PROGRESS REPORTS

2006

FISH DIVISION

Oregon Department of Fish and Wildlife

2006 Borax Lake Chub Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: 2006 Borax Lake Chub Investigations

PROJECT NUMBERS: Contracts E-2-40, E-2-40 supplement, and TNC

PROJECT PERIOD: 1 January 2006 - 31 December 2006

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

CONTENTS

INTRODUCTION

Borax Lake chub (*Gila boraxobius*) is represented by a single population that inhabits a 4.1 hectare geothermally-heated alkaline lake in Harney County, Oregon. The Borax Lake chub is a small minnow endemic to Borax Lake and adjacent wetlands in Oregon's Alvord Basin (Williams and Bond 1980). 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 in 1991-1996 indicated a fluctuating population ranging from a low of 8,144 fish to a high of 34,634 fish (Salzer 1997). 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).

Numerous 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).

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. From 1998-2004, data describing the abundance of the Borax Lake chub population are not available. Abundance estimates were obtained from 1986-1997 by The Nature Conservancy (Salzer 1997) (Figure 1). Abundance estimates for 1986-1990 are not comparable with those obtained in 1991-1997. Prior to 1991, estimates were obtained only from traps set around the perimeter of the lake. In 1991, estimates were obtained from traps set on a regularly spaced grid throughout the lake. A study comparing the methods suggests that prior to 1991 abundance was under estimated, perhaps by as much as 50 percent (Salzer 1992).

A recent 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 this time. The chub population has experienced substantial fluctuations in abundance over the time period (1986-1997) when abundance data are available (Figure 1). At the time of the review, the most recent abundance estimates that were obtained in 1996 and 1997 were some of the lowest estimates since 1991.

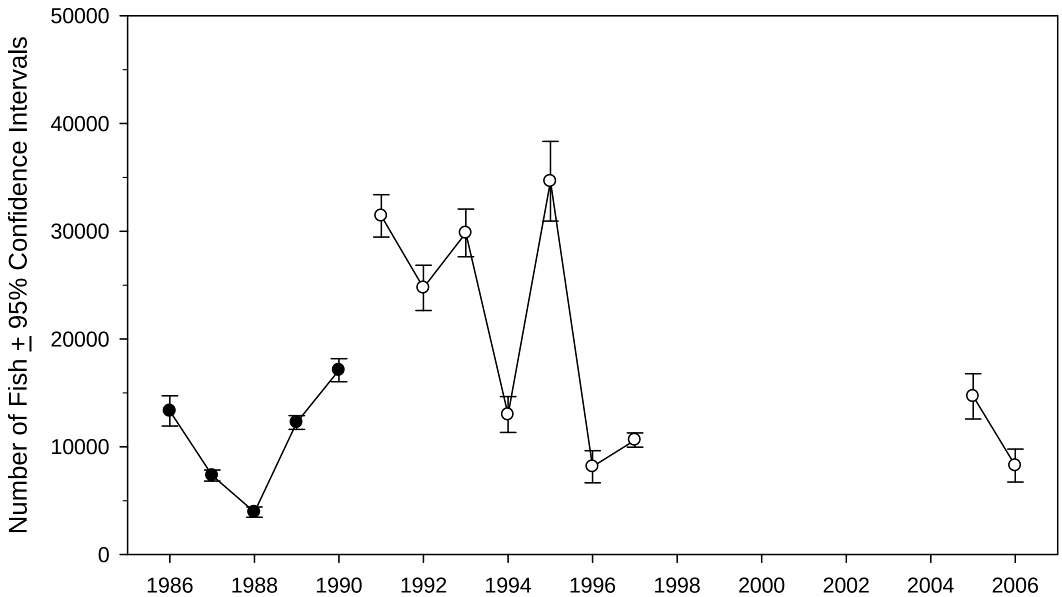

Figure 1. Borax Lake chub population abundance estimates from 1986 to 1997 and 2005 to 2006. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid symbols), only the perimeter of the lake was trapped. After 1990 (open symbols) the entire lake was trapped. Estimates are not directly comparable across these time periods.

There are limited data on population age structure that offer valuable insight into the productivity of Borax Lake chub. Williams and Bond (1983) examined length-frequency data and concluded that the population consisted primarily of age 1 fish, with few age 2 and age 3 fish present. Limited opercle bone aging of chub collected in 1992-1993 also indicated that most Borax Lake were less than one year of age (67-79%), yet a few individuals were aged at 10+ years (Scoppettone 1995). Because Borax Lake chub are only found in one location and the population is apparently dominated by a single year-class of adults, the species has a high inherent risk of extinction.

The objectives of this study were to: 1) obtain a mark-recapture population estimate of Borax Lake chub, and 2) to evaluate ways to reduce handling of Borax Lake chub when monitoring population abundance both by modifying previous mark-recapture protocols and by developing snorkeling survey protocols to use as an alternative to mark-recapture estimates. In addition, we collected data regarding lake temperatures, chub size (age) structure, and the condition of the fragile lake shoreline and outflows.

METHODS

The Oregon Department of Fish and Wildlife's Native Fish Investigations Project used baited minnow traps to obtain a mark-recapture population estimate. We fished 72 traps overnight (16 hours) and during the following day (6 hours). 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 recorded the total number of marked and unmarked fish captured. We estimated population abundance using single-sample mark-recapture procedures (Ricker 1975). Fish marked in the lake were given a different mark than those marked in the wetland and outflow channels. We calculated 95 percent confidence intervals using a Poisson approximation (Ricker 1975). Traps were fished at locations that included the variety of habitat types present. We measured total length (TL) on a sample of 101 fish collected in the traps.

We recorded physical habitat parameters in Borax Lake. The open water area (m^2) was measured using a laser range finder (+/- 0.5 m). Water depth was measured using a graduated depth staff (+/- 0.01 meter) or a digital depth sounder (+/- 0.5 m). Water temperature (^oC) was monitored at four locations using Hobo® recording thermometers from 3 April - 9 September, 2006. Temperature was recorded at 5-hour intervals. We used a Global Positioning System (GPS) to record site locations (UTM coordinates).

Protocols developed in 2005 were used to determine whether snorkeling counts could be used as an alternative to mark-recapture techniques to index chub abundance and monitor trends in abundance over time, while reducing the handling of fish. Five transects were established including two transects across the lake and three shoreline transects (Figure 2). The transect start and end points were marked with rebar and flagging on the bank and with foam floats suspended in the water. Shoreline transects ranged from 75 to 91 meters in length and cross-lake transects ranged from 171 to 196 meters in length. Transect start and end point positions were recorded using a GPS. Floating ropes were stretched across the lake to mark the transects that crossed the lake. For two successive nights, four surveyors swam the transects and counted all Borax Lake chub observed. Night surveys began approximately 30 minutes after sunset and lasted approximately 2 hours. Dive lights were used to illuminate the transects. Surveyors swam approximately 2 meters from the shore during shore line surveys and counted fish between themselves and the shoreline. For transects across the lake surveyors counted fish in an approximate 2 meter band while swimming across the lake. The number of fish observed in each transect was recorded on a dive slate then transferred to data sheets at the end of each sampling period. The order in which the transects were surveyed was varied for each sampling period for each surveyor, to evaluate the effect of surveyor order on transect counts. Water temperatures and weather conditions were recorded for each sampling period. Sources of variation were evaluated using an analysis of variance. Sources of variation included sampling period, transect, surveyor, surveyor order, and error. Snorkel counts were compared with mark-recapture estimates to determine whether counts can be used as an index to monitor trends in chub abundance.

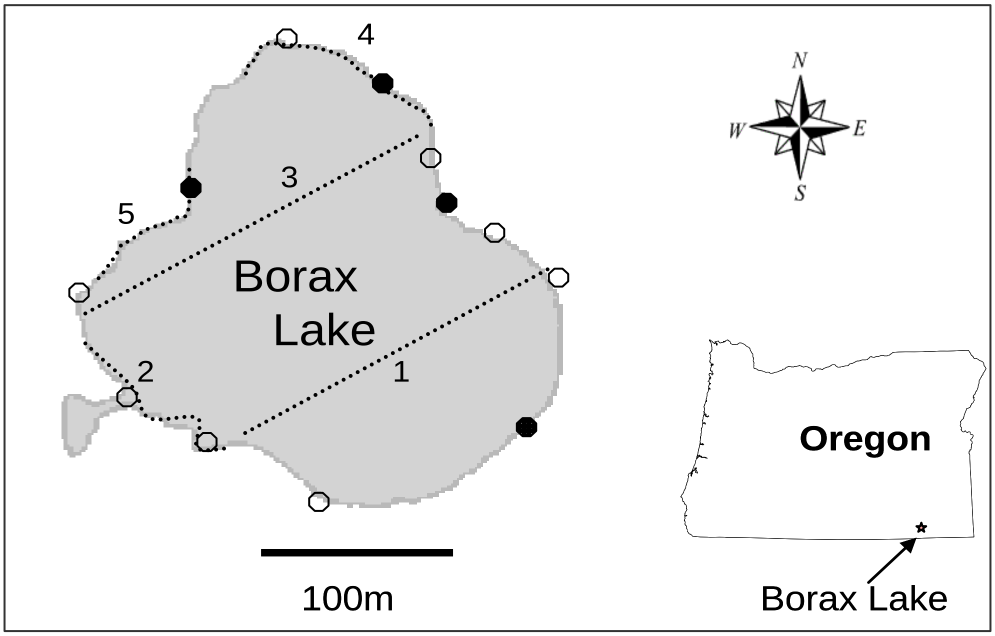

Figure 2. Map of Borax Lake showing the five transects established for snorkel surveys (dotted lines) and the locations of photo points (circles). The dark circles indicate the location of both photo points and thermographs.

We conducted pedestrian surveys to monitor the condition of the lake shoreline, lake outflows, and adjacent wetlands. We established 12 photo points around the perimeter of lake (Figure 2). 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 (**APPENDIX A**).

RESULTS

Population Estimate

The Borax chub population estimate obtained on 25 September 2006 was 8,246 fish (95% CI: 6,715-10,121), down substantially from the 2005 estimate of 14,680 fish (95% CI: 12,585 and 17,120) (Table 1). This estimate includes chub ranging from 34-103 mm TL. Length-frequency analysis suggests the presence of few age-classes with only one apparent peak (Figure 3). The 2006 population estimate was within the range

Table 1. Mark-recapture population estimate details for Borax Lake chub, 2005-2006.

2005

Entire lake (including wetland and outflow)

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
1216	1941	160	**14680**	12585	17120

Wetland only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
150	125	20	**906**	596	1365

Outflow only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
50	144	16	**435**	274	682

Lake only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
1016	1672	124	**13612**	11432	16203

2006

Entire lake (including wetland and outflow)

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
646	1146	89	**8246**	6715	10121

Wetland only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
40	147	14	**405**	248	650

Outflow only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
50	103	18	**279**	180	429

Lake only

Marked	Catch	Recaptures	Population estimate	95% Confidence Limits lower	95% Confidence Limits upper
556	896	57	**8614**	6675	11105

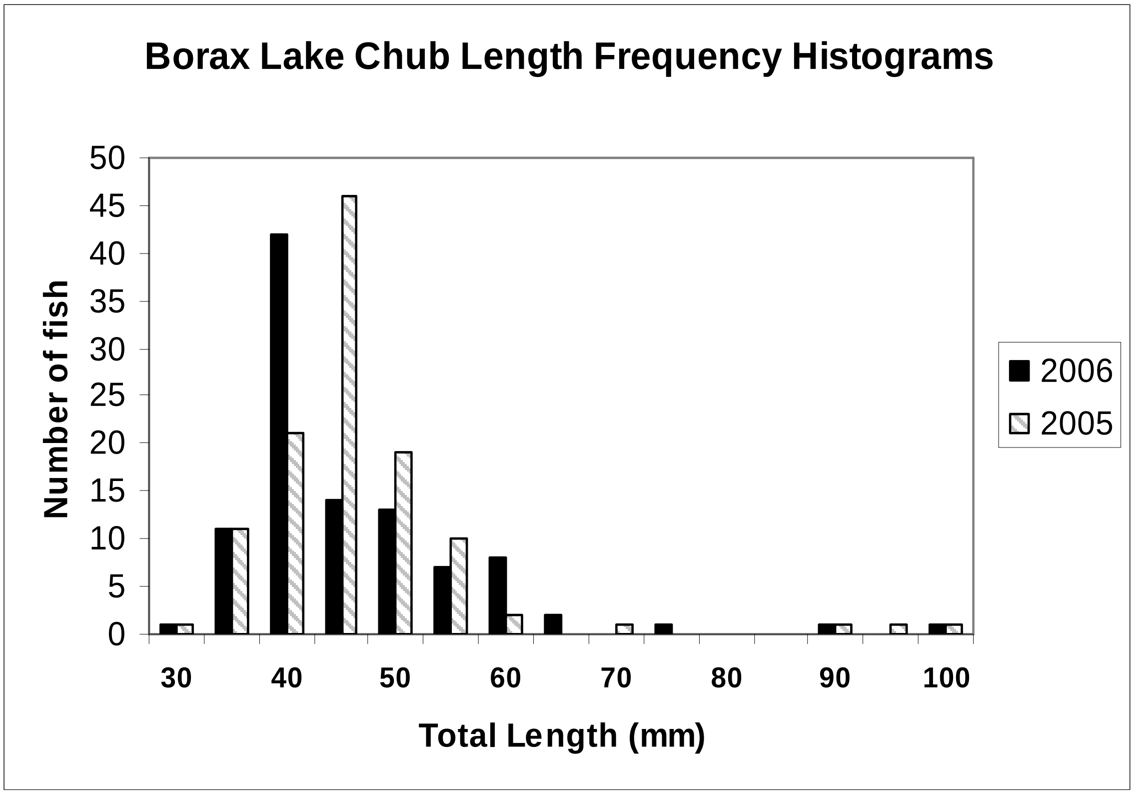

Figure 3. Length-frequency histograms for Borax Lake chub, 2005-2006.

of estimates obtained from 1986 through 1997 (3,934-34,634). Separate estimates for the wetland alcove located on the south side of the lake ($\hat{N}$ = 405, 95% CI: 248-650) and for the main outflow channel on the north side of the lake ($\hat{N}$ = 279, 95% CI: 180-429) showed proportionately similar declines in abundance compared to 2005 estimates.

Habitat Conditions

The water temperatures recorded in Borax Lake from 3 April through 9 September 2006 varied by location. Average temperatures ranged from a high of 31.5 ^{o}C on the northwest shoreline nearest the thermal vents to a low of 27.1 ^{o}C on the northeast shoreline. Daily fluctuations were typically 4-5^{o} C, with the exception of temperatures recorded in mid-July on the northeast shoreline, which varied up to 16^{o} C (Figure 4). This thermograph may have been exposed to the air or malfunctioned during this period (note the truncated peak temperatures in July). Water temperatures fluctuated in unison from location to location with peak temperatures (37.4-39.4^{o}C) occurring from mid-June through late-July.

The total habitat available for chub in Borax Lake, including the surrounding wetlands was approximately 4.1 hectares. Water depth of the lake averaged approximately 1.0 m with a maximum depth of 27 m measured in the vent. Most of the substrate was covered by a thick layer (0.5 m) of fine flocculent silt, with localized patches of bedrock and fine gravel. Approximately 25% of the substrate had a sparse growth of the aquatic macrophyte *Chara* sp. *Scirpus* sp. was abundant around the margins of the wetland alcove. For more detailed descriptions of the lake habitat see Scoppettone (1995).

We conducted shoreline pedestrian surveys and found most of the shoreline to be in good condition. However, we did observe localized areas on the northern shore with substantial off-road vehicle damage. We noted other human impacts to the shoreline including evidence of campfires and a few dried cow pies (age unknown).

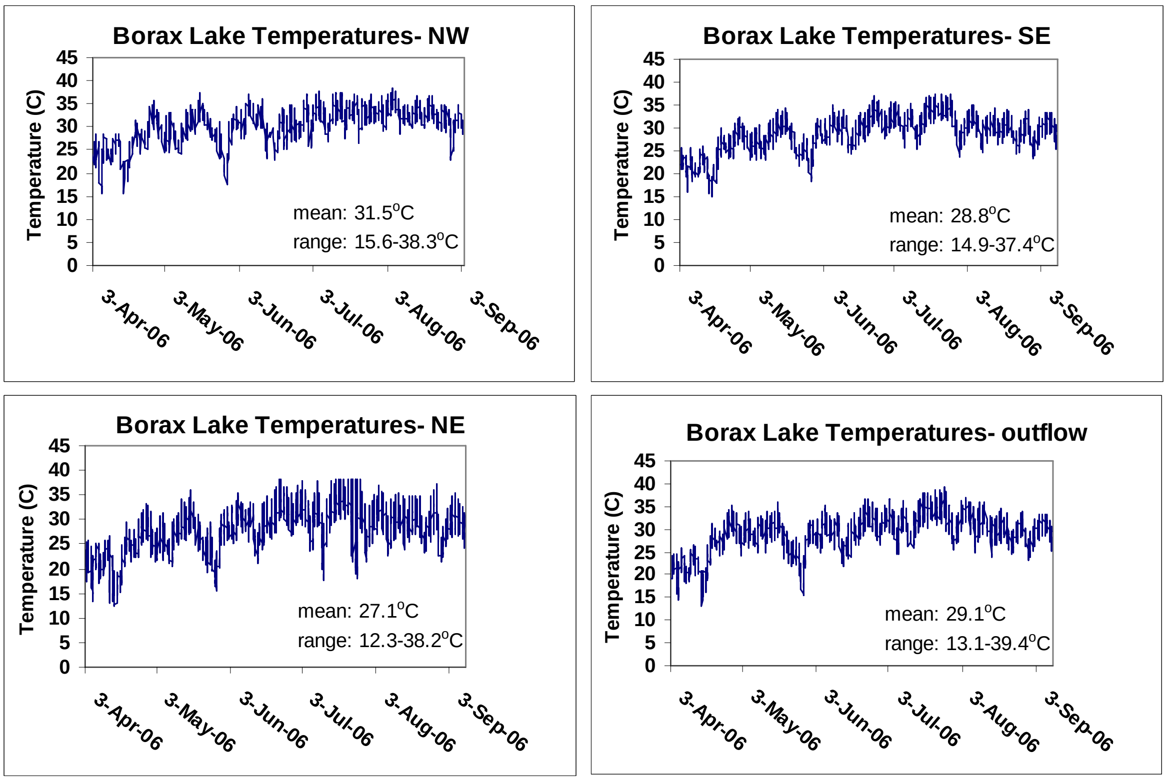

Figure 4. Water temperatures recorded at four locations in Borax Lake in 2006.

Snorkel Surveys

We conducted snorkel surveys in Borax Lake in 2005 and 2006 to determine whether snorkeling could be used to monitor trends in chub abundance over time, while reducing the handling of fish. In 2005 and 2006, we evaluated the sources of variation and relative contribution of these sources to overall variability in snorkel counts. Sources of variability included survey date (3 nights in 2005 and 2 nights in 2006), surveyors (4), transects (4), and the order of observation (first surveyor to snorkel a transect versus subsequent surveyors to snorkel the same transect). In both 2005 and 2006, we found that most of the variation was attributable to differences between surveyors ($P = 0.0098$ and $P = 0.0023$) and between transects ($P = 0.0266$ and $P = 0.0007$) (Table 2, **APPENDIX B**). Differences between surveyor order and survey night were not significant. To reduce the effects of these differences, we developed an index which pooled the counts for all transects into a total count per surveyor per night then averaging the counts for all surveyors to obtain an average total count per night.

Table 2. Results of an analysis of variance of 2005 and 2006 snorkeling surveys for Borax Lake chub.

Source	Degrees of Freedom	Mean square	F-value	P-value
2005				
Transect	3	56,997.6	3.50	0.0266
Night	2	20,980.8	1.29	0.2899
Surveyor	3	73,061.2	0.00	0.0098
Order	1	16.1	0.34	0.9133
2006				
Transect	3	14,283.0	8.73	0.0007
Night	1	4,043.0	2.47	0.1317
Surveyor	3	11,266.3	6.88	0.0023
Order	1	65.0	0.04	0.8441

Comparison of the mean number of fish observed during snorkel counts (for all transects, all surveyors, and all nights) with mark-recapture estimates obtained in 2005 and 2006 provides a measure of sensitivity of this protocol for monitoring changes in chub abundance, i.e. whether the proportion of the population estimate represented by the snorkel index shows consistency. In 2005, the mean number of fish observed for all transects by all observers was 1,012 or 7.4% (range 6.3-8.3%) of the "lake only" mark-recapture estimate of 13,612 fish (Scheerer and Jacobs 2005). In 2006, the mean number of fish observed was 378 fish or 4.4% (range 3.7-5.0%) of the "lake only" mark-recapture estimate of 8,614 fish (**APPENDIX B**). Our population abundance estimates declined by 37%, but the mean number of fish observed by snorkeling declined by 63%. Because the proportion of the population that surveyors observed declined by 41% (7.4% to 4.4%), this method appears to lack the sensitivity necessary to detect anything other than large changes in abundance over time.

DISCUSSION

Williams et al. (2005) identified the challenges in defining recovery for Borax Lake chub and other listed species that are restricted to small geographic areas and specific, rare habitat types. They argue that recovery to the point where protections are no longer needed is largely unattainable. Because the Endangered Species Act's primary purpose is to prevent species extinctions, the strength of the act can also be a deterrent to delisting, since doing so would remove those same protections needed to prevent extinction (Goble and Scott 2006; Williams et al. 2005). Scott et al. (2005) suggest an alternate approach for recovery of "conservation-reliant" species like Borax Lake chub where recovery is defined as a continuum of states rather than a simple recovered/not recovered dichotomy. Under this approach the recovered status would include some forms of active management.

In 2003, a status review was conducted to assess the current status of Borax Lake chub and its ecosystem, to identify remaining threats, to identify needed management efforts, and to determine whether a change in listing status was warranted (Williams and

Macdonald 2003; Williams et al. 2005). The status review included: 1) review of recovery plan implementation, 2) field investigations to assess habitat and shoreline conditions, 3) review of the five listing/delisting factors from Section 4 of the Endangered Species Act, and 4) convening a 16-member scientific review panel to provide scientific opinion regarding the remaining threats, listing status, and needed management and monitoring. The review panel concluded that substantial progress has been made towards recovery, but that several threats to the species and its habitat remained. The primary threats include habitat degradation of the lake shoreline resulting from increased recreation use in the area, an increased 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). The panel concluded that despite current protections, due to its restricted range Borax Lake chub are vulnerable to catastrophic loss. The panel recommended implementation of regular population and habitat monitoring to detect and act on any future threats (exotic species or shoreline degradation). The panel further concluded that no change in listing/delisting status was appropriate at this time, yet reclassification of the species status from endangered to threatened could be appropriate in the near future, dependant primarily upon implementation of a regular monitoring program (Williams et al. 2005).

There was concern that excessive handling of fish during mark-recapture estimation posed an additional threat to the species (D. Salzer, TNC and T. Walters, ODFW, personal communication). During previous abundance estimates, between 44 and 61 percent of the population was handled during marking and recapturing. 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 percent by marking approximately 1,000 individuals and handling a total of 2,500-3,000 individuals. In 2005 and 2006, we obtained mark-recapture estimates with relatively high precision while reducing the proportion of the population that was handled. In 2005, we marked 1,216 fish (8 percent of the population), handled a total of 2,997 individual fish (20 percent of population), and obtained a relative precision of ± 14% (Scheerer and Jacobs 2005). In 2006, we marked 646 fish (8 percent of the population), handled a total of 1,703 individual fish (21 percent of population), and obtained a relative precision of ± 19%. It is the opinion of the authors that the handling of 20% of the population to obtain estimates with precision within 14-19 percent is acceptable and not a threat to the listed species. Only three trap mortalities resulted from our mark-recapture protocols (both years combined). Furthermore, given expected precision of ± 14-19%, we have the ability to detect a 26-33% change in abundance. We do not recommend use of snorkel surveys because they lacked sensitivity to detect all but major changes in population abundance.

During the 2006 Borax Lake Chub Working Group Meeting, one topic of discussion focused on the comparability of present and past abundance estimates, which were obtained using different sampling protocols. Salzer (1992) compared estimates obtained from trapping that occurred only around the lake perimeter (1986-1990) with a whole lake sampling protocol (1991-1997), where traps were laid out on a 25 m by 25 m grid pattern (USFWS 1991). He found that perimeter-only sampling resulted in a substantial underestimation of population abundance. For this reason we do not consider the pre-1991 estimates to be comparable to post-1990 estimates.

We used two approaches to assess the comparability of systematic grid trapping protocols (1991-1997) with the random trapping protocols that were used in 2005 and 2006. Because we obtained independent estimates for the lake, the wetland, and the outflow channel and because past estimates did not include the wetland and outflow channels (for unknown reasons), it is important to use our "lake only" estimates when comparing past and present estimates. To assess whether we met the assumption that the marked fish mixed randomly with the unmarked fish and have a capture probability that is equal to that of the unmarked fish (Ricker 1975), we first compared the proportions of marked fish (marked:unmarked ratio) from traps fished at different locations throughout the lake during the recapture events. We found that the proportion of marked fish was independent of the location of trapping sites ($p>0.10$) (Figure 5).

Next, we simulated a randomized trapping design using data from the 1991 sampling (Salzer 1992). We selected a random 50% subsample (32 traps) of the data from the 63 traps fished on a grid pattern on 22 October 1991 and calculated a single-sample mark-recapture estimate using the catch data (marked and unmarked fish) from this subsample. When we compared this estimate to the estimate from all 63 traps, we found the estimates were essentially identical (within 4%) (**APPENDIX C**). The random selection of traps from the grid simulates our random placement of traps within the lake. From these analyses, it is our opinion that estimates obtained from random trapping are comparable with estimates obtained from grid-based trapping.

The habitat conditions at Borax Lake in 2005 and 2006 did not appear to differ from those reported in the past (Williams and Bond 1983, Scoppettone et al. 1995). The water was clear and visibility was good. The lake substrate included bedrock in the southeast areas of the lake, fine gravel and bedrock in the northern areas of the lake, and a flocculent silt dominating the remaining areas of the lake. The shoreline surveys found evidence of recreation use including ashes from campfires and substantial off-road vehicle usage. Several members of the public visited with us during our population estimates, some driving their vehicles to the lakes edge.

We recommend continued future investigations at Borax Lake that include obtaining mark-recapture population estimates using protocols that limit handling to approximately 20 percent of the total population size. Because Borax Lake chub are an annual species, i.e. most fish are $\leq$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 also recommend continued annual shoreline pedestrian surveys to assess the condition of the fragile lake crust. 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 reduce the impacts of off-road vehicular traffic.

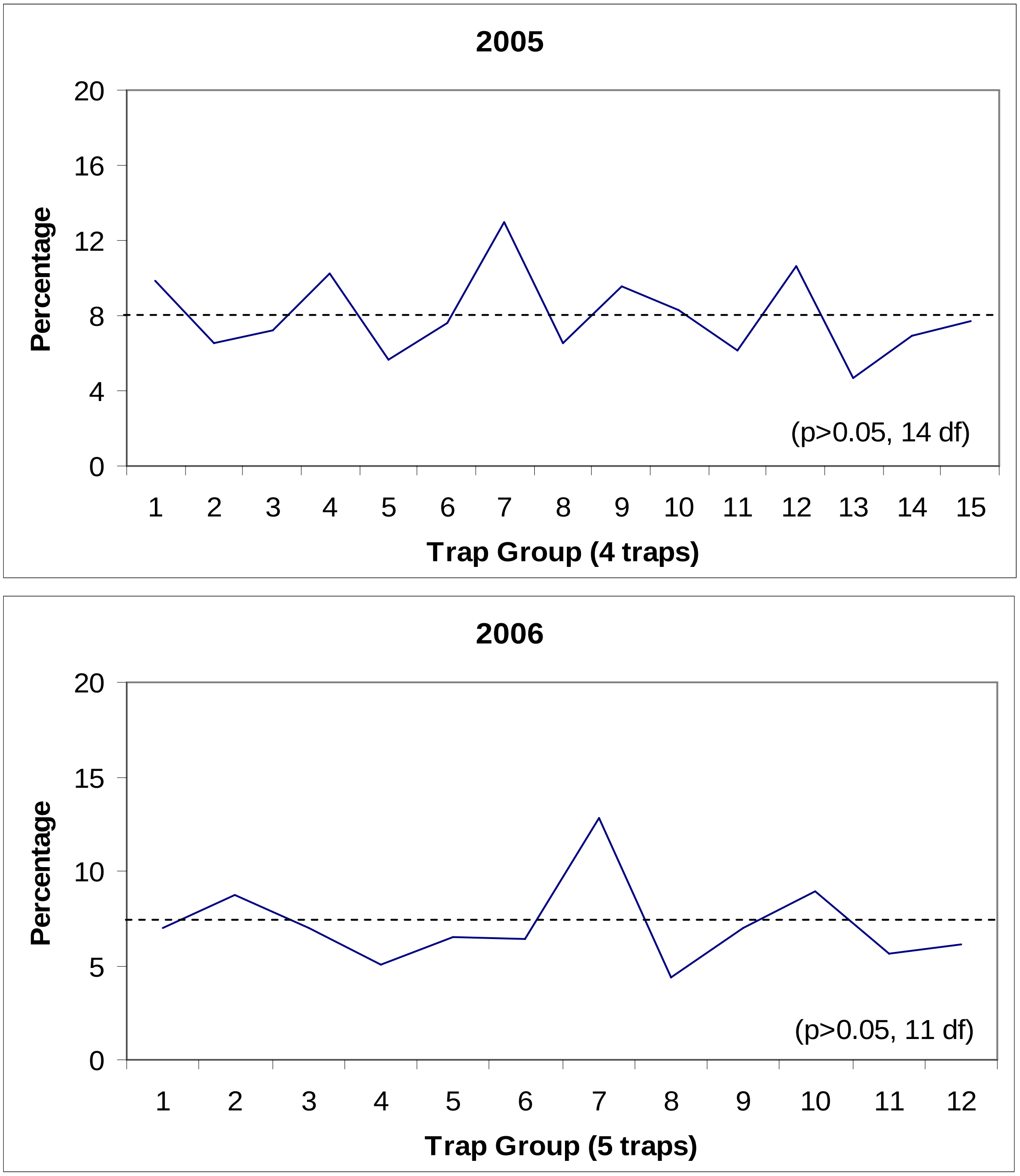

Figure 5. Comparison of the proportion of marked fish from groups of traps fished within different locations in Borax Lake during mark-recapture population estimates with the proportion of marked fish from all traps combined, 2005-2006. Dotted lines represent the proportion of marked fish for all traps combined, for each year.

ACKNOWLEDGEMENTS

We are grateful to Teri Moore, Alan Mauer, Steve Dowlan, and Frank Bird for assistance with the field work and Mary Buckman for assistance with the statistical analyses. We thank Darren Brumback and the Bureau of Land Management for their support and for use of the housing facilities in Fields. We gratefully acknowledge funding provided for this study by the US Fish and Wildlife Service, the Bureau of Land Management, and The Nature Conservancy.

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APPENDIX A. Borax Lake shoreline photo point locations and descriptions.

Photo point	Location			Description
	Zone	Easting	Northing	
1	11T	367889	4687154	near 2 "T" posts, old ditch to L. Borax Lake
2	11T	367902	4687127	at wetland bridge (board), marker F (southeast side)
3	11T	367901	4687125	at marker H (west side), start of snorkel transect 2
4	11T	367938	4687066	at marker J, near exclosure (Anadarko monitor)
5	11T	368089	4687079	at marker K2 (southeast side), hobo deployed
6	11T	369121	4687123	at marker H (east side)
7	11T	368123	4687172	at marker G (east side), smaller outflow
8	11T	368104	4687196	at marker F (east side), main outflow w/ pools, hobo deployed
9	11T	368072	4687235	at marker E (east side)
10	11T	368037	4687291	at marker C (northeast side), hobo deployed under rock
11	11T	367947	4687252	between marker B & C, start of snorkel transect 5
12	11T	367907	4687199	at marker D (west side), start of snorkel transect 3

APPENDIX B. Snorkel counts of Borax Lake chub, 2005-2006. Shaded boxes represent counts made the first time a transect was sampled each night. Numbers in italics represent the average total number of fish observed as a proportion of the mark-recapture estimate for the lake, excluding the wetland and outflow which were not snorkeled.

September 12, 2005

	Transect				
Sampler	1	3	4	5	total
1	64	86	39	66	255
2	305	382	271	331	1289
3	213	266	141	356	976
4	318	272	86	209	885
mean	225	252	134	241	851

September 13, 2005

	Transect				
Sampler	1	3	4	5	total
1	244	112	363	82	801
2	212	231	385	347	1175
3	218	297	478	212	1205
4	252	205	338	229	1024
mean	232	211	391	218	1051

September 14, 2005

	Transect				
Sampler	1	3	4	5	total
1	227	162	263	92	744
2	309	291	718	190	1508
3	207	187	795	129	1318
4	263	196	366	136	961
mean	252	209	536	137	1133

Mean of 2005 totals	1012
% of M/R estimate	*7.4*

September 10, 2006

	Transect				
Sampler	1	3	4	5	total
1	49	51	70	26	196
2	172	91	243	87	593
3	114	154	285	43	596
4	115	101	64	65	345
mean	113	99	166	55	433

September 11, 2006

	Transect				
Sampler	1	3	4	5	total
1	73	14	99	29	215
2	136	73	189	63	461
3	102	56	169	38	365
4	74	55	79	43	251
mean	96	50	134	43	323

Mean of 2006 totals	378
% of M/R estimate	*4.4*

APPENDIX C. Comparison of population estimates and 95% confidence intervals from the grid sampling protocol used in 1991 and a random subsample of these data.

1991 data (63 traps distributed on a 25 m by 25 m grid)

					95% Intervals	
Marked	Catch	Recaps	Recaps/Catch	Estimate	lower	upper
7942	4801	1352	0.28	**28191**	26729	29733

Random subsample of 1991 data (32 traps)

					95% Intervals	
Marked	Catch	Recaps	Recaps/Catch	Estimate	lower	upper
7942	2259	606	0.27	**29181**	26952	31595

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