# PROGRESS REPORTS

## 2005

## FISH DIVISION

### Oregon Department of Fish and Wildlife

Borax Lake Chub Population Assessment and Monitoring Strategy

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: Borax Lake Chub Population Assessment and Monitoring Strategy

PROJECT NUMBERS: Contract 134204M129

PROJECT PERIOD: 12 August 2004 - 30 September 2006

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

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## 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 is 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. Data describing the abundance of the Borax Lake chub population (Borax Lake SMU) over the last seven years 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 pre-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 is available (Figure 1). The most recent abundance estimates, obtained in 1996 and 1997, were some of the lowest estimates in recent years.

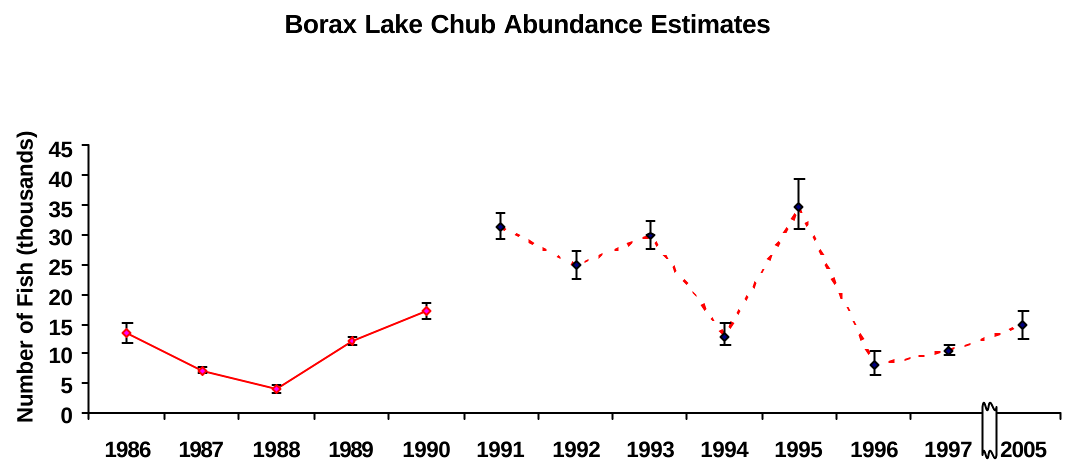



**Figure 1.** Borax Lake chub population abundance estimates from 1986 to 1997 and 2005. Horizontal bars represent 95% confidence limits. In 1986-1990 (solid line), only the perimeter of the lake was trapped. After 1990 (dashed line) the entire lake was trapped. Estimates are not directly comparable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

There are limited population age structure data that offer valuable insight into Borax Lake chub productivity. Williams and Bond (1983) examined length-frequency data and concluded that the Borax Lake chub 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, 2) 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, and 3) develop a long-term monitoring strategy for the endangered Borax Lake chub and its habitat in Borax Lake. 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 returned them to the water. Marked fish were distributed 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). 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 104 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 using a Hobo® recording thermometer. Temperature was recorded every 5-hours from early-June through late-August. Additional thermographs were deployed in September 2005 at four locations; these will be uploaded in 2006. We used a Global Positioning System (GPS) to record site locations (UTM coordinates).

Protocols were developed 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 three successive nights and one day, 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 m 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. The snorkel counts will be compared with mark-recapture estimates obtained in 2005-2007 to determine whether counts can be used as an index to monitor trends in chub abundance.

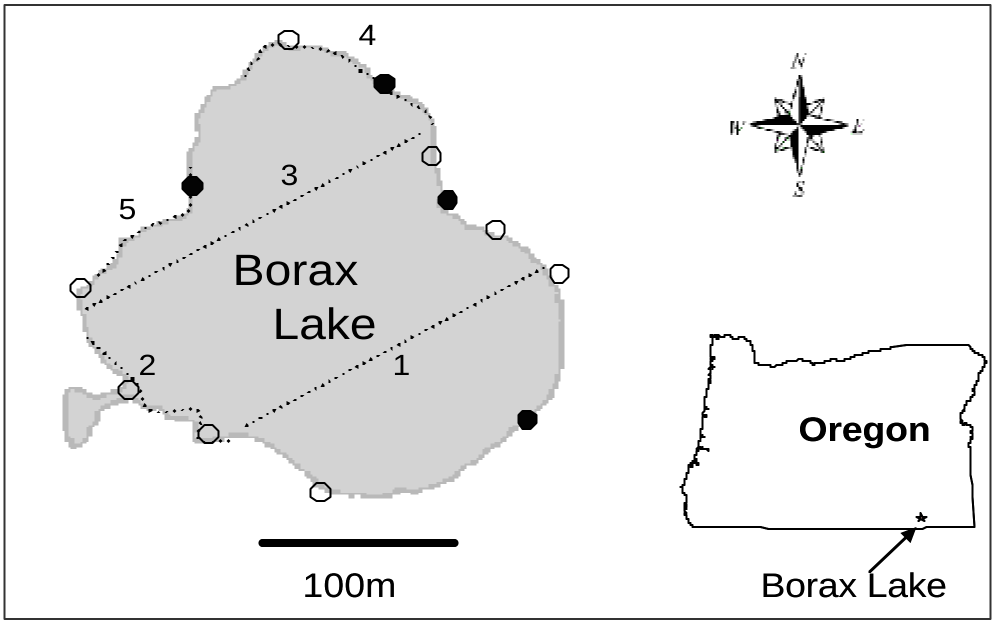



**Figure 2.** Map of Borax Lake showing the five transects established for snorkel surveys (dotted lines) and the locations of photo points (circles). The dark circles indicate the location of both photo points and thermographs that were deployed in September 2006. Temperature data obtained in the summer of 2005 came from the thermograph (dark circle) located in transect 5.

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. Temperatures were recorded at each photo point location. 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 September 29, 2005 was 14,680 fish. The 95% confidence limits for this estimate were 12,585 and 17,120 fish (Table 1). This estimate includes chub ranging from 33-100 mm TL. Length-frequency analysis suggests the presence of few age-classes, with only one apparent peak (Figure 3). The 2005 population estimate is larger than the most recent prior estimates obtained in 1996 and 1997 (8,144 and 10,625, respectively) and within the range of estimates obtained from 1986 and 1995 (3,934-34,634). We obtained separate estimates for the wetland alcove located on the south side of the lake ( $\hat{N}$ = 906, 95% CI: 596-1,365) and for the main outflow channel on the north side of the lake ( $\hat{N}$ = 435, 95% CI: 274-682).

**Table 1.** Mark-recapture population estimate details for Borax Lake chub, fall 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 |

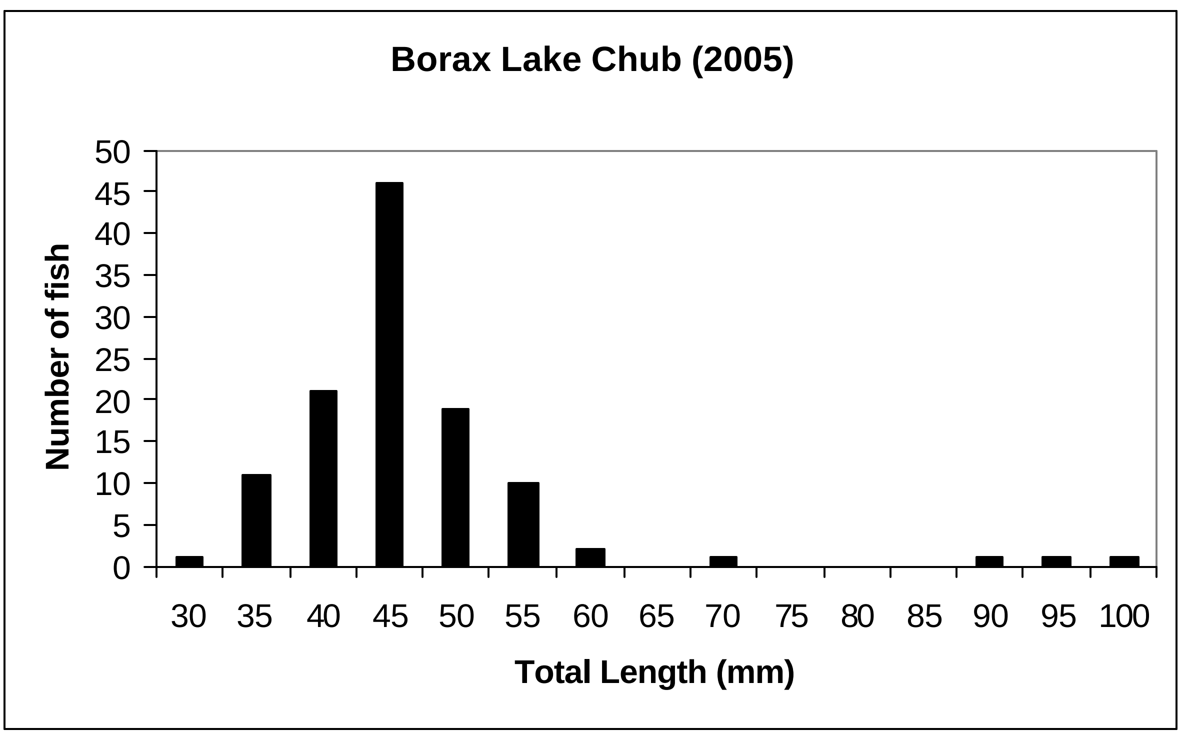
**Wetland only**

| 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 |

**Figure 3**. Length-frequency histogram for Borax Lake chub, September 2005.



Habitat Conditions

The water temperatures recorded in Borax Lake from June 9 through September 19, 2005 averaged 31.7°C (range 22.5-38.3°C). Daily fluctuations were typically 4-5°C (Figure 4). Peak temperatures were recorded in early to mid-July and in early-August.

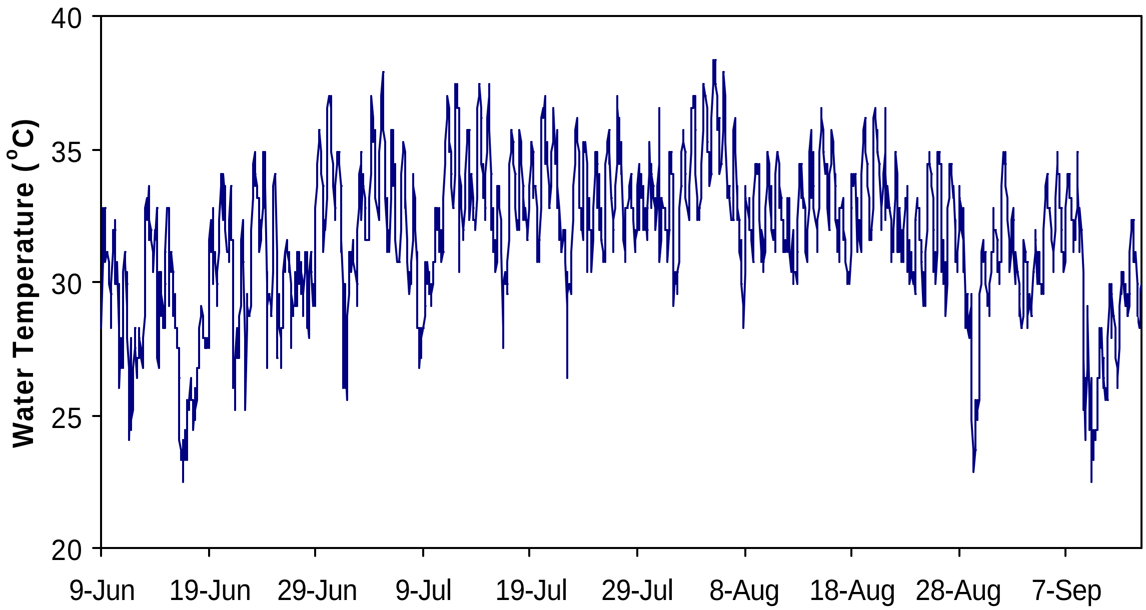



**Figure 4.** Water temperatures recorded in Borax Lake during summer 2005. Water temperatures were recorded at 5-hour intervals.

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 pond 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 pond 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 (Figure 5). We noted other human impacts to the shoreline including evidence of campfires and a few dried cow pies (age unknown).

**Figure 5.** Off-road vehicle damage to the north shoreline of Borax Lake in 2005.

Snorkel Surveys

We conducted snorkel surveys in Borax Lake in September 2005 to determine whether snorkeling could be used to monitor trends in chub abundance over time, while reducing the handling of fish. The true test will be to determine whether variation in population abundance is adequately described by snorkel counts. In 2005, 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), surveyor (4), transects (5), and the order of observation (first surveyor to snorkel a transect versus subsequent surveyors to snorkel the same transect). We found that most of the variation was attributable to differences between surveyors (P = 0.0098) and between transects (P = 0.0266) (Table 2, **APPENDIX B**). Differences between surveyor order (P = 0.9133) and survey night (P = 0.2899) were not significant. We decided to drop the daytime snorkel survey results from the analysis, because the presence of very large schools of chub made counts unreliable. In addition, transect 2 was dropped because of turbidity. Inclusion of transect 2 did not change the overall results. These results indicate that increasing the number of samplers or the number of transects would decrease the variability more than increasing the number of nights. Since it is likely that the counts from the transects will be pooled as we develop an index to obtain an unbiased estimate of chub abundance, increasing the number of samplers may be the best option for obtaining a less variable index.

**Table 2.** Results of an analysis of variance of snorkeling surveys for Borax Lake chub.

| Source | Degrees of Freedom | Mean square | F-value | P-value |
|---|---|---|---|---|
| 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 |

## 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 area 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, and where 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 (Williams and Macdonald 2003; Williams et al. 2005). 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 due to its restricted range, Borax Lake chub is vulnerable to catastrophic loss, despite current protections. 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 2005, we evaluated ways to reduce handling while obtaining population estimates. We examined existing data from mark-recapture abundance estimates obtained for other species (Oregon chub and coho salmon) 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, we succeeded in obtaining a mark-recapture estimate with relatively high precision while reducing the proportion of the population that was handled. We marked 1,216 fish representing 8 percent of the population, handled a total of 2,997 individual fish (20 percent of population), and obtained an abundance estimate of 14,680 fish with a lower 95 percent confidence interval of 12,585 fish (within 14% of the point estimate). It is the opinion of the authors that the handling of 20% of the population to obtain estimates with precision of approximately 14 percent is acceptable and not a threat to the listed species. Only one known mortality resulted from our mark-recapture protocols. Furthermore, given an expected precision of +/- 14%, we should be able to detect a 26% decline in abundance.

It is premature to assess whether snorkel surveys will provide an index that is useful to monitor changes in population abundance of chub at Borax Lake. Comparison of the snorkel counts with mark-recapture estimates obtained over the following 2 to 3 years will provide 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. Statistical power analysis of these data should assist in defining the required sampling effort needed to determine a specific change in mean snorkel counts at predetermined levels of significance and power to guard against type I (rejecting the null hypothesis of no difference when it is true) and type II (failure to reject the null hypothesis of no difference when it is false) errors (Gryska et al. 1997). If we choose snorkel indices to monitor trends in abundance this type of analysis is important, because the consequences of failure to identify the decline of an endangered species when it is actually occurring (type II error) may be irreversible. Initial statistical analysis showed that variation attributable to different sampling dates and the order of surveys was a small and insignificant portion of the total variation. The variance attributable to different surveyors was found to be significant and may be problematic, unless the same surveyors are available to conduct estimates each year. However, if the proportion of the population estimate represented by the population estimate is variable from year to year, then snorkel indices may lack sufficient sensitivity, regardless of sampling effort.

The habitat conditions at Borax Lake 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.

## MONITORING STRATEGY

Williams and Macdonald (2003) proposed development and implementation of a monitoring strategy to conserve Borax Lake chub and the Borax Lake ecosystem. This strategy is important to identify any new disturbance to the ecosystem and to identify introduced species. We reviewed the authors' suggestions and propose the following strategy:

1) <u>Chub population monitoring</u>- Implement regular population monitoring to estimate chub abundance, assess abundance trends over time, and to detect the presence of exotic species. We recommend repeating the snorkel surveys and mark-recapture abundance estimates in 2006 and 2007 to determine whether a reliable relationship exists between the snorkel counts (indices) and the mark-recapture estimates. If the snorkel estimates prove to be a reliable method, then snorkel surveys could be

conducted annually with a mark-recapture estimate obtained every five years. If the snorkel estimates do not prove to be useful, mark-recapture estimates should be obtained at least every three years. The total number of fish handled should be limited to less than 25 percent of the total population. ODFW would conduct the mark-recapture and snorkel estimates, with assistance from BLM and USFWS personnel.

2) Habitat and shoreline monitoring and protection- Implement regular habitat and shoreline surveys to: 1) evaluate the threat of shoreline degradation due to off-road vehicle use, 2) detect presence of nonnative fishes, 3) monitor the condition of outflows and adjacent wetlands, and 4) note other disturbances. We (ODFW) established photo points and conducted pedestrian surveys in September 2005. Photo points were marked with flagging and rebar and locations were recorded using a GPS (*see* **APPENDIX A**). Site visits should occur at regular intervals (quarterly?) to monitor the condition of the shoreline, outflows and adjacent wetlands, to evaluate the condition of fences and gates, to make observations of fish, and to record observations of recreational use. ODFW could conduct these surveys in the fall when obtaining abundance estimates and BLM or TNC personnel could conduct the surveys in the spring, summer, and winter. To protect the ecosystem from impacts of off-road vehicle use, we recommend the creation of a parking area on the dirt road that leads to the lake and limiting public lake access to foot traffic. BLM has proposed installation of a new fence on BLM land on the east side of the south entrance road that would run to the fork in the road and then west to the private land boundary. A parking area would be established at the fork in the road and the fence would restrict entrance onto the lake shore crust. A locked gate would be installed to allow access for biological monitoring. This fencing would minimize the threat from vehicular traffic to the fragile shoreline crust and may reduce the risk of unauthorized introduction of nonnative fishes. The Bureau of Land Management and The Nature Conservancy would maintain the perimeter fencing, cattle gate, and create the parking area. We suggest maintaining only a single access gate and closing the western and northern access roads.

3) Public Education- Habitat protection would benefit from public education through the design and installation of interpretive signs that would describe both the historical and ecological aspects of the ecosystem. The signs could be installed near the gate at the proposed parking area (ecological sign) and near the historic borax vat (historical sign). BLM has already purchased and designed the historical sign. The ecological sign could be designed by BLM with assistance from TNC, USFWS, and ODFW. BLM would install these signs when they are completed. Safety information should be included in the ecological sign stating the dangers of the hot springs (near boiling temperatures) and the danger of collapse of the undercut banks of some hot springs under the weight of a vehicle or humans. Additionally, a phone number for the public to report disturbances or vehicle trespass could be posted.

4) Vehicle Management Plan and Monitoring- Develop a vehicle management plan. BLM and TNC could take the lead with assistance from USFWS and ODFW. This vehicle plan would include visitor use assessments to quantify the number of visits and determine compliance with regulations and access restrictions. Assessment of vehicle usage in the area could be monitored by installing vehicle counters and from the habitat and shoreline surveys (item 2 above). The vehicle management plan would include specifics regarding allowable access beyond the parking area by

agency and TNC personnel, and the types of activities where access is allowable (population monitoring, shoreline surveys, etc.). Permits could be assigned for access beyond the parking area and records of these permits could be used to document the types and frequency of scientific studies being conducted at the site.

5) NEPA Compliance and ESA Consultation- Implementation of the vehicle management plan (parking, signs, etc.) may require NEPA compliance documentation and consultation with USFWS. BLM, TNC, and USFWS would work together with USFWS to meet these requirements.

6) Invertebrate and Water Quality Monitoring- Annual invertebrate and water quality monitoring were identified by Williams and Macdonald (2003). The purpose of the invertebrate monitoring is to track the status of rare aquatic macroinvertebrates and to identify any introduced macroinvertebrate species. A rare native snail, *Planorbella oregonensis* is of particular importance (Furnish et al. 2002). Water quality monitoring would be useful to detect changes that may occur in the lake chemistry and to infer relationships with fish and invertebrate abundance. It is uncertain whether agency personnel have the expertise to conduct this monitoring or precisely what these surveys would entail. The USFWS Environmental Contaminants Group, located in Oregon State Office in Portland, may be able to assist or conduct this task. Alternately, this work could be contracted out to OSU or private consultants. Specifics regarding the need and extent of these surveys should be discussed by the Borax Lake Chub Working Group.

7) Annual Borax Lake Working Group Meetings- An annual meeting should be held to review the results of monitoring conducted during the preceding 12 months. Any new information would be shared at this time. Monitoring information would be shared with all interested parties including, but not limited to USFWS, BLM, ODFW, and TNC. Current management and monitoring activities would be evaluated and any needed changes would be discussed. Notes regarding the review and recommended management or monitoring changes would be distributed to all interested parties in a timely manner. USFWS would take the lead in scheduling and facilitating these meetings.

## ACKNOWLEDGEMENTS

We are grateful to Teri Moore, Alan Mauer, Mike McGee, and Frank Bird for assistance with the field work. We thank Darren Brumback and the Bureau of Land Management for his support, for coordinating use of the housing facilities in Fields, and for the loan of traps. We thank Mike McGee and Jack Williams for suggestions regarding the monitoring strategy.

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**APPENDIX A** Borax Lake shoreline photo point locations, descriptions, and water temperatures.

| Photo point | Location Zone | Easting | Northing | Description |
|---|---|---|---|---|
| 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 snorkel transect 5 |
| 12 | 11T | 367907 | 4687199 | at marker D (west side), start snorkel transec 3 |

| Photo point | Photos | Temperature (C ) | Temperature locations | Comments |
|---|---|---|---|---|
| 1 | 1-2 | 27.0 | lake | left, right |
| 2 | 3-8 | 20.5 | wetland | vent (grebes), left, right, wetland channel, wetland pond, vent |
| 3 | 9-12 | 26.0 / 15.0 | lake, isolated p | left, right, small isolated pond (~10 x 6.5 m)- 2 photos |
| 4 | 13-16 | 23.0 | lake | left, right, south, exclosure |
| 5 | 17-19 | 24.0 | lake | left, right , east |
| 6 | 20-22 | 25.0 | lake | left, right, north, cow activity (old?) |
| 7 | 23-25 | 25.0 | lake | left, right, small outflow |
| 8 | 26-28 | 24.5 | outflow | left, right, large (main) outflow |
| 9 | 29-35 | 24.0 | lake | left, right, ORV usage near markers E-D (4), small outflow near markers C-D |
| 10 | 36-39 | 25.5 | lake | left, right, ORV usage (2) |
| 11 | 40-42 | 28.0 | lake | left, right, east |
| 12 | 43-45 | 27.0 | lake | left, right, fire evidence |

**APPENDIX B**. Snorkel counts of Borax Lake chub in September, 2005. Shaded boxes represent counts made the first time a transect was sampled each night.

September 12, 2005 (night)

| | Transect | | | | | |
|---|---|---|---|---|---|---|
| Sampler | 1 | 2 | 3 | 4 | 5 | total |
| 1 | 64 | not sampled | 86 | 39 | 66 | 255 |
| 2 | 305 | 137 | 382 | 271 | 331 | 1426 |
| 3 | 213 | 128 | 266 | 141 | 356 | 1104 |
| 4 | 318 | 81 | 272 | 86 | 209 | 966 |
| mean | 225 | 115 | 252 | 134 | 241 | 938 |

September 13, 2005 (night)

| | Transect | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | total |
| 1 | 244 | 52 | 112 | 363 | 82 | 853 |
| 2 | 212 | 103 | 231 | 385 | 347 | 1278 |
| 3 | 218 | 88 | 297 | 478 | 212 | 1293 |
| 4 | 252 | 53 | 205 | 338 | 229 | 1077 |
| mean | 232 | 74 | 211 | 391 | 218 | 1125 |

September 14, 2005 (night)

| | Transect | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | total |
| 1 | 227 | 27 | 162 | 263 | 92 | 771 |
| 2 | 309 | 88 | 291 | 718 | 190 | 1596 |
| 3 | 207 | 64 | 187 | 795 | 129 | 1382 |
| 4 | 263 | 131 | 196 | 366 | 136 | 1092 |
| mean | 252 | 78 | 209 | 536 | 137 | 1210 |

September 14, 2005 (day)

| | Transect | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | total |
| 1 | 151 | 14 | 5 | 0 | 32 | 202 |
| 2 | 272 | 31 | 14 | 337 | 83 | 737 |
| 3 | 384 | 88 | 17 | 600 | 66 | 1155 |
| 4 | 360 | 8 | 51 | 767 | 59 | 1245 |
| mean | 292 | 35 | 22 | 426 | 60 | 835 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Length (m) | 196 | 90 | 171 | 75 | 91 | 623 |

OREGON
Fish & Wildlife

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