PROGRESS REPORTS

2009

FISH DIVISION

Oregon Department of Fish and Wildlife

2009 Borax Lake Chub Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: 2009 Borax Lake Chub Investigations

PROJECT NUMBERS: Contracts 13420-08-J814 (USFWS) and L07PX02726 (BLM)

PROJECT PERIOD: 28 August 2009 - 31 December 2014 and 21 September 2009 – 1 June 2011

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

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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 chub are represented by a single population that inhabits a 4.1 hectare geothermally-heated alkaline lake. 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 since 1991 indicate a fluctuating population ranging between approximately 4,000 and 34,000 fish (Salzer 1997; Scheerer and Jacobs 2008). 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 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.

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 by Oregon Department of Fish and Wildlife's Native Fish Investigations Project in 2009.

METHODS

We used baited minnow traps to obtain a mark-recapture population estimate. We fished 124 traps overnight (~16 hours) and the traps were distributed haphazardly at locations around the lake, associated wetland, and outflow channel. 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 (N=100) 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 200 fish collected in the traps.

We recorded physical habitat parameters in Borax Lake. From 17 September 2008 through 23 September 2009, we monitored water temperatures (^oC) 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 (Universal Transverse Mercator coordinates).

We conducted pedestrian surveys to monitor the condition of the lake shoreline, lake outflows, and adjacent wetlands. We established 15 photo points around the perimeter of lake and the wetland in 2005 (Figure 1). 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 23 September 2009, we obtained a Borax Lake chub population estimate of 14,115 fish (95% CI: 12,793-15,573) which ranged from 25 mm to 91 mm TL. This estimate was within the range of estimates obtained since 2005 and significantly higher than the 2006 and 2007 estimates (Table 1; Figure 2). The population has not exhibited a significant trend in abundance for the past 5 years (p=0.78). We re-examined past estimates obtained at Borax Lake to evaluate whether bias in these prior estimates may have resulted in overestimates of abundance in 1991, 1992, 1993, and 1995, years when chub abundance was more than double the current estimates. We found strong relationships between the recapture rate (numbers recaptured divided by numbers marked) and between the trapping efficiency (number of fish per trap) and the abundance estimates (**APPENDICES A and B**). We found that in the early 1990's, when the Borax chub abundance estimates were highest (~25-35,000 fish), larger numbers of chub were captured per unit of effort (one trap fished overnight), a larger proportion of the population was marked, and recapture rates were higher. Higher recapture rates act to reduce abundance estimates, but these were offset by the higher proportion of population that was marked fish, resulting in higher abundance estimates in the early 1990's. Note that the proportion of the total population marked in the early 1990's was more than double the proportion marked since 2005 (Scheerer and Jacobs 2008).

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.

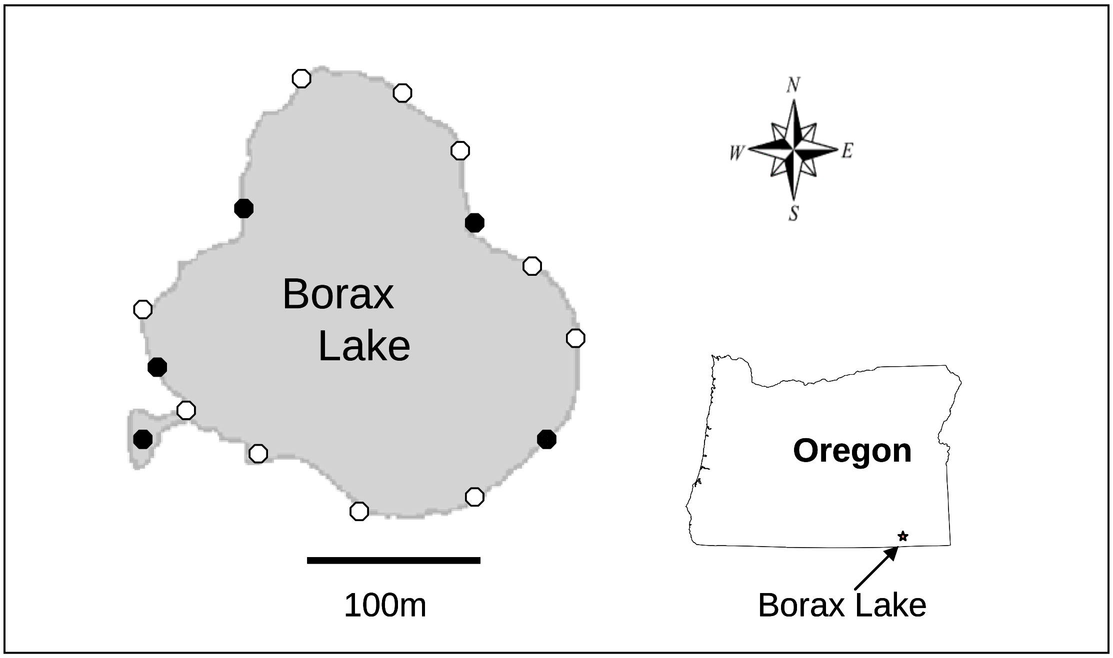

Figure 1. Map of Borax Lake showing the locations of photo points (circles). The dark circles indicate the location of both photo points and thermographs.

Table 1. Details of mark-recapture population estimates for Borax chub, 2005-2009.

					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	2087	2676	395	14,115	12,793	15,573

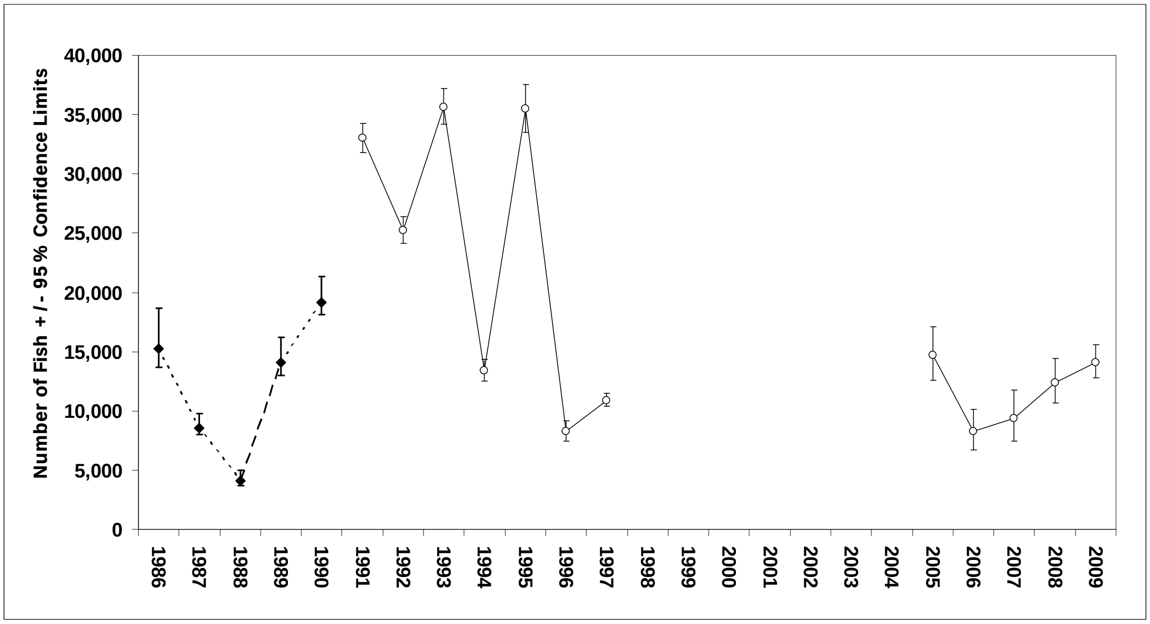

Figure 2. Borax Lake chub population abundance estimates from 1986 through 1997 and from 2005 through 2009. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols), the entire lake was trapped. Estimates are not directly comparable across these time periods.

Water Temperatures

The water temperatures recorded in Borax Lake from 17 September 2008 through 23 September 2009 showed similar patterns throughout the lake with peak temperatures (33.6 °C to 39.2°C) occurring in July and August (Figure 4). Average temperatures ranged from highs of 27.3-27.9°C on the northern shoreline to lows of 22.9-23.0 °C on the southeast shoreline and in the wetland at the southwestern end of the lake. Daily temperature fluctuations were typically $\leq$4-5° C. The maximum daily temperatures recorded on the northwestern shoreline of Borax Lake (the warmest of our thermograph locations) showed different patterns during the summers of 2005 through 2009, with 2008 being the coolest (Figure 5). However, the maximum 7-day running averages were similar at this site from year to year, ranging from 36.4 °C to 38.6°C. These interannual temperature fluctuations are in the range of daily temperature fluctuations at locations in the lake as well as within the range of variation in lake temperatures among locations throughout the lake on any given date. The maximum 7-day average temperatures in the lake represent some of the most extreme conditions that exist in the lake and exceed the species critical thermal maximum of $\underset{\sim}{}$35°C (Williams and Bond 1983). This thermograph is in an area where a series of small geothermal vents extend north from the main vent. However, fish can seek refuge from the warmest temperatures by moving to cooler areas of the lake, including the wetland and the southeastern shoreline (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.

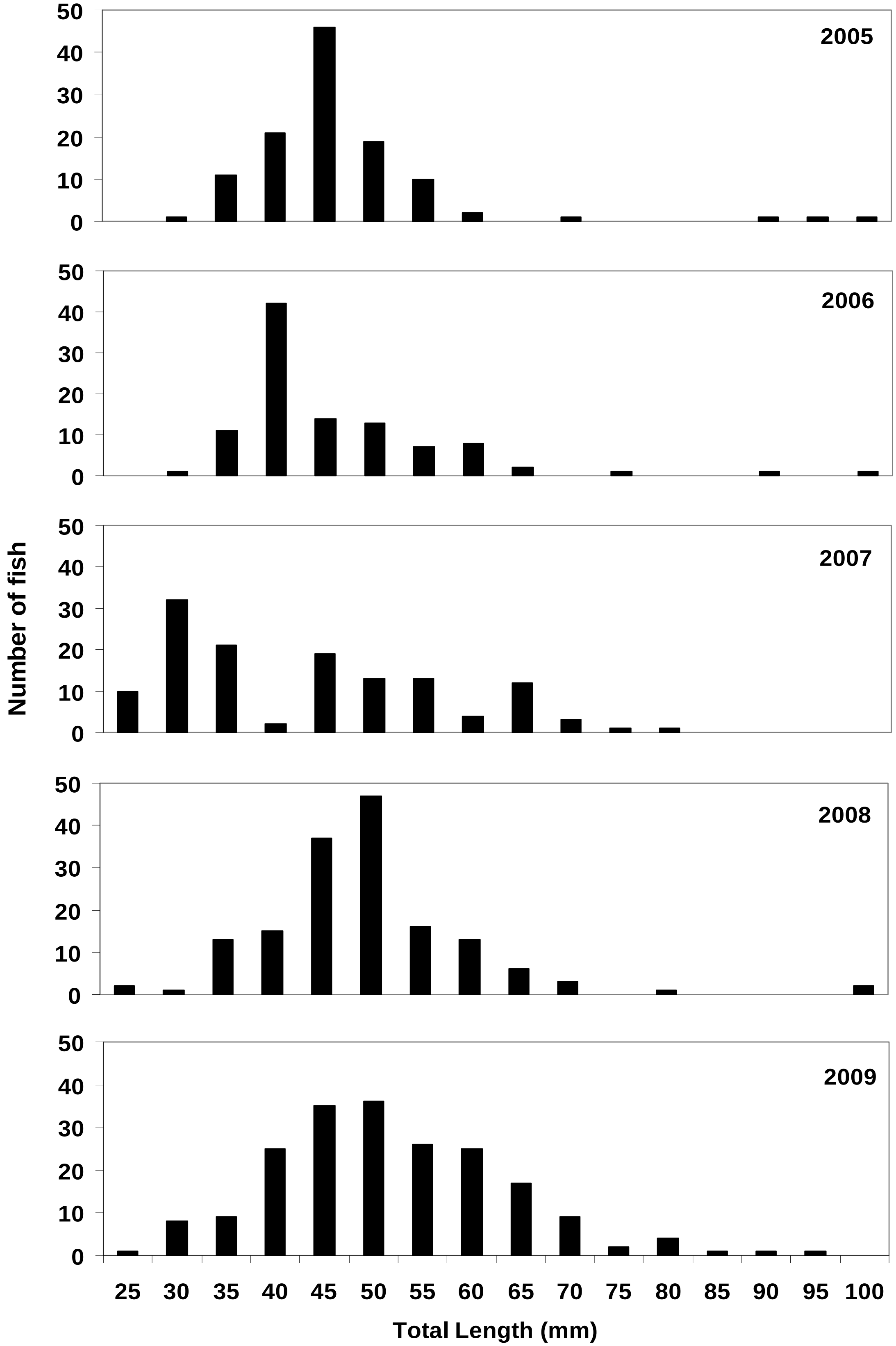

Figure 3. Length-frequency histograms for Borax Lake chub, 2005-2009.

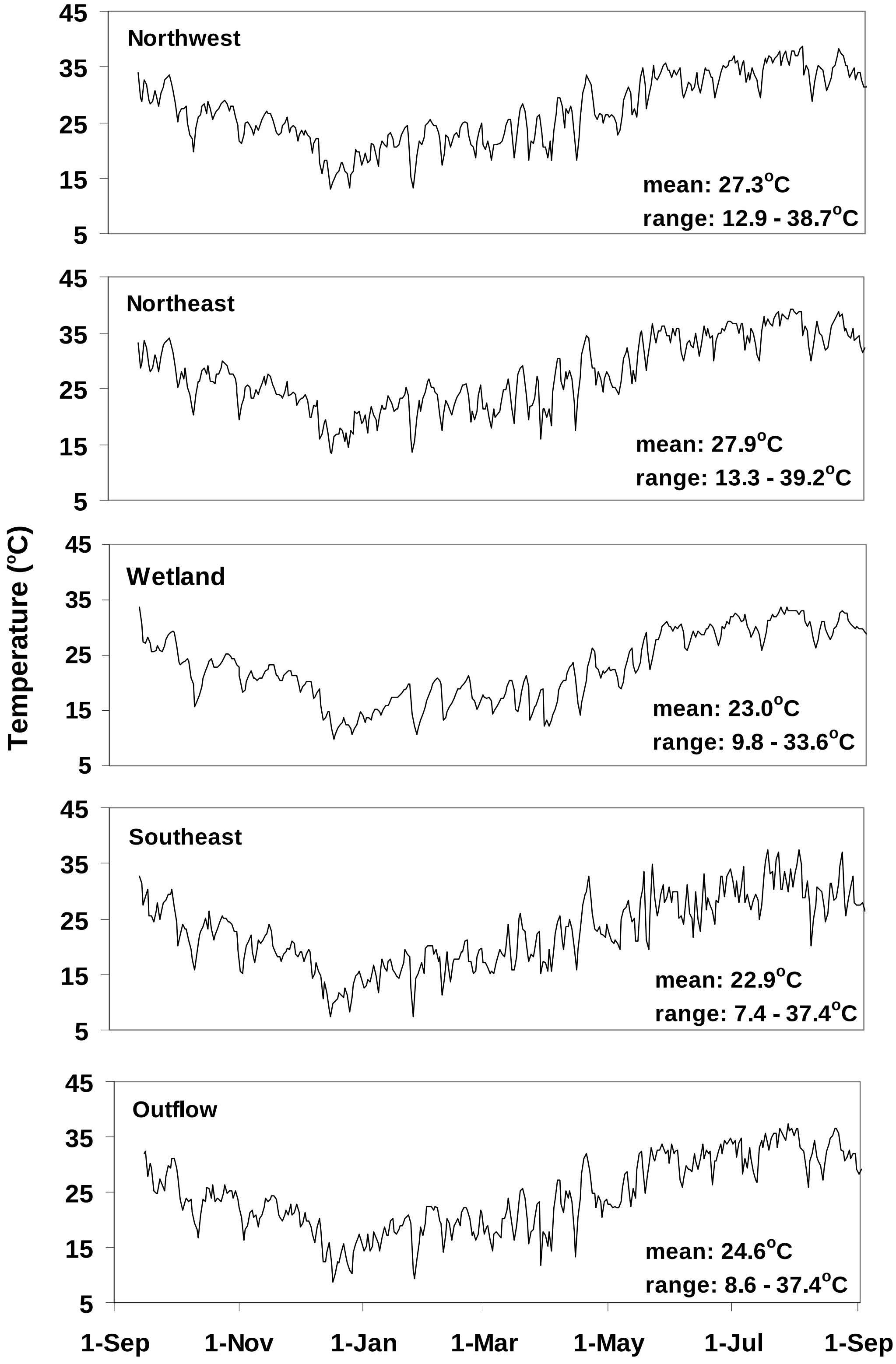

Figure 4. Water temperatures recorded at five locations in Borax Lake from September 2008 through September 2009.

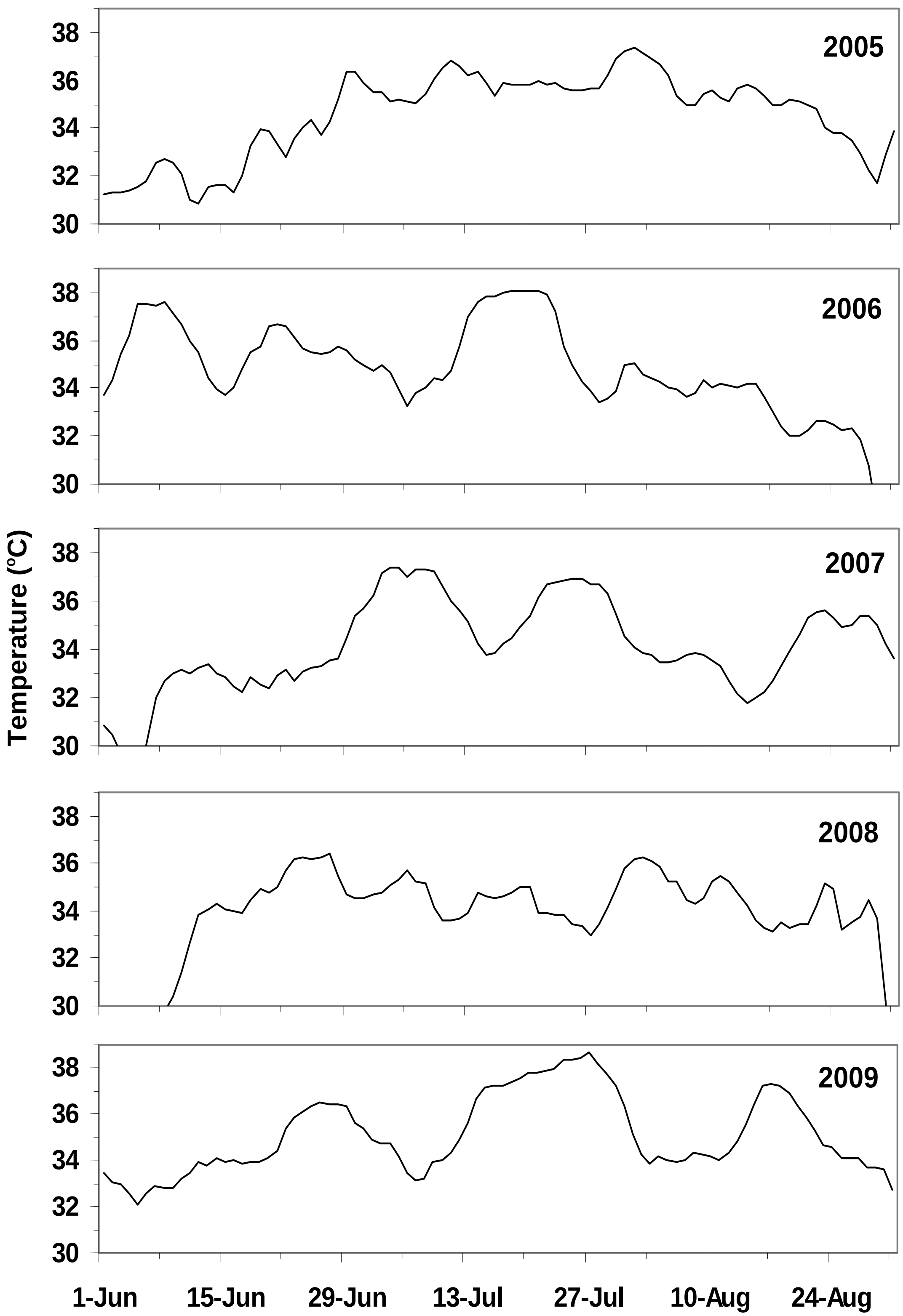

Figure 5. Seven-day running averages of maximum daily temperatures recorded on the northwestern shoreline of Borax Lake, 2005-2009.

Figure 6. Off road vehicle damage on the north shore of Borax Lake.

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 substantial off-road vehicle damage (Figure 6). We have not observed any notable change in shoreline conditions over the past five years.

DISCUSSION

There has been substantial progress made towards recovery of Borax Lake chub, but several threats to the species and its habitat remain. 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 that excessive handling of fish during mark-recapture estimation posed an additional threat to the species (D. Salzer, The Nature Conservancy and T. Walters, ODFW, personal communication). When mark-recapture abundance estimates were obtained between 1985 through 1996, an average of 49% (range 27% to 68%) of the population was handled during the marking and recapturing events (Table 2). 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% by marking approximately 1,000 individuals and handling a total of 2,500-3,000 individuals.

From 2005 through 2009, we obtained mark-recapture estimates with an average precision of 15% (Table 2). We handled an average of 22% of the population and were able to detect average annual declines in abundance of 27% (Table 2, Figure 5). It is our opinion that handling approximately 22% of the population to obtain estimates with precision of 9-20% is acceptable and not a threat to the listed species. In addition, during the five years of our study, we had only 15 trap mortalities (<0.1% of fish handled) from our mark-recapture protocols.

The habitat conditions at Borax Lake in 2005 through 2009 did not differ from those reported in the past (Williams and Bond 1983; Scoppettone et al. 1995; Scheerer and Jacobs 2005; 2006; 2007; 2008), except that water diversions were discontinued in 1993, resulting in higher lake elevations. The water was clear and visibility was good. The lake substrate included bedrock in the southeast areas of the lake, fine gravel and stromatolitic accretions (bedrock) in the northern areas of the lake, and a flocculent silt dominating the remaining areas (majority) 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 lake's edge.

Table 2. Comparisons of the proportion of fish marked, the proportion of fish handled, and the precision of population estimates and detectable declines in abundance.

Years	Proportion marked	Proportion handled	Precision	Decline detectable
1986-1997	22% (8 - 42)	49% (27 - 68)	7% (4 - 10)	13% (9 - 20)
2005-2009	9% (7 - 15)	22% (17 - 31)	15% (9 - 20)	27% (18 - 34)

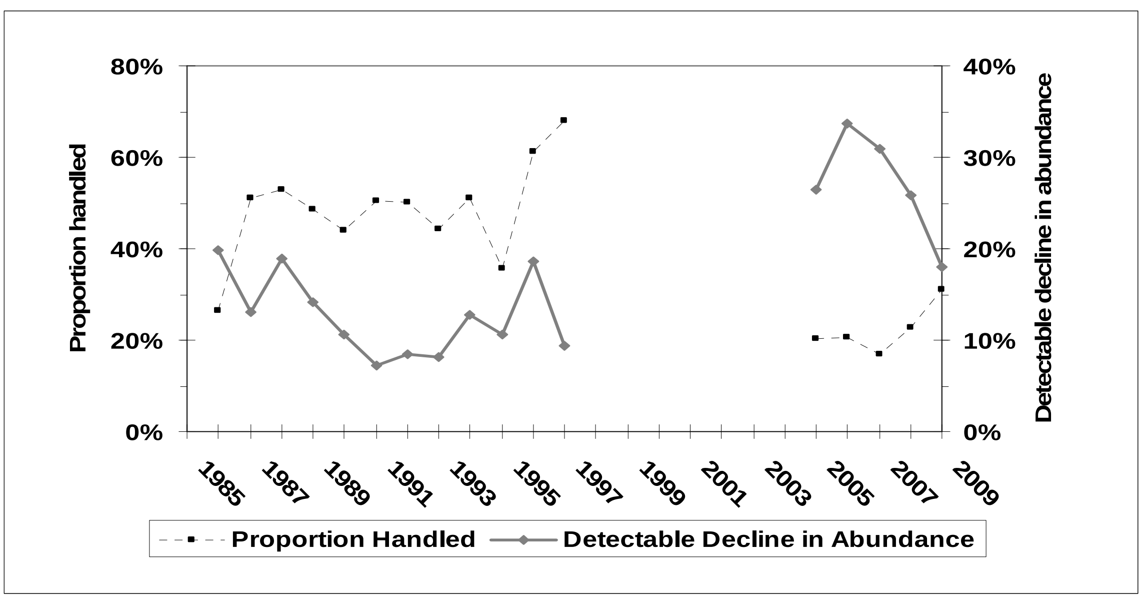

Figure 5. Comparisons of the proportion of the Borax Lake chub population handled and the detectable decline in abundance for abundance estimates obtained in 1985 through 1996 and from recent abundance estimates obtained by ODFW in 2005 through 2009.

Borax chub abundance has averaged nearly 12,000 fish over the past 5 years. Compared to the mean abundance of approximately 29,000 fish from 1991 through 1995, current abundance estimates are down substantially. However there is no evidence of major changes in lake temperatures, habitat conditions, or productivity, nor is there evidence that the estimates from the early 1990's were biased. It is unclear what has changed to result in the lower abundance estimates in recent years.

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. Because Borax Lake chub are presumably an annual species, i.e. most fish are ≤ 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 validate and 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. This could be accomplished by sacrificing a relatively small number of individuals (60-100 fish or <0.1% of the population). We recommend continuing annual shoreline pedestrian surveys to assess the condition of the fragile lake crust. We also recommend continued lake water temperature monitoring to provide a baseline and to monitor the effects of recently proposed geothermal development, if it is permitted to occur on private lands near Borax Lake. 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 to reduce the impacts of off-road vehicular traffic.

ACKNOWLEDGEMENTS

We are grateful to Daryl Bingham, Christine Bates, Jana Mort, Louis Clayburn, and Matt Obradovich 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 U. S. Bureau of Land Management.

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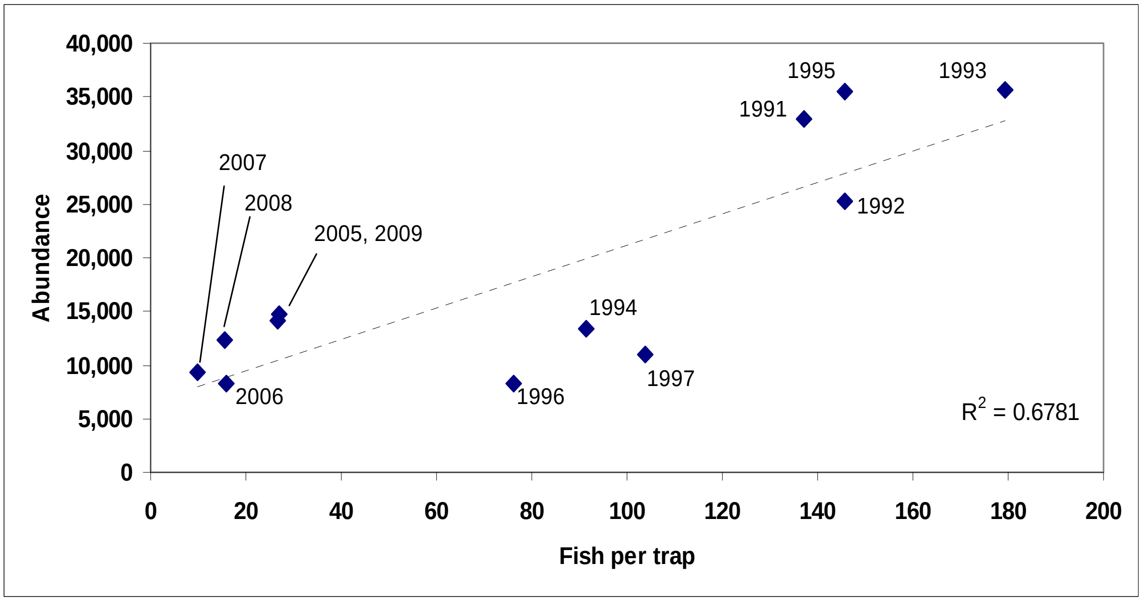
APPENDIX A. Details of Adjusted Peterson mark-recapture estimates obtained for Borax Lake Chub, 1986-2009. Fish per trap was calculated using the total number of fish caught on the recapture date divided by the number of traps fished on that date. Agency codes: TNC- The Nature Conservancy and ODFW- Oregon Department of Fish and Wildlife.

Year	Number of traps	Fish/trap	Marked	Catch	Recaptures	Number handled	Percent handled	Percent marked	Recaptures/ Marked	**Estimate**	95% Confidence limits lower	95% Confidence limits upper	Agency
1986			2,365	2,007	310	4,062	27%	15%	13%	**15,276**	13,672	17,068	
1987			2,569	2,579	772	4,376	51%	30%	30%	**8,578**	7,994	9,204	
1988			857	1,670	346	2,181	53%	21%	40%	**4,132**	3,720	4,589	
1989			5,923	1,548	652	6,819	49%	42%	11%	**14,052**	13,016	15,172	
1990			4,836	4,813	1214	8,435	44%	25%	25%	**19,165**	18,117	20,273	
1991	84	137	7,942	11,524	2773	16,693	51%	24%	35%	**33,000**	31,795	34,251	TNC
1992	63	146	5,486	9,172	1992	12,666	50%	22%	36%	**25,255**	24,170	26,388	TNC
1993	63	179	6,587	11,298	2087	15,798	44%	18%	32%	**35,650**	34,154	37,212	TNC
1994	63	91	1,922	5,764	825	6,861	51%	14%	43%	**13,421**	12,537	14,368	TNC
1995	63	146	4,720	9,179	1221	12,678	36%	13%	26%	**35,465**	33,533	37,510	TNC
1996	63	76	623	4,790	361	5,052	61%	8%	58%	**8,259**	7,451	9,153	TNC
1997	60	104	2,730	6,232	1560	7,402	68%	25%	57%	**10,905**	10,377	11,459	TNC
2005	72	27	1,216	1,941	160	2,997	20%	8%	13%	**14,680**	12,585	17,120	ODFW
2006	72	16	646	1,146	89	1,703	21%	8%	14%	**8,246**	6,715	10,121	ODFW
2007	100	10	687	981	71	1,597	17%	7%	10%	**9,384**	7,461	11,793	ODFW
2008	120	16	1,127	1,879	170	2,836	23%	9%	15%	**12,401**	10,681	14,398	ODFW
2009	100	27	2,087	2,676	395	4,368	31%	15%	19%	**14,115**	12,793	15,573	ODFW

APPENDIX B. Relationships between (A) trapping efficiency and estimated Borax chub abundance and (B) recapture rates and proportion of the population handled during mark-recapture abundance estimates. The year is listed next to each data point.



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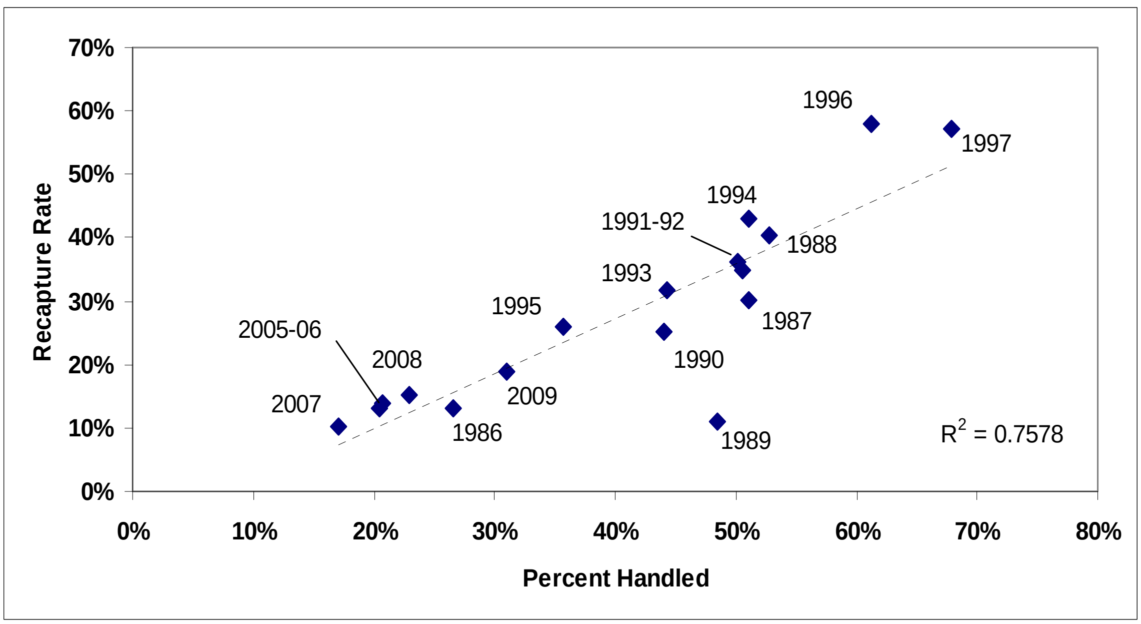

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