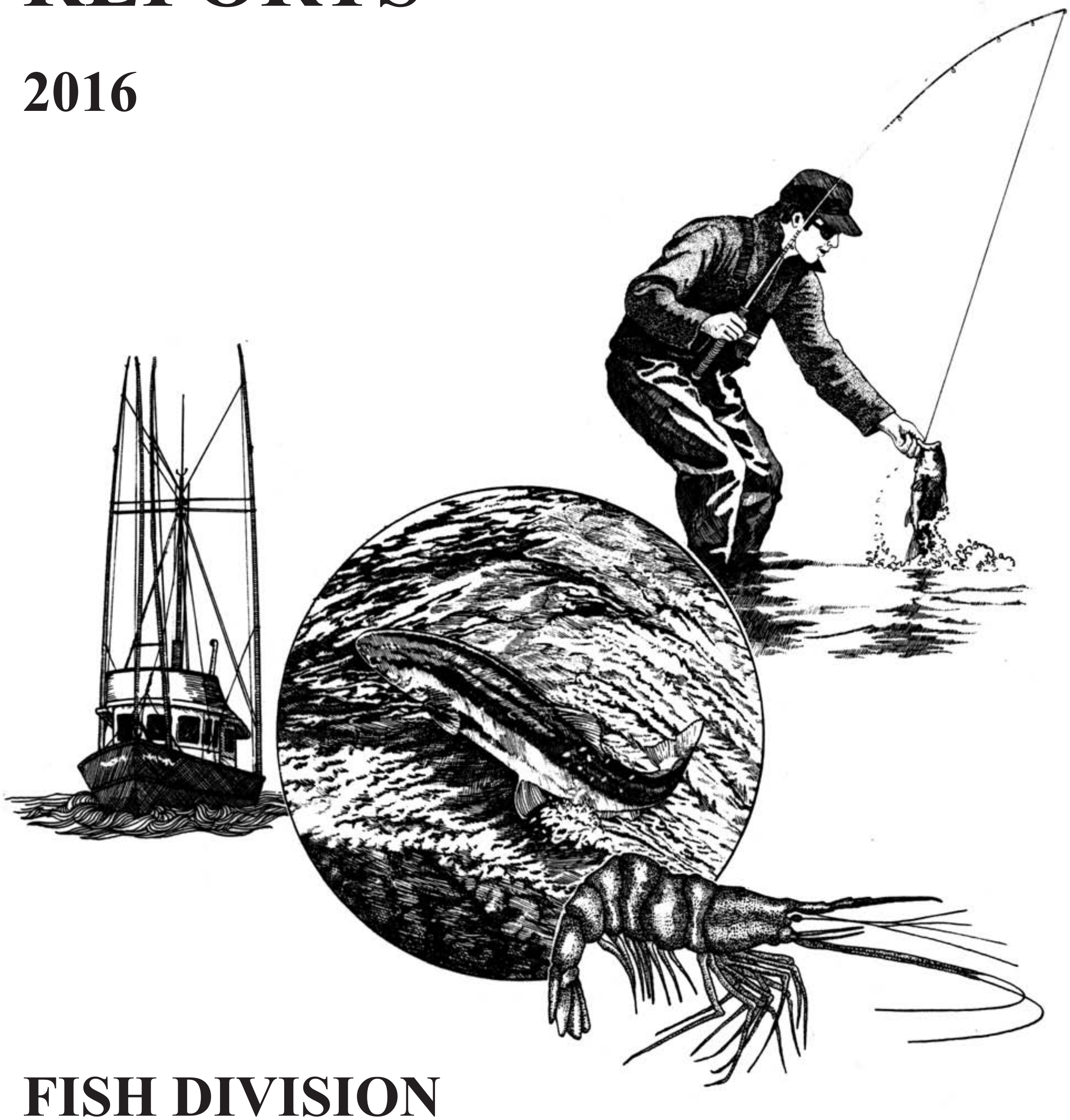
PROGRESS REPORTS

2016



FISH DIVISION

Oregon Department of Fish and Wildlife

2016 Borax Lake Chub Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: **2016 Borax Lake Chub Investigations**

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Paul D. Scheerer[1], James T. Peterson[2], and Michael H. Meeuwig[1]

[1]Oregon Department of Fish and Wildlife, 28655 Highway 34, Corvallis, Oregon 97333

[2]USGS Oregon Cooperative Fish and Wildlife Research Unit, 104 Nash Hall, Oregon State University, Corvallis, OR 97331

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Abstract— Borax Lake chub (*Gila boraxobius*) are small minnows endemic to Borax Lake in southeastern Oregon. The species was listed as endangered by the U.S. Fish and Wildlife Service in 1982 because of their limited range and threats from geothermal development and irrigation withdrawals. Over the past three decades, focused recovery actions have addressed the major threats that were identified at the time of listing. Our 2016 study objectives were to: 1) obtain a population estimate of Borax Lake chub in Borax Lake, the adjacent wetland channel and pond, and the outflow channel, 2) describe the habitat conditions, including a description of annual fluctuations in water temperatures and water levels, and the condition of the fragile lake shoreline and outflows. We used a state-space model, which allows us to vary capture probabilities for different sized fish and habitats, to estimate Borax Lake chub abundance. In 2016, Borax Lake chub abundance was 9,003 individuals, a significant increase from the 2015 estimate of 1,242 individuals, despite desiccation of the wetland pond. In contrast to 2015 when June through mid-July water temperatures were unseasonably warm, 2016 maximum daily water temperatures were at or below the 2005-2016 average for most of the summer. For the first time in a decade, we observed no evidence of off-road vehicle trespass or damage to areas near the lake.

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 ha, geothermally-heated alkaline lake, which is perched 10 m 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 advocated protection of the lake ecosystem through the acquisition of key private lands, protection of groundwater and surface water, controls on access, and the removal of livestock grazing (U.S. Fish and Wildlife Service 1987).

Population abundance estimates obtained from 1991-2015 fluctuated from approximately 1,200 to 37,000 fish (Salzer 1997; Scheerer et al. 2012; 2015). However, 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 ~1 m) and situated above borosilicate deposits on the desert floor, alteration of the salt crust shoreline could reduce lake water levels and have a dramatic effect on the quantity and quality of habitat available to Borax Lake chub.

Recovery measures implemented since listing have addressed many of the threats to Borax Lake chub, primarily by protecting the habitat (Scheerer and Clements 2015). When the species was listed, critical habitat was designated on 259 ha of land surrounding the lake, including 129 ha of public lands and two 65-ha 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, which directs protection of threatened and endangered species habitats in need of special management attention. 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. 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 from development on private lands. The BLM and TNC fenced the area surrounding the lake to exclude vehicular access in 2011 and installed locked gates in 2013. Additionally, detailed studies of Borax Lake chub and their habitat in the 1990s improved knowledge about the biology of Borax Lake chub 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 in 2016. Our objectives were to: 1) obtain a population estimate of Borax Lake chub in Borax Lake, the adjacent wetland channel and pond, and the outflow channel, 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 Borax Lake chub using baited minnow traps (n=114; 1.6 mm mesh) over a three-day period from 29 through 31 August 2016. On the first day we distributed the traps about 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 wetland channel (the wetland pond was dry) and in the outflow channel. In past years when the wetland was wetted, we set 2 minnow traps in the wetland channel and 10 in the wetland pond. In 2016, we set 2 traps in the wetland channel, consistent with past years. On the second day we collected the traps in the morning, cleared them of Borax Lake chub, recorded the number of Borax Lake chub in each of three size categories (small <35 mm total length (TL), medium 35-59 mm TL, and large $\geq$60 mm TL), and measured TL of a sub-sample of fish (n=236). After all fish were counted, we returned them to the water, distributing them throughout the lake or into the outflow or wetland channel near where they were collected. The same afternoon, we re-set the traps at about the same locations. On the third day we collected the traps in the morning, cleared them of Borax Lake chub, and recorded the number of fish in each size category.

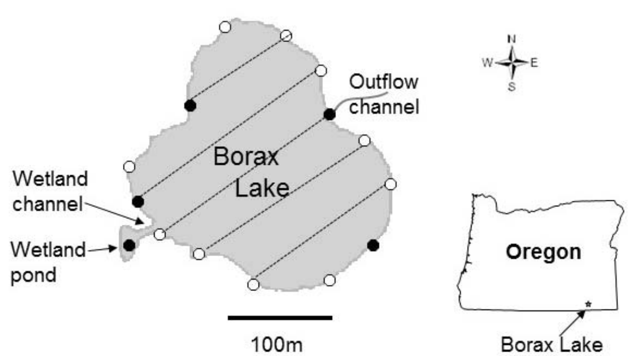

Figure 1. Map of Borax Lake showing the locations of open water transects (dotted lines), the outflow channel, the wetland pond, the wetland channel, shoreline photo points (all circles), and thermographs (black circles only). Transects were based on those established by Scoppettone et al. (1995).

We estimated the abundance of Borax Lake chub separately for Borax Lake, the wetland channel, and the outflow channel using a state space model (Bolker 2008), which allowed us to vary capture probabilities for different sized fish and habitats. Fish capture 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, $\hat{p}$ is the estimated capture probability, and $\hat{N}$ 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 to two sampling occasions in 2016 as compared to the three sampling occasions used in 2012, and required no 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. The number of iterations and burn in 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% confidence intervals (CIs) for the estimates according to Chao (1987).

We monitored water temperatures (˚C) at five locations with Hobo® recording thermographs. The thermographs recorded temperature at 1-h intervals. We downloaded data (water elevations and temperatures) from water level data loggers that we installed in 2011 (Scheerer and Bangs 2011) to describe the changes in wetted area and water volume associated with seasonal fluctuations in water elevation. We compared 2016 maximum daily water temperatures to the 2005-2016 average maximum daily water temperatures during the summer months (June 1-August 31).

We assessed the condition of the lake's shoreline, the wetland, and the outflow channels by revisiting and re-photographing the shoreline at photo points that we established in 2005 (Scheerer and Jacobs 2005). These are qualitative surveys where we looked for evidence of damage to the shoreline crust from vehicular trespass and/or manipulation of the crust to alter water outflow.

RESULTS

<u>Population Estimate</u>

We estimated the 2016 abundance of Borax Lake chub at 9,003 fish (95% CI: 8,045-10,560), which is significantly higher than the 2015 estimate of 1,242 fish (95% CI: 1,077-1,456) and similar to the 2012 estimate of 9,702 fish (95% CI: 9,042-10,452) (Figure 2). We observed significant increases in Borax Lake chub abundance in the lake and outflow channel from 2015 to 2016 (Table 1). The 2016 abundance estimate in the wetland channel was not significantly different from the 2015 estimate in the wetland pond and channel. However, the Borax Lake chub density in this habitat was substantially higher in 2016, considering the large reduction in wetted area that resulted from the drying of the wetland pond in 2016.

Borax Lake chub varied in length from 20 to 72 mm in 2016 with two apparent size classes (Figure 3); these size classes may represent different age classes of Borax Lake chub. We captured smaller fish in the wetland channel and outflow channel than in the lake and observed many young-of-the-year Borax Lake chub (≤20 mm TL) in the outflow channel, which were not captured in minnow traps.

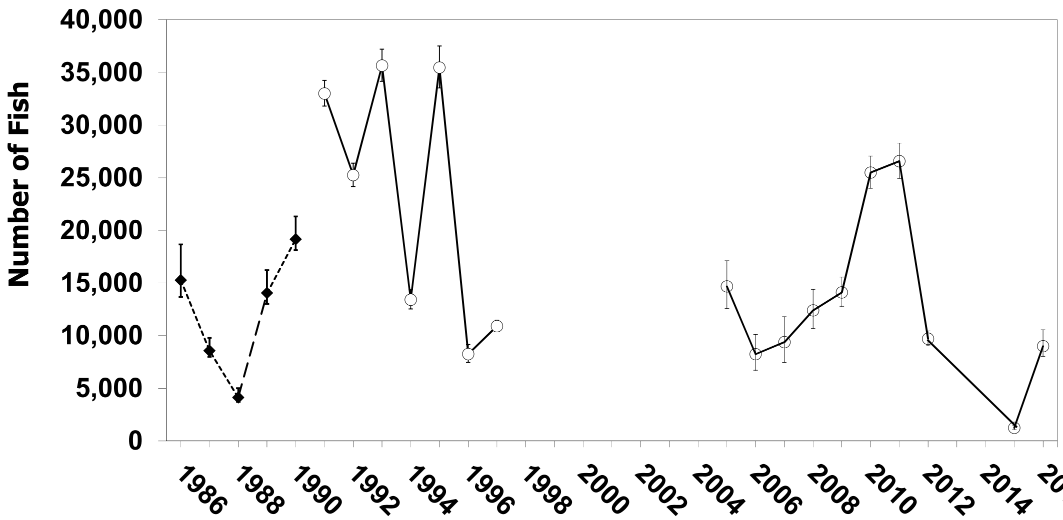

Figure 2. Borax Lake chub population abundance estimates obtained since 1986. Error bars represent 95% confidence intervals. In 1986-1990 (solid symbols), only the perimeter of the lake was sampled. After 1990 (open symbols), the entire lake including the wetland, wetland channel, and outflow channel were sampled. Estimates are not directly comparable across these time periods (Salzer 1992).

<u>Water Temperatures</u>

The general pattern of seasonal fluctuations in Borax Lake water temperature was similar at all monitoring sites (except in the wetland), from September 2015 through August 2016 (Figure 4). Daily temperature fluctuations were typically less than 5˚C. Average daily maximum water temperatures in the main portion of the lake ranged from 25.6–27.6˚C, whereas the average daily maximum water temperature in the wetland was 9.9˚C (range: 3.1–24.4˚C) during the period when it was wetted (Table 2). The wetland desiccated in late-May 2016 and was still dry during our late-August site visit. The average water temperatures were significantly cooler in the outflow channel in 2016 compared to 2015. At several of the other locations (wetland, northeast, and southeast), mean water temperatures were cooler in 2016 than in 2015, but temperature differences were not significant.

We noted substantial interannual differences in the deviation of daily maximum temperatures from the 2005-2016 mean maximum daily temperature. In 2012 and 2015, summer water temperatures were generally warmer than the 12-yr average compared

Table 1. 2015-2016 Borax Lake chub abundance estimates by location and fish size category. Size classes: small- <35 mm TL, medium- 35-59 mm TL, and large- >60 mm TL). Abundance estimates are significantly different between years (for any location by fish size category combination) when the 95% confidence intervals do not overlap.

	2015			2016		
Location by fish		95% Confidence limits			95% Confidence limits	
size category	Estimate	Lower	Upper	Estimate	Lower	Upper
All areas						
Small	**197**	99	351	**1,565**	1,225	2,023
Medium	**567**	496	643	**5,592**	5,542	5,647
Large	**478**	378	619	**1,846**	963	3,362
All sizes	**1,242**	1,077	1,456	**9,003**	8,045	10,560
Lake						
Small	**7**	0	25	**852**	628	1,125
Medium	**424**	357	496	**4,997**	4,990	5,000
Large	**132**	58	259	**1,825**	943	3,342
All sizes	**563**	458	705	**7,675**	6,764	9,206
Wetland						
Small	**189**	92	342	**499**	261	881
Medium	**142**	119	167	**228**	196	263
Large	**344**	284	416	**1**	0	4
All sizes	**675**	556	841	**728**	487	1,112
Outflow						
Small	**1**	0	5	**214**	168	269
Medium	**2**	1	4	**367**	329	409
Large	**1**	0	4	**20**	10	36
All sizes	**4**	1	9	**601**	539	671

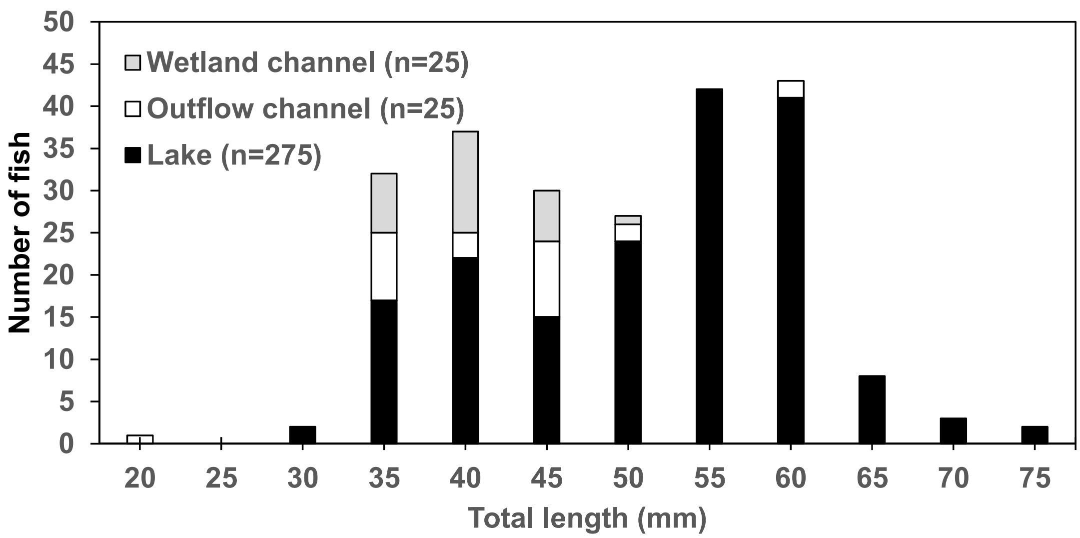

Figure 3. Length frequency histogram for Borax Lake chub collected in the lake, wetland channel, and outflow channel of Borax Lake in 2016.

to those recorded in 2010-2011, which were generally cooler than the 12-yr average (Figure 5). Since we began our monitoring activities at Borax Lake in 2005, Borax Lake chub abundance was highest in 2010 and 2011, perhaps due to more favorable (cooler) water temperatures in these years. On most dates in 2016, maximum daily water temperatures were at or below the 2005-2016 average (Figure 5).

In 2016, as was the case in most years since 2005, maximum daily temperatures recorded in the lake during the summer periodically exceeded the Borax Lake chub critical thermal maximum of 34.5^{o}C (Williams and Bond 1983). 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 Borax Lake chub congregated in cooler portions of the lake.

Table 2. Mean daily maximum water temperatures recorded in different areas of Borax Lake, 2009-2016 (see Figure 1 for water temperature logger locations). The numbers in parentheses represent the 95% confidence intervals. Different superscripts within a column indicate a significant difference in mean temperature between years, i.e. 95% confidence intervals do not overlap. Note, the thermograph in the northwest area of the lake was missing when we visited the lake in 2015.

	Location					
Year	Wetland	Northeast	Outflow	Southeast	Northwest	Southwest
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)		(26.7-27.9)
2016	**9.9**[d]	**25.6**[b]	**25.7**[c]	**27.2**[c]	**27.6**[a]	**27.4**[a]
	(9.3-10.6)	(24.8-26.3)	(25.0-26.3)	(26.5-27.9)	(27.9-28.3)	(26.7-28.0)

Seasonal Water Level Fluctuations in the Lake

In 2016, we observed minimal fluctuation in lake water elevations. The difference between the minimum and maximum lake elevations was 0.1 m, representing an approximate 2% fluctuation in surface area and a 6% fluctuation in water volume (see Scheerer and Bangs 2011).

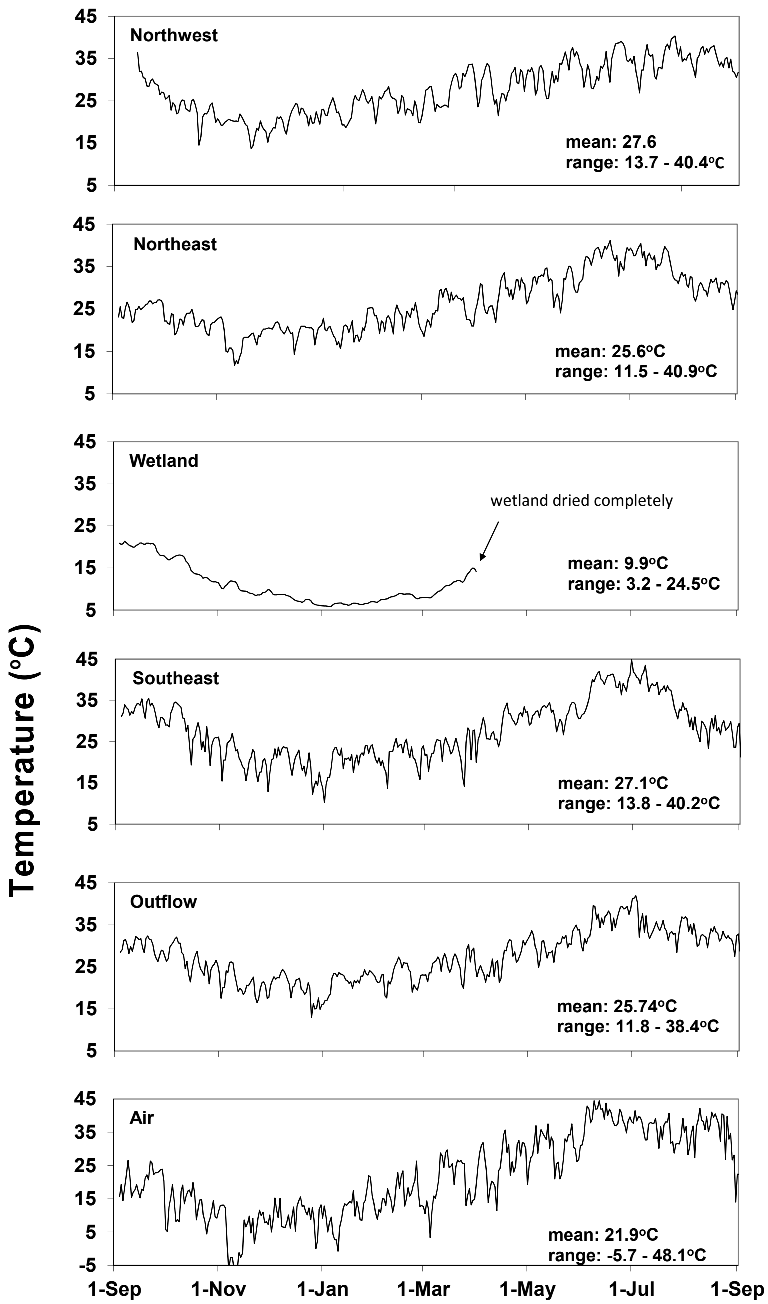

Figure 4. Water temperatures recorded at five locations in or near Borax Lake from September 2016 through August 2016. Also included are air temperatures.

Shoreline Surveys

For the first time in a decade, we observed no evidence of off-road vehicle trespass or damage to areas near the lake in 2016. Additionally, we have not documented any substantial changes in the shoreline crust at Borax Lake since Oregon Department of Fish and Wildlife's monitoring began in 2005 (Scheerer and Jacobs 2005; 2006; 2007; 2008; 2009; 2010; Scheerer and Bangs 2011, Scheerer et al. 2012; 2015).

Figure 5. Deviation of the maximum daily temperature (°C) recorded on the northwestern shoreline of Borax Lake from the 2005-2016 mean of maximum daily temperatures at the same location. White boxes indicate no deviation in maximum daily temperature from the 12-yr mean. Blue and red boxes indicate that the daily maximum temperature was cooler than and warmer than the 12-yr mean, respectively. Borax Lake chub abundance estimates are listed at the bottom of the figure for each year.

DISCUSSION

In 2015, we observed a significant decline in Borax Lake chub abundance from the previous estimate in 2012 (Scheerer et al. 2015). The 2015 Borax Lake chub abundance estimate of 1,242 was the lowest on record and only one chub was captured in the outflow channel. From 2015 to 2016, we observed a significant increase in chub abundance to 9,003 fish and greater number of Borax Lake chub in the outflow channel. Borax Lake chub are short lived and highly fecund (Scoppettone et al. 1995), which allows them to increase their population abundance rapidly when conditions are favorable, and these traits may be responsible for the substantial interannual fluctuations in abundance that have been observed since 1986.

Temperature may limit Borax Lake chub survival and abundance in Borax Lake. Borax Lake chub typically experience water temperatures that are at or near their thermal critical maximum (34.5°C; Williams and Bond 1983), thus chub survival and recruitment are likely higher during years when lake temperatures are cooler. In prior years, when Borax Lake daily maximum water temperatures were substantially cooler than the 12-yr average (e.g., 2010 and 2011), Borax Lake chub abundance estimates exceeded 25,000 fish and were some of the highest on recent record. Borax Lake water temperatures were especially high in June and July 2015, warmer than the 12-yr average, and these elevated temperatures may have been the cause of the substantial decline in Borax Lake chub abundance that we observed between 2012 and 2015. In late-summer 2015 and in the summer of 2016, water temperatures in the lake were typically at or below the 12-yr average, which may have resulted in improved Borax Lake chub recruitment and survival and the significant increase in abundance (625%) that we observed in 2016.

The recent decline in Borax Lake chub abundance appears to be due to natural causes and possibly to thermal conditions of Borax Lake. The wetland adjacent to Borax Lake is typically cooler than many areas of the lake and therefore may act as thermal refugia for Borax Lake chub when lake temperatures are high. Consequently, activities that maintain connectivity between Borax Lake and its surrounding wetlands should be considered and evaluated by all appropriate stakeholders (e.g., TNC, BLM, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife).

We recommend continued periodic monitoring of Borax Lake chub population abundance and habitat conditions at Borax Lake. Because Borax Lake chub are a short lived fish (few survive beyond 1 year; Scoppettone et al. 1995), we recommend that abundance should be estimated every three to five years. In 2016, minnow trap catch varied substantially between sampling occasions in the lake (APPENDIX A), thus we recommend recalibrating the abundance model the next time abundance is estimated. Our understanding of Borax Lake chub population dynamics would benefit from additional research evaluating what environmental factors and habitat conditions are responsible for the large interannual fluctuations in chub abundance.

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APPENDIX A. Numbers of fish captured, by fish size category, in different habitats in Borax Lake on successive days (30-31 August 2016).

		Day 1	Day 2
Lake			
	small	57	64
	medium	521	2,443
	large	43	265
		621	2,772
Wetland			
	small	40	33
	medium	94	76
	large	0	0
		134	109
Outflow			
	small	58	66
	medium	206	191
	large	7	6
		271	263
All Areas			
	small	155	163
	medium	821	2,710
	large	50	271
		1,026	3,144

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4034 Fairview Industrial Drive SE

Salem, Oregon 97302