks after we obtained the population estimate. Over the past six years, we have observed a decline in mean water temperature in the wetland, suggesting changes in the spring inflow (volume and/or temperature) to this habitat. Additionally, declining spring inflow into the wetland has resulted in noticeable mortality of the sedges on the east, south, and west edges of the wetland, and a dense growth of sedges blocking the channel connecting the wetland to the lake.

Shoreline Pedestrian Surveys

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 and noted several vehicles which had bypassed the gates (drove over a downed section of fence near the gate where turnbuckle was removed from gate post) and entered the vehicle restricted area when we were sampling in October. However, we have not documented any substantial changes in the shoreline habitat conditions at Borax Lake in recent years (Scoppettone et al. 1995; Scheerer and Jacobs 2005; 2006; 2007; 2008; 2009; 2010; Scheerer and Bangs 2011, Scheerer et al. 2012).

Seasonal Water Level Fluctuations in the Lake

In 2011, we installed a piezometer and mapped the bathymetry of Borax Lake, including the wetland, and created maps showing the spatial distribution of lake depths and temperatures (Scheerer and Bangs 2011). We identified the water elevation when the wetland would disconnect from the lake (0.25 m drop). We also calculated the effects of reduced water elevations on habitat area and 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. Only the vent and wetland would be wetted if water elevations were reduced by 1.5 m.

From fall 2012 through fall 2015, we observed minimal fluctuation in lake water elevations. The difference between the minimum and maximum lake elevations was 0.1 m (<4 in), representing an approximate 2% fluctuation in surface area and a 6% fluctuation in water volume. However, when we conducted our 2015 sampling, the wetland was disconnected from the lake and the water elevation was ~1.2 m lower than the lake. However, just days after our estimate, the wetland elevation increased by ~1.0 m (Jarod Lemos, BLM, personal communication). Because the lake piezometer only measures changes in water elevations in the lake, we installed a second piezometer in fall 2015 to monitor changes in water elevation in the wetland if/when it is disconnected from the lake.

DISCUSSION

We have observed a significant decline in Borax Lake chub abundance since 2011 and estimated the lowest chub abundance to date in 2015. In 2010 and 2011, the Borax Lake chub population abundance estimates exceeded 25,000. In those years, we recorded substantially cooler lake temperatures than we recorded in 2006 through 2009 and since 2011. Because Borax Lake chub typically experience water temperatures that are at or near their thermal critical maximum (Williams and Bond 1983), chub survival and recruitment are likely higher during years when lake temperatures are cooler. The unseasonably high water temperatures in June-July 2015, and the warmer lake temperatures in recent years, are the probable cause for the recent decline. Data also suggests limited recruitment in recent years in these habitats. However, small chub were more common in the wetland in 2015, suggesting the importance of this habitat as a source of chub recruits during years when lake temperatures are elevated.

The recent decline appears to be due to natural causes. If the increased summer water temperatures are a result of climate change or recent changes in geothermal inflows and temperatures, then the long-term persistence of the species may be in question. This risk may be reduced by addressing the current isolation of the cooler wetland habitat, which acts as a thermal refuge, from the lake. We propose hand excavating a channel connecting the wetland to the lake to provide chub with access to the wetland during periods of high lake temperatures and access for the recruits produced in the wetland to enter and repopulate the lake. We will meet with our partners (TNC, BLM, and ODFW district) this winter to discuss options to maintain the channel (installing a liner, etc.).

We recommend continuing monitoring of changes in population abundance and habitat conditions at Borax Lake. 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 annually until the population rebounds and at least every two years thereafter. Additional research could focus on evaluating which environmental factors and habitat conditions are responsible for the large fluctuations in annual chub abundance. To assess the condition of the fragile lake crust, we recommend continuing annual shoreline pedestrian surveys. We recommend continued monitoring of lake water temperatures and water elevations to provide baseline data in the event it becomes necessary to gauge the effects of geothermal development. We also recommend the initiation of a genetic study to describe the relationship between Borax Lake and Alvord chub (*Gila alvordensis*); the results of which could have implications on the conservation and listing status of both species.

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