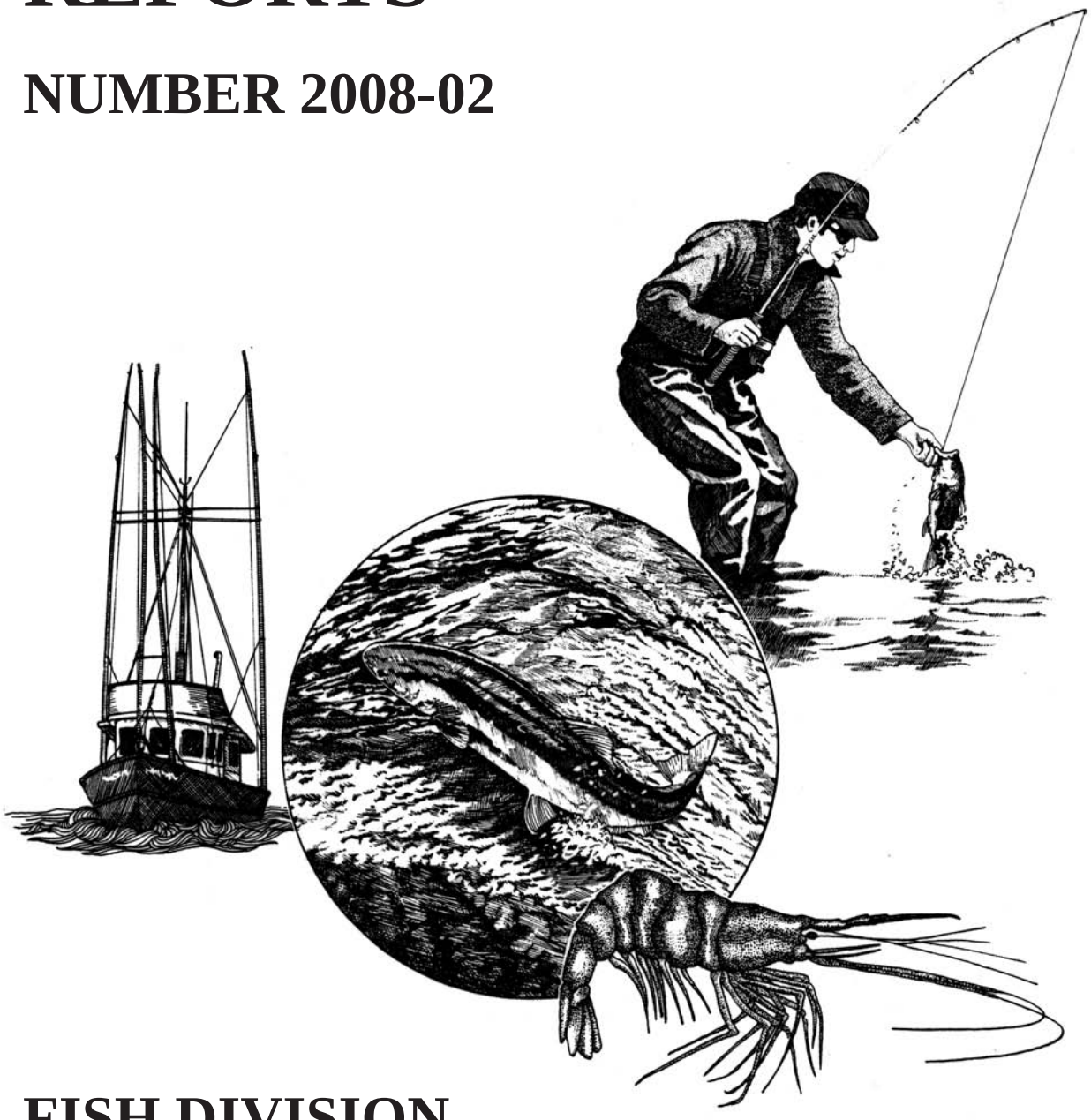
INFORMATION REPORTS

NUMBER 2008-02



FISH DIVISION

Oregon Department of Fish and Wildlife

Status and Distribution of Native Fishes in the Goose Lake Basin

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Status and Distribution of Native Fishes in the Goose Lake Basin



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June 2008

This project was financed with funds administered by the U.S.D.A. Forest Service contract 2007-PA-110602-033 and U.S. Fish and Wildlife Service contract E-2-48.

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INTRODUCTION

This study describes the current distribution of the nine native fish species in the Oregon portion of the Goose Lake basin (Lake County): Goose Lake redband trout *Oncorhynchus mykiss* ssp., Goose Lake lamprey *Entosphenus* sp., Goose Lake tui chub *Siphateles bicolor thalassinus*, Goose Lake sucker *Catostomus occidentalis lacusanserinus*, Modoc sucker *Catostomus microps*, Pit-Klamath brook lamprey *Entosphenus lethophagus*, speckled dace *Rhinichthys osculus*, Pit roach *Lavinia symmetricus mitrulus*, and Pit sculpin *Cottus pitensis*.

The Goose Lake basin is an endorheic, or topographically closed basin located in south central Oregon and northeastern California. The basin is within the usually closed northeastern extremity of the adjoining Sacramento River basin, astride the Oregon-California boundary. Although most of the lake lies in California, most of its valley and nearly two-thirds of the total drainage area (~722 sq. mi.) are in Oregon. The largest streams in the basin are Drews, Cottonwood, and Thomas Creeks. Annual precipitation averages about 36 cm per year (Phillips and van Denburgh 1971). Goose Lake overflowed briefly into the North Fork Pit River in 1868 and 1881, but storage and diversion of irrigation water has substantially reduced the inflow and future overflow is unlikely (USGS 1971). The lakebed was dry in the summers of 1926, 1929-1934, and 1992. About half the basin is forestland, 20% is hay fields and pastureland, and 16% is shrub and rangeland. Currently, almost 35% of the inflow is diverted for irrigation (OWRD 1989).

The Goose Lake basin is home to four endemic fish taxa: the Goose Lake redband trout, lamprey, sucker, and tui chub. Endemic fishes of the Goose Lake basin split their life histories between Goose Lake and its tributaries, as opposed to the five native but non-endemic species that primarily occupy stream habitats. Pit roach and all endemic fishes except Goose Lake tui chub are listed as a “species of concern” by the USFWS, a designation that implies there is concern about species viability, but not enough information is known to initiate a listing review for threatened or endangered status. The Modoc sucker was listed as a federally endangered species in 1985 (USFWS 1985). No formal recovery plan was required due to an existing “Action Plan for the Recovery of the Modoc Sucker” (USFWS 1984). Most of the recovery actions outlined in the action plan were either completed or are no longer relevant (Stewart Reid, Western Fishes, personal communication). However, actions 26 and 27 pertaining to range expansion remain incomplete. Action 26 suggests reclassification to threatened upon establishment of safe populations (for 3-5 years) throughout the Rush and Turner Creek watersheds in the Pit River basin. Action 27 suggests delisting upon establishing safe populations in two other historic streams. At the time of listing, the historic range of Modoc sucker was thought to have included only two small tributaries of the Pit River in Modoc and Lassen Counties, Ash and Turner Creeks (USFWS 1985). Therefore, a major recovery goal was to expand the species’ range with additional populations (USFWS 1984). In 2001, re-examination of historical documents and museum specimens established that Modoc suckers had also historically occupied Thomas Creek in the Goose Lake basin. Field collections in 2001, with subsequent morphological and genetic analysis, confirmed that the population was still present in Thomas Creek (Stewart Reid, Western Fishes, personal communication); however, the broader range of Modoc sucker in the Goose Lake watershed was not known.

In 1995, the Goose Lake Fishes Working Group drafted a conservation plan for “pre-listing” recovery of all native fish in response to severe drought and habitat degradation (GLFWG 1995). The Aquatic Inventories Project of the Oregon Department of Fish and Wildlife (ODFW) conducted habitat and fish distribution surveys (1991-1995) to obtain baseline information to help inform recovery efforts (ODFW, unpublished data). Since then, field work to

monitor the distribution and abundance of Goose Lake fishes has been limited and sporadic, targeting only Goose Lake redband trout and Modoc sucker (Dambacher 2001; Reid 2007). No comprehensive follow up work has been conducted to evaluate fish response to climatic conditions, habitat restoration projects, and continued irrigation activities. ODFW recently drafted a status review of native fish of Oregon (ODFW 2005). Except for redband trout, Goose Lake fishes were not included in the status review due to a lack of new information since the previous status review in 1995 (Kostow et al. 1995). Further, the review of Goose Lake redband trout was limited by a lack of long-term data series.

The first objective of this study was to document the current distribution of native fishes in Oregon's portion of the Goose Lake basin and assess changes in distribution that may have occurred since the last surveys were conducted 12 years ago. The second objective was to provide new information about the distribution of Modoc suckers within the basin. The third objective was to determine relative abundance and age-class diversity of native fishes at randomly selected sample sites. All objectives were addressed throughout the potential riverine distribution of fish in the Oregon portion of the Goose Lake basin. Information gathered in this study is critical to effective conservation and management of each species and its habitat. In addition, this report describes the distribution and relative abundance of nonnative fishes (fathead minnow (*Pimephales promelas)*, brown bullhead (*Ameiurus nebulosus)*, white crappie (*Pomoxis annularis)*, yellow perch (*Perca flavescens)*, pumpkinseed (*Lepomis gibbosus)*, and brook trout (*Salvelinus fontinalis*)) in the basin. Unlike prior efforts, this study used a statistically-based design to select sample points with the aim of achieving a representative sample across the Oregon portion of the Goose Lake watershed. Additionally, a wide array of fish sampling gear was employed to maximize our ability to capture all fish species present across the diversity of habitat types encountered.

METHODS

We employed the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) sample design to draw representative sample sites from a pre-determined sample frame. EMAP employs a probabilistic sampling design that allows resource assessment over large areas, based on data from representative sample locations. EMAP uses a sample design called a Generalized Random Tessellation Stratified design (GRTS) (Stevens and Olsen, 2004) to achieve a spatially-balanced point distribution that is nonetheless random. The EMAP design takes into account spatial patterns of resource distribution when calculating estimates of variance to provide higher precision for a given level of sampling effort (Stevens and Olsen 2002).

Potential cumulative distribution of all native fish in the Oregon portion of the Goose Lake basin during summer base flow totaled 655 stream km and was determined by consulting ODFW, BLM, and USFS biologists and examining past sampling efforts. This cumulative distribution was portioned into two sample frames that partially overlapped (Figure 1). Separate sample frames were developed to allow integration of this study with a concurrent study to monitor redband trout in the Oregon portion of the Great Basin, including the Goose Lake basin (http://oregonstate.edu/dept/ODFW/NativeFish/GreatBasinRedband.htm). Sample frames were based on a 1:24,000 digital stream coverage. The redband trout sample frame consisted of 329 stream km in which 150 sample sites, stratified by population, were selected in the initial draw. The nongame sample frame consisted 234 km that overlapped with the redband trout sample frame and 325 stream km outside of this sample frame. Sites selected in the portion of the redband frame with overlap were also sampled for nongame fish. Additionally, the initial

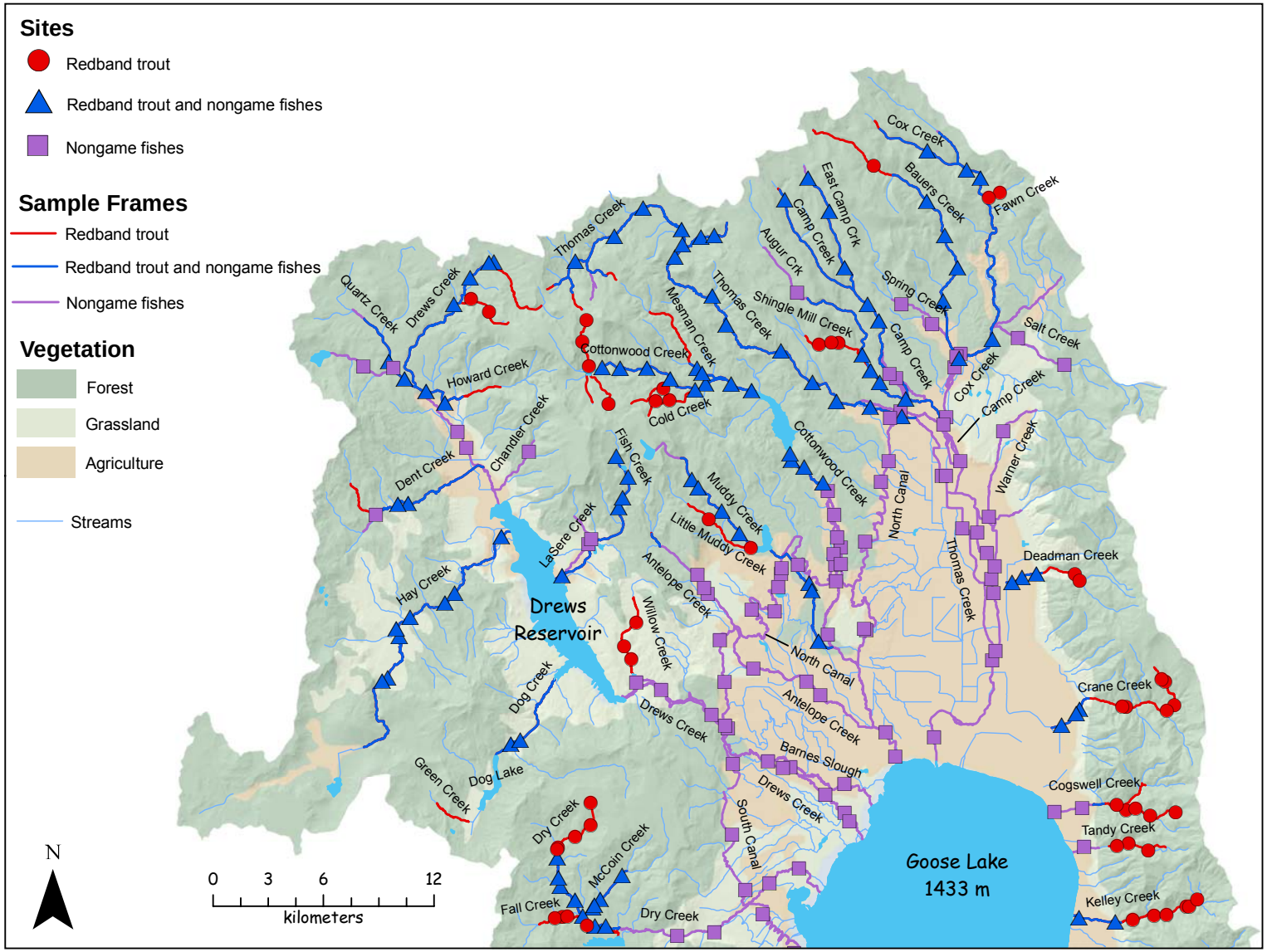

Figure 1. Potential fish distribution and sample sites from the initial sample draw for native fishes of the Oregon portion of the Goose Lake basin, 2007

draw included 90 sites in the non-overlapping portion of the nongame sample frame. Additional sites were selected for use as replacements when original sites were unsuitable (e.g., stream channel was dry or access permission was denied on private property). Total sampling effort was less than the targets due to time constraints.

Each sample site was associated with UTM coordinates. Site coordinates were plotted on USGS 1:24K topographic maps and uploaded into hand held GPS units. If the site was located on private land, landowners were contacted to obtain permission prior to accessing the site. If permission was granted or if the site was located on public land, we navigated to the site using topographic maps and GPS units. The UTM coordinates represented the downstream site boundary. If the UTM coordinates did not fall on the stream, the downstream site boundary was assigned to the point on the stream nearest the pre-assigned coordinates. The upstream site boundary was determined by measuring the wetted channel width and measuring 30 channel widths upstream. In narrow or wide channels a minimum site length of 30 m or a maximum site length of 100 m was used. Site boundaries were occasionally modified to avoid splitting channel units (e.g. the middle of a pool). Block nets were installed at the lower and upper site boundaries to prevent fish movement into or out of the site during sampling.

Sampling methods varied by site and depended on the sample frame and habitat characteristics. At sites in the nongame sample frame, methods included passive traps (e.g. fyke netting, minnow trapping, and hoop netting), dip netting, seining, and single-pass electrofishing (including lamprey-specific electrofishing waveforms). Depending upon logistics and effectiveness of sampling gears, relative abundance of species encountered at each sample site was estimated. At sites in the redband trout sample frame, multiple-pass electrofishing techniques were used. Each pass consisted of a systematic upstream and a downstream sweep and sampling effort was approximately equal during each electrofishing pass. A minimum of two passes with a 50% reduction in redband trout >60 mm between passes was required for a population estimate. At sites in the overlapping redband trout-nongame sample frame, both multiple-pass electrofishing techniques and passive traps were used. Impacts of electrofishing techniques were evaluated on-site, and implemented only if injury and mortality issues were not probable. At all sites, electrofisher settings (pulse width, voltage, and frequency), the starting and ending times, and the water temperature were recorded. Site dimensions and habitat complexity (e.g. amount of large wood and substrate) were quantified following fish sampling. Sampling occurred from 26 June through 21 September.

All captured fish (except redband trout >200 mm) were anesthetized prior to processing with buffered MS-222. Fish were identified to species, enumerated, and measured to the nearest millimeter (mm). Length measurements were recorded as fork length (FL) for all species except lamprey and sculpin, for which total length (TL) was recorded. When large numbers of a species were captured at a site, lengths were measured from a subsample (n=20 fish). Following processing, fish were allowed to fully recover in aerated water before release near the location of capture.

Data was spatially analyzed using a Geographic Information System (GIS, ArcGIS 9). Presence of individual species was graphically displayed at each sample site. The resulting distributions were compared to those previously documented by ODFW (unpublished data 1991-1995) and to a Fremont National Forest GIS coverage that consists of data compiled from multiple sources (unpublished data 1925-1995). When applicable, relative abundance of each species was displayed for two categories to distinguish sites having high abundance from sites having moderate to low abundance. Sites categorized as having high abundance for a species had catches greater than the mean catch for the species at all sites plus two standard errors.

RESULTS

We sampled 143 sites in the Goose Lake basin in 2007 (Figure 2); 49 sites were part of the nongame sample frame, 33 sites were part of the redband trout sample frame, and 61 sites were part of an overlapping nongame and redband trout sample frame. In addition, sites that were selected but were not sampled included 53 with dry channels and 67 where access was denied. Land ownership of the sites that were visited closely corresponded to the land owner composition of the sample frames. Fifty-eight percent of the redband trout sample frame and 55% of the sample sites accessed within this frame were distributed on private land. For the independent portion of the nongame sample frame 93% of the frame and 91% of the accessed sites were on private land. The high rate of dry sites in our sample indicates that 21% of the sample frame was dry during the period of our sampling.

Sample sites were geographically stratified throughout the Goose Lake subbasin with 40 sites in the Drews Creek drainage, 35 sites in the Cottonwood Creek drainage, 38 sites in the Thomas Creek drainage, 17 sites in the small tributaries on the east side of Goose Lake, and 13 sites in the Dry Creek drainage. Sites that occurred in irrigation canals were considered part of the nearest subbasin for these totals. Only the major delivery canals were included in the sample frame.

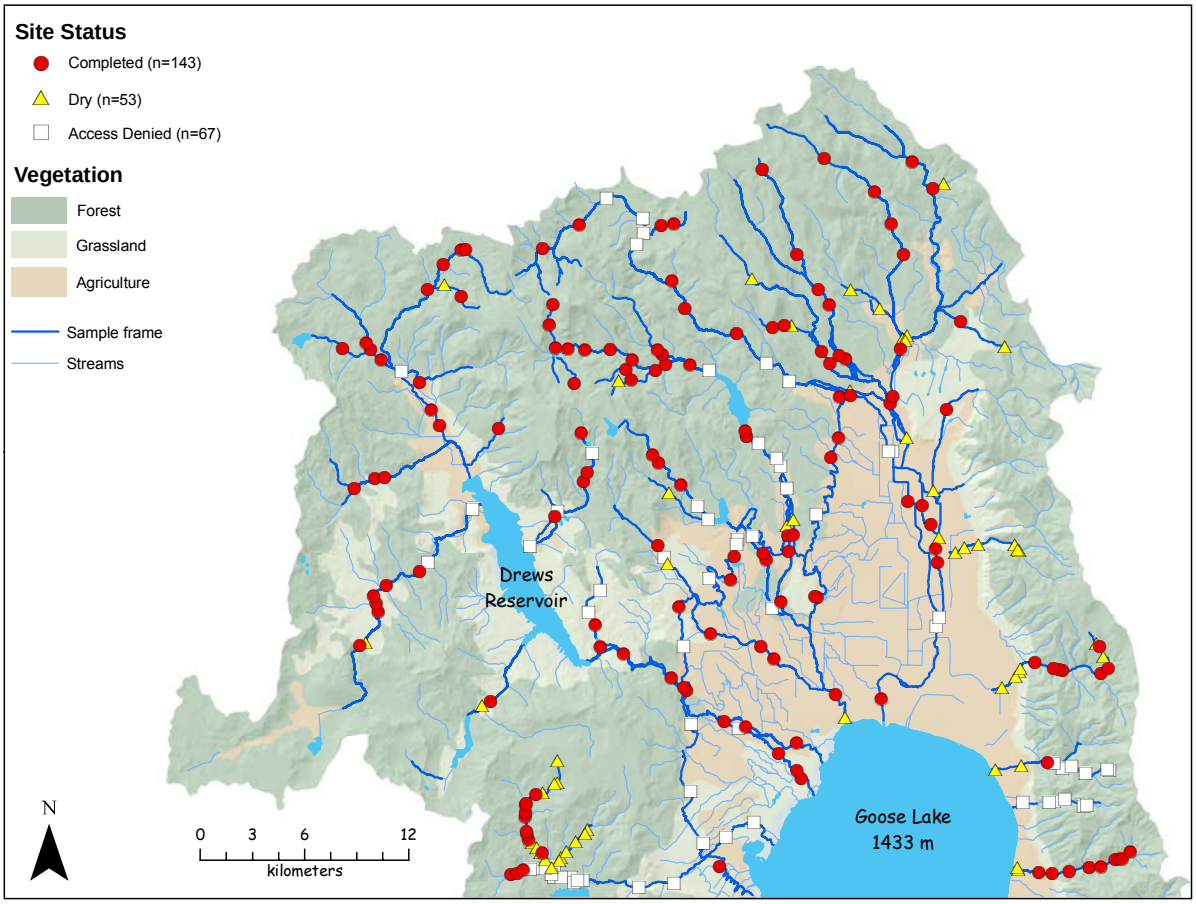

Figure 2. Sample sites, dry sites, and sites where access was denied in the Oregon portion of the Goose Lake basin, 2007.

We collected all nine species of native fish (Goose Lake redband trout, Goose Lake lamprey, Goose Lake tui chub, Goose Lake sucker, Modoc sucker, Pit-Klamath brook lamprey, speckled dace, Pit roach, and Pit sculpin) and six species of non-native fish (white crappie, pumpkinseed, yellow perch, brown bullhead, fathead minnow, and brook trout) in the 2007 sampling. Photographs of each species are shown in **APPENDIX A**.

The following is a description of the current distribution of each species and a comparison to data from previous surveys conducted by ODFW, and to a Fremont National Forest GIS coverage that consists of data compiled from multiple sources, some that date back to the 1940's. Note that the Goose Lake basin experienced below average precipitation in 2007 and current distribution was affected by the availability of wetted channels.

Goose Lake Redband Trout

Goose Lake redband trout were collected from 69 locations which represent 35% of all sites sampled and 31% of the sample frame (Figure 3). Redband trout were collected from 50% of the streams targeted for redband sampling (redband sample frame). Redband trout was the second most common species encountered. Distribution of redband trout was primarily restricted to the forested headwater streams of the basin. The 2007 distribution was similar to that from previous sampling efforts. In addition, our 2007 sampling documented redband trout at locations that were not sampled in 1991-1995. These include sites in the Dry Creek drainage, in tributaries to Drews Creek (Dent and Fish Creeks), and in tributaries to lower Cottonwood Creek (Antelope and Muddy Creeks). Sites (n=20) where relatively large numbers ($\geq$65 fish) of redband trout were collected were located in Dry, Fall, upper Drews, Antelope, Cottonwood, Muddy, Camp, Bauers, Crane, and Kelly Creeks. The length-frequency histogram for redband trout shows a broad range of sizes and two apparent peaks, representing age 0 (young-of-the-year) and fish ≥ age 1 (Figure 4). A summary of the results from the 2007 surveys targeting redband trout is available at: http://oregonstate.edu/dept/ODFW/NativeFish/GreatBasinRedband2007.htm.

Goose Lake and Modoc Suckers

Suckers were collected from 39 locations which represent 20% of sites sampled and 24% of the sample frame (Figures 5 and 6). Because of the difficulty in distinguishing between Goose Lake suckers and Modoc suckers in the field, the current distribution of each species is somewhat uncertain. The two species overlap in counts of dorsal fin rays, the only discerning field characteristic. Modoc suckers have 9-11 dorsal fin rays and Goose Lake suckers have 11-13 dorsal fin rays. Most of the suckers captured had 11 rays and were labeled as unknown suckers. If a sucker had more than 11 rays, it was identified as a Goose Lake sucker. If a sucker had fewer than 11 rays, it was identified as a Modoc sucker. A sub-sample of the suckers with fewer than 11 rays was examined by Dr. Stewart Reid from each location where they were collected; all samples were confirmed to be Modoc suckers (i.e. all Modoc sucker locations shown on maps were confirmed).

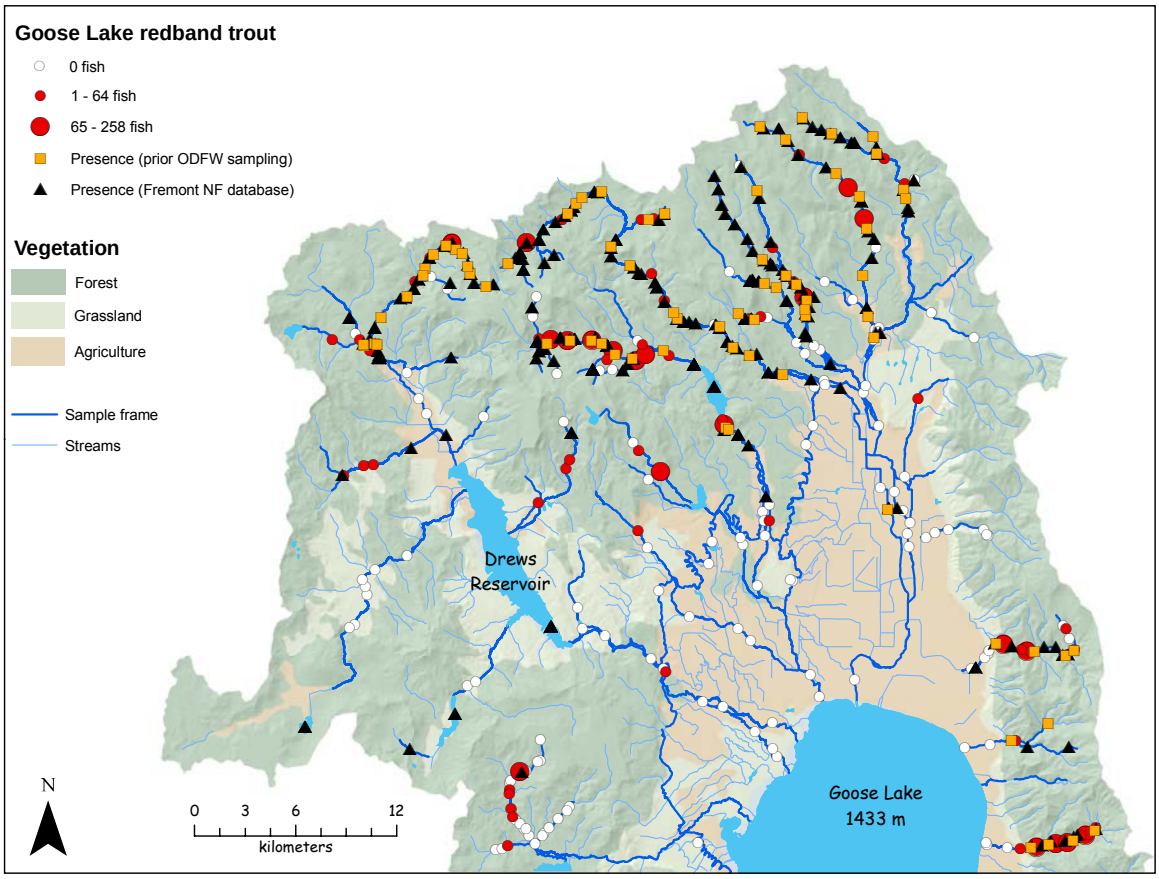

Figure 3. Distribution of Goose Lake redband trout collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

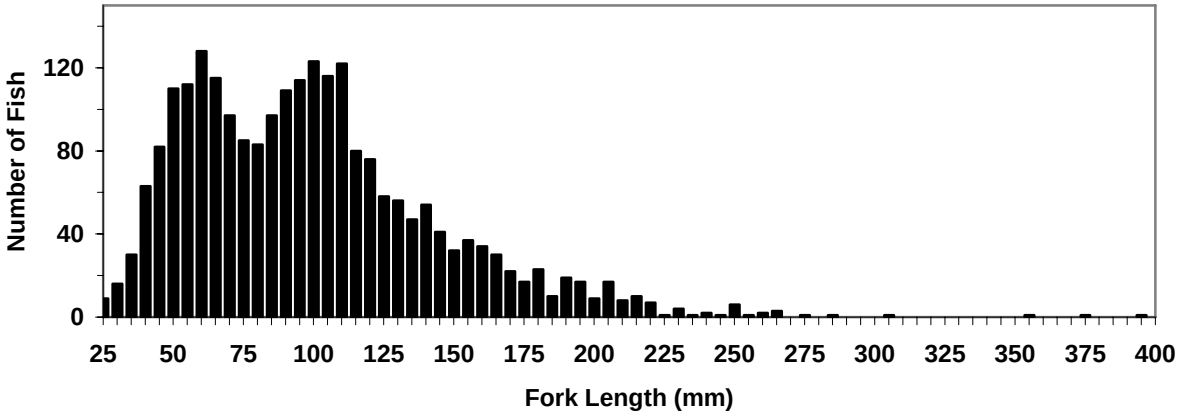

Figure 4. Length-frequency histogram for Goose Lake redband trout collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

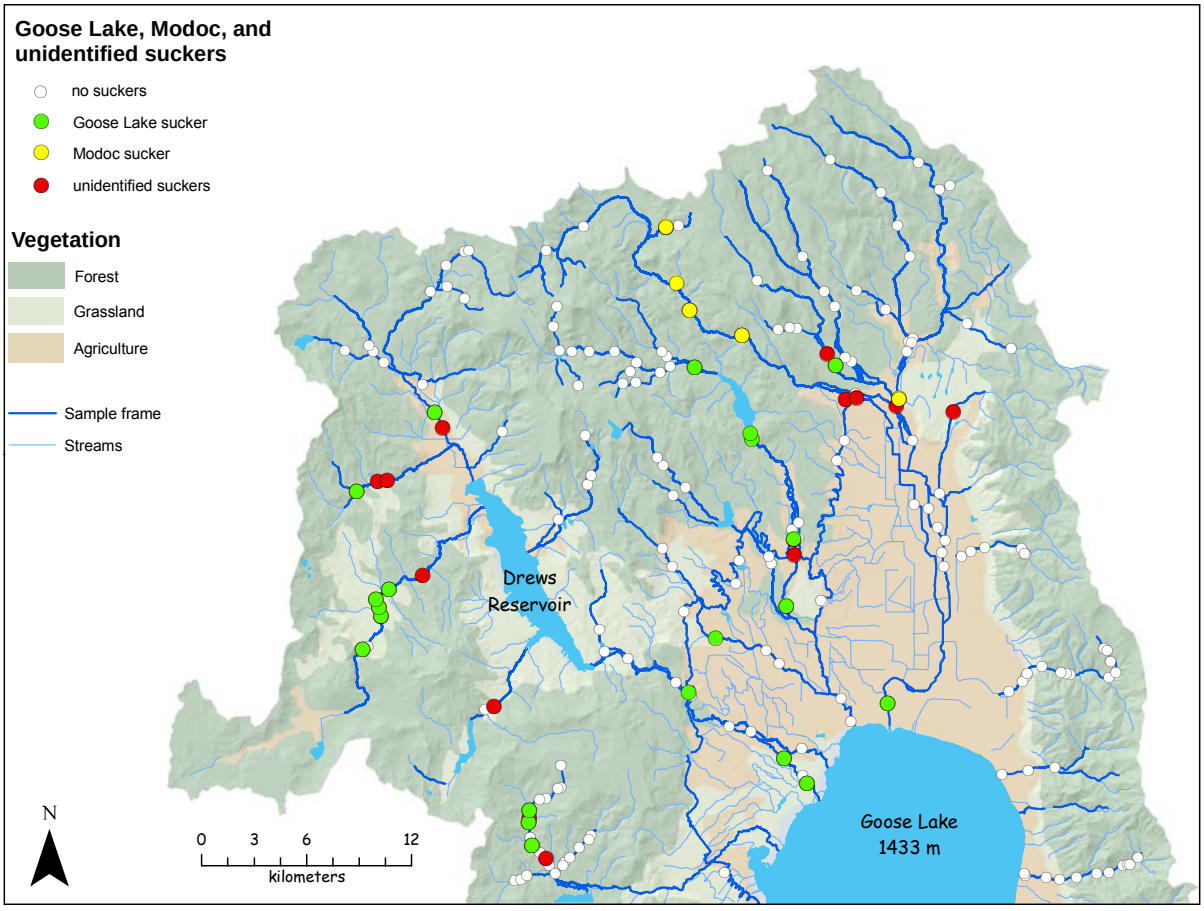

Figure 5. Distribution of Goose Lake suckers, Modoc suckers, and unidentified suckers collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Suckers confirmed to be Modoc suckers were only collected from 5 locations which represent 4% of sample frame; all were located in the Thomas Creek drainage (Figure 5). The length-frequency histogram for Modoc suckers shows a range of sizes but no apparent peak (Figure 7). Goose Lake suckers and unidentified suckers were collected throughout the Goose Lake basin: Dry Creek, Drews Creek and tributaries (Dog, Hay and Dent Creeks), Antelope Creek, Cottonwood Creek, and Thomas Creek and tributaries (Augur, Cox, and Warner Creeks). There was no overlap in confirmed Modoc and Goose Lake sucker distributions. The 2007 sucker distribution was similar to that from previous sampling efforts (Figure 6). Sites (n=8) where relatively large numbers ($\geq$78 fish) of suckers were collected were located in Dry Creek and Drews Creek tributaries (Dent and Hay Creeks). Length-frequency histograms for Goose Lake suckers and unidentified suckers show a broad range of sizes, but are not informative for discerning individual age classes beyond the presence of age-0 through adults in the sample (Figure 7).

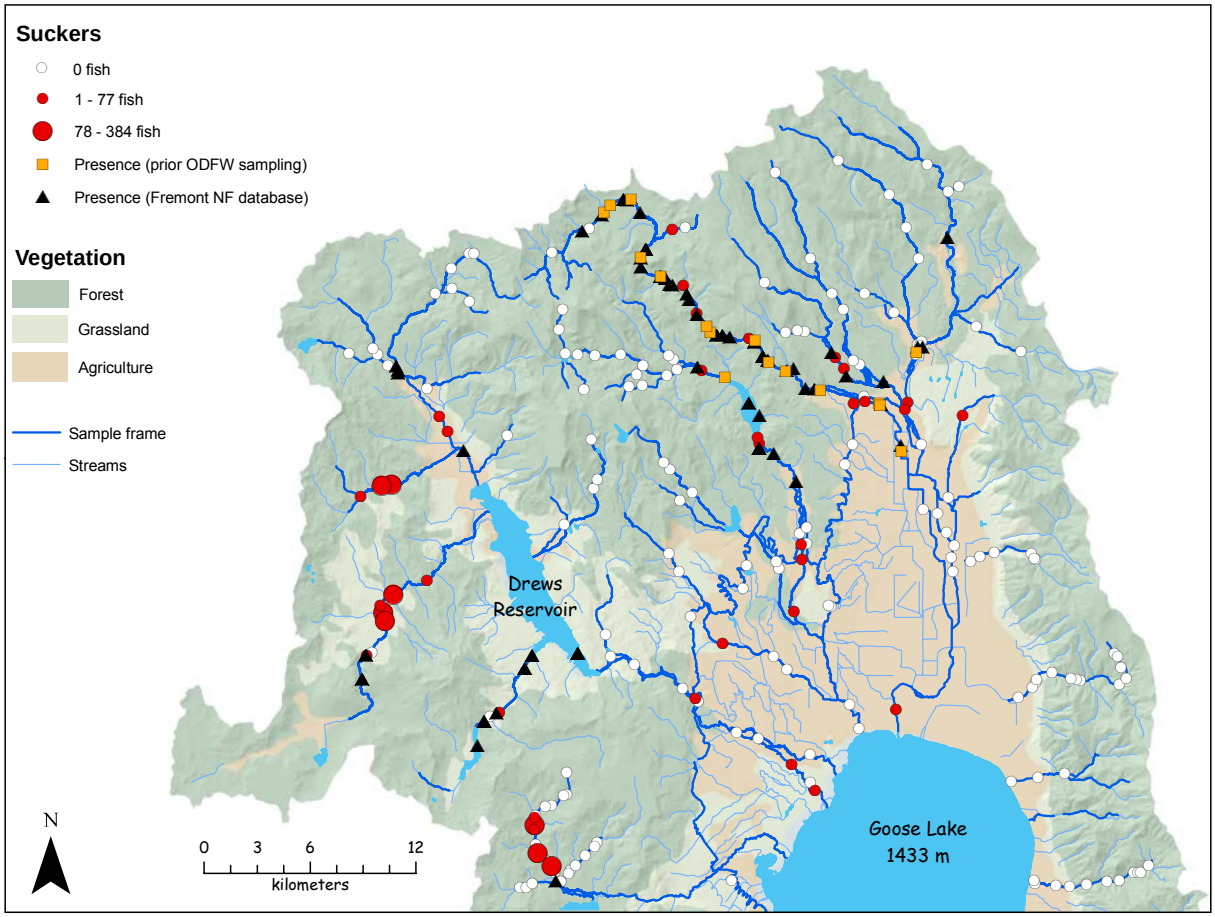

Figure 6. Distribution of suckers collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

Goose Lake Tui Chub

Goose Lake tui chub (tui chub) were collected from 25 locations which represent 13% of sites sampled and 16% of the sample frame (Figure 8). Distribution of tui chub occurred in low gradient streams located primarily in lower elevation, non-forested streams in the basin but also less frequently in streams located in forested, higher elevation areas. Locations where tui chub were captured included Dry Creek, Drews Creek and tributaries (Dog, Hay, and Dent Creeks), Antelope Creek, Thomas Creek, Cox Creek, and the north and south irrigation canals. The 2007 distribution was similar to that from previous sampling efforts, although these earlier surveys documented tui chub presence higher up in three subbasins (Drews, Cox, and Bauers Creeks). The 1995 ODFW surveys (unpublished data) noted tui chub in lower Cottonwood Creek, the only surveys where tui chub were documented to occur in this drainage. It is possible that these fish were Pit roach misidentified as tui chub or that tui chub were more widely distributed during prior surveys. In 2007, access was denied to sample sites in the portion of lower Cottonwood Creek where ODFW sampled in 1995.

Sites (n=6) where relatively large numbers (≥112 fish) of tui chub were collected included Dry, Drews, Dent, Hay, Thomas, and Cox Creeks. The length-frequency histogram for tui chub shows a broad range of sizes; however discrete age-classes cannot be discerned (Figure 9).

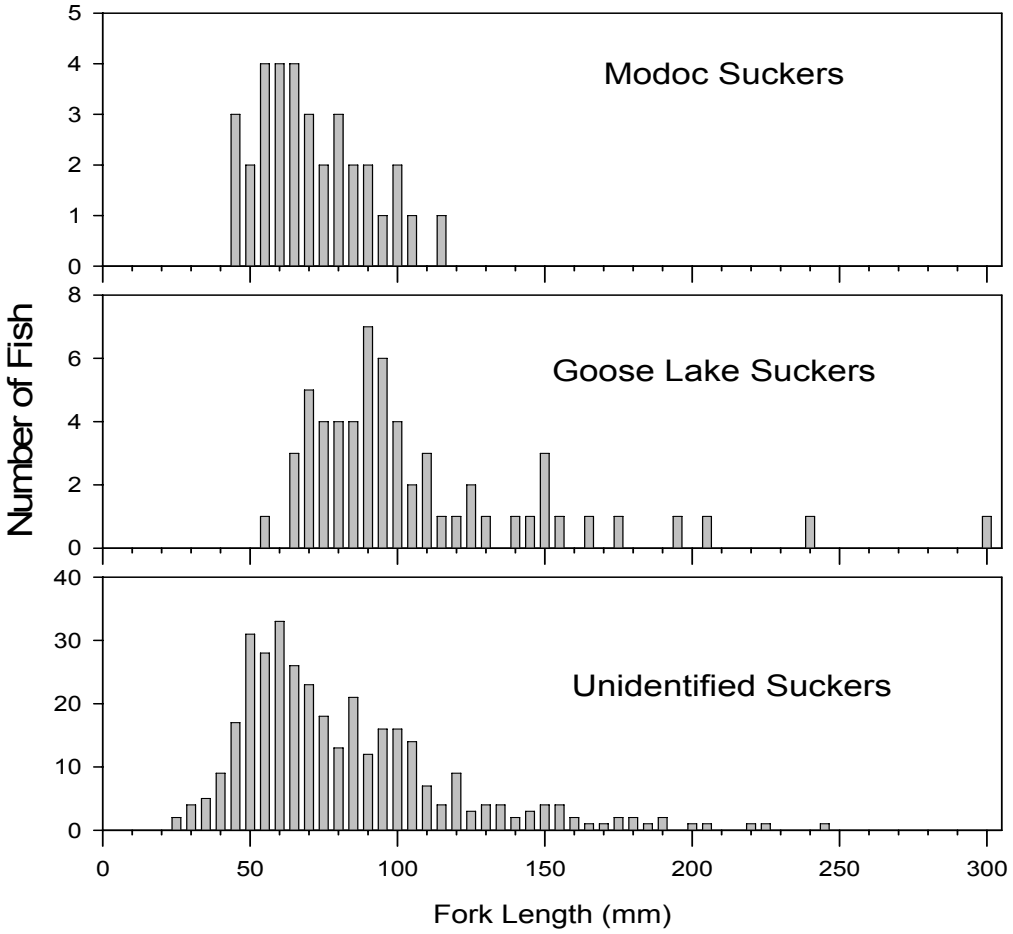

Figure 7. Length-frequency histograms for suckers collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Pit Roach

Pit roach were collected from 40 locations which represent 20% of all sites sampled and 25% of the sample frame (Figure 10). Distribution of Pit roach was primarily restricted to the lower gradient, lower elevation, non-forested streams of the basin. Locations where Pit roach were captured included Dry Creek and tributaries (Hay and Dent Creeks), Cottonwood Creek and tributaries (Antelope and Muddy Creeks), Thomas Creek and tributaries (Augur, Camp, Bauers, and Cox Creeks), and the north and south irrigation canals. The 2007 distribution was more extensive than the distribution documented from previous sampling efforts. The less frequent roach occurrences noted in the 1991-1995 ODFW surveys may have been a result of misidentification of some Pit roach as tui chub. The length-frequency histogram for Pit roach shows a broad range of sizes; however discrete age-classes cannot be discerned (Figure 11). Sites (n=11) where relatively large numbers (≥80 fish) of Pit roach were collected were located in Dry, Drews, Hay, Dent, Muddy, and Augur Creeks.

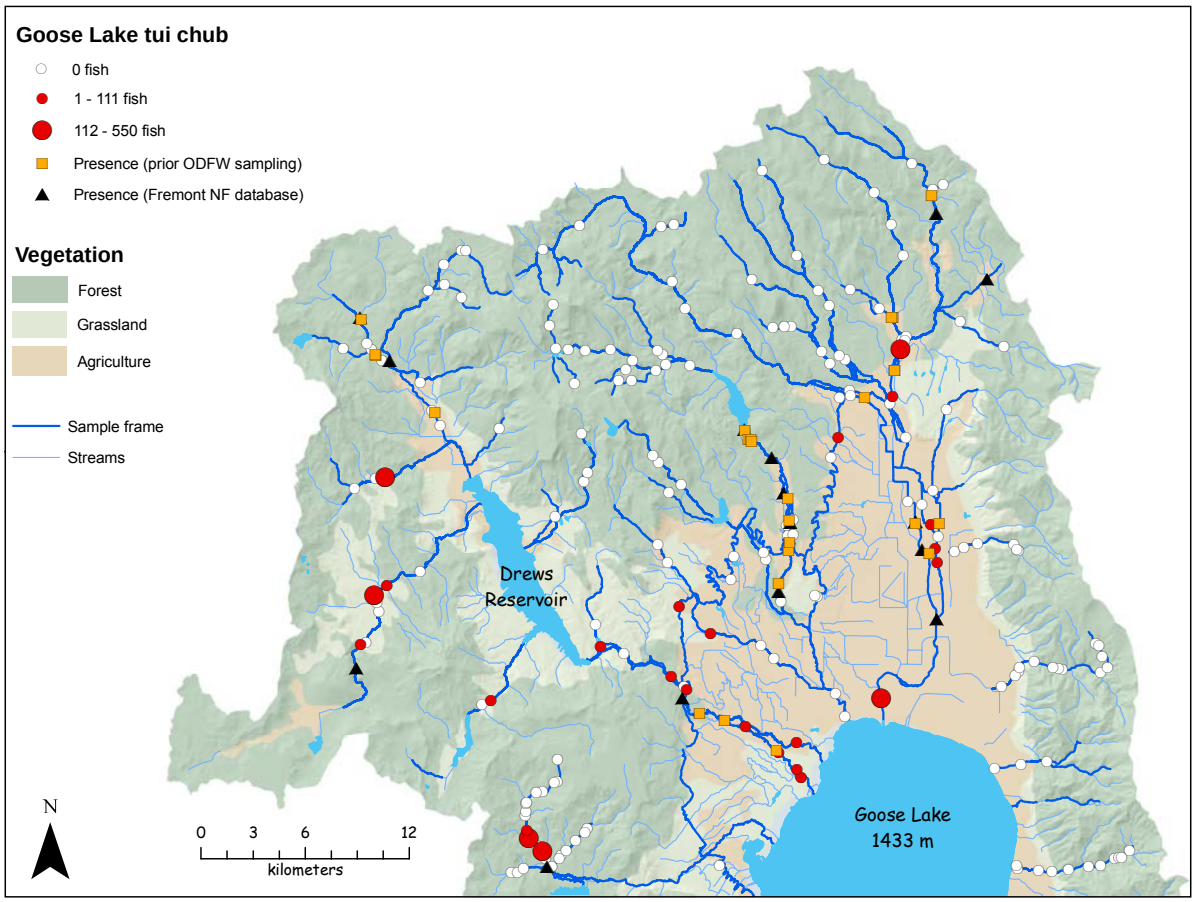

Figure 8. Distribution of Goose Lake tui chub collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

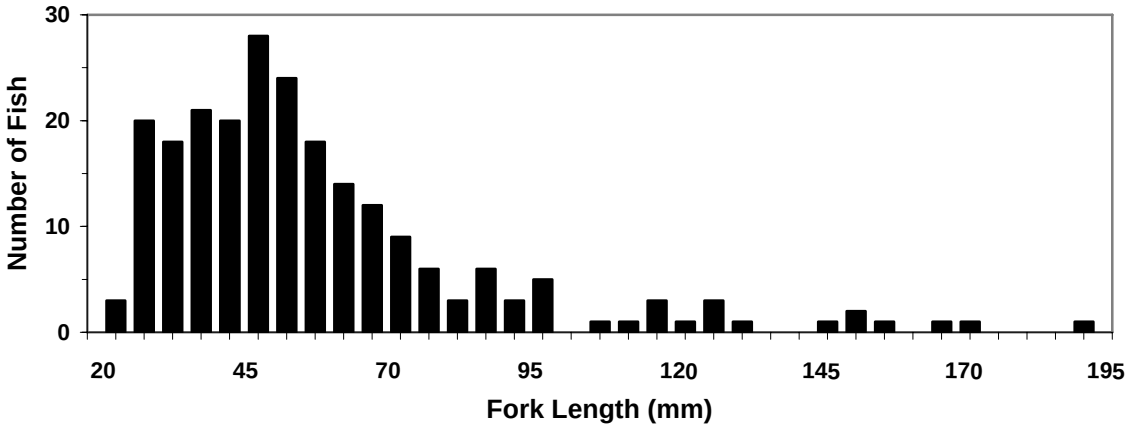

Figure 9. Length-frequency histogram for Goose Lake tui chub collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

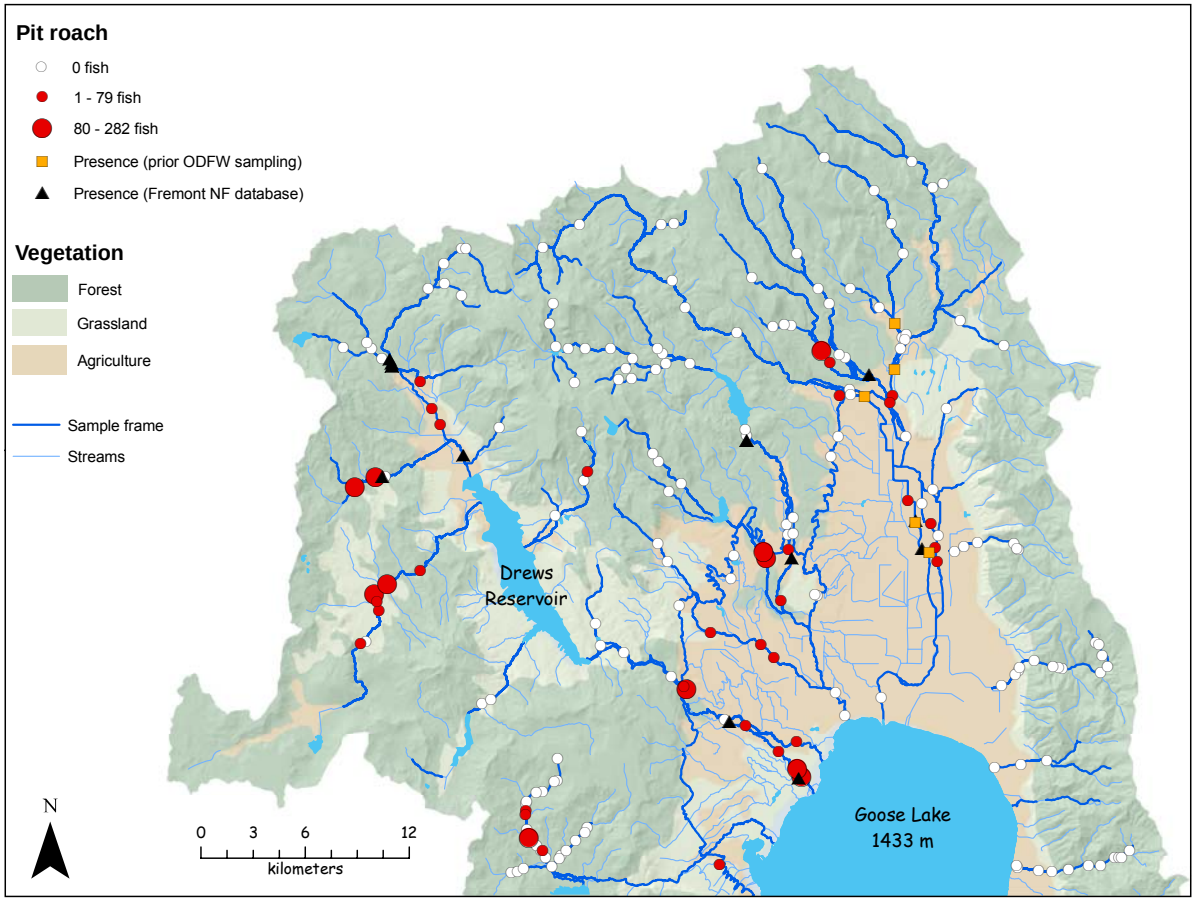

Figure 10. Distribution of Pit roach collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

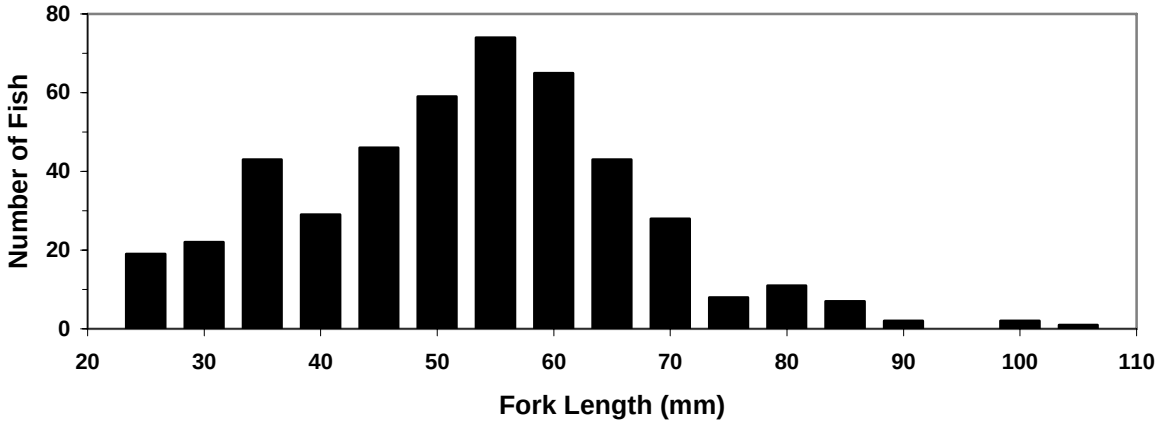

Figure 11. Length-frequency histogram for Pit roach collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Speckled Dace

Speckled dace were collected from 73 locations which represent 37% of sites sampled and 45% of the sample frame (Figure 12). Speckled dace was the most commonly encountered species in 2007, with occurrences ranging from lower agricultural areas to headwater streams. The 2007 distribution was similar to that from previous sampling efforts. The length-frequency histogram for speckled dace shows a broad range of sizes; however discrete age-classes cannot be discerned (Figure 13). Large numbers of speckled dace ($\geq$110 fish) were collected from 26 sites widely distributed throughout the Goose Lake drainage.

Pit Sculpin

Pit sculpins were only collected from two locations which represent 1% of sites sampled and 1% of the sample frame (Figure 14). These sites were located in upper Drews Creek (n=42 fish) and in Camp Creek, a tributary to Thomas Creek (n=33 fish). Pit sculpins were the least common species encountered in 2007. Although exceedingly rare among our samples, Pit sculpins were relatively abundant in both locations. Previous ODFW surveys reported Pit sculpins from four sites in upper Drews Creek and from one site in upper Cottonwood Creek. They were somewhat more widespread in the Fremont National Forest GIS coverage that consists of data compiled from multiple sources, with records from 1953-54 and 1979 in lower Cottonwood Creek, records from 1954 in upper Thomas Creek, as well as records from upper Drews and Cottonwood Creeks. The length-frequency histogram for Pit sculpins captured in the 2007 surveys shows a broad range of sizes with two or three peaks (Figure 15). This length frequency distribution likely represents two or three distinct age classes.

Goose Lake and Pit-Klamath Brook Lampreys

Lampreys were collected from 45 locations which represent 23% of sites sampled and 27% of the sample frame (Figure 16). Most of the specimens collected were ammocoetes, or larval lampreys, which were unidentifiable to the species level. In many cases smaller adult lampreys (that had potentially just recently metamorphosed) were also not identified to the species level. Adult Goose Lake lampreys were collected from four sites (2% of the sample frame), including locations in upper and lower Drews Creek and lower Cottonwood Creek. Adult Pit-Klamath brook lampreys were collected from seven sites (4% of the sample frame), including locations in Dry Creek, upper Drews Creek, a Drews Creek tributary (Hay Creek), Upper Cottonwood Creek, and Thomas Creek. Unidentified adult lampreys were collected from 12 sites, including locations in lower Drews Creek, Thomas Creek, Thomas Creek tributaries (Augur, Bauers, and Cox Creeks), and the north irrigation canal.

Lamprey ammocoetes were collected from 40 locations representing 24% of the sample frame. Streams where ammocoetes were collected included Dry, Hay, Drews, Muddy, Cottonwood, Thomas, Augur, and Camp Creeks. Eight sites had relatively large numbers of lampreys ($\geq$32 fish). These were located in upper Dry Creek, upper Drews Creek, Upper Cottonwood Creek, and in a Thomas Creek tributary (Camp Creek) (Figure 16). Overall, the distribution of lampreys was comparable to that from previous sampling efforts, although some differences exist (Figure 17). The 2007 surveys documented lampreys in areas where previous surveys did not, such as lower Drews, Dry, Hay, Antelope, and lower Cottonwood Creeks.

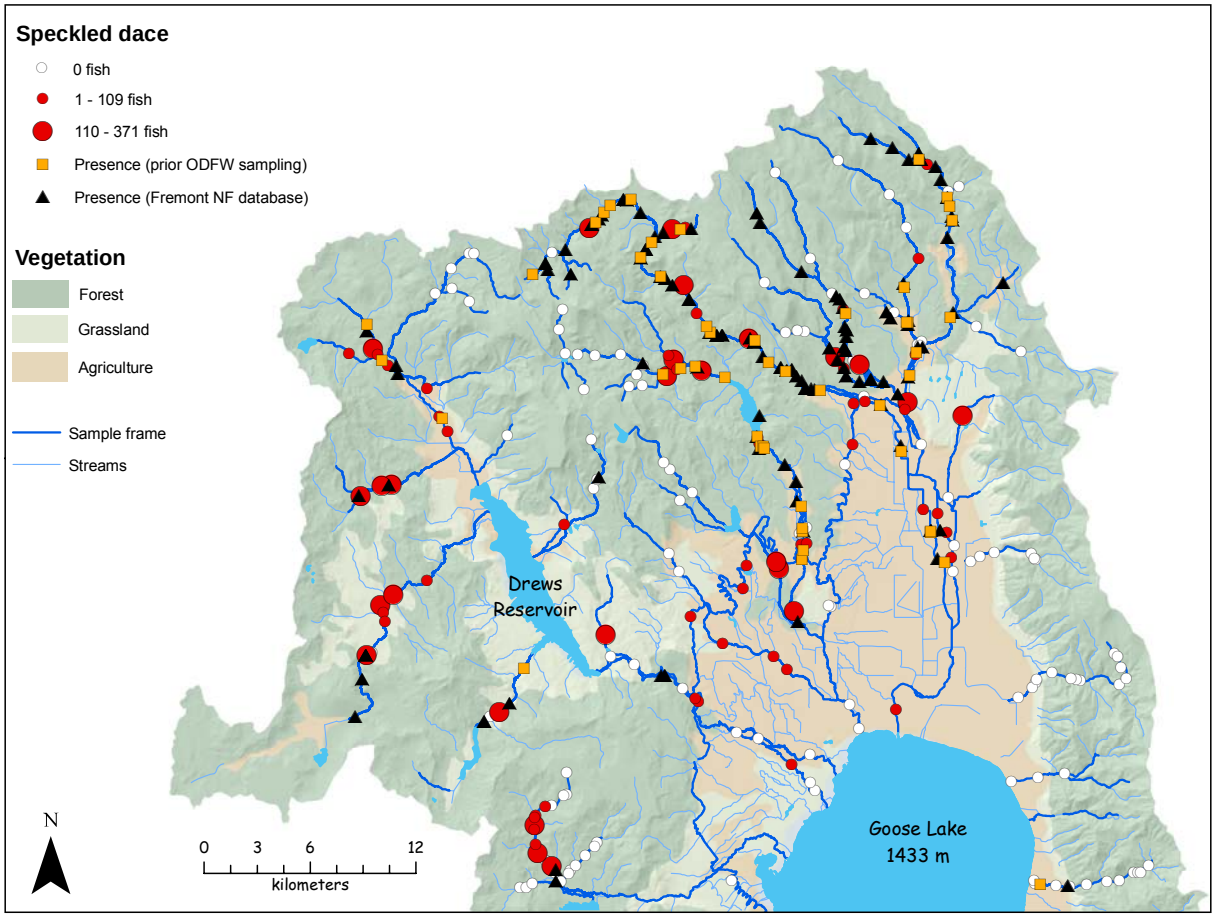

Figure 12. Distribution of speckled dace collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

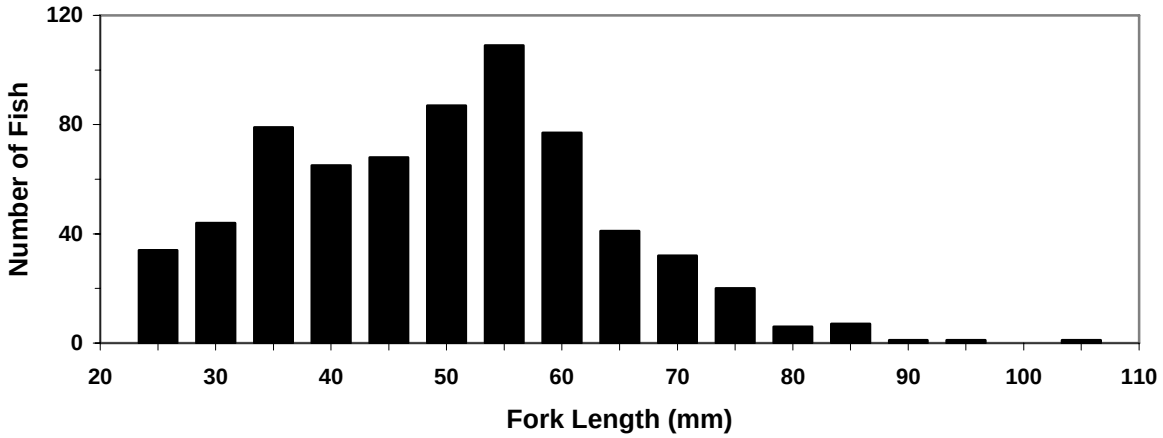

Figure 13. Length-frequency histogram for speckled dace collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

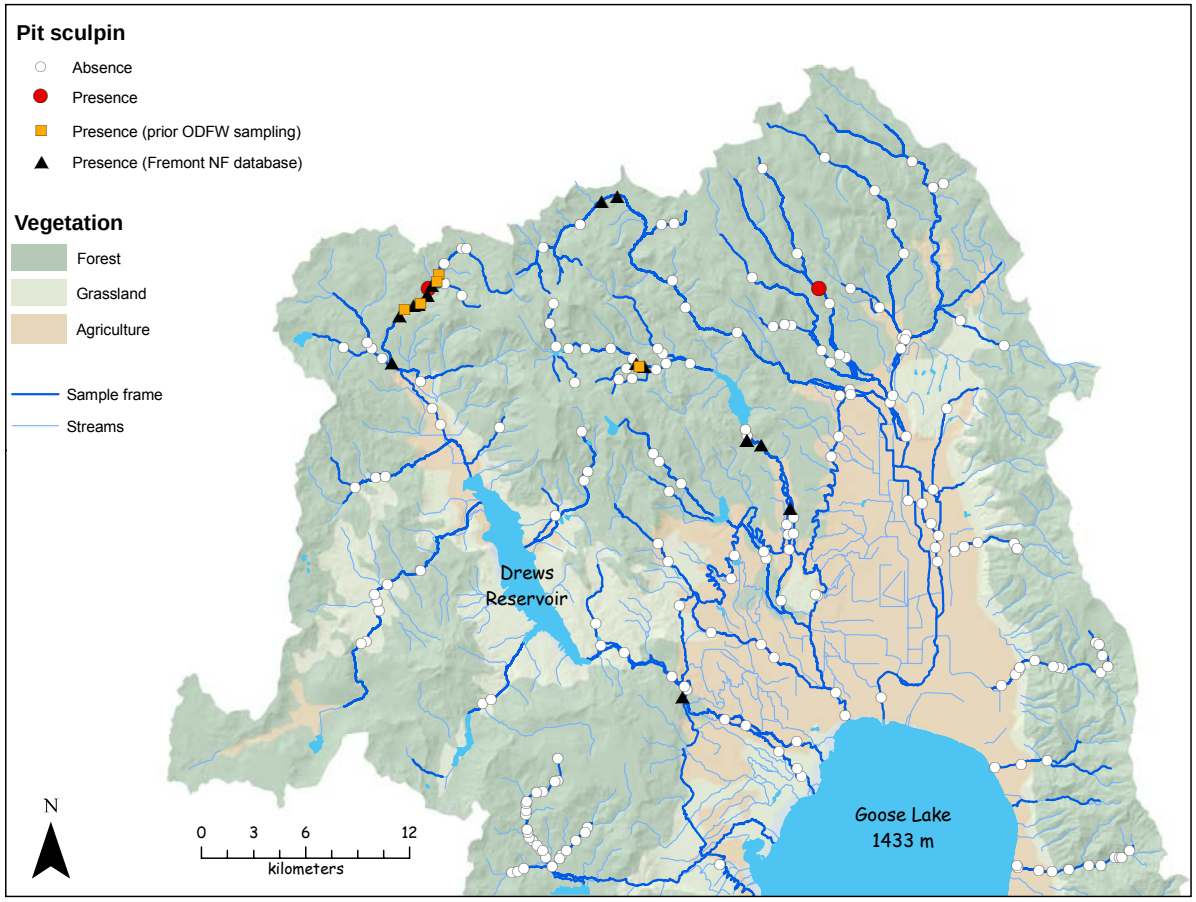

Figure 14. Distribution of Pit sculpin collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

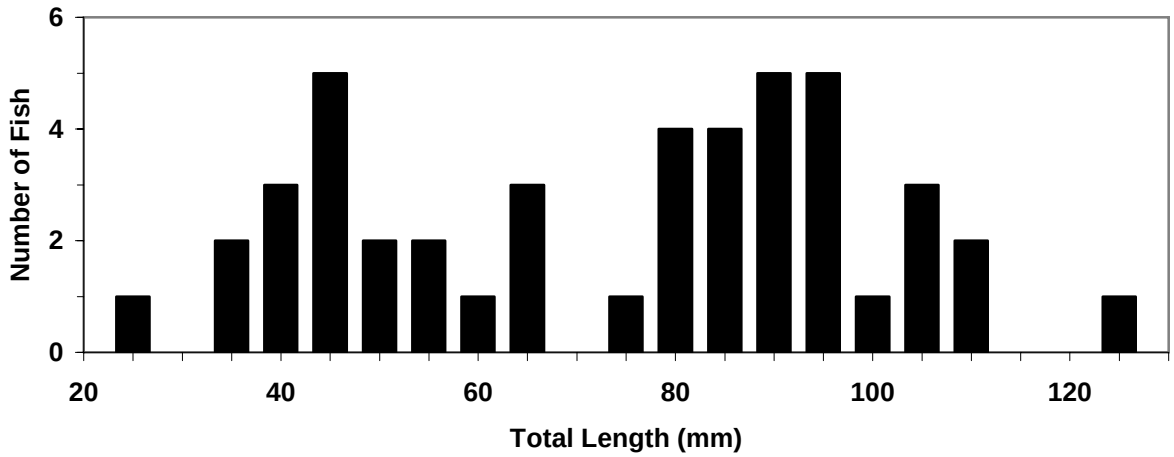

Figure 15. Length-frequency histogram for Pit sculpin collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

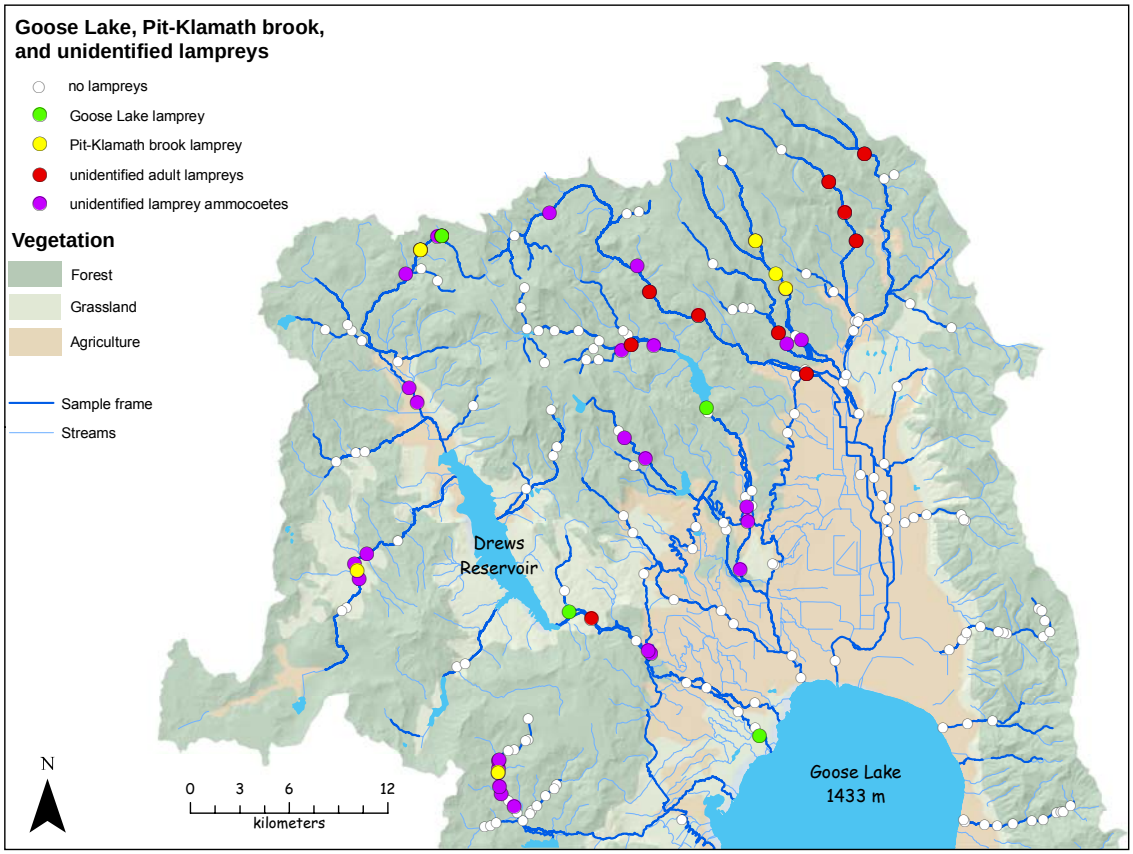

Figure 16. Distribution of Goose Lake lampreys, Pit-Klamath brook lampreys, unidentified adult lampreys, and lamprey ammocoetes collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Furthermore, previous surveys found lampreys in areas where the 2007 surveys did not (Dent and lower Thomas Creeks). The length-frequency histograms for ammocoetes and adult lampreys show broad ranges of sizes; however discrete age-classes cannot be discerned (Figure 18). The largest positively identified adults were Goose Lake lamprey. Lengths of adult Pit-Klamath brook lampreys overlapped with the lengths of larger ammocoetes. This overlap in size between older larvae and adults is consistent with the non-feeding adult life history of this species.

Fathead Minnow

Nonnative fathead minnows were collected from 51 locations which represent 26% of sites sampled and 33% of the sample frame (Figure 19). Fathead minnows were the most common nonnative species encountered in 2007 and were common in the lower gradient channels in lower Drews, Antelope, Muddy, lower Cottonwood Creeks, and in irrigation canals. They were also collected from forested stream channels in Dry Creek, upper Drews Creek, a Drews Creek tributary (Hay Creek), and Cottonwood Creek. Sites (n=12) where relatively large numbers (≥81 fish) of fathead minnows were collected were located in lower Drews Creek, lower Antelope Creek, lower Thomas Creek, a Thomas Creek tributary (Warner Creek), and in irrigation canals.

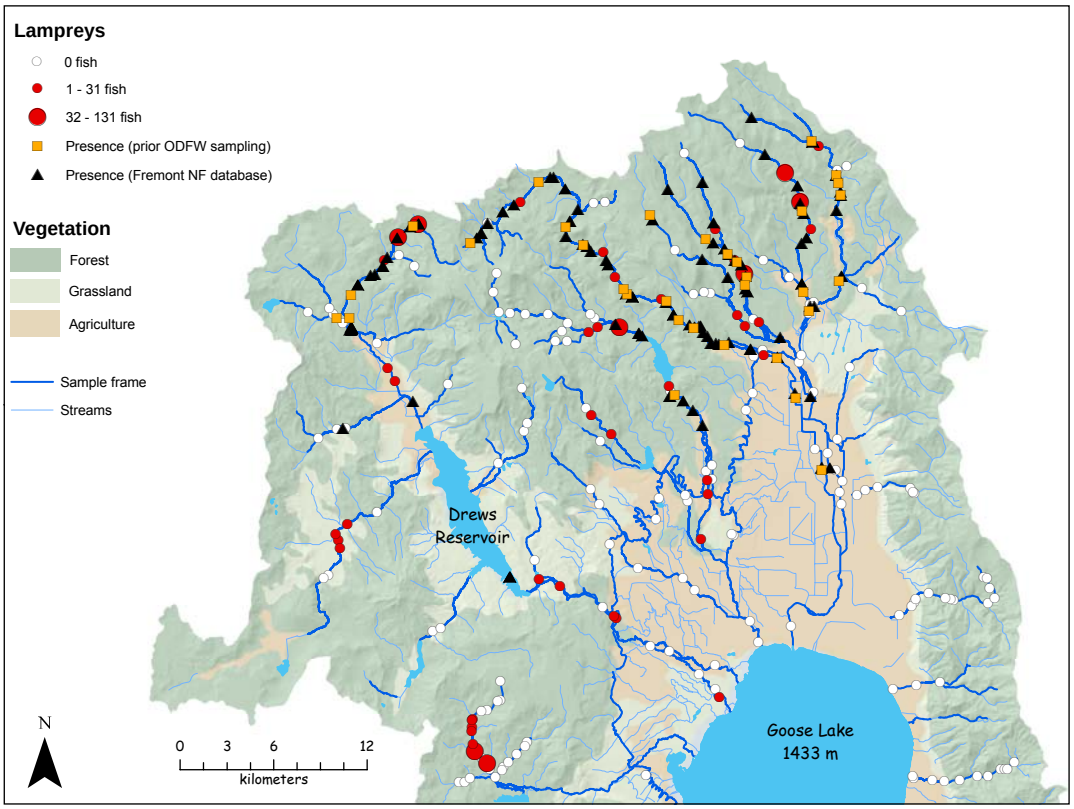

Figure 17. Distribution of lampreys collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

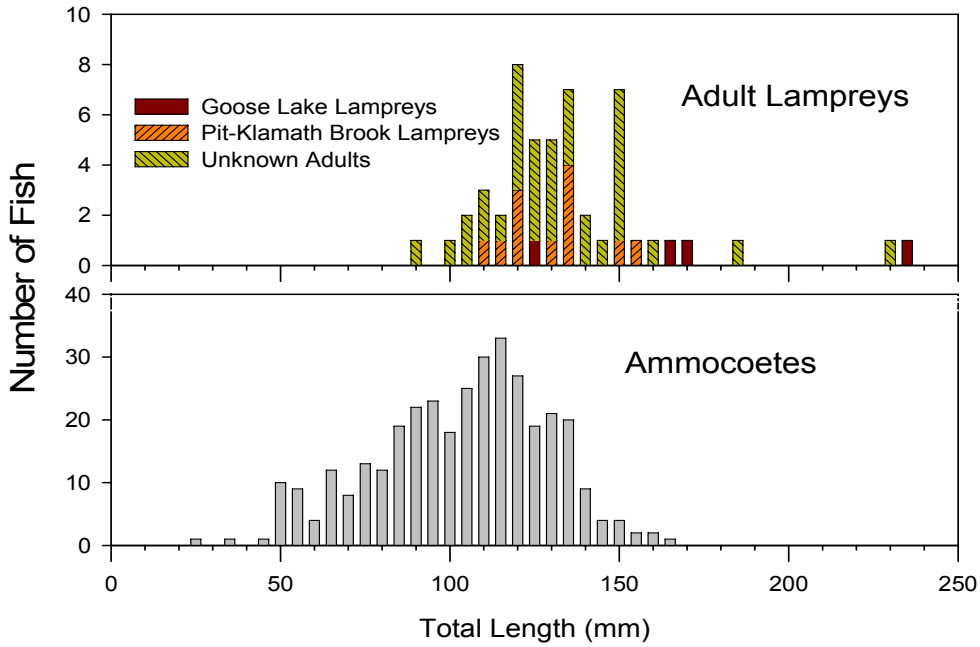

Figure 18. Length-frequency histogram for lampreys collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

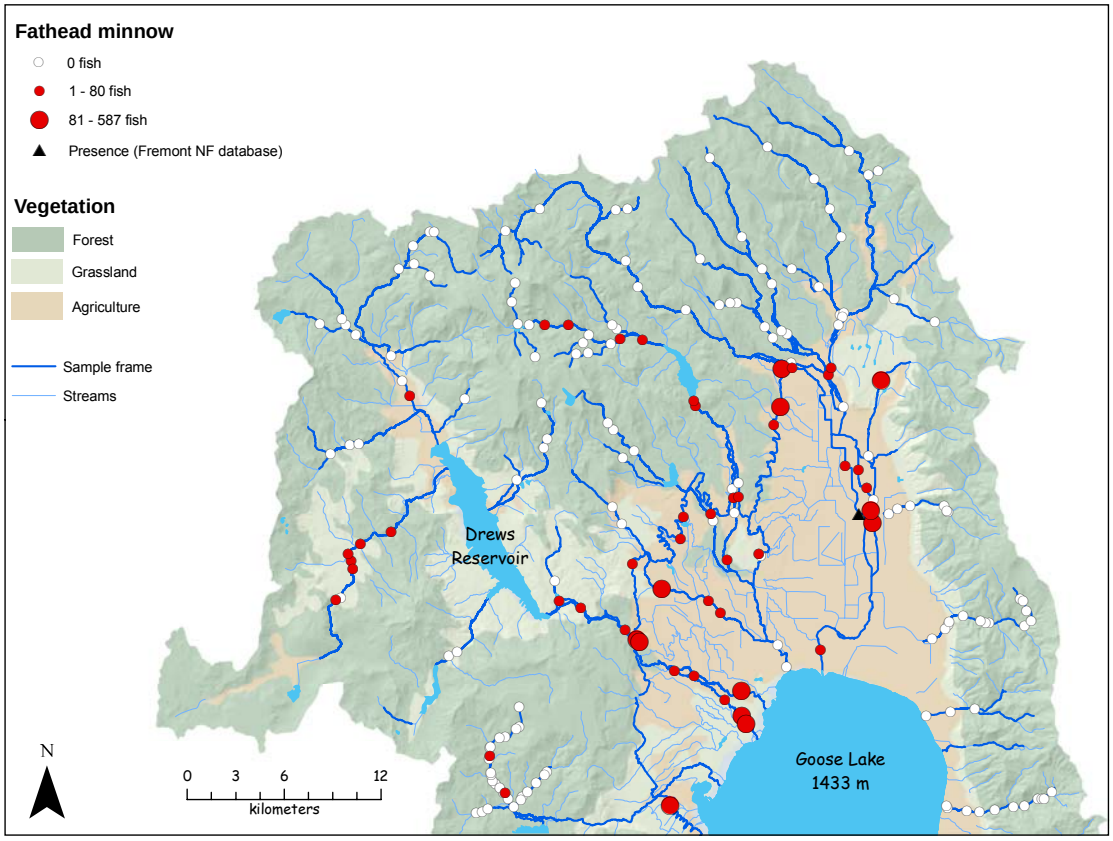

Figure 19. Distribution of nonnative fathead minnows collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007 and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources. No fathead minnows were noted in ODFW surveys conducted in 1991-1995.

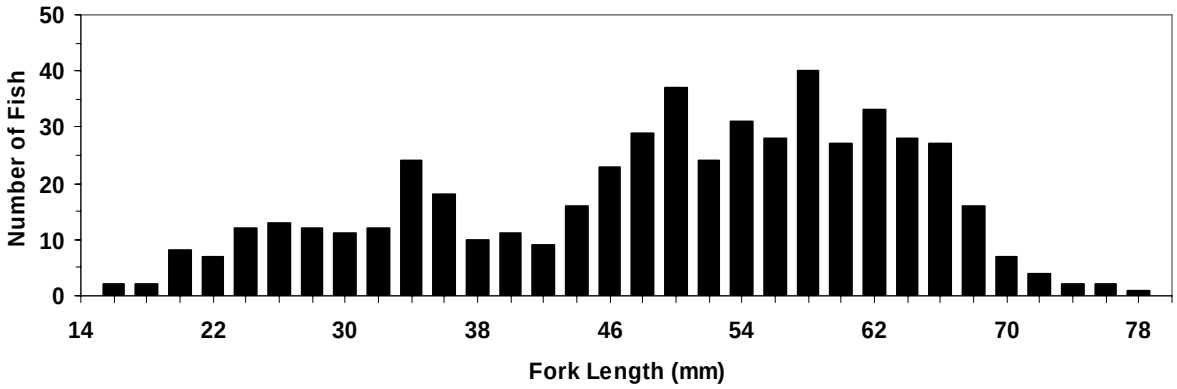

Figure 20. Length-frequency histogram for nonnative fathead minnows collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Only one record of fathead minnows was mentioned in the Fremont National Forest GIS coverage that consists of data compiled from multiple sources and no mention of fathead minnows was made in the 1991-1995 ODFW surveys. The lack of extensive historic observations could indicate that prior surveys were not designed to detect this exotic species.

Alternatively, the lack of historic observations coupled with the current widespread observation may indicate a relatively recent expansion of fathead minnows in the Goose Lake Basin. The length-frequency histogram for fathead minnows shows a broad range of sizes; however, discrete age-classes cannot be discerned (Figure 20).

Brown Bullhead

Nonnative brown bullheads were collected from 21 locations which represent 11% of sites sampled and 16% of the sample frame (Figure 21). Brown bullheads were the second most common nonnative species encountered in 2007 and were common in lower Drews, lower Cottonwood, and lower Thomas Creeks. They were also collected from upper Drews Creek, Hay Creek, and irrigation canals. Brown bullheads without eyes were found at two locations, both in lower Drews Creek. Sites (n=4) where relatively large numbers of bullheads (≥65 fish) were collected were located in lower Drews and lower Cottonwood Creeks. Only three records of brown bullheads were in the Fremont National Forest GIS coverage that consists of data compiled from multiple sources from upper Dog and Hay Creeks in the Drews subbasin and from an unnamed tributary to Cox Creek. No mention of bullheads was made in the 1991-1995 ODFW surveys. The length-frequency histogram for bullheads shows a broad range of sizes and three apparent age-classes (Figure 22).

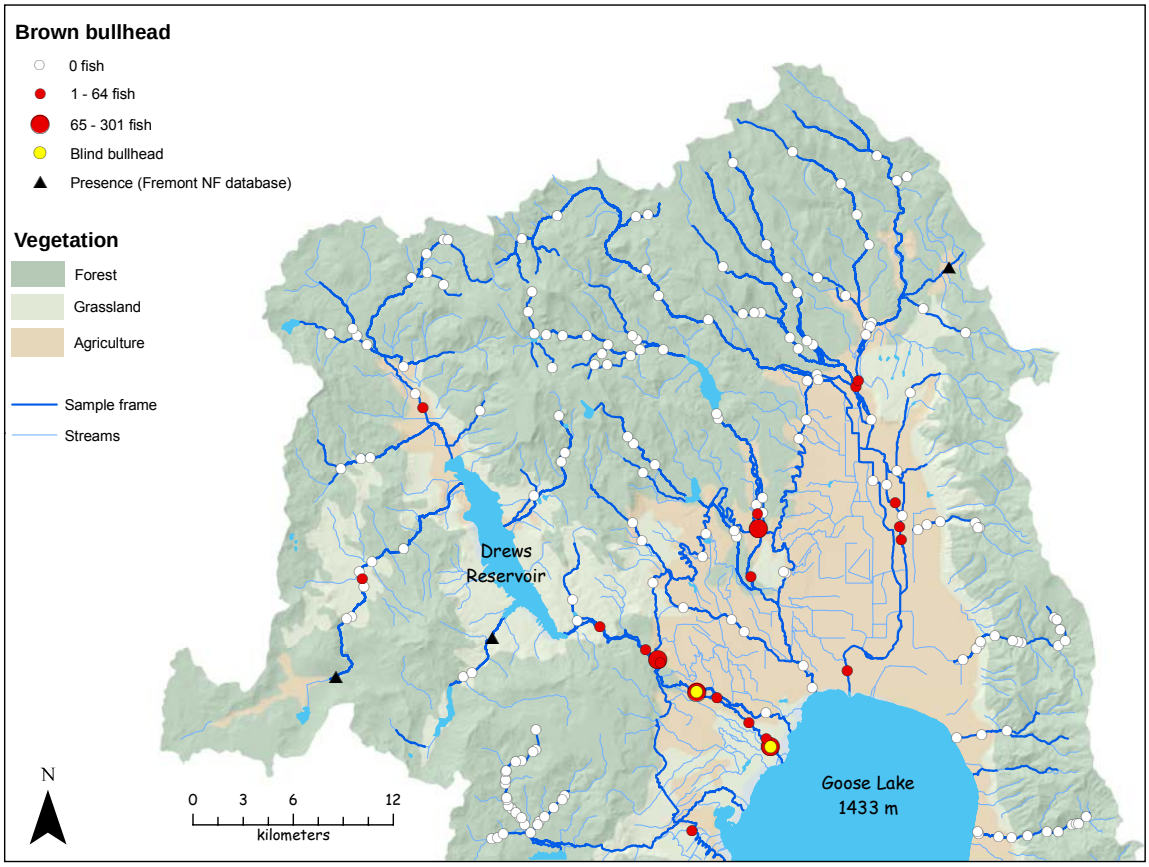

Figure 21. Distribution of nonnative brown and blind bullheads collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007 and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources. No bullheads were noted in ODFW surveys conducted in 1991-1995.

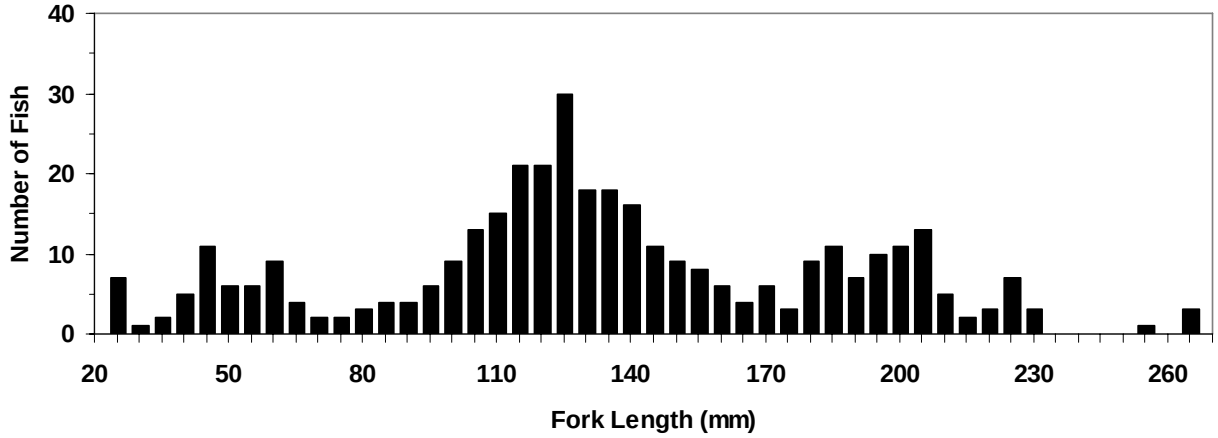

Figure 22. Length-frequency histogram for nonnative brown bullheads collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Other Exotic Fish Species

Nonnative brook trout were collected from four locations in the upper portion of Cottonwood Creek between Cottonwood Meadow Lake and Cottonwood Reservoir (Figure 23). Numbers of brook trout captured at these sites ranged from one to 141 fish. Previous surveys found brook trout in the same portion of upper Cottonwood Creek, but the Fremont National Forest GIS coverage that consists of data compiled from multiple sources also show brook trout in the Drews Creek subbasin (Dog Lake, Drews Reservoir, and Fish Creek) and in Camp Creek in the Thomas Creek subbasin. The length-frequency histogram for brook trout shows a broad range of sizes and three apparent age-classes (Figure 24).

Yellow Perch were found in five locations in lower Drews Creek and in one Drews Creek tributary (Hay Creek) (Figure 23). Previous surveys in the Fremont National Forest GIS coverage that consists of data compiled from multiple sources documented yellow perch only in Hay Creek. There were no yellow perch recorded from the 1991-1995 ODFW surveys. Lengths of the 13 fish that were collected showed a broad range of sizes up to 185 mm; however, no fish smaller than 75 mm were present.

An individual nonnative pumpkinseed was collected from one site in lower Cottonwood Creek (Figure 23). Pumpkinseeds were reported from only one location in the Fremont National Forest GIS coverage that consists of data compiled from multiple sources (Hay Creek) and no pumpkinseeds were reported from the 1991-1995 ODFW surveys.

White crappies were found in lower Drews Creek, lower Cottonwood Creek, and the north irrigation canal. No white crappies were reported from the 1991-1995 ODFW surveys. The Fremont National Forest GIS coverage that consists of data compiled from multiple sources showed white crappie only in Drews Reservoir. The lengths of collected fish had a broad range, although most fish were $\leq$35 mm FL, presumably young-of-the-year.

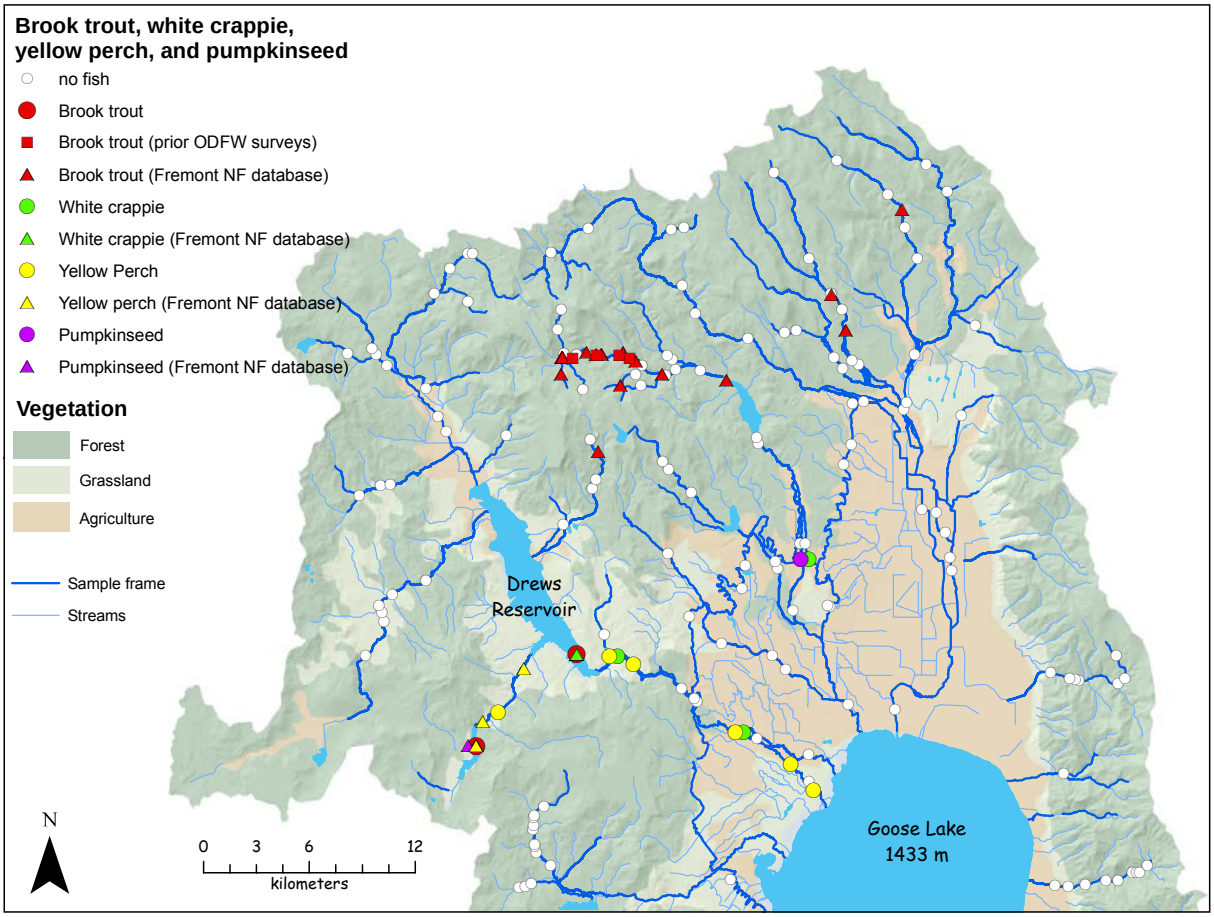

Figure 23. Distribution of nonnative brook trout, white crappie, yellow perch and pumpkinseed collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007, from surveys conducted by ODFW in 1991-1995, and from a Fremont National Forest GIS coverage that consists of data compiled from multiple sources.

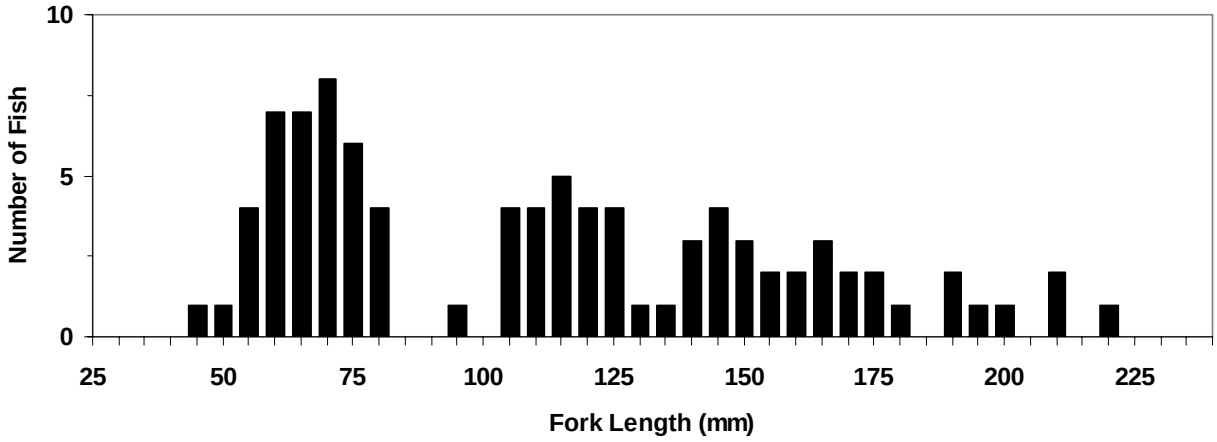

Figure 24. Length-frequency histogram for nonnative brook trout collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007.

Fish Assemblages

The composition of the fish assemblages in the Goose Lake basin varied considerably both between and within major tributary drainages. Within drainages, assemblage composition depended, in part, on whether a sample site was located in a forested headwater area or a low gradient agricultural bottomland (Figure 25). Redband trout was the numerically dominant species in the catch in the upper Cottonwood Creek drainage, upper Antelope Creek, the upper Thomas Creek drainage, and in the east side tributaries. Speckled dace was the numerically dominant species in the much of middle to lower Thomas Creek drainage, in the irrigation canals, and in Drews Creek tributaries. Pit roach was the dominant species at several lower Drews and Antelope Creek sites. Lamprey was the dominant fish in upper Drews Creek. Goose Lake tui chub was the dominant species at a few locations in lower Thomas and Drews Creeks. Nonnative fishes (primarily fathead minnow) dominated the catch at many sites in lower Drews and Cottonwood Creeks and in several irrigation canal sites. It was not uncommon to find a combination of redband trout and lamprey or redband trout and speckled dace in the

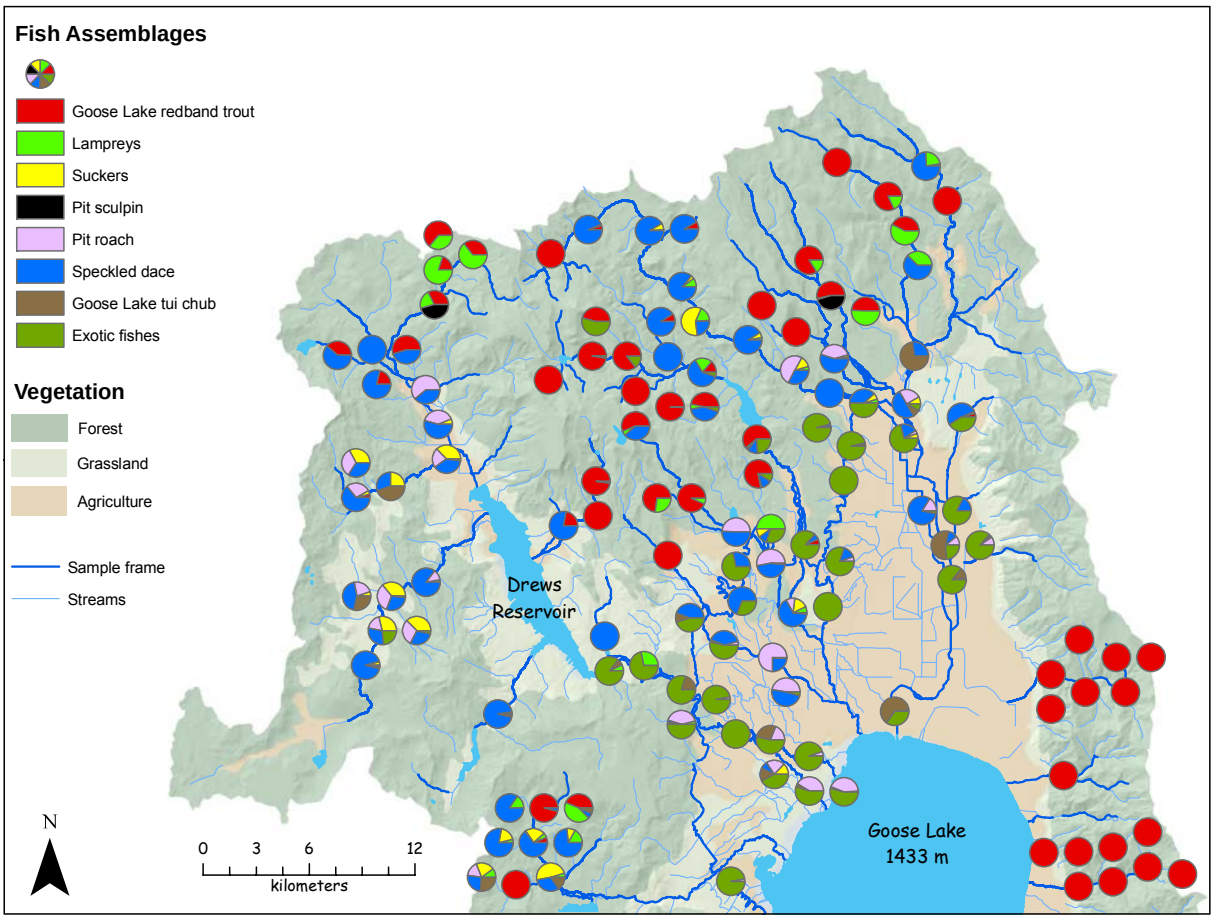

Figure 25. Distribution of fishes collected in the Oregon portion of the Goose Lake basin from surveys conducted in 2007. Pie charts show the proportion of the total catch of each species at each sample site. Catch is combined for all gear types. Exotic (nonnative) fishes include fathead minnow, brown bullhead, white crappie, pumpkinseed, and yellow perch.

upper reaches of the basin, and combination of Pit roach, tui chub, and exotic fishes (fathead minnows and bullheads) in the lower reaches of the basin. Combinations of Pit roach, speckled dace, and suckers were common in Drews Creek tributaries (Hay and Dent Creeks).

Comparisons of Sampling Gears

A variety of gear types was used to sample fishes in the Goose Lake basin. The types of gear used were driven both by sample frame and site-specific habitat characteristics. Sampling gears differed by sample frame as follows: 1) at sites in the nongame frame, methods included passive traps (e.g. fyke netting, minnow trapping, and hoop netting), dip netting, seining, and single-pass electrofishing techniques (including lamprey specific electrofishing waveforms), 2) at sites in the redband frame, multiple-pass electrofishing techniques were used, and 3) at sites in the overlapping nongame and the redband frame, a combination of multiple-pass electrofishing techniques and passive traps was used. Site-specific habitat characteristics that affected the choice of sampling gears included water velocity, depth, turbidity, temperature, aquatic vegetation, and instream obstacles. Our approach was to maximize the detection of all fish present at each sample site by employing a diversity of gear types. Assessing the efficacy of various gear types to detect individual species is useful for guiding future sampling efforts.

There were 36 sites where lampreys were collected using backpack electrofishing. At 35 of these locations, lampreys were collected using both standard and ammocoete-specific settings. The additional effort of conducting an ammocoete-specific pass yielded only one additional encounter which represented 3% of the lamprey sample. This result indicates that for sites suitable for electrofishing, conventional electrofishing methods should be adequate for detecting the presence of ammocoetes.

At 33 sites, a combination of electrofishing and passive gear (fyke nets and minnow traps) was used. Both methods were nearly equally effective at capturing suckers, tui chub, and speckled dace (Table 1). The passive traps appeared to be somewhat more effective than electrofishing at capturing Pit roach and fathead minnow and substantially more effective at capturing brown bullhead. Electrofishing is more effective than passive traps at capturing redband trout and lamprey ammocoetes.

DISCUSSION

The Goose Lake basin supports a diverse fish fauna with nine native species, four of which are endemic. The status of the native fish fauna is affected by cyclic droughts, water withdrawals, and the introduction of nonnative fishes. When Goose Lake went dry in 1992 following seven years of drought, fishes and their stream habitats became threatened in both California and Oregon. In response, a unique bi-state working group was formed to protect and reestablish native fishes in the basin (GLFWG 1995). The Goose Lake Fishes Working Group includes local ranchers, landowners, interest groups, and representatives of state, local, and federal agencies. Members of the Working Group developed a memorandum of understanding (MOU) emphasizing the need for a conservation strategy which would consider social, economic, and environmental issues. The MOU provided an opportunity for local residents to take part in setting recovery priorities and developing restoration projects. Tasks identified in the conservation strategy included conducting fish surveys to determine the overall distribution of native fish species and analyzing the effects of introduced fishes (GLFWG 1995).

Table 1. Comparison of the number of sites where each fish species was collected using backpack electrofishing, a combination of fyke nets and minnow traps, and both electrofishing and traps/nets. Sites listed (n=33) were those where all three gear types were used.

	Number of sites where a fish species was captured		
Species	Electrofisher only	Fyke nets & minnow traps only	Both methods
Redband trout	3	0	11
Sucker sp.	3	3	11
Tui chub	1	3	9
Pit roach	1	7	9
Speckled dace	1	3	20
Pit sculpin	0	0	1
Ammocoetes	8	0	3
Adult Lamprey	5	1	2
Fathead minnow	2	6	9
Brown bullhead	1	6	1

In 2007, ODFW conducted basin-wide surveys to assess the distribution and status of the native fishes in the Oregon portion of the Goose Lake drainage. Data collected describe the current distribution and status of Goose Lake fishes and provide a comprehensive baseline for assessing the effectiveness of future restoration and recovery activities. Our sampling was based on a statistical sampling design that provided a spatially balanced and representative sample. This design allowed us to draw inference on the distribution of all sampled fish throughout the basin. Further, this sample design enabled us to sample streams located on private property in proportion to their occurrence. During the 2007 sampling season, approximately 20% of the sample frame was dry. The high rate of dry channels likely affected fish distribution. Stream flow conditions encountered in 2007 were likely influenced by below average precipitation during the 2007 water year. It would be informative to repeat a comparable fish survey in the Goose Lake Basin during a more abundant water year.

All nine native fish species were collected in addition to six nonnative species. Most of the native fishes were widely distributed, with the exception of Modoc sucker and Pit sculpin. Our surveys were more comprehensive than prior surveys, with a greater representation in streams on private agricultural and range lands; consequently, we documented broader distributions of several species than was previously reported.

Endangered Modoc suckers were first confirmed to be present in Thomas Creek in 2001 (Stewart Reid, Western Fishes, personal communication). A snorkel study in 2007 found Modoc suckers to be continuously distributed and relatively common in upper Thomas Creek from a waterfall at ~1490 m elevation and extending upstream ~23 km (Reid 2007). In addition to this section of Thomas Creek, we found Modoc suckers in lower Cox Creek, approximately six kilometers downstream of the waterfall. Modoc suckers have also been found in higher abundance in Ash and Turner Creeks in California (Moyle et al. 1982; Stewart Reid, Western Fishes, personal communication).

These recent results suggest that the status of Modoc suckers is more robust than that known at the time of listing. Furthermore, chances of hybridization with Goose Lake suckers appear low; no Goose Lake suckers have been documented in Thomas Creek above the waterfall (Reid 2007).

The Fremont National Forest GIS coverage that consists of data compiled from multiple sources indicate that Pit sculpins were once more widely distributed in the Goose Lake drainage, with occurrences in lower Drews, Cottonwood, and upper Thomas Creeks. Most of these records are over 30 years old. Surveys in 2007 found Pit sculpins from only two sites out of the 143 that were sampled: one in upper Drews Creek and one in Camp Creek (tributary to Thomas Creek). These sites are approximately 70 river km apart and probably represent independent populations. The Camp Creek collection was the first documented from that drainage. The Drews Creek collection was located in close proximity to sites where Pit sculpins were collected in 1994 by the ODFW Aquatic Inventories Project. Although populations in Oregon appear to be low, Pit sculpin are relatively common and abundant in the Pit River and tributaries in California (Li and Moyle 1976; Reid et al. 2003).

Nonnative fishes were relatively uncommon in our surveys. These fishes, primarily fathead minnow and brown bullhead, were most commonly found in low gradient agricultural streams. These species were more widespread in 2007 as compared to past surveys (ODFW unpublished data; Fremont National Forest compilation). This may be due to an under representation of these habitats in the previous surveys, and it is unclear whether these species have expanded their range in recent years. However, in the adjacent Klamath subbasin, fathead minnows expanded rapidly after their introduction (Markle and Dunsmoor 2007). Nonnatives were collected from 60% of the irrigation canals that were sampled (n=10) and were present in the irrigation reservoirs (GLFWG 1995). These reservoirs may seed the downstream habitats.

To some extent, biases associated with sampling gear affected both species and size of fish captured at a particular site; however, most species and size classes were collected with all gear types used. Exceptions include the relative ineffectiveness of electrofishing for capturing bullheads and smaller sized fishes and the ineffectiveness of traps and nets in capturing Pit sculpins and lampreys. This knowledge allows managers to confidently compare fish distributions between past and present surveys.

The Goose Lake Fishes Conservation Strategy outlined desired future conditions for the Goose Lake Watershed (GLFWG 1995). Desired future conditions were defined as: 1) dynamic and resilient aquatic habitat consistent with local climate, geology, land-forming processes, and potential natural vegetation, 2) habitat that is characterized by excellent water quality and complex physical attributes similar to those in healthy, unimpacted watershed ecosystems, and 3) native fish that are naturally produced and exist at levels near the potential productive capability of the aquatic and riparian habitats in the basin. Desired water quality/quantity and physical attributes should provide safe and open passage for upstream and downstream migrants, clean spawning substrates, foraging habitats, hiding and thermal cover, and water temperatures to meet physiological requirements. In addition, stable fish populations and adequate refugia should be established to withstand future droughts and major disturbances to ensure the long-term viability and adaptability of the native fish species. While some progress has been made to achieve these conditions, there is work left to be accomplished. An update at the recent Working Group meeting noted numerous restoration projects that are being implemented, or are being planned, in the basin. Our interactions with local landowners found a general enthusiasm to enhance native fishes and a willingness to cooperatively work to improve

habitat conditions. We recommend periodic fish distribution surveys in the basin to monitor native and nonnative fish distribution and status, to assess the effects of restoration efforts, to assess the impacts of water year on fish distribution and abundance, and to guide future restoration efforts.

ACKNOWLEDGEMENTS

We thank E. Gilbert for GIS assistance. We acknowledge the tireless efforts of the field sampling crew: J. Simon, J. Kingdon, J. Bennett, and K. DeHart. We thank the staffs of the Fremont Winema National Forests and the ODFW High Desert Region for supporting this effort. We thank C. Corrarino, D. Hogen, D. Markle, and B. Tinniswood for critical review of this manuscript. We also thank the numerous landowners who graciously granted us permission to sample on their properties.

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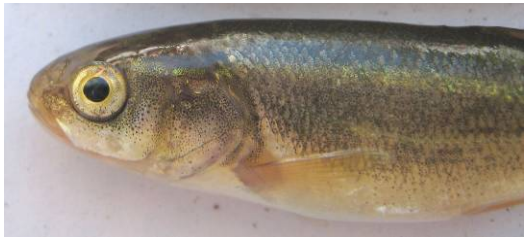
APPENDIX A. Photographs of fish species collected in the Goose Lake subbasin.



Goose Lake redband trout (*Oncorhynchus mykiss* ssp.)



Pit roach (*Lavinia symmetricus mitrulus*)



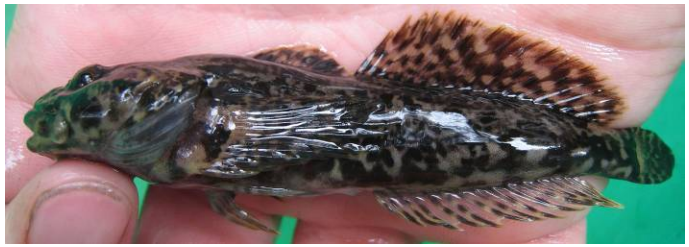
Goose Lake sucker (*Catostomus occidentalis lacusanserinus*)



speckled dace (*Rhinichthys osculus*)



Modoc sucker (*Catostomus microps*)



Pit sculpin (*Cottus pitensis*)



Goose Lake tui chub (*Siphateles bicolor thalassinus*)



Goose Lake lamprey (*Entosphenus* sp.)

APPENDIX A continued.



Pit-Klamath brook lamprey (*Entosphenus lethophagus*)



fathead minnow (*Pimephales promelas*)



brown bullhead (*Ameiurus nebulosus*)



blind bullhead



brook trout (*Salvelinus fontinalis*)



yellow perch (*Perca flavescens*)



pumpkinseed (*Lepomis gibbosus*)



white crappie (*Pomoxis annularis*)



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